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# EXCAVATION & GRADING HANDBOOK

*Revised*

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# UNDERSTANDING ROAD SURVEY STAKES


This manual is a practical guide to excavation, grading, paving and pipelines. My aim in writing is to provide information on the best methods available to increase your productivity in, and knowledge of, this very important field. This book can benefit anyone in the construction trade, from beginners just starting out to contractors with years of experience — whether you work in this field, or you just need information to help you understand the process. It's written in simple terms and covers each step of the excavation and grading process, from how to read and understand grade stakes, through paving, laying pipe and cutting drainage channels.

Since the mid 1970s, when my first grading and excavation book was published, there have been many changes in construction methods and equipment. Adapting lasers, sonar, and GPS to control the equipment to carry grade is by far the biggest change I've dealt with in this field. Using sonar and slope control on graders to fine trim has greatly increased production in the last few years. The operator using a GPS has the precise location where he is working right on his screen, showing the parameters of the lot pad and the elevation needed. GPS is now used on dozers, scrapers and compactors, and is also used for surveying. I'll be covering GPS in detail in a later chapter in the book.

In the trenching department, the biggest change is that backhoes have replaced most trenchers, and hoes with compaction wheels have eliminated most trench jetting.

In the first four chapters of this book we'll cover the basics: reading and following survey stakes, understanding excavation plans, and how excavation contractors use contour line drawings. If you've been working in the excavation and grading business for a while, most of what you read in the first few chapters you probably know already. But if you need a brush-up on plan reading and stake markings, or if you're new in the field, these chapters explain it in terms I use throughout the book.

So let's start at the beginning — with surveying and staking. Everyone — the inspector, superintendent, foremen and grading equipment operator, needs a good understanding of how surveyors stake the job. Not under-standing the stakes is like having the specifications and not being able to read. Today, most large jobs and many small ones are excavated using GPS to guide equipment. And even fewer stakes will be used in the future, making the stakes that *are* set more important than ever to read. The basic information on the stakes has changed little in the last few years. However, the way the surveyors compute that information has changed.

## Survey Stakes

Excavation for roads, buildings and pipelines begins with a survey of the area where the excavation will be done. A survey crew working for the engineering firm that's designing the project will set out stakes and *hubs* that identify points on the construction plans. When a precise distance or elevation is needed, a surveyor's tack on top of the hub establishes the point from which elevations and distances are measured.

Beside each hub there will be an *information stake* marked in surveyor's code. It explains the grades at various distances from the hub

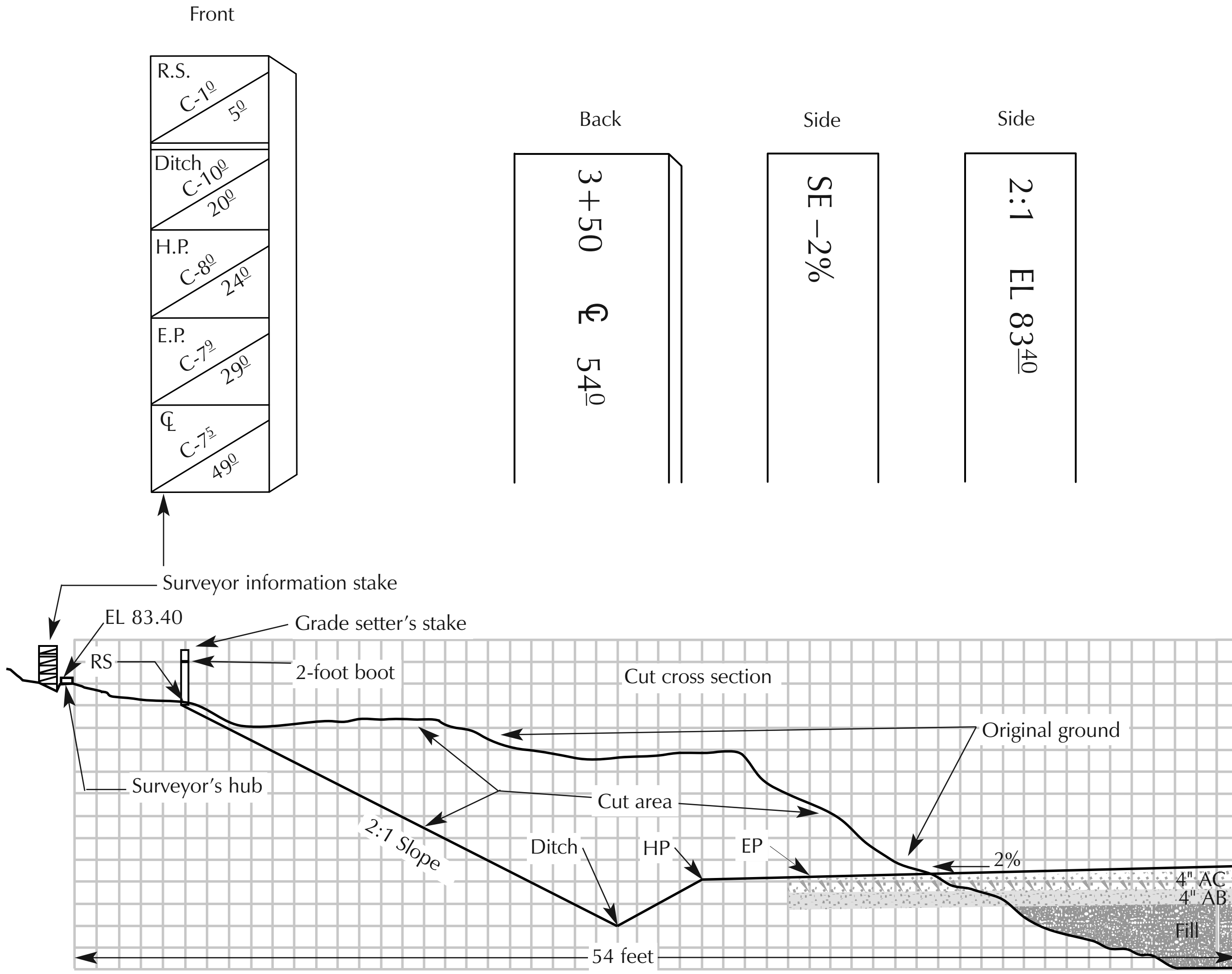



***Figure 1-1*** *Reading cut stakes*

or other reference stake or point. It's essential that you know how to read the markings on these information stakes and follow the instructions they provide. The surveyor may write on one or all sides of the stake.

## *Cut Stakes*

The stakes are usually called *cut, fill* or *slope* stakes, depending on the type of excavation required. Figure 1-1 shows the kind of markings you'll find on an information stake. In this case, we're looking at a cut stake for a road excavation. The front, back and both sides of a cut stake are shown in the figure. Below the stake there's a cross section drawing of the existing grade and final road grades that are described on the stake. Refer to the drawing as I explain the markings on the information stake in the figure.

Look first at the stake labeled *front* in the upper left of Figure 1-1. That's the front of the information stake. The *RS* at the top of the stake means that there's a reference stake to be established, and that reference stake is the point from which measurements and elevations are taken. The location of the reference stake is the point that the projected cut slope meets or catches original ground, also referred to as a *catch point*. Find the reference stake in the drawing. It's labeled *RS* and it's in the upper left-hand corner of the drawing. Below the letters *RS* on the information stake you see $C\text{-}1^{\underline{0}}$. Below that you see a diagonal line and $5^{\underline{0}}$. These markings above and below the diagonal line identify the amount of cut and distance needed to establish the correct grade at the reference stake. The number above the diagonal line is the elevation and the number below the diagonal line is the distance. In this case, the information stake shows a *cut* of 1.0 foot (below the level of the surveyor's hub) to be made 5.0 feet from the hub for the RS point.

Some surveyors may use *RP* instead of *RS*. *RP* means reference point. Treat it exactly the same as the RS.

Notice that distances and elevations are measured in feet and tenths (or hundredths) of a foot, not feet and inches. The small number above the small horizontal line shows decimals of a foot. That's a little different from what you're probably used to, but you'll appreciate the difference when adding and subtracting feet and decimals of a foot rather than feet, inches and fractions of an inch. I'll explain more about this measuring system, called *engineer's measure*, later in this chapter.

The two horizontal lines below the first set of measurements are very important. All measurements above the double horizontal line are taken from the hub beside the information stake. The double horizontal line means *and then*, indicating that all measurements and elevations from that point down on the stake are taken from the RS point and not the surveyor's hub. Note this very carefully: If the double horizontal line was replaced with a single horizontal line, all measurements and elevations would be taken from the surveyor's hub rather than reference stake or hub established by the grade setter. On the other hand, if the surveyor uses a double line *after each grade*, then each cut becomes the reference for the next. We'll look at this last method shortly.

The next information on this stake shows the elevation and location of the ditch cut (*C-10º / 20º*). It's to be 10 feet lower than the RS point and 20 feet from it. The grade falls 10 feet over a horizontal distance of 20 feet, thus creating a 2:1 slope. You can see this indicated on the drawing (about lower middle). For every foot of cut, the grade line moves horizontally 2 feet. Notice that all measurements are made from the reference stake. The ditch is cut 10 feet below the reference stake and 20 feet from that stake. Also note that the 20-foot distance is measured horizontally, not diagonally, from the reference stake. Look again at the drawing to be sure you understand how the 20-foot distance to the ditch is measured. Remember, each square on the survey drawing represents 1 horizontal and 1 vertical foot.

The next reading is the *hinge point (HP)* grade and distance. Note the hinge point on Figure 1-1. It's 2 feet above the ditch cut. The HP information on the stake shows an 8-foot cut at 24 feet, indicating the grade must come up 2 feet and move out 4 feet. By computing the amount the HP rises from the ditch and the distance it moves towards the center of the road, you can see that it's again a 2:1 slope.

Reading down the information stake, the next grade and distance is the *edge-of-pavement (EP)* point. The grade will be 7.9 feet below the reference stake hub. Notice the cut at EP is 0.10-foot less than the HP cut. The reason for this is that the road grade rises 2 percent in the 5 feet from HP to EP. Multiplying 5 feet by 2 percent gives the amount the shoulder rises in that distance ($5.00 \times 0.02 = 0.10$).

The next markings give the centerline cut. You can see that the cut is again less than the previous cut at EP. Subtracting the 29 feet at EP from the 49 feet to the centerline leaves 20 feet. So the centerline is 49 feet from RS and 20 feet from EP. The cut at the centerline is 0.40 foot less than EP cut, making the centerline 0.40 foot higher than EP. Again, we have a 2 percent slope from the centerline to EP. You can check this by multiplying the 20 feet by 2 percent ($20.00 \times 0.02 = 0.40$). These are all finished grades so the grade setter must add the thickness of the road section to the EP and centerline grade to get the correct subgrade elevation that must be excavated.

Look at the back of the cut stake. It's marked *3+50*, indicating that this station is 350 feet from station 0+00, the point from which the survey began. Below the station number is the distance from the

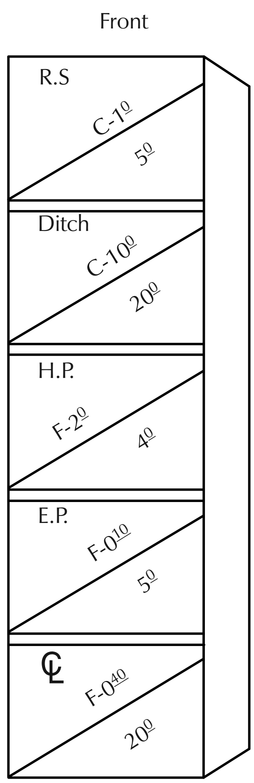



***Figure 1-2*** *Cut stake with double lines*

surveyor's hub to the center of the road. This includes 5 feet to the RS and 49 feet from the RS to the centerline, a total of 54 feet (*54⁰*).

Now let's look at the sides of the stakes. Note the first drawing of the stake labeled *side*. This side of the stake identifies the percentage of slope from the centerline to HP. The minus sign indicates that the centerline slopes down to the HP. If it were a plus sign instead, the centerline would be sloping *up* to the HP. The second *side* stake drawing shows the rate the cut slope falls from RS to the ditch. In this case, it's 2 feet out for every foot downward. The second group of numbers is the elevation of the surveyor's hub above sea level.

Here's another method a surveyor might use to indicate measurements and elevations. I mentioned earlier that the line between each grade on the surveyor's information stake was very important. A double horizontal line means *and then*. So, if the surveyor uses a double line after each grade on the information stake, then each cut becomes the reference for the next. The information stake in Figure 1-2 shows the same information as the one in Figure 1-1, except it's written with a double line between each grade. Notice that by adding the double line, the last three distances change.

In Figure 1-2, if you add the distances on the stake to centerline together (the distances indicated under the diagonal lines), you'll get 54 feet from the surveyor's hub to centerline. Now look at the back of the stake in Figure 1-1. It also reads 54 feet to centerline from the surveyor's hub. By using the double lines between grades, the last three cuts in Figure 1-1 become fills in Figure 1-2. The reason is because the HP grade must now be computed from the ditch grade, which is 2 feet lower, creating a fill of 2 feet. This method is also used to determine the centerline grade. The EP grade is 0.10 foot higher than the HP, and the centerline is 0.40 foot higher than EP.

If you encounter a stake marked like the one shown in Figure 1-2, for better control and accuracy you should set a hub at each point as a reference to shoot your next grade from. If you study Figures 1-1 and 1-2 carefully, you'll notice each distance and elevation are exactly the same. Only the methods for computing them are different.

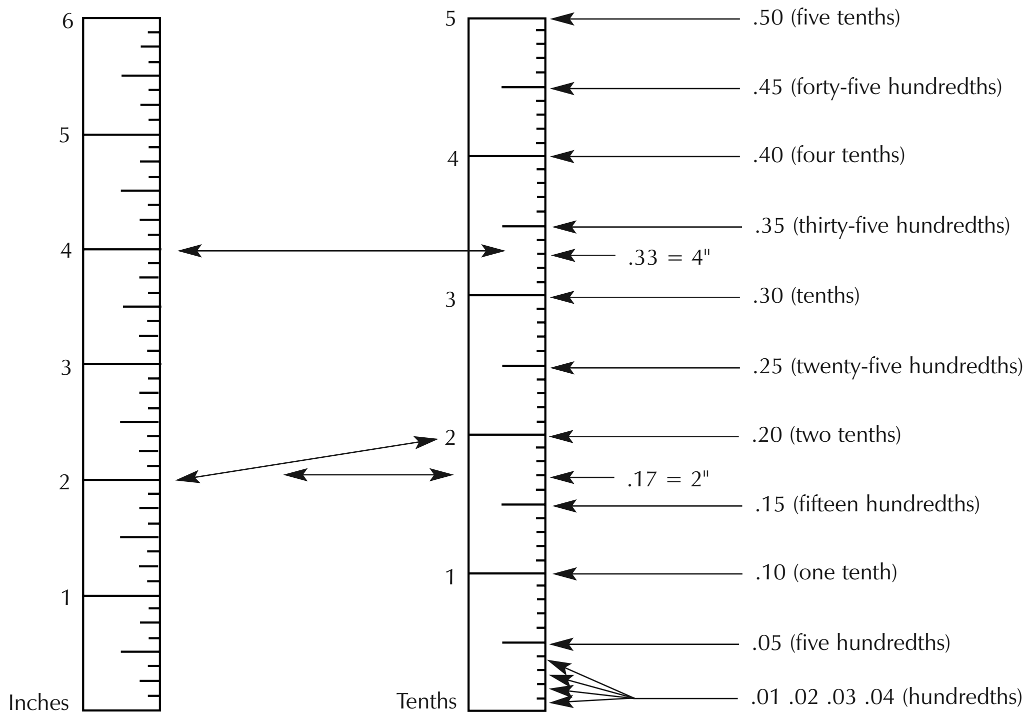



***Figure 1-3*** *Compare inches with decimals of a foot*

### Comparison of Inches and Decimals of a Foot

Setting grades requires many additions and subtractions. Using decimals speeds the work and makes errors less likely. Figure 1-3 compares inches with decimals of a foot. If you're uncomfortable reading distances in tenths and hundredths of a foot, think of one foot as being like a dollar bill. One dollar is the same value as 100 pennies; one foot is the same distance as 100 hundredths of a foot. One dollar is the same value as 10 dimes; a foot is the same distance as 10 tenths of a foot. Pennies are hundredths. Dimes are tenths.

## *Fill Stakes*

We've looked at a cut stake where material must be excavated to reduce the existing grade to the finish grade (Figure 1-1). Figure 1-4 shows a typical fill situation where soil has to be deposited to build up the existing grade. Again, the illustration shows four sides of the stake and the road cross section. The *RS* at the top of the stake means that the

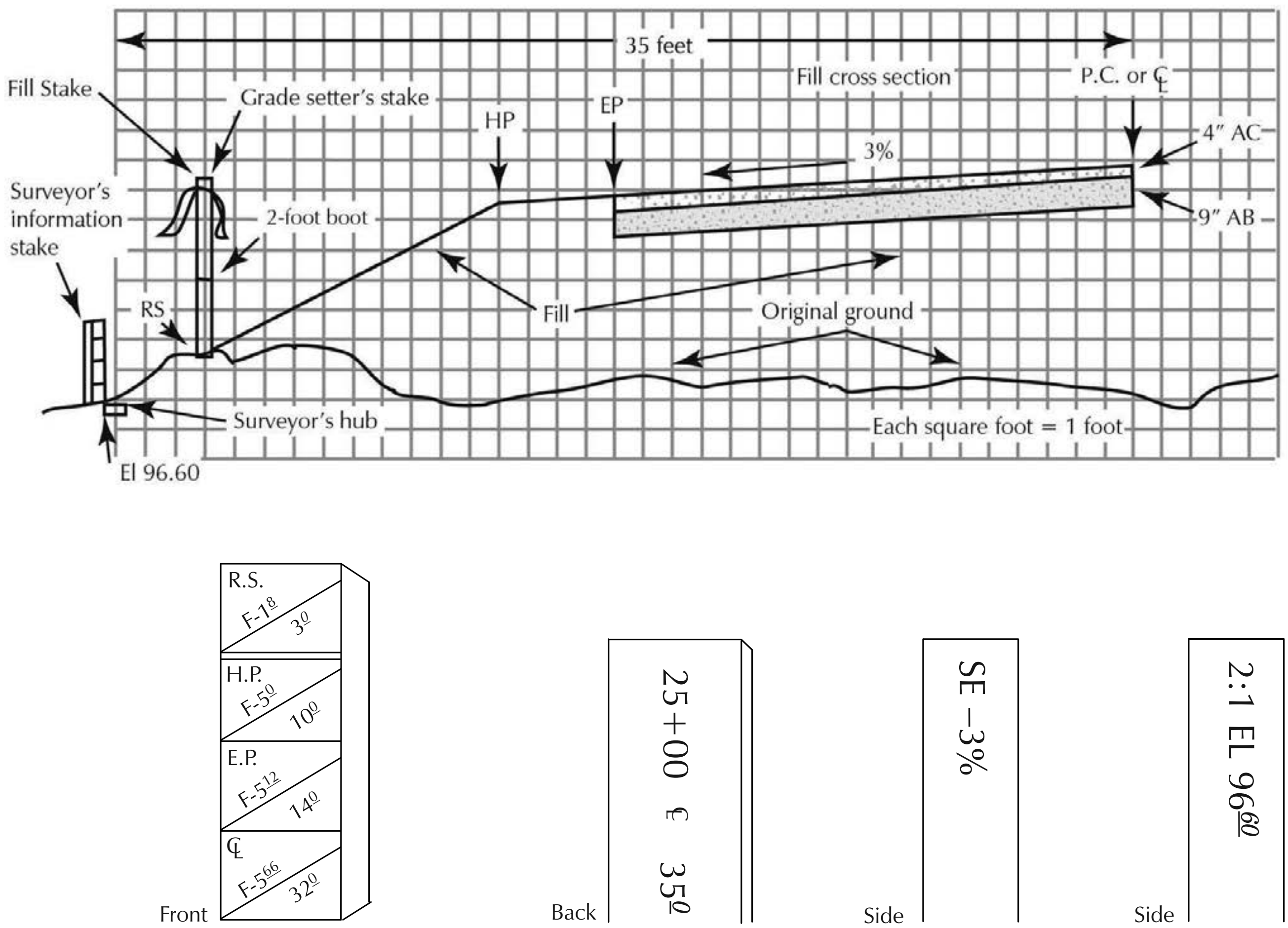



***Figure 1-4*** *Reading fill stakes*

reference stake (to the right of the hub) is the starting point and the place from which all measurements and grades are measured. Cut or fill information given for the RS point will be measured from the surveyor's hub. Here, the RS is located 1.8 feet above the hub and 3 feet from it. The grade setter will have to set the reference stake at the indicated horizontal distance from the hub and draw a horizontal line on the stake at the elevation given on the surveyor's information stake. If the ground hasn't been disturbed at that point, his line will match the existing ground.

The grade setter should add a boot to his stake with a horizontal line 1 foot above his RS grade. Because this is a fill, if the fill is made correctly, the overfill will cover his finished grade line. By placing a 1-foot boot above his finished mark, he'll save the time it would take him to dig it out later. So when the grade setter returns to set a second slope stake at HP, he can use the 1-foot boot to compute the next vertical grade needed. He'll just subtract his 1-foot boot from the vertical grade he wants.

Reading down the surveyor's stake, the two horizontal lines mean *and then*, indicating that the grade setter must measure from the RS point for the next fill and distance, instead of measuring or shooting grades from the original surveyor's hub. For the *hinge point (HP)*, measure 10 feet from the RS hub or lath. At this point, a fill of 5 feet must be made to obtain the required grade. The hinge point is the place where the fill slope stops and the road grade begins. A stake won't be set at HP until the fill reaches that point. It would be in the way. The operator will get that grade from the RS stake set by the grade setter. It'll show the fill needed 10 feet out, and that the fill slope should be 2:1 for the HP grade. If the fill were to be 20 feet high (rather than 5 feet), the grade setter would set slope stakes every 5 feet the fill rises to HP.

There are times when the grade setter must offset the reference stake. Let's look at how he would do this. We'll say that the grade setter set his reference stake 5 feet out from the surveyor's hub. It often happens that the ground level is disturbed during clearing. What if, during the clearing operation, 1 foot of the existing ground is removed and the grade at the RS no longer matches the surveyor's information stake? When there is a 1 foot difference in grade, the grade setter working a 2:1 fill should move the reference stake back 2 feet. He must then mark his RS lath to reflect the change. His new fill and distance to HP will be F-6$^{\underline{0}}$/ 12$^{\underline{0}}$. By moving the RS 2 feet back, once the fill is made 1 foot high at a 2:1 slope, it will match the grade and distance on the original RS set at 5 feet. If he didn't do this, the slope would be off line with the remaining RS points that were not undercut during clearing.

On a cut slope, you may have to offset the RS for the equipment. You'd again move the RS back 2 feet to provide clearance for the grader's blade. This will keep the grader operator from having to slow down and adjust his cutting edge in from its normal grading position to avoid the stake. The grader would use the same cut and fill given for the 5-foot RS distance, but the grade setter would mark a *2* in a circle at the top of his lath to indicate the actual RS point is offset 2 feet. He should also mark the actual RS point with a paint line for the grader operator to follow. It's very important to set the RS point precisely because it controls the entire cut or fill elevation and alignment.

Let's return to reading the information stake in Figure 1-4. The next point referenced is the *EP*. This is the edge of the pavement and it shows a fill of 5.12 feet *(F-5*$^{\underline{12}}$*)* at 14.0 feet from RS.

Below the EP data is the *centerline*, represented by a C and an L (one overlapping the other). From the RS, you measure 32 feet and fill 5.66 feet. This will put the centerline 18 feet from the EP and 0.54 foot higher.

The back of the stake has *25+00*. That signifies that this stake is 2,500 feet up the line from the point where the measurements started (the beginning of the road construction in this instance). The point the surveyors start from is most likely marked 0+00. These are station numbers. The number *35.0* below ℄ means that the center of the road is 35 feet out from the surveyor's hub (not RS). Look again at the front of the stake and notice that when the RS distance of 3 feet is added to the ℄ distance of 32 feet, the total is 35 feet, the same distance as that marked on the back of the stake.

The first stake labeled *side* is marked *SE –3%*. This is the percentage that the roadbed slopes from the centerline to the hinge point. On the right-hand stake marked *side*, the first reading is *2:1* (2 to 1). This is the rate the fill slope will rise from RS to HP. Notice that the front of the stake shows HP with a 5-foot fill over a 10-foot distance. This is what the 2:1 indicates. The next item on the side stake is *EL 96*$^{\underline{60}}$. This is the elevation of the hub at the surveyor information stake. The surveyors computed all cuts or fills from that hub.

What I've described so far in this chapter is more or less standard procedure for indicating elevations and distances on road stakes. However, surveyors in some counties and cities follow slightly different procedures. Some surveyors provide more information on the stakes and some less. The surveyor stake in Figure 1-5 shows what you might see on some county or city road stakes.

The front of the stake begins with a *2* with a circle around it. This indicates that the first cut starts 2 feet out. The next markings indicate that the ditch cut is 4 feet at a distance of 10 feet from the stake. The slope will again be 2:1 because the first 2 feet aren't cut and the cut over the next 8 feet is 4 feet. Look at the figure again. Notice that there's no double *and then* line. This means that you must take all measurements and grade shots from the hub set by the surveyors rather than from an RS or RP point, as on the previous stakes we've looked at.

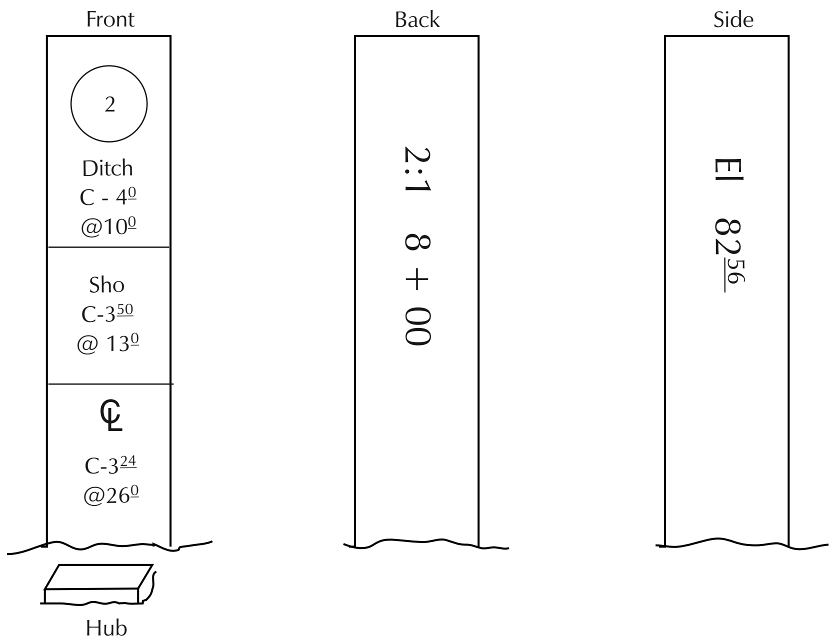



***Figure 1-5*** *Surveyor information stakes*

Reading down the stake, we find a second group of numbers that show the top of the shoulder cut *(Sho)*. This is the HP, or hinge point, referred to on previous stakes. Notice there's no EP distance or elevation on this stake. You must look at the plans for the distance from the shoulder to the edge-of-pavement, and the elevation. Notice that there's only 13 feet from the shoulder to the centerline, which indicates a possible aggregate shoulder. In this case the shoulder would be brought up to subgrade and not finished grade.

Engineering companies follow different conventions when marking their stakes. But the plans should clarify what's intended and which points are actually indicated. If something isn't clear, don't guess. Call the engineering company that created the drawing and marked the stakes. They should be eager to help.

The second drawing in Figure 1-5 is the back of the stake. It shows the rate of fall of the cut slope *(2:1)* and the station number *(8+00)*. It doesn't have the centerline distance because all the front measurements are from the hub and not an RS or RP point. Many stakes have just the details required to allow you to set the grades. Even though other information may be absent, they always have the station number on the

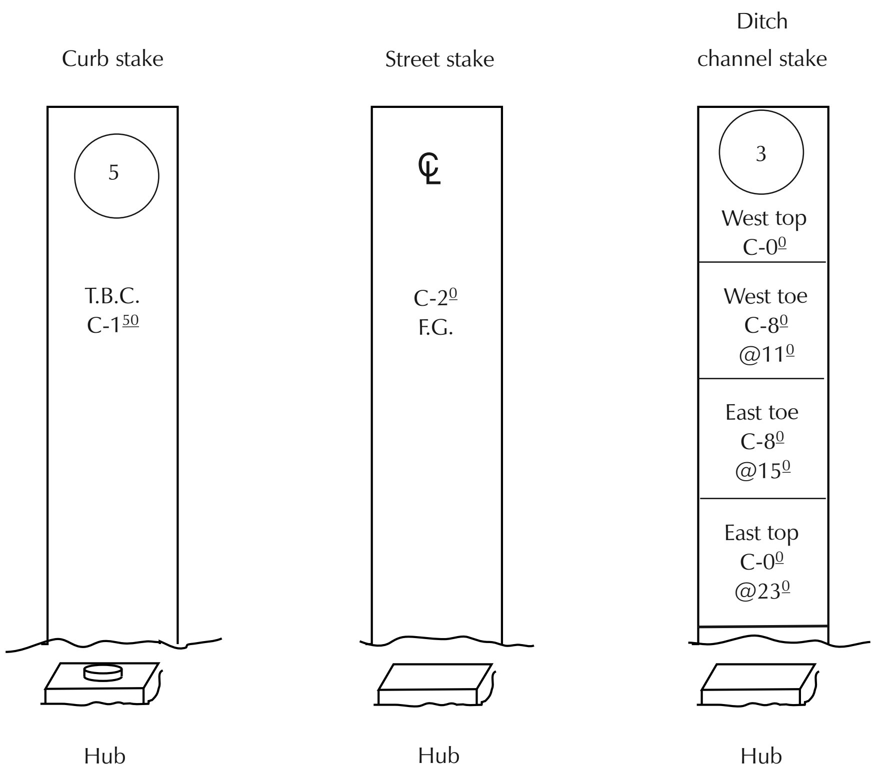



***Figure 1-6*** *Miscellaneous information stakes*

back. The side of the stake is shown in the right-hand illustration. It gives the elevation above sea level *(EL 82$^{\underline{56}}$)*. In some cases the hub elevation won't be on the stake at all. It may be replaced with the percentage of slope for the road, or both may be omitted entirely.

## *Miscellaneous Information Stakes*

**Curb stake —** Now look at Figure 1-6. The stake at the left is what you'd expect the surveyor to set for cutting and setting curb grades. From the hub at the base of this information stake, you'd move out 5 feet and down 1.50 feet to the *top-back-of-curb (TBC)* to set the curb forms or for the top of the concrete pour.

In some cases, the surveyors may also give the front lip grade or even the flow line grade. If not, you'll have to determine the distance from the back of the curb to the lip. This information is available in the plans or job specifications. When setting curb subgrade, determine the thickness of the curb plus any aggregate base, if it's called for under the curb. The thickness of one or both must be added to the cuts and subtracted from the fills to find the subgrade rather than the finished grade level. Notice that there's a tack in the hub in front of the curb stake. The tack marks the exact spot from which the surveyor took his measurements. Without this marker, the measurements could be as much as $1^1/_2$ inches off (using a 2 × 2-inch hub). The tack provides greater accuracy.

**Street stake —** The center stake in Figure 1-6 is a street stake you'd expect to find on a rural road first cut. The front of the stake indicates the centerline of the street and the cut or fill to the finished grade. In this case, there's a 2-foot cut to the *finished grade (FG)*. The plans should show the road width, percentage of slope or crown, and the thickness of the road section. Remember to add the thickness of the road to this cut. The station number may be on the back or front of the street stake. Surveyors rarely stake the street centerline. The stakes are usually offset behind the back of the curb or a roadside ditch and will carry enough information for the grade setter to establish a centerline grade. Those are the common methods for staking roads.

**Ditch channel stake —** The stake at the far right in Figure 1-6 is a grade stake for a ditch or small channel. The *3* in the circle (read *3-foot offset*) is the distance from the hub where the first cut starts (which would be the catch point or top-of-slope). The *west toe* grade indicates the first slope and the bottom of that slope. The *east toe* is the bottom of the slope on the opposite side of the ditch. Both toe cuts are the same, so the bottom is flat. The *east top cut* is where the cut will be started on the opposite side. Subtracting the 3-foot offset from the 23-foot distance to the east top cut gives the distance across the top of the ditch, 20 feet. Subtract the small toe distance from the larger. This gives the width of the ditch bottom, 4 feet.

To find the rate of slope from the top cut to the toe of the channel, subtract the distance given to the top cut from the distance given to the toe cut. The 3-foot offset must be subtracted from the west side distance of 11 feet. This will make the distance 8 feet from top cut to toe on each side. Dividing the cut of 8 feet into the 8-foot horizontal distance gives an answer of 1. This indicates that for every foot cut vertically, the slope moves out 1 foot horizontally. That's a 1:1 slope.

A stake with only a few markings will usually provide all the information you need to do the excavation. If something is still unclear, the plans should have the answer you're looking for.

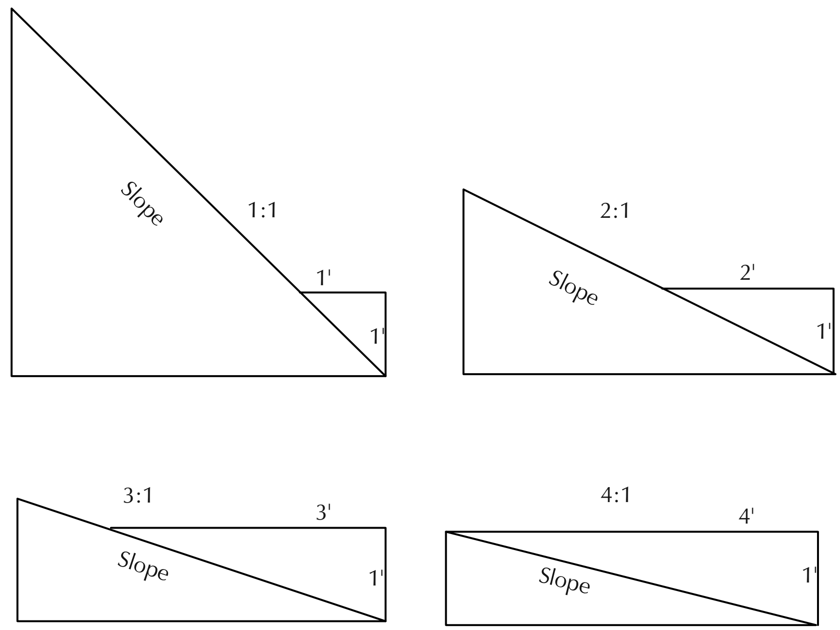



***Figure 1-7*** *1:1 to 4:1 slopes*

In this chapter we've described grades by either a ratio of run to rise, or as a percent above the horizontal. Most grades in excavation work are expressed as a ratio of horizontal distance (run) to vertical distance (rise), or run to rise (run:rise). Figure 1-7 illustrates the four most common slope ratios, and should help you visualize most of the slopes you work with in excavation.

If you're still confused about the work required after reading the surveyor's stakes and checking the plans, ask the survey crew about it if they're still on the job. If they've left, call the engineer and have him clarify the problem or send the survey crew out for a field meeting. *Be sure you know what's required before beginning the work*. Earthmoving is far too time-consuming and expensive for you to be taking your best guess and hoping you're right!

# CHAPTER 1 QUESTIONS

**1. What does RS stand for?**

A) Rate of slope
B) Road surface
C) Reference stake
D) Rear station

**2. What do the markings above and below the diagonal lines on a cut stake indicate?**

A) "And then"
B) The amount of cut is above the diagonal and the distance is below
C) Take all measurements below the diagonal from the next cut
D) The amount of cut is above the diagonal and the fill is below

**3. What other abbreviation means the same as RS?**

A) PG
B) IS
C) EP
D) RP

**4. If the RS distance is followed by a double line, where must the remainder of the grades and distances be established from?**

A) The surveyor's hub
B) Grade setter's RS hub
C) Each following cut or distance
D) The HP

**5. How much will a 2 percent slope rise or fall in 20 feet?**

A) 0.20 foot
B) 0.30 foot
C) 0.40 foot
D) 0.60 foot

**6. Where is the elevation on the side of the surveyor information stake taken from?**

A) The survey hub
B) The centerline
C) The reference stake
D) The catch point

**7. What does it mean to the grade setter if every distance on a surveyor's stake is followed by a double line?**

A) He must take the next grade and distance from each preceding point
B) He must measure back to the survey hub for distance and elevation
C) He must measure back to the survey stake for distance only
D) It indicates that all the following measurements are cuts

**8. Which of the following is equal to 4 inches?**

A) 0.16 foot
B) 0.20 foot
C) 0.33 foot
D) 0.40 foot

**9. What is the purpose of a second horizontal line on a fill stake located 1 foot above the finished grade?**

A) To locate the hub set by the surveyor
B) To indicate the overfill point to the equipment operator
C) To help the grade setter set the next fill stake
D) To help the grade setter establish the elevation at the projected centerline grade

**10. What do the west and east toe grades on a ditch channel stake indicate?**

A) The distance across the channel
B) The amount of fill required at the base of the west and east slopes
C) The slope of the channel from west to east
D) The bottom of the slope on each side of the channel

# PLAN READING

# 2

The markings on survey stakes are a shorthand way of expressing what's on the plans. You need to be able to read and understand both the survey stakes and the plans to develop a picture in your mind of how the finished job will look.

This chapter covers how to read survey drawings of street and subdivision plans, including grading plans and contour lines, underground pipelines, profile sheets, road sections and cross sections and detour plans. During the course of a project you'll frequently be referring to the plans. It's essential that the grade setter and foreman understand the plans completely in order to do the work correctly. Any time a surveyor uses an unfamiliar abbreviation or notation on a stake, the foreman or grade setter will have to check the plans to see what it means. We'll look at the most common notations so you'll recognize them when you see them on plans you're reading.

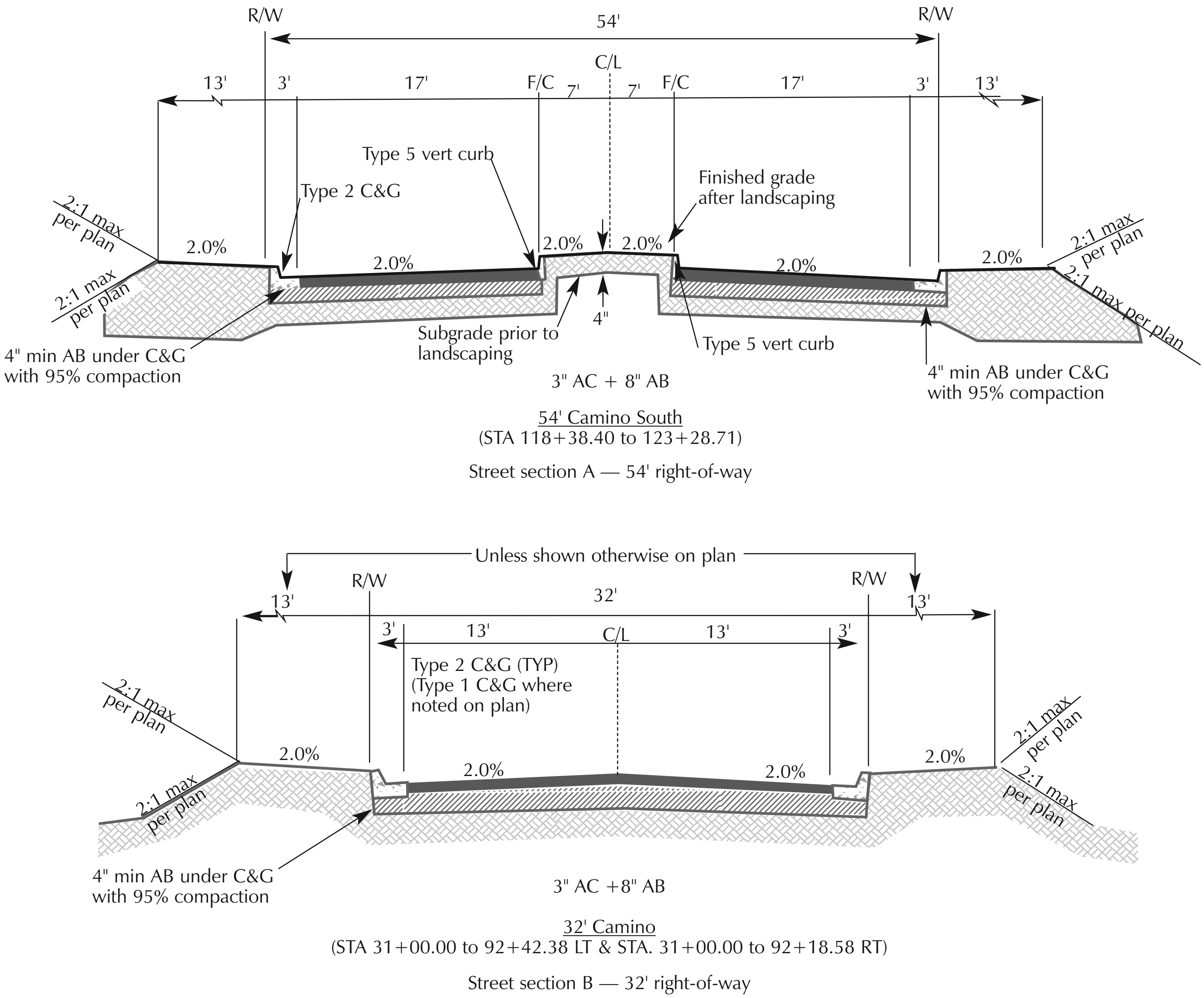



***Figure 2-1*** *Typical street sections*

# Subdivision Plans

Figure 2-1 shows two street cross sections. These street section drawings, usually referred to as the “typicals” are found in the front section of the subdivision plans. The engineer may elect to draw only half of each street, as that’s all you need when both halves are exactly the same. However, the engineer who drew the typicals in Figure 2-1 chose to draw the full width of the street section.

If there's a gap in the stationing on the typical street sections, it's because there's a transition area from one street section detail to another. Always check the station numbering closely to avoid a mistake. If the numbers indicate a missing section, you must look for the street section or sections that complete the distance. For example, if the stationing marked under the street section reads 31+00 to 36+00 — 40+00 to 68+00, you must locate the section that covers the 400-foot gap between station 36+00 and 40+00.

The two street sections in Figure 2-1 are part of a plan with a total of eight street cross sections for the same job. We selected these two because they show the greatest change in street width. Notice that the station numbers in street section A represent 490.31 feet of the street (subtract 118+38.40 from 123+28.71 or 11,838.40 from 12,328.71). Also notice that in street section B, the information provided covers a longer section of the left side of the street (31+00.00 to 92+42.38 = 6,142.38 feet) than the right side (31+00.00 to 92+18.58 = 6,118.58 feet). *LT* indicates the left side of the street and *RT* indicates the right side. That tells you that the change on the left side of the street goes 23.8 feet beyond the change to the right side.

## *Reading Station Numbers*

Let's take a closer look at how to read station numbers. We'll use the last station in Figure 2-1B, 92+18.58, as our example. The first number to the left of the + is a 2. That indicates 200 feet. The second number to the left of the + is 9, which indicates 9,000 feet. So, the numbers to the left of the + represent 9,200 feet. Now let's look at the numbers to the right of the +, 18.58. They represent feet and hundredths of a foot, just as they appear, 18.58 feet. The number to the right of the + can only go to 99 feet before it moves to the left and becomes 100 feet (represented by a 1), just like the numbers after the decimal point can only go to 0.99 foot before they become 1.0 foot. All station numbers begin at 0+00, so when you see station number 92+18.58, that tells you this point is 9,218.58 feet from the first station at 0.00.

To better understand this numbering system, let's read some other station locations:

| | | |
|---|---|---|
| Station 7+00 | = | 700.00 feet |
| Station 12+05.30 | = | 1,205.30 feet |
| Station 25+19 | = | 2,519.00 feet |
| Station 130+42.10 | = | 13,042.10 feet |

Remember, these are all distances from the first station at 0+00.

Street section A in Figure 2-1 indicates that it may be found on the plans from *Station 118+38.40 to 123+28.71*, and there's 54 feet from right-of-way line to right-of-way line. Notice that each right-of-way line is indicated at the back-of-curb. This is important for the grade setter. He needs to check the cross section to be sure that the back-of-curb and the R/W are the same distance. A street *cross section* shows details of the street in 50-foot sections, and will show any deviations in widths not shown on the typical. The surveyor may only give the distance to back-of-curb with a cut or fill to the top-of-curb. The surveyor's stake would be set 4 feet back-of-curb, so the front of the stake would read *4* (the 4 is circled) *R/W & BC* with a grade for the curb and centerline. If it were a subdivision street, the surveyor would set a stake at the lot setback line with distance and grades for back-of-curb, centerline and lot grades, but not for right-of-way.

The note directly under the curb tells the grade setter that 4 inches of aggregate base (AB) are required under the curb. He'll have to add the thickness of the curb and the 4 inches of AB together to compute his subgrade elevation. The ideal subgrade situation occurs when the curb subgrade and street subgrade are the same and there's no need for a notch to be cut up or down from curb grade. Looking at the street section, you can see that this is the case here. There's a line drawn the width of the street for subgrade with no notch, indicating that the subgrade and curb grade match.

Below the right-of-way line (R/W) measurements, you'll see the measurements for a 13-foot dirt shoulder, 3-foot curb, 17 feet of pavement and 7 feet of island from the face-of-curb to the centerline (CL). The same measurements are shown for the other side of the road as well, with both sides matching.

Now let's look at the finished slope grade, starting at the far left. First you'll see *2:1 max / per plan* on one line slanting up and one line slanting down at the same angle. This indicates you must build a two-in-one (2:1) slope from the dirt shoulder, regardless of whether it's a cut or a fill. This is the same on the right side slope as well; the slope moves 2 feet horizontally for every 1 foot of rise or drop.

Next you see *2.0%* above the shoulder. That tells you that the 13-foot shoulder slopes 2 percent from the slope hinge point (HP) to the top-back-of-curb. Continuing towards the centerline, there's a notation saying that a *Type 2 C&G* (curb and gutter) is required. The grade setter will then have to find a cross section of the Type 2 curb. Usually it's in the agency's specifications rather than on the plan. The specifications will show the height from the top of the curb to the bottom, and the thickness of concrete required. It will also show the rate of slope of the curb pan, the flat or gutter portion of the curb and gutter.

Continuing to read to the centerline, you'll see the percentage of fall for the pavement from the island curb to the curb and gutter. Notice that the island curb is a vertical curb, not a curb and gutter. The rate of fall is shown as *2.0%* and the distance is 17 feet. So the grade setter will compute the fall rate by multiplying 17 feet by 2 percent. Using a calculator, enter 17 × 2, and then press the percent key — the result will read 0.34. The 0.34-foot fall is from the front of the island curb to the lip of the curb and gutter. To cut subgrade, the curb width on each side must be added to the 17-foot pavement width. An island curb is usually 8 inches wide and the curb and gutter 3 feet wide, for a total of 3.67 feet. So the distance would then be 20.67 feet. Multiplied by 2 percent, that gives you a 0.41-foot fall across the entire subgrade.

The street detail shows a minimum of 4 inches of aggregate to be placed under the curb. The street section calls for 3 inches of asphalt concrete (AC) plus 8 inches of aggregate base (AB) for a total depth of 11 inches. This information is located on the drawing just above the street name, Camino South. Cutting the subgrade 2 percent, which is a 0.41 drop in 20.67 feet across from the back of both curbs, would make the subgrade and the curb subgrades the same. The curb grade is often steeper than the street grade. If you cut 2 percent to back-of-curb, it'll add more than 4 inches of aggregate under the front lip-of-curb. These are items the grade setter and foreman must take into consideration when excavating to subgrade elevations.

The next item we come to is the barrier curb at the island. The note above indicates a *Type 5 vertical curb*. Again, the grade setter must check the specifications for the height and width of the Type 5 curb. The *2.0%* indicated on the top of the island is the amount the finished landscaping will fall from the centerline to the back of the island curb. Again, the specifications or notes on the plans will specify what material is required for the island section and how much below top-of-curb the subgrade should be.

There are two important things the grade setter must pay attention to: first, that the aggregate road base runs to the back, not the front, of the island curb; and second, that the subgrade between island curbs must be left 4 inches below the finished landscape grade. This is indicated by the note under the island on the street detail sheet and the measurement noted below. If the grade setter missed those two items in the specifications, the island choker would be left too wide and high, causing a major problem if no one noticed them before the subgrade was trimmed.

The 2 percent aggregate base grade in the street sections (both A and B) doesn't match the bottom of the curb and gutter, so the curb must be trimmed and poured before the final trim on the aggregate can be completed. The curb pan usually slopes 7 percent. The street section doesn't show the slope for the bottom-of-curb. That information, as well as other curb measurements, is in the curb specification.

The second street section (B) is essentially the same as the first, minus the island at centerline. In addition to the street cross section drawings, there's usually a sheet index for other streets, a grading plan, a water plan, a sewer and drainage plan, and an electrical and landscaping plan. There may also be a plan of standard drawings and notes in the index.

## *The Grading Plan*

Figure 2-2 is a partial subdivision grading plan showing several lots and the streets running through them. This sheet will supply the foreman and grade setter with all the information needed to cut the streets and to grade these lots. Each lot is numbered. The lot number is the large number in the center of the lot. The underlined numbers you see just below the lot numbers are the finished lot or pad elevations. Notice that lot pad 41 has a finished grade of 440.0. This means that the pad is 440 feet above sea level. Lot pad 40 has a finished lot pad grade of 442.2, which indicates it's 2.2 feet higher than lot pad 41.

Between the lots there are two lines very close together and some that appear to be one thick line. These are the property lines and toe-of-slope lines. Somewhere on the plans there will be a lot detail drawing indicating the required slope and how far from the property line the slope will start. Usually the slope between lots is no less than 2:1, and begins 1 foot out from the property line of the highest lot. From the toe-of-slope line on the drawing there are several elongated Y's that indicate the direction the slope falls. The top of the Y is at the top of the slope. Some plans will indicate the slope direction with a V, with the small end of the V being the toe. You may find a vertical cut for a wall rather than a slope is indicated. If a retaining wall is called for on this rough grade sheet, you won't see the elongated Y's. The lines will probably show small squares, indicating

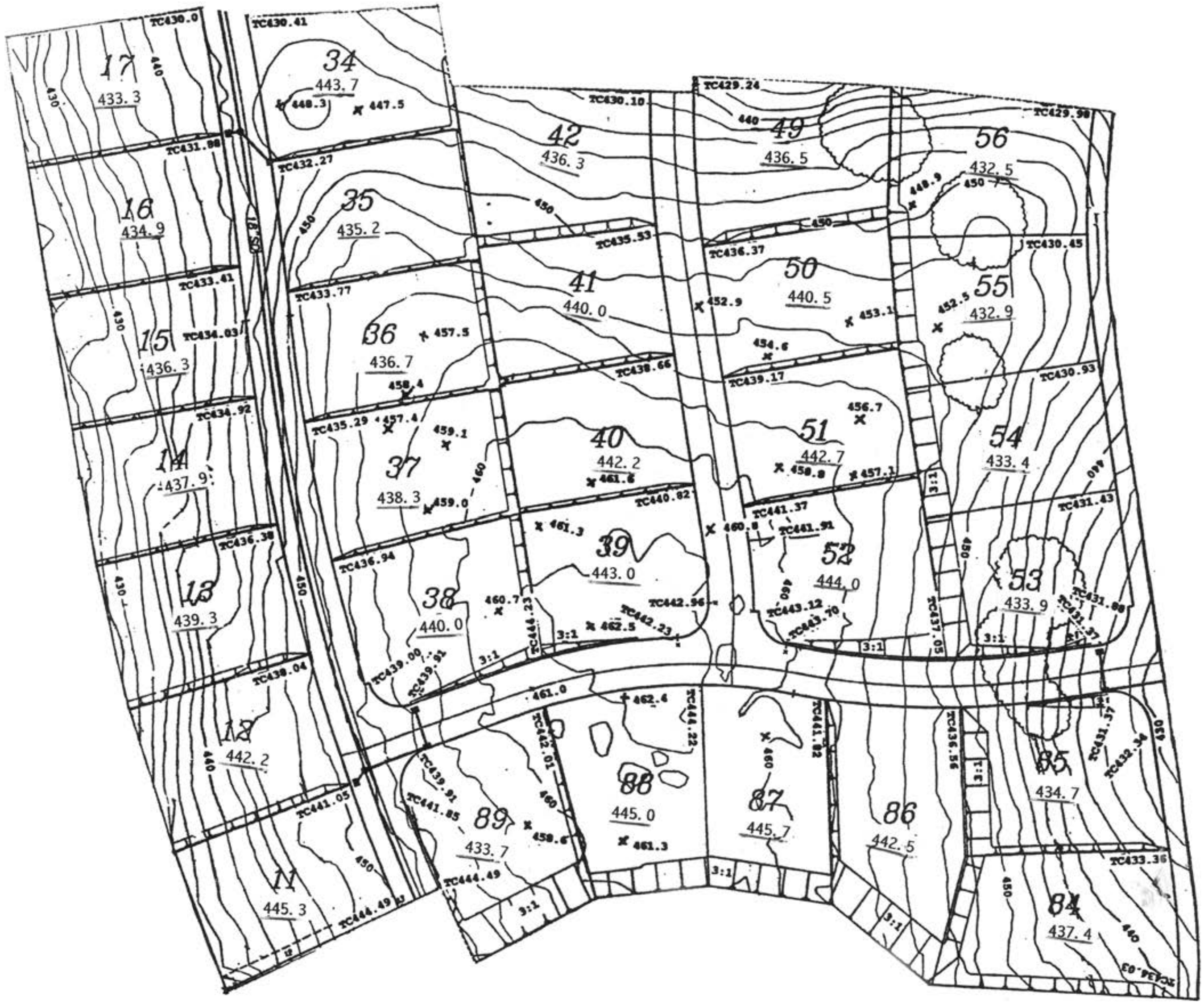



***Figure 2-2*** *Grading plan*

blocks or posts. If this is the case, be sure to overcut the vertical enough for the wall to be placed. The grading plan will have a detail drawing of the wall for you to study.

Find lots 51 and 52. Like most lots on this plan, these lots have a slope on both sides and the back. You can tell by how short the Y's are between them that there isn't much of an elevation change — only 1.30 feet, to be exact. Now look at the back and side yard at the street. You'll see the stems of the Y's have stretched out considerably. You have to look very closely at this drawing because the Y's are so small it's difficult to determine which end is the top of the fill. However, you can always look at the elevations to find which lot is higher. Check the top-of-curb elevation at the back corner of pad 52. It reads *TC 437.05*. Pad 52 elevation reads *444.0*. That's a difference of 6.95 feet, almost 7 feet, from the lot pad to the back corner. Just keep in mind when looking at grading plans that the longer the Y's, the more grade change there is between lots.

The engineer who designed the grading plan has indicated a 3:1 slope along the street side of lot 52, extending around the back for several lots. Look at the elevation difference between lot 52 and lot 54. It's 10.6 feet. You find this by subtracting the lower lot elevation (lot 54, EL 433.4) from the higher lot elevation (lot 52, EL 444.0). The engineer doesn't indicate a slope at the front of each pad, but there's always one there. Check the elevations for top-of-curb at the front corners of lot 51. One reads *TC 439.17*. The other reads *TC 441.37*. Now subtract those numbers from the lot pad elevation of 442.7. The result shows that one corner is 3.53 feet lower than the pad and the other corner is 1.33 feet lower.

The reason a slope with elongated Y's isn't shown at the front is because when the lots and streets are rough graded, the fronts are always undercut. There'll be front lot stakes offset from the lot corners at the point that the front slope to the curb begins. This is called the *setback* line. A lot pad detail drawing will give the distance from back-of-curb to the setback line. (The chapter on Excavating Subdivisions will cover front lot excavating in detail.)

Notice the cut slopes usually begin 1.0 foot out from the property line of the highest lot and the slope itself is part of the lower lot. The only time this would change is if there were an existing property that wasn't part of the project. In that case, the slope wouldn't be built onto the adjacent property.

### Contour Lines

The irregular lines running throughout the grading plan are called *contour lines*. In this drawing, they indicate the existing ground elevation before grading begins. Contour lines help the foreman and grade setter establish an excavating plan. By following the contour lines, you'll notice all the center lots are cuts. The only fill lots are the backs of lots 11 through 17 and a small back area near the property line on lots 84 and 85. The contour lines marked on this plan show an elevation at every 10-foot change in elevation. If you look at lot 15 you'll see a contour line marked 430. Wherever that line wanders, it will always be at elevation 430.

Now, look at lot 12. It has a contour line marked 440 that you can follow all the way through to lot 17, where it's once again marked. On lot 17 you'll notice there are five contour lines between the 430 contour line and the 440 contour line. This indicates that each contour line between 430 and 440 is a 2-foot rise in elevation. Looking at the street area in front of lot 13, you'll find a 450 contour line. Following that line, you'll see it makes a semicircle around the grading plan, crossing through lots 35, 42, 56, 55, 54, and 53 before running between lots 85 and 86 and then off the map through the back of lot 84. Keep in mind that there's a 2-foot difference in elevation from one contour line to the next regardless how close or how far apart they are.

To establish a fill area you must find where the contour line elevation is lower than the lot pad or street elevation. Looking at lots 13, 14, 15, 16 and 17 you can see that contour 430 runs through the back of each one. If you look at finished pad grade on these lots, you'll see that the finished grade will be higher than 430, so a fill is required. The same is true of lots 11 and 12. Contour line 440 running through lots 11 and 12 indicates a fill will be required to reach their lot pad grades of 445.3 and 442.2. Contour line 430 runs through the front corner of lot 85. That lot will require fill at the front in order to bring it up to the finished pad elevation, even though the center of the lot requires a cut.

Notice there are several grades with small x's next to them throughout the plan. Lot 37 has three of these elevations marked. These are an added bonus the engineer has left on the grading plan. They're shots the surveyors took while establishing contours, and are helpful in determining the existing ground elevations in the cut and fill areas.

By following contour lines and checking them against TC (top-of-curb) elevations and lot elevations, the grade setter or foreman will know before the job is staked where the cuts and fills are required. It's a good idea to color the plans — shading the cut areas in red and the fill areas in blue — so they're easily distinguished from one another. Some contractors have computer programs that will color-code the plans and also estimate the yardage of fill or cut required, saving the foreman or grade setter the time of figuring this work. These programs make it easy to anticipate problems and get the maximum productivity from the equipment. The foreman can study the computer printout before starting work and have the excavation procedures worked out before ever seeing a stake.

The estimator can also use this grading plan to determine the length of the hauls from cut to fill, and to figure the cost per yard for excavating and compacting for his estimate.

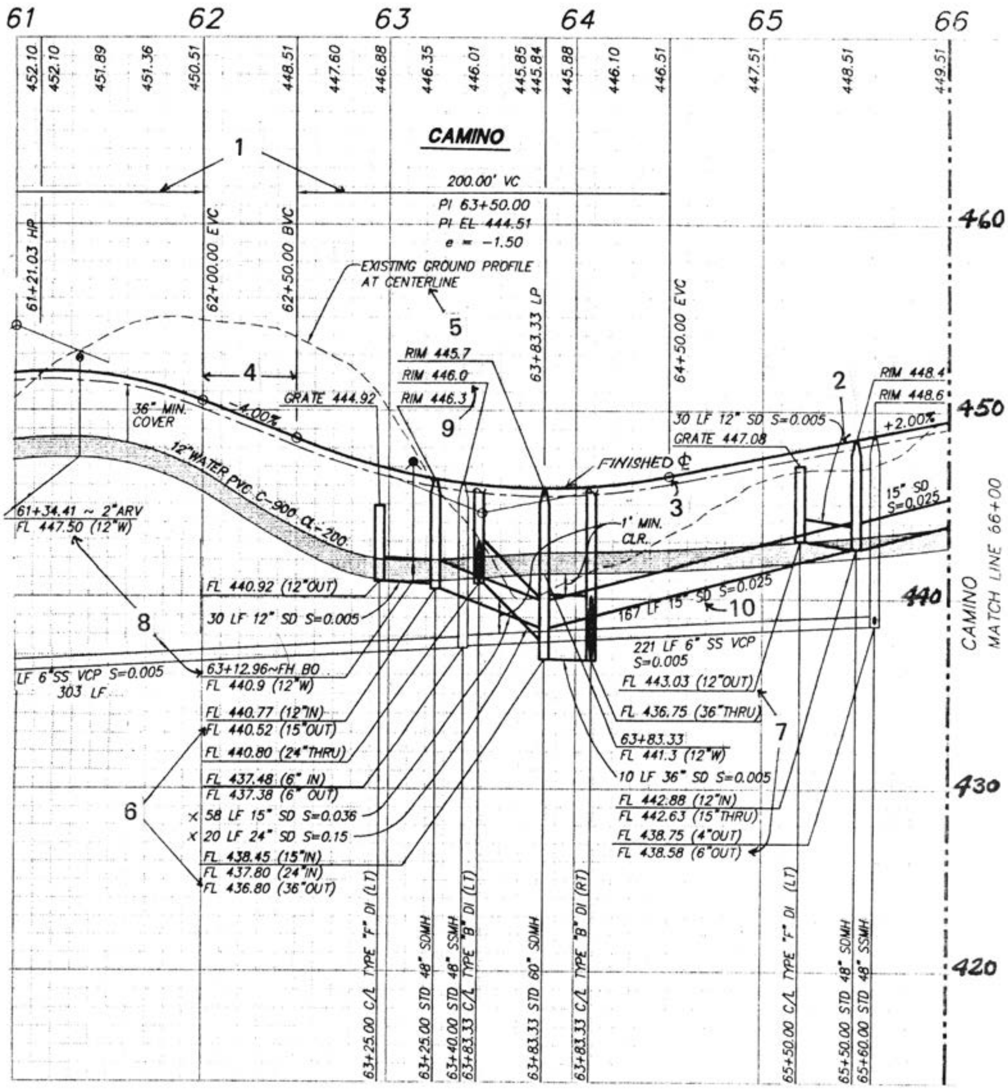



**Figure 2-3** *Profile sheet*

## Plan and Profile Sheets

There will be a plan and profile sheet similar to Figures 2-3 and 2-4 for every street in the project. The plan and profile sheets add information not provided on the grading plan or the street cross-section drawings. Figure 2-3 is the profile of a 500-foot section of Camino Drive, including a plan for the sewer, water and drainage lines. Profiles are drawn on graph paper. In this case, each large square represents 10 vertical feet and 10 horizontal feet. The small squares that are faintly visible each represent 1 square foot.

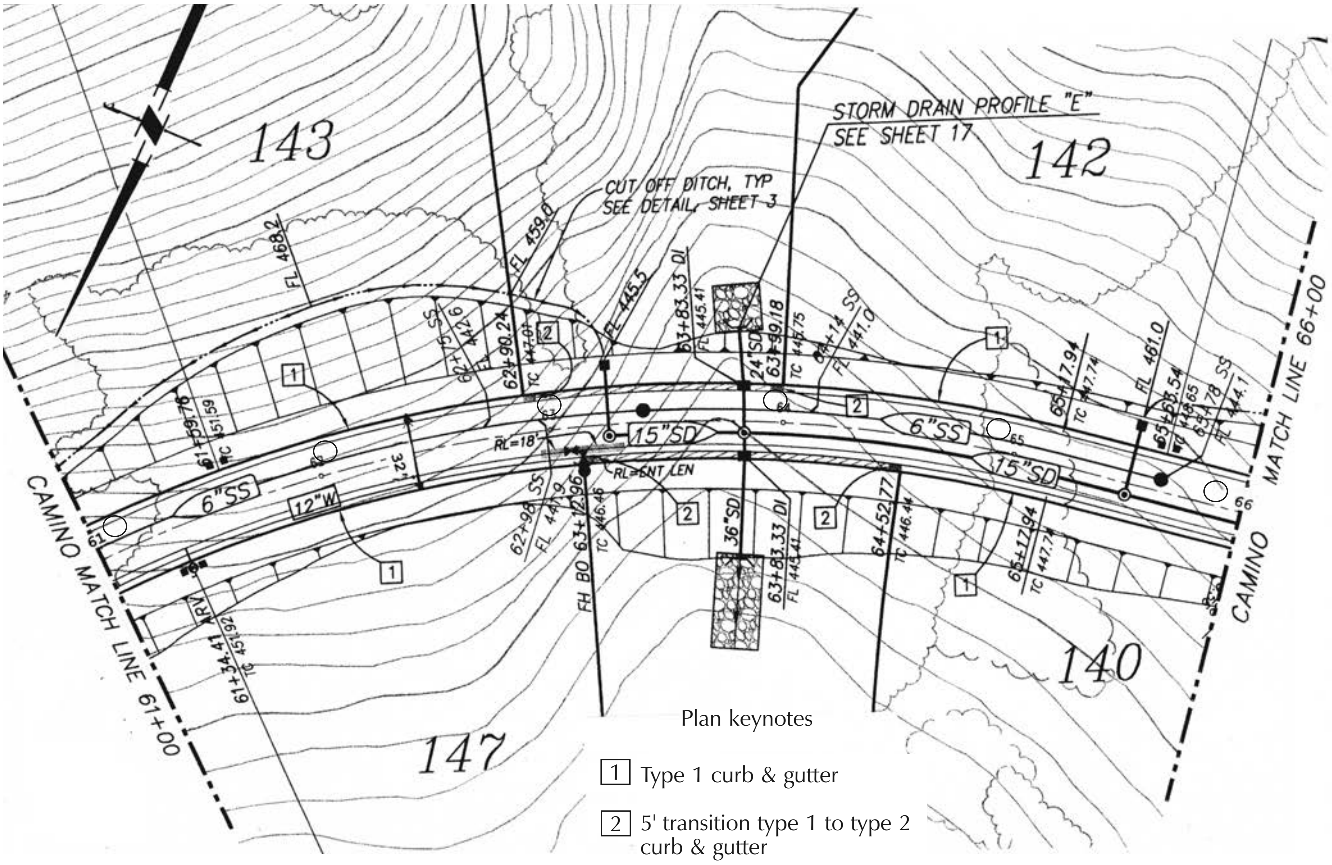



***Figure 2-4*** *Plan sheet*

Going up the right side of the graph paper are the elevations, from 420 to 460 feet above sea level. At the top of the graph are numbers from 61 to 66. These are the stations indicated along the centerline. These stations are also shown at centerline on the plan drawing in Figure 2-4.

There are callout numbers added to the profile plan in Figure 2-3 to help locate the areas that we'll be discussing. Find number *1*. The arrows point to lines indicating the length of the two vertical curves on this sheet. The vertical curve in the center of the plan is a concave vertical curve. The one to the left is half of a convex vertical curve. Both are 200 feet long. These vertical curves indicate what the centerline grade is doing. Number *2* points to the centerline. To the right of the point indicated by *2* you see *+2.00%*. The + in front of the 2% indicates the grade is increasing from the smaller station numbers to the larger ones. Follow the centerline to the left until you see a small circle and the number *3*. The circle indicates where the vertical curve stops and the *2* percent grade starts. Further to the left, number *4* shows a small 50-foot section of street between the vertical curves that falls –4%. That would be a drop in grade of 2 feet in 50 feet. Notice also in the same area that there are small circles on the centerline that show where the concave vertical curve starts and ends, and another indicating the end of the convex vertical curve (located at number *3*, to the right).

Number *5* indicates the existing ground profile (represented by the broken line) in relation to the centerline. Notice that the existing ground line shows that there's mostly cut on the left side of the profile sheet and mostly fill needed on the right in order to build the street to the finished centerline grade.

Between elevations *460* and *450* on the right, and reading to the left across the page, you can see five station numbers written vertically. They are *64+50.00 EVC (end vertical curve), 63+83.33 LP (low point), 62+50 BVC (begin vertical curve), 62+00 EVC (end vertical curve)* and *61+21.03 HP (high point)*. The numbers are the precise station at the center and end of each vertical curve.

At the very top of the profile plan are the elevations of the street centerline finished grade. Looking down at the centerline below (refer again to number *2*), you'll see a smaller broken line that follows the centerline grade, but just below it. That's the curb flow line grade. Because the curb flow line exactly parallels the centerline grade, no curb grade is present. With a constant 2 percent street grade from centerline to curb, the surveyor can easily compute the flow line from the centerline grades. If there were a variation in the curb elevations or the street percentage from centerline to curb, there would be a second set of elevations for curb grades marked below the centerline elevations.

The bottom of the profile plan has station numbers written vertically that indicate the center locations of *manholes (MH)*, *drop inlets (DI)*, *sanitary sewer (SS)* lines and *storm drain (SD)* lines. Manholes are also indicated on the profile sheet by two parallel lines that come to a point at the centerline. Drop inlets are usually two parallel lines with a flat top.

Number *6* shows a string of elevations for pipe in and out of manholes, with the size and *flow line (FL)* elevation. The two marked with X's indicate 58 linear feet *(*LF*)* of 15-inch storm drain pipe and 20 linear feet of 24-inch storm drain pipe. It gives the rate of slope for each, and points to the area where they'll be placed. Number *7* (top) shows the flow line elevation and pipe size for a manhole and storm drain and the bottom arrow shows sanitary drain and service piping elevations. All the numbers in this lower area are for the underground placement for water, sewer and drainage piping.

Number *8* indicates two items. The first is the station elevation for a 2-inch air relief valve (*2" ARV*) and the flow line elevation of the 12-inch water line (*12" W*), and the second (lower arrow) is the station elevation where a fire hydrant blow off (*FH BO*) will be installed and the flow line elevation of the 12-inch water main.

Notice just below and to the left of the number *3*, there's a small notation that reads *1' MIN. CLR.* If you follow the arrows, the first one points to the drain and sewer lines and the second to the drain and water lines, indicating that there must be a minimum clearance of 1 foot between these lines. There's another notation just below the centerline at station 62+00 that shows that 36 inches of cover is required over the water line.

Number *9* points out three groups of numbers showing the street level elevations for three manhole rims (*RIM*). The grate elevation to the left of these (444.92) is the top of the drop inlet grate, which is located behind the curb area, and picks up water from a ditch at the toe-of-slope.

Notice that below all sewer and drain pipe you'll find a notation indicating the type and size of pipe, the rate of slope and the length of pipe needed. If there's no room under the pipe for this information, there'll be a line with an arrow and a note below that with the information. Number *10* shows *167 LF - 15" SD S=0.025*. That's 167 linear feet of 15-inch storm drain with a slope of 0.025. You can use the slope to compute the amount of fall in that section of drain line. Multiply 0.025 by 167 feet. This will tell you the pipe falls 4.175 feet in 167 feet ($0.025 \times 167 = 4.175$). The street grade is 2 percent per 100 feet. To compute the fall of the street grade, multiply $100 \times 0.02 = 2.00$, which shows the grade drops 2 feet every 100 feet. You can also calculate this using the percentage key on your calculator. Enter $100 \times 2$ and hit the % key. You'll get the same answer.

### Plan Sheet

Figure 2-4 is a top view of Figure 2-3. If you look closely, you can find the street width identified as 32 feet in about the middle of the left-hand side of the drawing. This is the width of the street from right-of-way to right-of-way, as shown in the street section detail, Figure 2-1, street section B. The thin line down the street is the centerline. It has a small circle every 100 feet indicating the stations from 61+00 to 66+00. The station is marked at each circle with 62, 63 and so on.

Above the centerline, the plan indicates a 6-inch sewer line, *6"SS*, with two manholes (these were shown in Figure 2-3 as well). The manhole at station 65+63.54 shows the 6-inch sewer ends there. There's also a sewer service coming from that manhole to back-of-curb at station 65+78 marked, *SS FL 444.1*.

There's a 12-inch water main running just inside the curb on the lower side of the street drawing (see *12"W* indicated on the left side of the drawing). It shows an air relief valve at *ST 61+34.41 ARV* and a fire hydrant blow off at *FH B0 63+12.96*. In addition, it shows two valves next to the fire hydrant blow off, indicated by the two black bowtie-looking symbols (they are perpendicular to each other and a little hard to see in this drawing). You can also see sewer services connecting to the lots at stations *62+75 SS, 62+98 SS* and *64+14 SS*, as well the one already mentioned at *65+78 SS*.

The squares with the numbers 1 and 2 in them pertain to plan keynotes at the bottom of the drawing indicating the type of curb required at that location. The elongated Y's on the upper side of the street indicate a slope coming down to the road shoulder ditch, with a swale or shallow channel at the top of the slope which will drain water away from the road. The flow line arrows indicate the direction of water flow. Notice they point in opposite directions away from the summit elevation marked *FL 468.2*. The elongated Y's on the lower side of the road indicate a slope from the road shoulder going down. These slopes are 2:1 or less, as indicated in Figure 2-1. The large arrow (top left) with the "*N*" indicates the direction to North.

The small black squares located at stations *61+34.41, 61+59.76* and *65+63.54* indicate the water services to those lots. There's also a 15-inch storm drain line on the lower side of the street. The bullet-shaped box indicates the size of the pipe and the direction of flow. There are three drop inlets on the upper side of the street and one on the lower. These drop inlets are designated by a black square with a line running to the manhole (circle with a black dot) on the storm drain line. Notice two of the drop inlets are behind the curb on the upper side and only one is in the curb. There are three manholes shown on the 15-inch drain.

There are two rock erosion control pads at each end of the cross drain line at station *63+83.33*. This cross drain goes from a 24-inch to a 36-inch pipe as it picks up water running down the slope and out the other end.

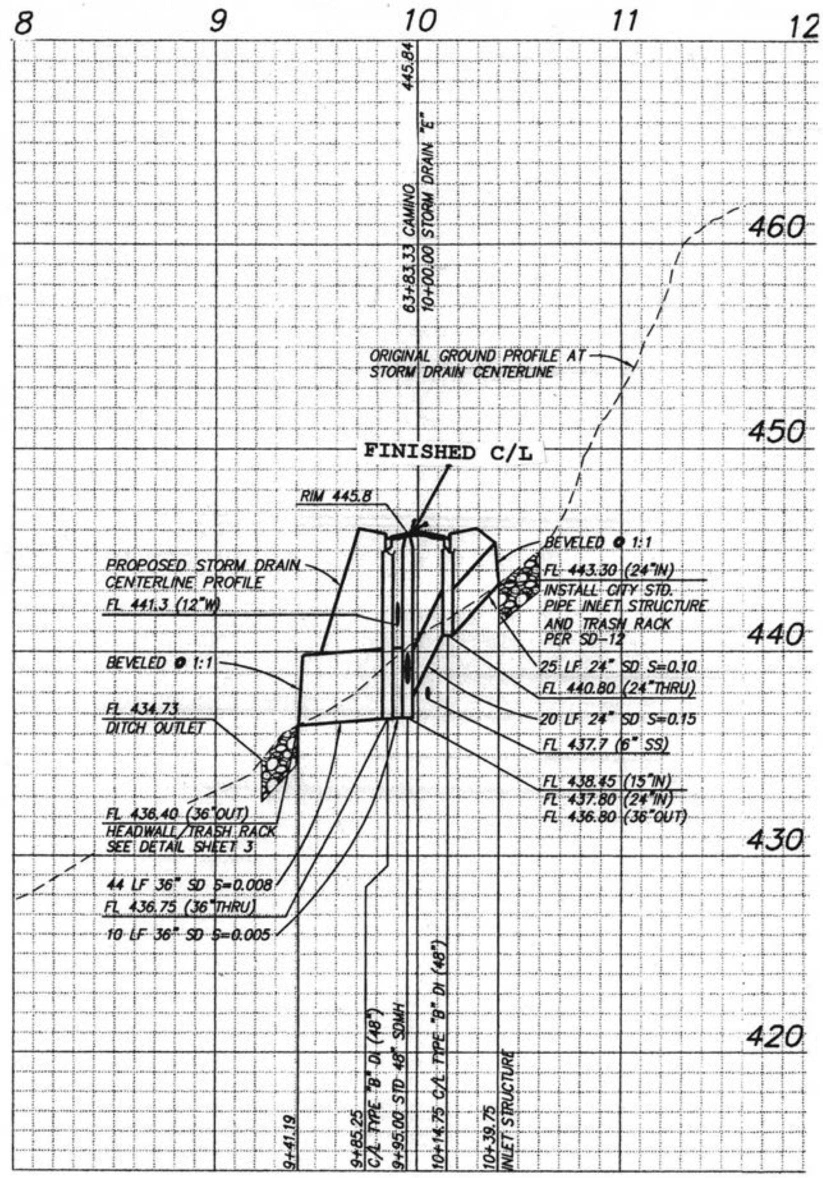



***Figure 2-5*** *Drain profile "E"*

There's a note pointing at the upper end of the drain pipe that says: *Storm Drain Profile E, See Sheet 17*. Figure 2-5, titled Drain Profile "E", shows a cross section of that area. Looking at Figure 2-5 you can see the dashed line indicating the original ground profile. This gives you a better idea of why the cross drain pipe is needed, and also shows the two drop inlets in the curb. Notice the height of the road fill. Also note that the ditch inlet and outlet on each side of the road match the existing ground.

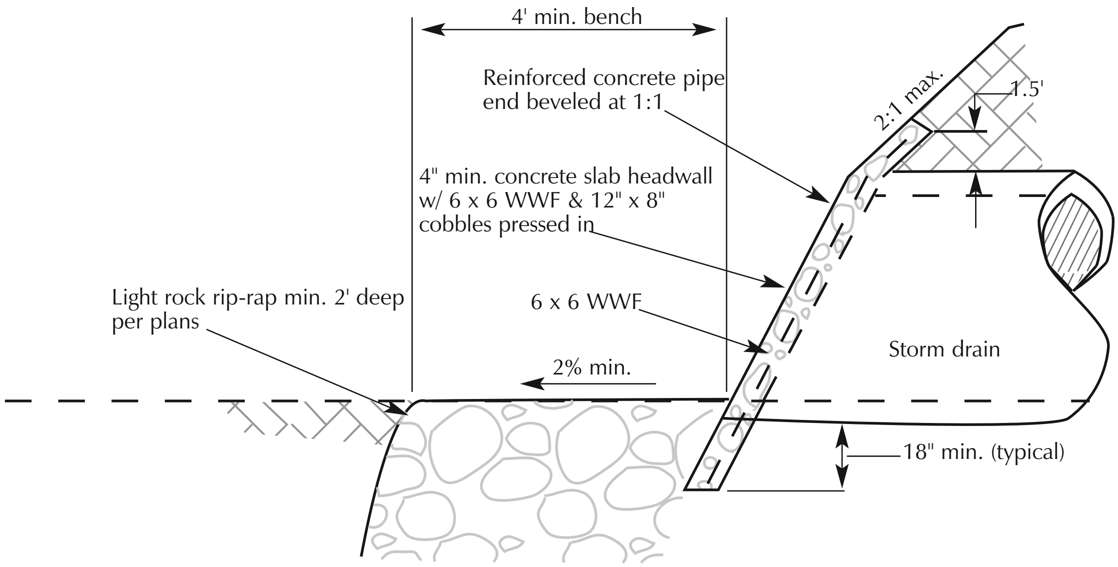
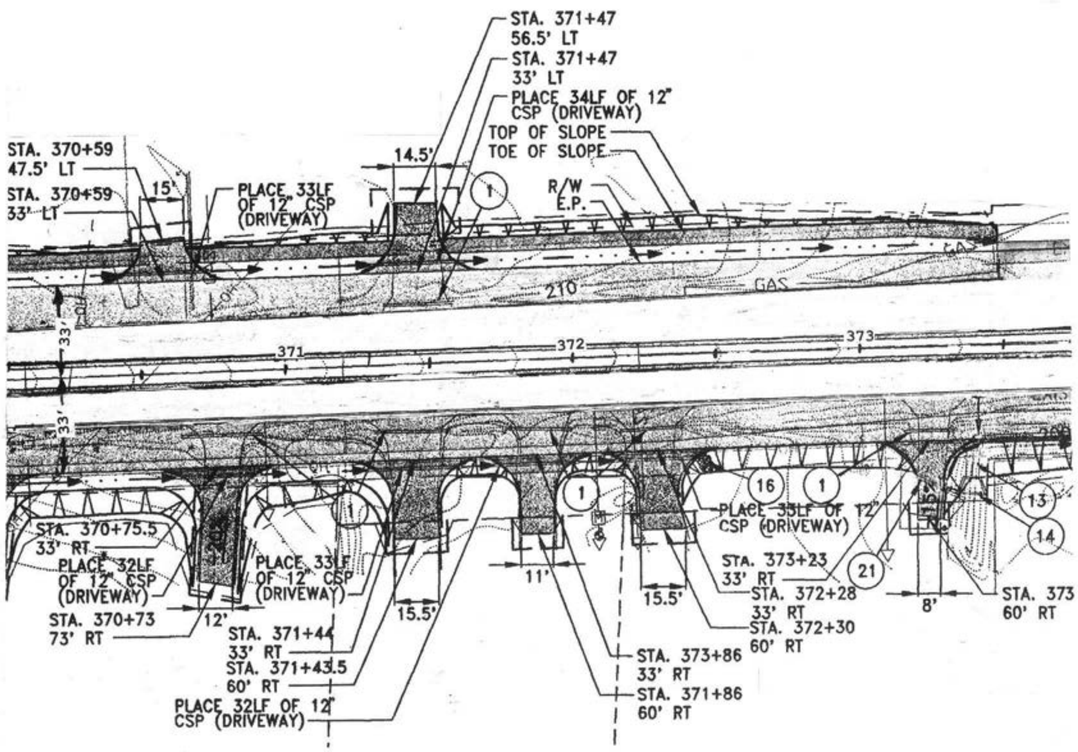



***Figure 2-6*** *Headwall detail*

You can see the road section and shoulders at the top of the drawing in Figure 2-5 and a slope down to the pipe on each side. The slopes look much steeper than they actually are. The long cylindrical objects in the street area indicate a manhole and drop inlets. This drain profile is the same as the one shown in Figure 2-3 except with more detail. It gives all the pipe elevations, with the required pipe lengths and sizes.

Under the pipe and erosion control pad on the left side of the detail drawing there's a note referring to *Detail Sheet 3*, which is shown in Figure 2-6. Looking at that figure, you'll see that it provides the details for building the outlet headwall. It shows the wall 1.5 feet above the pipe and 18 inches below, tells how much concrete is needed, the size of welded wire fabric (WWF) required, and what size cobbles must be used. It gives the length and depth of the rip-rap and calls for a 2 percent minimum slope. It also shows the dirt slope above the headwall to be a 2:1 maximum slope.

These are all the types of details you'll find on the plans and job specifications. This should give you an idea of how much information you can get from the profile and plan drawings and how important it is to have a clear understanding of what's required before you start working. Looking at Figures 2-3, 2-4, 2-5 and 2-6, it's obvious that it takes all four drawings to give you a complete picture of what's needed and how and where to build it. Studying the plans makes reading the survey stakes much easier.




(16) 4' x 8' (32 SF) rock energy dissipater, light, Method B

(21) Place 21LF of 12" CSP,
STA: 373+17, 44' RT elev. = 203.8
STA: 373+35, 53' RT elev. = 202.0

(1) Remove driveway culvert

(13) Place 10LF of 53" x 41" SRPA, 14 GA, S=0.023
FL @ 3-piece elbow = 199.27'
FL @ headwall = 199.50'

(14) Construct inlet structure with trash racks,
see Detail Sheet, ST-02

***Figure 2-7*** *Road plan*

# Highway Plans and Cross Sections

Highway projects are more complicated because traffic control is usually required. The work might need to be done in stages to allow for continuing road use. The highway plans will include sheet drawings for the road signage, landscaping, street and traffic lighting, and a striping plan. If the work is to be done in stages, there'll be a detour staging plan as well. A road built through open acreage with no traffic or utilities is much easier and faster to build.

Let's look at a road improvement project where an existing road is to be widened, some old surface removed, and some overlaid (Figure 2-7). What you'll probably notice first when you look at the figure are all the darkened areas and the notes with elevations and numbers on the sheet. The darkened areas indicate the new pavement sections. The notes with circled numbers 1, 13, 14, 16 and 21 are instructions. Look at note number *1,* bottom right side. It reads: *Remove driveway culvert*. There are four areas designated with the number 1. They're the existing driveways and culverts that need to be removed.

Let's look at the other notes. Find note number *13*. It reads: *Place 10 LF* (linear feet) of *53" × 41" SRPA* (steel-reinforced pipe assembly), *14 GA* (gauge is the pipe thickness), *S=0.023* (the pipe slope when laid). Below that it reads: *FL @ 3-piece elbow = 199.27'* and *FL @ headwall = 199.50'*. By subtracting 199.27 from 199.50 you get a 0.23-foot difference in the flow line from the entrance of the headwall to the entrance of the pipe assembly elbow.

Number *14* reads: *Construct inlet structure with trash racks, see Detail Sheet ST-02*. It's typical throughout a set of plans to be directed to a Detail Sheet for more information. Sheet ST-02 will be a drawing of the headwall trash rack that shows how it connects to the 53- × 41-inch steel-reinforced pipe assembly in number 13. Notice at the bottom right of the drawing that numbers 13 and 14 are together.

Look at number *16* on the left side of the drawing. It reads: *4' x 8' (32 SF) rock energy dissipater, light, Method B*. Now locate 16 along the street plan. Notice it points to a dark shaded area where the 4- × 8-foot pad of rocks is to be placed. If you look closely at the same spot, there's a note: *Place 33 LF of 12" CSP (Driveway)*. Above number 16 are several small V's (rather than Y's), indicating a slope. This shows that the corrugated steel pipe (CSP) is running under the driveway and coming out at the upper portion of the slope, and a 4- × 8-foot rock pad is needed to prevent slope erosion.

The last note, number *21*, reads: *Place 21 LF of 12" CSP, STA: 373+17, 44' RT elev. = 203.8, STA: 373+35, 53' RT elev. = 202.0*. This is the only driveway culvert on this sheet that gives an elevation at each end, and the exact distance to the right of centerline for each end to be placed. This is so it won't conflict with the 3-piece elbow and headwall (see 13 and 14) located in the same area.

The other notations that say *Driveway* give the size and length of pipe, but not the elevations. That's because the ditch for those driveways will be cut to grade using the surveyor's grade stakes. The stakes will be set for excavating the road. And once the ditch is cut to grade and the ditch slopes are finished, the driveway culvert will be laid to match the ditch grade.

*STA. 371+47* in the top center of the plan has an arrow pointing down to a darkened edge. This indicates that *STA. 371+47, 56.5' LT* is where the new driveway pavement ends. The 56.5' LT means 56.5 feet left of the road centerline. Reading down, you see *STA. 371+47, 33' LT*. That arrow points to the start of the driveway pavement, 33 feet left of the centerline. The driveway length is 23.5 feet, and the width is shown as 14.5 feet. The plan will also include a driveway detail that will provide information on what radius taper is needed where the asphalt drive meets the street asphalt.

Reading down to the next note you see: *Place 34LF of 12" CSP (Driveway)*. This indicates a 12-inch driveway culvert is to be laid. The arrow points to a small double line indicating a pipe. There's no pipe elevation given, indicating it will match the ditch grade when laid. Reading down, the next lines read: *Top-of-Slope, Toe-of-Slope, R/W* (right-of-way line), and *EP* (edge-of-pavement). All the other notes cover the same subjects. The only difference is the station numbers, the length of the pipe, the distance and direction (left or right) from the centerline, and the width of driveways.

The light-colored area in the center of the plan is the existing road with an island running down the center. The thin line down the center of the island is the centerline. It has small black dashes marked every 50 feet and station numbers shown every 100 feet (371, 372 and 373). There's a paved sidewalk on the left side of the road at the back-of-ditch. We'll see the sidewalk details later.

Now look at Figure 2-8. These are cross-section drawings of each 100-foot station you reviewed on the plan drawing. The first cross section at the top shows station *371+00*. Notice that the left side of the drawing has the numbers 206 to 220, rising vertically from the bottom to the top. These are elevations; each horizontal line on the sheet represents 2 feet. The numbers across the bottom from 0 to 50 are the distance in each direction from the 0 centerline; each vertical line represents 10 feet. The distances to the left of centerline are given as minus numbers and the distances to the right are positive. The engineer who drew these plans used this method to indicate right and left of centerline, rather than RT and LT. Either method provides the surveyor with the information he needs.

Notice the two elevations marked vertically along each side of the 0 centerline at station 371+00. 213.5 is the centerline grade of the existing (old) road. The top broken line running horizontally across the middle of the drawing shows the ground profile and grade of the old road. The bottom broken line (in the center of the drawing) indicates the subgrade of the old road.

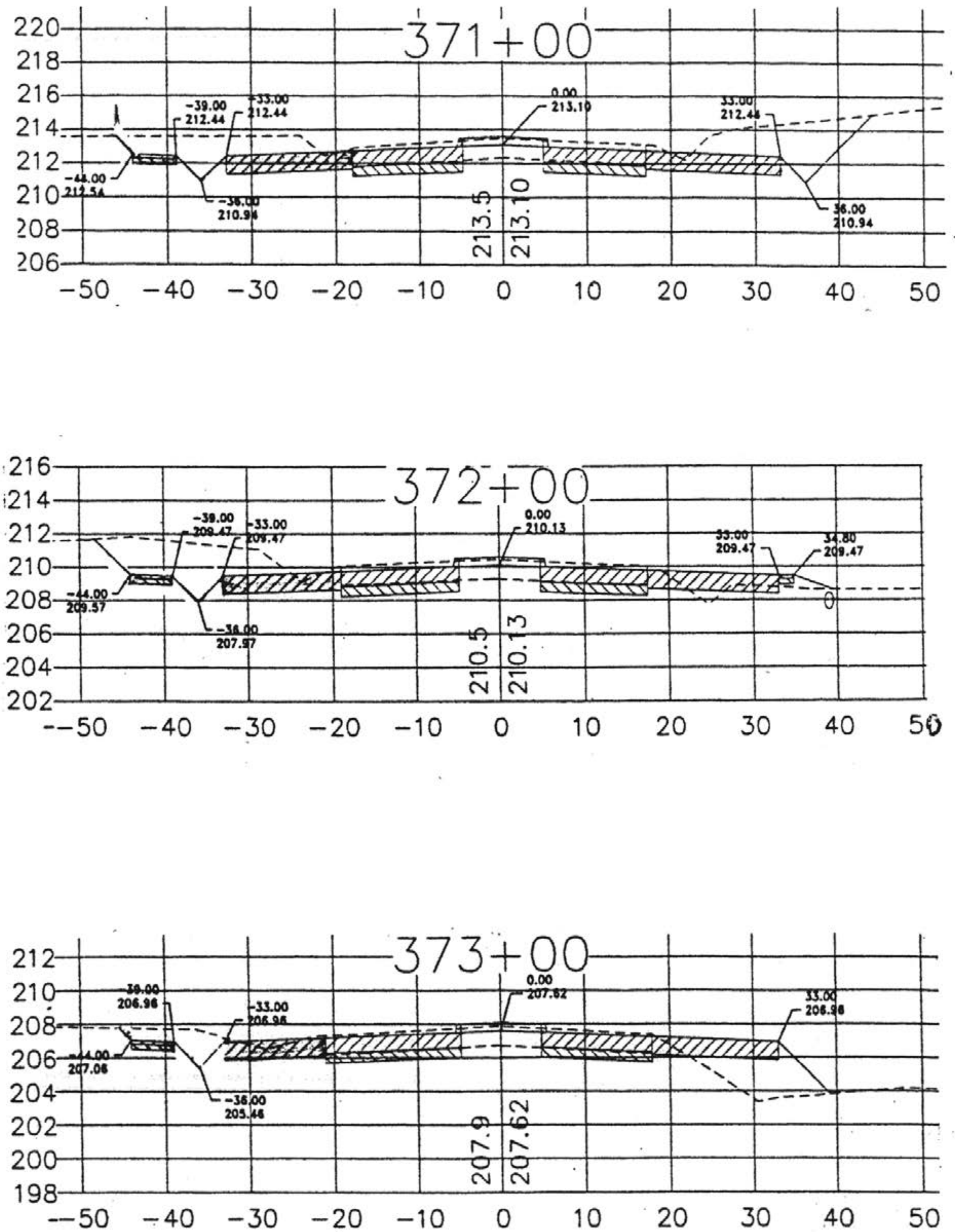



***Figure 2-8*** *Road cross sections*

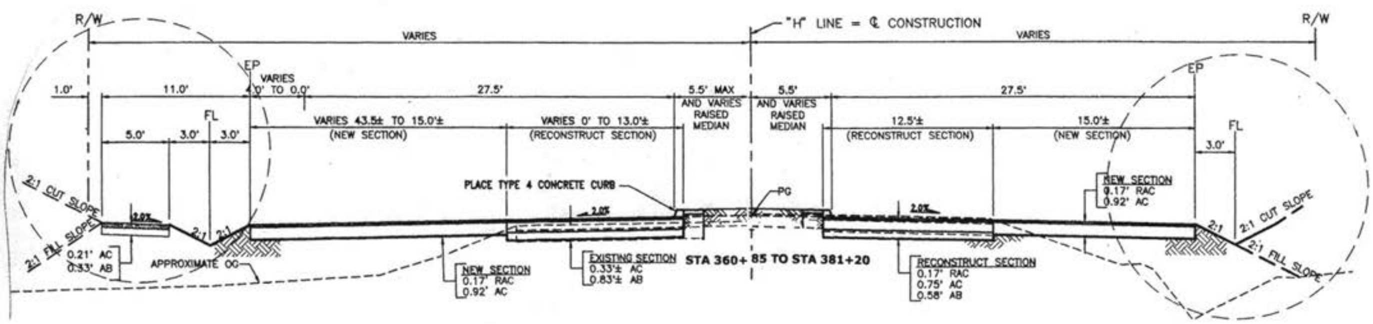



***Figure 2-9*** *Road section*

The second vertical number at 371+00, 213.10, indicates the new projected road grade. This information is also called out by a line pointing at the proposed centerline, labeled *0.00* and *213.10*. The 0+00 indicates center, and 213.10 is the projected centerline road grade. Looking to the left of the centerline, you'll see four other elevations and distances noted. The first is *–33.00* and *212.44.* These numbers indicate the edge-of-pavement, 33 feet left of the road centerline at 212.44 elevation. The next set of numbers to the left is for the ditch grade and location, which is *–36.00* (36 feet) left of the centerline at *210.94* elevation. The next two groups of numbers to the left are the top-of-sidewalk elevation and distance, and the back-of-walk elevation and distance. These read *–39.00* (39 feet), *212.44* (elevation) and *–44.00* (44 feet), *212.54* (elevation).

Now look to the right of the station 371+00 centerline and you'll see the distance to the right side edge-of-pavement and elevation, *33.00* (33 feet) and *214.44* (elevation), and the distance to the right ditch flow line and its elevation, *36.00* (36 feet) and *210.94* (elevation), with the slope going up to meet the existing ground.

Now look at Figure 2-9. This is still the same road section you looked at in Figures 2-7 and 2-8, but with even more detailed information. Starting at the top center, there's an arrow labeled *"H" Line =* ℄ *Construction* pointing to a dashed vertical centerline. A horizontal line runs through this centerline indicating the distance in each direction to the right-of-way line (R/W). There's no distance given, just the words *"Varies."* If you follow the right-of-way line on the left down inside the broken-line circle, it shows it *1.0*' back-of-walk. To the right of this, you see a second horizontal line that begins with a notation showing *11.0*' from the back-of-walk to the edge-of-pavement. This second line indicates that the foreman and grade setter must pay close attention to the left side because the widths on the left side will vary. However, the distance from edge-of-pavement to back-of-walk will stay at 11.0 feet.

Notice the other measurements on the second line. The distances on the right side show 5.5 feet for the island and 27.5 feet from the curb face to edge-of-pavement. The way the engineer has marked this side indicates that the shoulder and edge-of-pavement will hold a constant line and only the island pavement width will vary. The left reads *27.5*', but before it gets to the edge-of-pavement (EP), you see *Varies 4.0' to 0.0'*. This indicates that the road width will taper in and out up to 4 feet down the line in addition to the variations in the width of the island. Cross sections like the one in Figure 2-8 will show these changes and where they occur.

The third horizontal line in Figure 2-9 shows measurements from the back of the curb at the median, not from the centerline. On the right side of the centerline it says, *12.5'± (Reconstruct Section)*. Further right, you see *15.0'± (New Section)*. This indicates the old and new section on this side may vary plus or minus the widths given, but will maintain a width no narrower than the 27.5 shown above. At the far right you see that the flow line (FL) of the ditch is 3 feet from edge-of-pavement, and has a 2:1 slope.

On the left side center on the third line, you see: *Varies 0' to 13.0'± (Reconstruct Section)* and *Varies 43.5'± to 15.0'± (New Section)*. Further to the left it gives the distance from the edge-of-pavement to the ditch center, 3 feet; from the ditch center to the edge-of-walk, 3 feet; and 5 feet to the back of the walk. The ditch has a 2:1 slope on each side. Looking at how much the pavement width varies might give the impression the road may narrow and widen back and forth along its length. The island notations say that there's a raised median and the island widths may also vary. Remember, the road widths that we looked at in the cross sections in Figure 2-8 are precise. If there are any changes in the road widths or medians, these cross sections will reflect the width changes precisely. But keep in mind, this is a road widening and all these varied widths may just occur at the end where the new road narrows to meet the old existing road.

The projected centerline grade (PG) of the new road surface in Figure 2-9 indicates a 2 percent slope across the paved area on both sides of the road. At the edge-of-pavement, there's a 2:1 slope down to the ditch flow line. On the right side, if in a fill, it continues down at a 2:1 slope, or up at

2:1 in a cut area until it meets existing ground. On the left side of the road, the ditch slopes down 3 feet at 2:1, then back up 3 feet at 2:1 to the walk, for a total of 6 feet of horizontal distance. The 5-foot-wide walk has a 2 percent grade, with a 2:1 slope up or down at the edge-of-sidewalk. This section of sidewalk will be constructed of 0.21 foot of AC (asphalt concrete) over 0.33 foot of AB (aggregate base). There's a notation on the right side just above the pavement, and on the left side just below the pavement, that reads: *New Section, 0.17' RAC* (rubberized asphalt concrete), *0.92' AC* (asphalt concrete). This is the proposed thickness of the pavement on the new road section.

At the bottom center, below the road section, you see: *STA 360+85 to STA 381+20*. This indicates this section can be used for 2035 feet. To the right of this, there's a notation that reads: *Reconstruct Section, 0.17' RAC, 0.75' AC, 0.58' AB*. This means the old section will be completely removed and replaced with the new section. To the left of center, the notation reads: *Existing Section, 0.33'± AC, 0.83'± AB*. This existing section is to remain. However, note that the 0.17 feet of rubberized asphalt concrete will extend from the new section over the existing section just to the right.

Along the bottom of the section on the left is a broken line, labeled *Approximate OG*. This broken line is original ground. It continues in both directions to each edge, indicating that both sides of the road will be a fill.

## *Road Cross Section Through Open Land*

Let's look at a cross section through acreage with no obstacles, driveways, or pipe to place. Figure 2-10 shows both a profile and street cross sections. Notice how few details there are in these cross sections, compared to Figure 2-8, yet they have all the information needed to build the road. The existing horizontal ground line runs all over the place, indicating very hilly terrain. You can also see this by checking the elevations running vertically on each side. It shows this project to be located at over 1200.0 feet above sea level.

Across the bottom of each cross section are distances from centerline. Along the sides are the elevations, each horizontal line representing a 2-foot rise in elevation. At the top there's a ℄ for the centerline. Looking down the centerline you'll find two elevations at the bottom. The smaller elevation is the existing ground at centerline. The larger elevation is the finished road surface. The small rectangular curved shape in the center of the drawing is the road section. Notice that the only station that shows a cut is 55+50; all the others are fill stations.

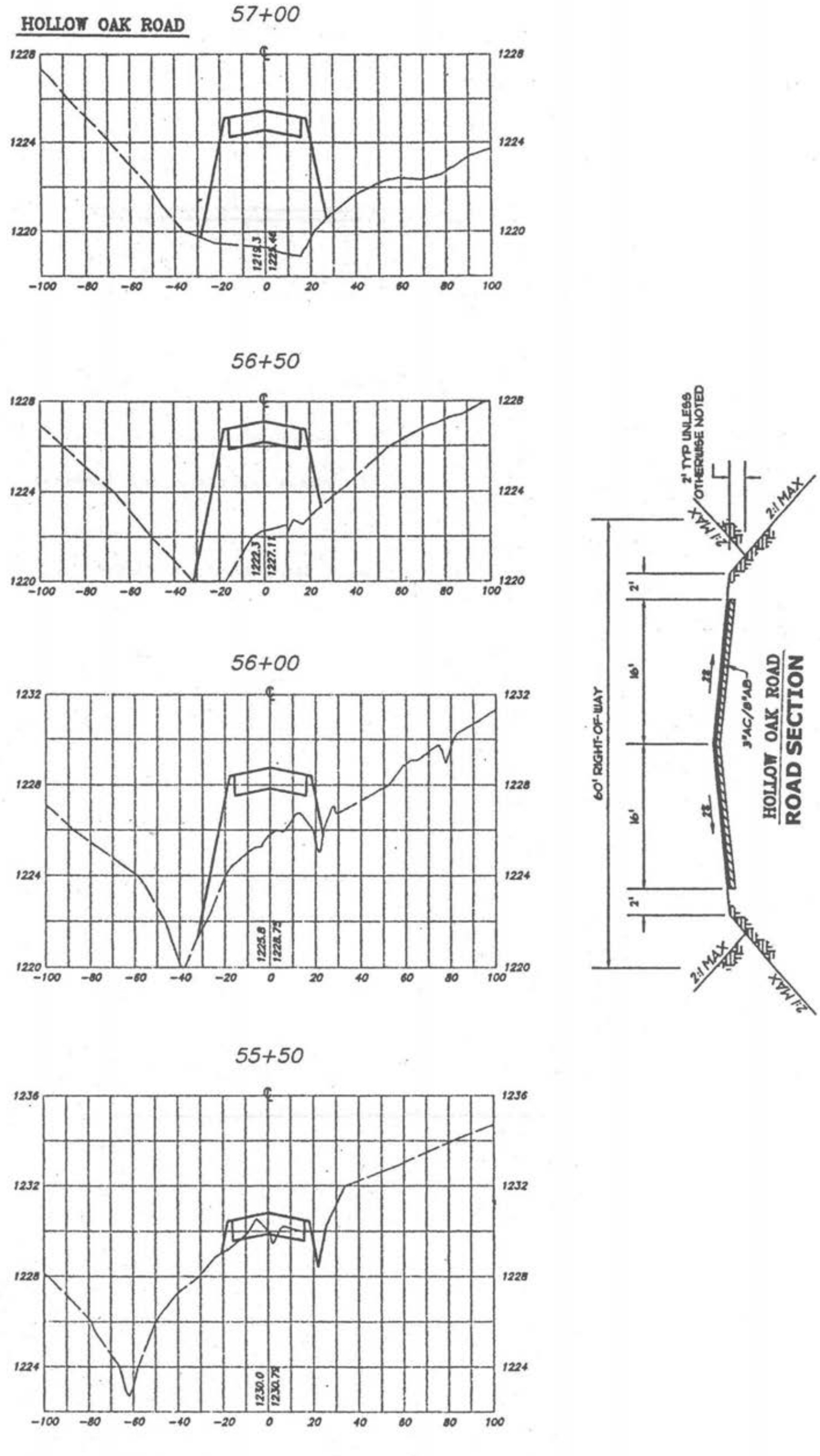



***Figure 2-10*** *Road cross sections with road section profile*

Now turn the figure so you're looking at the *Hollow Oak Road* section profile. It's also very simple to read. Let's start at the top and read down. It shows a 60-foot right-of-way, then two 16-foot sections of pavement with 2-foot dirt shoulders on each side. From the outer edge of the shoulder, which is the hinge point, there's a 2:1 slope down to the ditch flow line. From the ditch flow line, the back slope is 2:1 up to existing ground in a cut section. The slope detail also shows that if there's no ditch, the slope will continue down at a 2:1 slope to existing ground (toe-of-slope). The road slopes 2 percent each direction from the centerline. The pavement will be 3 inches of asphalt concrete (AC) over an 8-inch aggregate base (AB). Notice the small notation on the right side that says *2' TYP Unless Otherwise Noted*. This refers to the ditch, which is to be 2 feet deep in a cut section, unless the surveyors stake it differently.

There are always road cross sections in road job plans, but not usually in subdivision plans.

### *Traffic Plan and Street Section*

When the existing pavement must be removed and rebuilt on a road job, you usually need a traffic control plan. If the engineer hasn't included a traffic control plan, the agency (city, county or state) will require the contractor to submit one before the work proceeds. Figure 2-11 shows a plan drawing and street section of a traffic detour plan in two stages. The legend on the left side of the figure shows the symbols you'll see most often on a traffic detour plan. The first symbols indicate signs to be covered, removed, relocated, or where new signs should be placed. Other symbols deal with striping and pavement markers. The symbols you'll find on the two detour stages in Figure 2-11 are for the work zone, K-rail, flashing arrow board, signs, and traffic direction.

In the detour plan we're looking at, the road section for the southbound (S.B.) traffic (top) has been completed. There was no detour needed to finish the southbound walkway, ditch or road. All that was needed in the first stage of construction was for K-rail (temporary traffic barriers) to be set on the existing pavement. The existing road is 31-feet wide and no traffic lanes had to be realigned to make room for the K-rail.

In the second stage of construction, that's not the case. Looking at the Stage 2 plan drawing, you'll see a narrow section of road with hash marks on the lower (northbound) side of the drawing. The hash-marked section is the work area, and it gets wider as it moves from left to right. A temporary

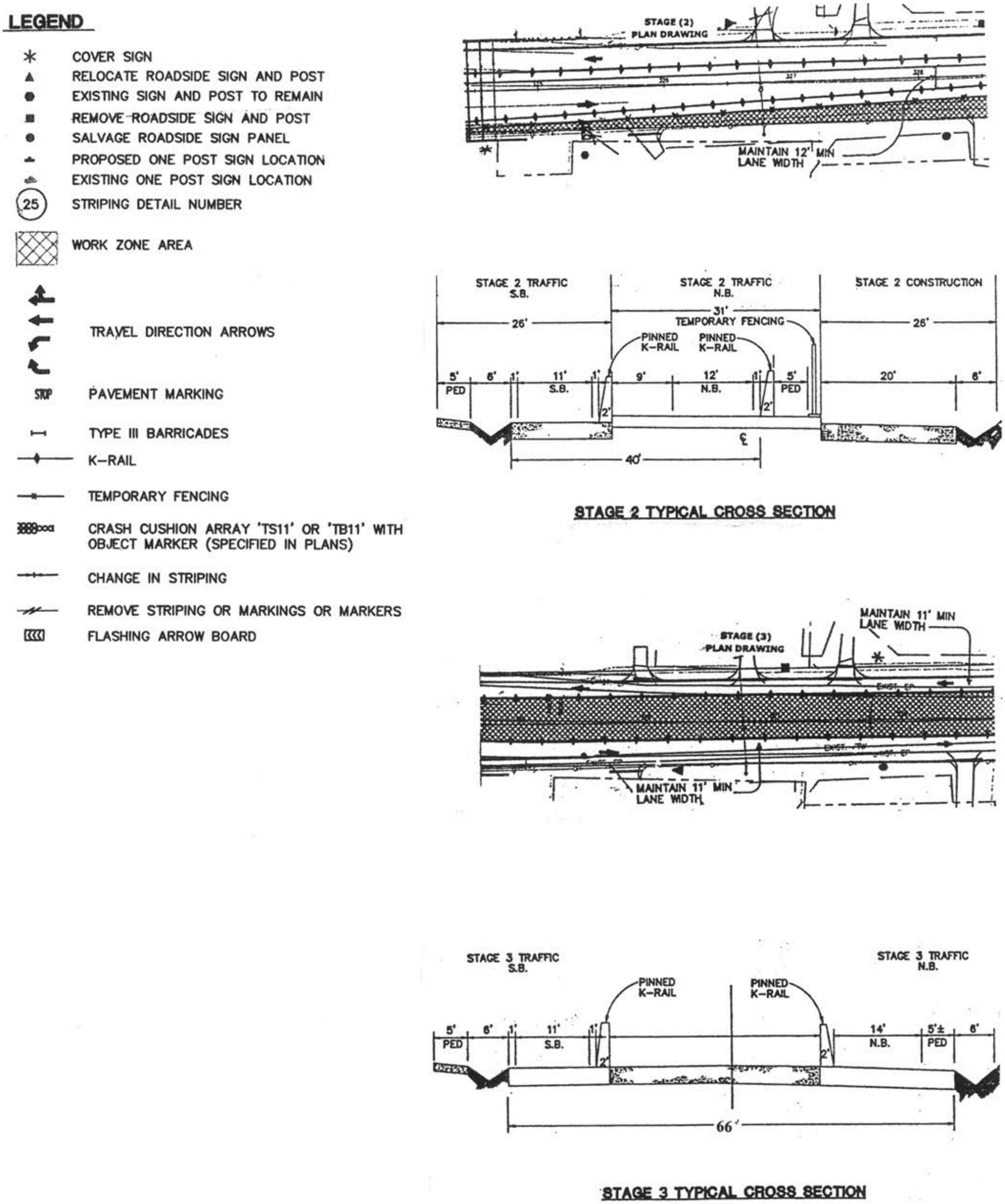



***Figure 2-11*** *Traffic control plan with cross sections*

fence, represented by a black line with x's, runs along the top edge of the work area. The two lines with diamonds in them indicate the K-rail. On the left, at the bottom edge of the hashed area, notice the arrow pointing to the symbol for a flashing arrow board. The flashing arrow board symbol is the last one listed in the legend.

The road section below the plan drawing shows where the K-rails and temporary fencing must be placed. The K-rail for Stage 2, separating the southbound and northbound traffic, is on the new road section (SB), not the old. The second K-rail barrier is placed on the old pavement. Between the K-rails there's a 9-foot buffer, a 12-foot lane for northbound traffic, then a 1-foot buffer space between the traffic lane and the K-rail. On the far side of the K-rail is a 5-foot temporary pedestrian walkway with a temporary fence separating the walkway from the construction area. On the southbound traffic side, the engineer has a buffer on each side of the 11-foot traffic lane; 1 foot at the shoulder and 1 foot at the K-rail. It's important to pay attention to all the details the engineer has provided.

Notice the Stage 3 K-rail directions, *Pinned K-rail.* This means that at each end of every K-rail section there must be two pins placed connecting the sections together, one at the top and one at the bottom.

After the new road construction in Stage 2 is completed, the Stage 3 detour plan goes into effect. Notice that in the Stage 3 cross section, the K-rail on the southbound traffic side hasn't been moved because it was already set on the finished road section. That side of the traffic area remains the same. On the northbound side, the temporary fence was removed and the K-rail was set on the edge of the finished Stage 2 road surface. The northbound traffic now has a 14-foot lane on the new road section and there's a 5-foot pedestrian (PED) walk along the outside edge. The work zone is in the center, where the old existing road section will be removed and reconstructed as needed.

The Stage 2 cross section shows the existing road in the center higher than the two new sides. The Stage 3 cross section shows the center section finished and the level matching on both sides.

This chapter should help you understand that it takes more than a plan drawing to get a complete picture of the job. Be sure that you have all the available cross sections, profiles, legends, job specifications and detail drawings before you begin work.

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# CHAPTER 2 QUESTIONS

1. **If the Camino street section in Figure 2-1B has a 2 percent slope, how much fall is that from centerline to lip-of-curb?**

   A) 0.19
   B) 0.26
   C) 0.27
   D) 0.32

2. **What is the elevation difference between lot 51 and lot 54 in Figure 2-2?**

   A) 7.90 feet
   B) 8.90 feet
   C) 9.30 feet
   D) 10.20 feet

3. **What is the manhole rim elevation at station 63+83.33 in Figure 2-3?**

   A) 445.70
   B) 445.84
   C) 445.85
   D) 446.30

4. **What is the length of the transition from type 1 to type 2 curb & gutter in Figure 2-4?**

   A) 3 feet
   B) 5 feet
   C) 6 feet
   D) 8 feet

**5. What is the flow line elevation of the sewer service line coming from the manhole in Figure 2-4?**

A) 439.10
B) 443.2
C) 444.1
D) 461.0

**6. How wide is the driveway at Station 371+47 in Figure 2-7?**

A) 14 feet
B) 14.5 feet
C) 15 feet
D) 15.5 feet

**7. What is the distance from centerline to EP, right and left, at Station 371+00 in Figure 2-8?**

A) 33 feet
B) 36 feet
C) 39 feet
D) 44 feet

**8. How thick is the AC base of the New Section in Figure 2-9?**

A) 0.17 foot
B) 0.58 foot
C) 0.83 foot
D) 0.92 foot

**9. Which cross section in Figure 2-10 shows some cut needed for the road?**

A) 55+50
B) 56+00
C) 56+50
D) 57+00

**10. When the construction in Figure 2-11 is finished, what will be the total width of all three completed sections?**

A) 32 feet
B) 58 feet
C) 64 feet
D) 66 feet

# GRADE SETTING


Every major project design requires an aerial photograph. Before this photograph can be taken, the surveyor must complete the following four steps in his ground survey:

1. Establish the project boundaries
2. Establish several Northern and Eastern coordinates inside the project boundaries
3. Establish the elevation where these coordinates intersect
4. Place large crosses or X's on the ground where the coordinates intersect and where the elevations are established.

The surveyor can make the crosses or X's with white plastic, paint or chalk. They should be at least 4 feet long and distinct enough to be seen from an airplane. Once these ground survey procedures are completed, the aerial photograph is taken.

If the project covers a wide distance, more than one flyover may be needed with each camera shot overlapping the previous aerial shot. Once the coordinates, elevations, boundaries and aerial photographs are completed, a topographical (topo) plan is created. A computer-assisted design (CAD) is then made using the topo and the engineer's drawings with his elevations and distances. With this set of plans, the surveyor can stake the job. This information is also used to design a GPS file for the base station. When the surveyor has finished staking the project, the contractor can proceed with the rough excavation.

## Setting Grade

Setting grade is the first and most important part of any project. The grade setter transfers information from plans and the surveyor's stakes to stakes that the excavation equipment operators read and follow. It takes skill, knowledge and attention to detail to do the job right. The grade setter must be both fast (to stay ahead of the equipment) and accurate (because any error can be very costly). In many cases, the foreman won't have time to check the grade setter's work and an error may not be discovered until days later — when it becomes embarrassingly obvious to the foreman and grade setter alike.

A good grade setter must be able to perform rapid mental arithmetic, adding, subtracting, and multiplying while transferring grades and distances off the original surveyor's stakes and setting new stakes and grades. Stakes are needed at every key grade change, and they must be located where the operator can see them, but not in the way of the equipment. Grade setters must stake the tops of slopes to be cut, the slopes themselves as they're trimmed to grade, and the toe of the slope once it's reached. They must also set stakes at ditch bottoms, road shoulders and road centerlines. They set, then reset, stakes throughout the grading process. They must also be able to determine when to set finished grade or subgrade stakes or hubs.

Grade setters must be able to set up the laser level for their use or for the equipment operator to grade with, whether the work is on level ground or a sloping grade. They must keep up with changes in equipment, including advancements in global positioning systems (GPS), have a good knowledge of how new systems work, and be able to put this information to use effectively.

Grade setting can be a dangerous job. The equipment operator has blind spots and may lose sight of the grade setter, so grade setters must constantly be aware of their surroundings. It's important that they don't become so engrossed in the work that they forget to keep track of where the grading equipment is at all times. Both the equipment operator and the grade setter must always be alert.

## Grade Setting Equipment

Grade setters need the right equipment to be efficient at the job. Their belts should include an eye level and a hatchet, a pouch to carry a 50- or 100-foot tape, marking pencil or crayon, ribbon or red or orange spray paint, and a ruler. On larger projects, they'll also need a laser level. Their burden also includes a sack, bucket, or carrying rack for the stakes and hubs. If they're working in hard ground, they may need a steel pin to drive a hole for the wood hubs.

Grade setters use fluorescent red or orange paint to spray hub and lath tops so they can be easily seen. They may also elect to spray paint grades on the ground. Spray painting is much faster than tying colored ribbon on the lath or marking blue crayon on hubs, and painted hubs are easier to find after the grader has passed over them. They should also carry a handful of plastic skirts to help locate hubs that are covered over. The skirts pop back up every time the grader passes over them. Finally, a grade setter should have a set of swedes in his pickup in case he needs them. Swedes are lath or metal rods with a base plate used to set grade at a center point by sighting across the three swede tops. Two lath or metal rods are placed at two known correct elevations and the third (the swede) is adjusted until it's also at the correct elevation (see Figure 3-1).

### *Keep the Eye Level Accurate*

Grade setters use a small hand-held eye level like the ones in Figure 3-2 to transfer grades from one point to another. Because this instrument gets rough use, and occasionally gets dropped, it should be checked for accuracy several times a week.

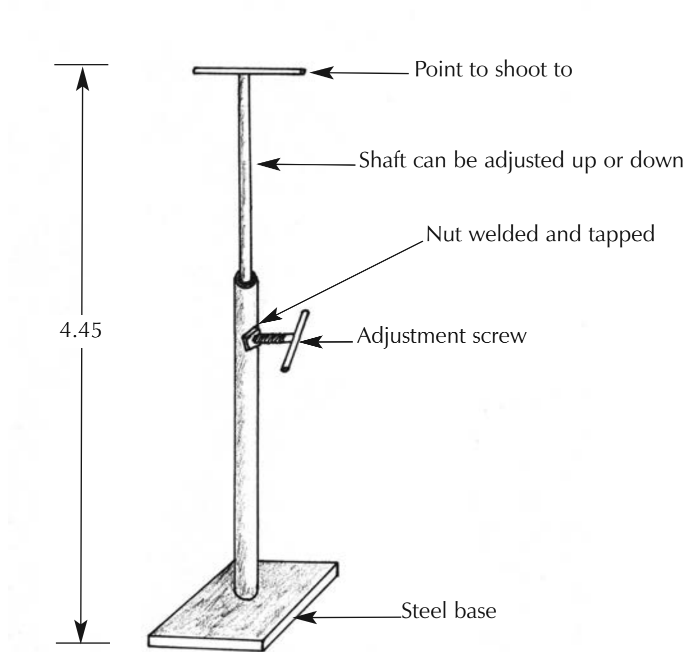


***Figure 3-1*** *Adjustable swede*

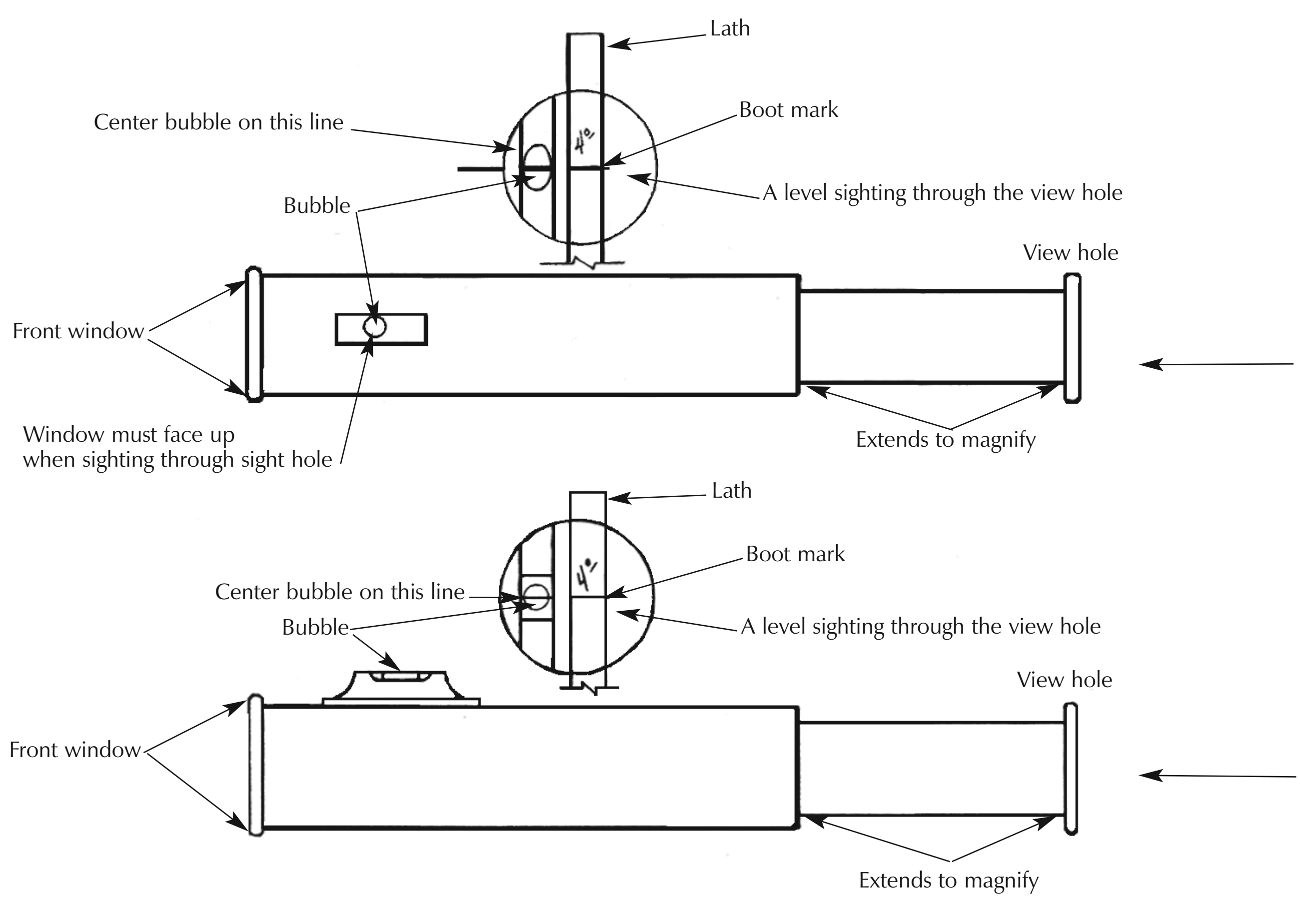


***Figure 3-2*** *Two types of eye level*

Here's a simple way to check your eye level:

- Set up two 4-foot-high stakes 30 feet apart. Wood lath makes the best stakes for this purpose. Clip a clothespin on each lath or tie a survey ribbon around each.
- Stand beside one lath and sight on the other, sliding the eye level up or down the lath. Adjust the level of the clothespin or ribbon on the lath near you until it's at the same level as the clothespin or ribbon on the lath 30 feet away.
- Then reverse the process. Go to the distant lath and sight back on the first lath.
- If both clothespins or ribbons are at the same level when you sight back, the instrument needs no adjustment. If you sight over or under the clothespin or ribbon on the first lath, then the eye level is off and needs adjusting.
- To adjust the eye level, unscrew the front lens and turn the front screw one turn. Sight back on the first lath.
- After sighting and adjusting the ribbon again, shoot back from the second lath. If the level is off more than in your first test, you've adjusted the screw the wrong way. Turn the screw back to the original point, and then back one more turn.
- Keep adjusting the screw and checking the points on your lath until you sight them level in both directions.

If you can't bring the level into adjustment, return it to your dealer for repair. Even the most experienced grade setter can't do a good job with an inaccurate eye level. And, just to be on the safe side, it's good practice to always have an extra eye level with you on the job.

## Checking Grade with Swedes and an Eye Level

Checking grades with an eye level is very accurate if you don't try shooting over 40 feet. Some grade setters are comfortable shooting grades farther than that, but I don't advise it unless you're working in an area that has a 0.20-foot tolerance.

The eye level is a good tool on roads in subdivisions and highways where the grade is never level and the shoulder stakes are close enough for accurate shots. It works well to check grade for trimming aggregate base on a subdivision road because the shots from centerline are usually less than 20 feet. The grade setter sets his swede on the lip-of-curb and computes the amount of rise of the street, usually 2 percent. He subtracts that from his centerline swede, adds in the thickness of pavement, and shoots back to the swede at lip-of-curb. Then he drives a hub to the grade needed.

Let's run through that procedure using a hypothetical street width of 15 feet from lip-of-curb to centerline, with a 2 percent slope from centerline to lip. Let's say the swede is 4 feet long, so if we shoot level from centerline to the swede, our ruler should read 4 feet. But we don't want a level grade — we want to come up 2 percent in 15 feet, which is 0.30 foot. So we subtract 0.30 from our 4.00 to get 3.70 feet. That gives us 2 percent from finish curb lip to finish centerline asphalt grade. But that's not what we want either. We want the aggregate base grade. So let's assume the asphalt section is 3 inches thick, or 0.25 foot. So we must add 0.25 to the 3.70. We now have 3.95. That's the level we must read on the ruler to get finished aggregate grade. From centerline, the grade setter shoots over to the swede on the curb lip, sliding his eye level up or down the ruler until he gets a level reading; then looks at his reading on the ruler. If it's 3.80, he subtracts 3.80 from 3.95, which gives a cut of 0.15 foot. The hub would be set 0.15 foot lower than the spot he shot from. If the ruler reading had been 4.10, the hub would be set 0.15 foot *higher* than the spot he shot from (4.10 − 3.95 = 0.15). The grade setter must be very careful to not mark a 0.15 fill when he actually wants a 0.15 *cut*. This is an easy mistake to make if he loses his concentration.

The grade setter would continue down the road, setting a hub every 50 feet, shooting for a ruler reading of 3.95 at every station unless the slope of the road changes. If that happens, he must compute a new ruler reading. Always keep in mind that this is the hardest part of grade setting. Pay very close attention. You must be sure you're adding or subtracting in the right direction for the proper elevation.

When the equipment operator is using sonar and slope control to trim the grade, the grade setter should shoot the lip-of-curb grade from one side of the street to the other to be sure both curbs are level. Even though the road profile calls for a 2 percent slope each direction from centerline, occasionally this isn't possible if the curb was a little off when poured.

Let's assume one curb is 0.06 foot higher than the curb directly across. It's not much, but enough to affect the grading when using sonar and slope control. The 0.06 error makes one side of the street a 1.6 percent slope if you've set a 2 percent slope from the opposite side. Depending on which side the grader cut first, one side would be 0.06 foot higher or lower than the other. This isn't a lot, but if you're trimming finished rock grade you only have a 0.05 tolerance. If the grader were cutting a perfect grade you'd be slightly out of tolerance. It's much wiser for the grade setter to split the difference as close as possible, making the centerline 0.27 foot rather than 0.30 foot. Then he'd let the grader operator know he must adjust the slope control at that point to read 1.80 percent to be on grade so both sides will match. 1.80 percent in 15 feet is the 0.27 needed, and only 0.03 foot out of tolerance.

When both curbs are level throughout the job, the grader operator may prefer not to have centerline hubs but just a paint mark at centerline every 50 feet. This is a common procedure when the grader is equipped with sonar and slope control. Even though the operator doesn't want hubs, the grade setter should check every pass the grader makes to be sure the equipment is working properly. If the curbs are close to level on each side, swedes are a good tool to use to check centerline grade. The grade setter will first set two swedes: one 4 feet long on the curb lip, and the second one at 3.95 feet for centerline. He'll then set his ruler (holding it at 4 feet), or a third 4-foot swede, at lip-of-curb on the opposite side of the street and sight across the tops of the two swedes. If the center swede is lower than the first one set at the lip-of-curb, then a fill is needed. If it's higher, then a cut is needed.

The grade setter can use swedes in three ways. He can use only one swede set at the lip-of-curb and shoot to it from centerline, using his ruler at centerline. He can use two swedes, one at curb and one at centerline and use his ruler as a third swede on the opposite curb. Or, if he has two helpers, he can use three lath, with the center lath cut to the length he wants. When using the three lath as swedes, the two helpers walk down the road and every 50 feet or so hold the lath in place so the grade setter can sight across them for the grade reading at centerline.

Checking centerline grade using these methods is amazingly accurate. We'll discuss it in more detail later in the book.

## String Lines

There are many types of excavation work where the grade is best set with a string line. These include setting forms, preparing for a curb machine and especially for laying pipe. The string line should be set with

***Figure 3-3*** *Set string line for grade allowing ample working space for equipment*

great care and stretched as tight as possible. A good nylon line is best for this type of work. Before setting the line, determine how much of an offset is needed so the string won't interfere with the equipment to be used. If you're using a trencher, the string line must be on the operator's side. For a backhoe, be sure to keep the string line back far enough to clear the equipment outriggers or tracks. See Figure 3-3.

When setting string line, keep three stations set up along the line so you can sight down the line to correct errors or any movement that occurs during setting or excavation. A faulty station grade can easily be detected this way. When you sight down the string line, each station should blend with the next, with no sudden rise or dip from one station to the next. If you detect a sudden grade change, check the measurements. Check the rate of slope shown on the plans if you can't find any error in your work. If the plans *don't* show a sudden grade change, the surveyors have made the error and it should be called to their attention.

If waiting for the surveyors to correct a faulty station would delay production, consider correcting it yourself. Set up three more stations with the string line and sight through the obviously-faulty station, lowering or raising the string until it flows smoothly into the correct grade. Usually the surveyors will have made an error at only one station and this will solve the problem without holding up the trenching operation. Always be sure the string line is straight. Look for any slight variations. If the trencher or hoe is using a laser for grade, you still need a string or paint line for direction to keep a good straight trench line. You don't need a string for line if you're using GPS.

If the steel pins used to hold the string line are offset to one side from the grade hub, use a carpenter's level and straightedge to transfer your grade from the hub to the grade pin. You could use an eye level, but this isn't good practice where a close tolerance is required. If the distance is too far for a straightedge, use a surveyor's level or laser level.

### *Setting Offset Strings*

Assume now that you're ready to transfer the surveyor's grades to the grade stakes. The surveyors have set stakes for 500 feet of 30-inch drainpipe. The contractor should have requested the distance that the surveyor's stakes are offset from the actual trench location, and the side of the offset. The width of the trench and direction the spoil will be thrown determines these two factors.

Let's assume the surveyors have set all their grade hubs on a 10-foot offset, and a hoe will be used for the excavation. The distance the string is offset from the surveyors' hubs depends on the type of hoe used. For a rubber-tired backhoe, an 8-foot offset will probably be needed to clear the downriggers. A large track hoe requires a 10-foot offset.

These offsets only work for smaller pipe, up to about 24 inches, in a shallow or vertical trench. For a trench that's 20 feet deep and must be sloped, you'd need a minimum of 15 feet on each side of the trench (not including the width of the pipe). You can see how many variables you have to consider in correctly setting offsets. For example, if the contractor didn't give the surveyors the correct offset to set the hubs, they could be in the ditch line if sloping were needed. Then the surveyors would have to be called back to reset them — at the contractor's expense.

When the equipment's using a laser for grade and a hoe is doing the trenching, you may not need a string line. A chalk or paint line on the ground may be all that's needed.

### *Setting String Line Height*

When setting a string line, there should be no less than four grade pins set at 50-foot intervals along 150 feet of trench at any time. Once the string line pins are up, the grade setter must transfer the grade given by the surveyors to the grade pins at an even foot. Assume that the terrain is reasonably level and the first four grades on the surveyor's stakes read as follows: $C\text{-}6^{\underline{80}}$, $C\text{-}6^{\underline{13}}$, $C\text{-}6^{\underline{03}}$ and $C\text{-}5^{\underline{90}}$.

An 8-foot-high string line is required because a 7-foot string would only be 0.20 foot off the ground at the first grade. A 9-foot line would be more than 3 feet above the ground at the last grade. A line 8 feet above the flow line of the pipe is high enough to clear most ground obstructions, yet low enough to step over easily. To set an 8-foot string line, add to each cut the number of feet (and hundredths of a foot) needed to total 8 feet even. For example:

C-6.13 + 1.87 = 8 feet
C-6.03 + 1.97 = 8 feet
C-5.90 + 2.10 = 8 feet

You can get the same answers by subtracting the cuts required from 8 feet, if you're using an 8-foot string line. Use the method that's easiest for you. Subtract 6.80 from 8 to get 1.20. Set a ruler on the surveyor's hub as shown in Figure 3-4, and measure up 1.20 feet on the ruler. Now set the straightedge against the 1.20 mark on the ruler. Hold the straightedge firmly against the ruler with your thumb and forefinger. Set a torpedo level on the straightedge or use a carpenter's level and level the straightedge, holding it against the grade pin. Once the straightedge is level, have someone mark the grade pin. Be sure that if the bottom of the straightedge is at 1.20 feet, the pin is also marked at the bottom of the straightedge and not the top. Tie the string at the mark on the grade pin. Follow the same procedure at each station to get a string line exactly 8 feet above the flow line.

If the terrain's steep, the grade line may have to be changed often to keep the string line from being too high or running into the ground. If there are large grade changes, you'll have to figure two measurements and tie the string in two spots on each grade pin. See Figure 3-5.

### *Above-Ground String Lines*

When setting a string line for a paving machine, self-grading curb machine or a grader trimming curb or street grade, there'll be fills on some of the stakes. If you're setting a 3-foot string line, just add the fill

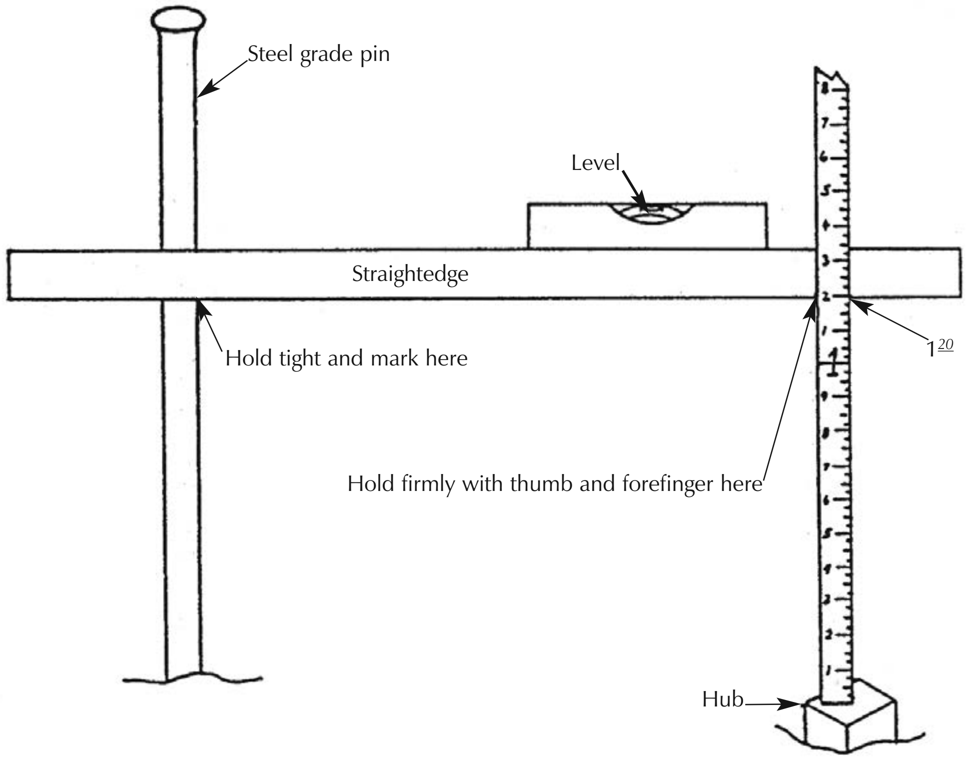


***Figure 3-4*** *Marking grade pins*

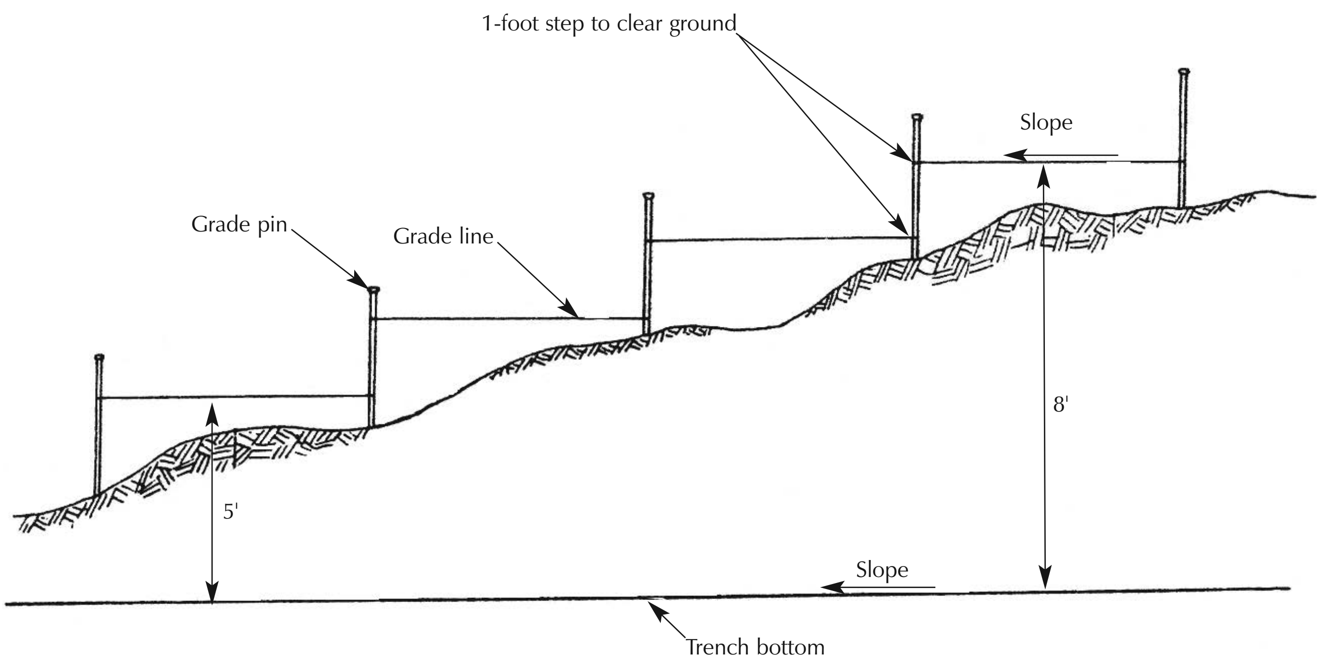


***Figure 3-5*** *Setting a string on a steep slope*

grade given, regardless of what the fill is, to 3 feet. Remember that even though the grade's being set for a surface grade, you should keep four grade pins set up at all times so any mistakes are easily seen.

If you're setting a string line for curb boards or anything where the string is to be placed at a finished grade and the grade's already trimmed, use the measurements given by the surveyor without any undercut. Let's say the surveyor's stake has a 1-foot cut to the top of the curb. Measure out the offset given and down from the level straightedge 1 foot and mark the pin. If the ground in front of the hub to the curb is higher than the hub, use an extension on the straightedge. The amount of extension added must be computed with the cuts and fills given on the surveyor's stakes. When you're setting a string line for forms of any kind, set up the pins and string so the pins will be on the outside of the boards, and the string around the pin is on the board side of the pin.

Corners are difficult to make when you're setting up a string line for a self-grading curb machine. You must set many pins to keep the string flowing evenly around the turn, or the line sensor will cause the machine to make an irregular curve. You can solve this problem by using a $^1/_2$-inch plastic pipe or a $^3/_8$-inch fiberglass rod in place of string on the corners. This makes the corner easier to set, requires fewer pins, and will help the machine turn out a smooth corner. See Figure 3-6.

If a grader's equipped with sonar and slope control, trimming from a string will cut job time considerably. See Figure 3-7. It's also much more accurate than hand-operating the equipment with a grade setter working ahead giving the cuts and fills needed.

## Laser Levels

Using a laser beam or GPS to check grades is replacing the hand-held eye level, especially on larger projects. The eye level's still an important tool, but lasers are so accurate at long distances that the grade setter can get more work done in less time using a laser. And with a laser, one grade setter can often handle a job that would otherwise require two people. A couple of things have made this possible: the laser units themselves, and grading equipment that uses sonar, slope control and laser-controlled systems. Under good conditions, the laser unit can be set in a central

***Figure 3-6*** *Use a fiberglass rod instead of string to make a smooth corner*

***Figure 3-7*** *Trimming sidewalk aggregate base from a string line*


***Figure 3-8*** *Flat line laser transmitter*

location and grade can be checked in a 360-degree radius for up to 300 yards. Of course, this is only possible when the work area's flat enough for the laser beam to hit the receiver as it's moved up or down on the rod.

A good grade setter will work well ahead of the equipment, spray painting marks for cuts and fills on the ground or setting crows feet (lath). Then, while the equipment's making the cuts or fills, the grade setter can double back and check what the equipment has just filled or cut. In many cases this can be done from a single laser level setup.

## *Setting a Laser Level*

Figure 3-8 shows a laser transmitter and Figure 3-9 shows the rod and receiver end of a laser leveling set. The transmitter must be leveled precisely so it can project a level beam as it rotates its full 360 degrees. When the receiver intercepts the beam, you'll hear a signal, and an arrow in the display window will indicate whether the receiver should be raised or lowered to intercept the laser beam exactly on center. If the laser beam isn't intercepted by the receiver, you won't hear any sound or see an arrow


***Figure 3-9*** *Rod with laser receiver*

pointer. In this case, you must slide the receiver up or down until you pick up the signal. When centered, the index line (the black line) in the window of the receiver indicates it's level with the beam and on grade if it's pointing to the desired rod reading.

To set a laser level like the one in Figure 3-8, rotate the adjustment wheels at the base of the level until it's level. On this unit there's a circle level located just above the adjustment wheels. Rotate the wheels until the bubble is centered in the level. Then it's ready to be turned on. Some laser levels have bar-type levels on two sides. In this case, both sides must show level. Most laser levels are self-leveling. If they're set close to level, they'll precisely level themselves. They'll also automatically shut off when bumped off level.

Once the laser unit is leveled and turned on, you'll want to determine the height of the level beam being projected by the laser unit. To do this,


***Figure 3-10*** *Laser receiver on a direct-reading rod with a movable tape*

take the rod with receiver attached to the nearest bench mark or known grade point. Set the base of the rod on the bench mark. Turn the receiver so it faces the transmitter. Slide the receiver up or down the rod until it intercepts the laser beam. It's on level when the receiver gives off a steady tone and only a bar appears in the receiver window. The receiver in Figure 3-10 shows that it's level with the laser beam. You can only see a bar, not an arrow pointing up or down. Set the elevation of the bench mark to the beam height on the rod. That's the correct elevation of the beam being transmitted, and can be used on all grades shot from that setup. The elevation shown on the rod is 7.92. Only the last three numbers show on the rod, so this elevation could be 27.92 or 17.92. Check the bench mark to be sure. The surveyors often set a lath showing the elevation at the bench mark. If not, the only way you'd know for sure is by checking the plans. The plans will always show the elevation of the bench mark you've chosen to set up on.

Because the laser must be able to project a level beam, using a laser transmitter and rod works well for large commercial pads or house pads, but isn't as efficient for road-job applications, which generally have irregular terrain and sloping grades.

## *Setting a Movable Tape*

Use only a direct-reading rod with a movable tape like the ones shown in Figures 3-9 and 3-10. This type of tape can save a lot of adding and subtracting. It's also likely to reduce errors.

Let's look at how to use a direct-reading rod. There are two nuts on the right side of the rod (see Figure 3-10). The top nut tightens the rod so it won't slide. The bottom nut holds a clip with a hook that fastens into the holes in the survey tape. The holes are 0.20 foot apart and each one is reinforced with a small brass ring. The clip keeps the tape from moving. Use the following instructions to set the tape on the rod:

- Loosen the bottom nut.
- Pull the clip with the hook outward so the hook disengages from the hole it's in. Now the tape can be adjusted.
- Use your thumb to slide the tape up or down. The tape rolls on the rod. Move the tape until the last three numbers of the elevation at the bench mark are at the pointer on the receiver. If a longer rod is needed, loosen the top nut and slide the rod up.
- Place the hook into a hole in the tape so that the numbers correspond to the level of the pointer.
- Tighten the nut again, securing the tape. Be sure the hook's in a hole before tightening the tape nut. The nut slides up and down so the clip is always able to reach a hole once the tape reading is marked.

Once the tape has been set this way, one person can check any elevation within range of the laser beam. Just move the rod to the grade being checked. Slide the receiver up or down until the tone is steady and only a bar is visible in the receiver window. Read the tape at the pointer to find the elevation at that location. No adding or subtracting is needed on the tape.

For example, assume that 127.92 is the bench mark elevation. Figure 3-10 shows the rod setting at this bench mark. The movable tape has been adjusted so the pointer on the receiver is at 7.92. After resetting the hooked clip so the tape can't move, check the setting for accuracy. Face the receiver toward the laser level. You should hear a steady signal. If the signal isn't steady, make the adjustments needed so that it reads exactly 7.92, as in Figure 3-10. That's the bench-mark reading. An arrow will appear pointing up or down if the receiver isn't on grade.

Now move the rod to another location, leaving the laser unit undisturbed at the same setup point. At the new location the receiver bar centers with the pointer at 1.10, as in Figure 3-9. Remember, that's only the last three numbers of the grade. The full elevation is 121.10. Now let's say the elevation you want at that location is 124.18. To find the cut or fill needed at that point, subtract 1.10 (the last three numbers in elevation you're reading) from 4.18 (the last three numbers in the elevation you want), and you get 3.08. That's the fill you need at that location to bring the grade up to 124.18. Remember, with a direct-reading rod, the larger the number, the higher above sea level it is. The smaller the number, the lower it is.

If the laser's beam is so far above or below the rod that you can't pick up a signal by moving the receiver up or down as far as it will go, you'll have to move the laser unit to a higher or lower elevation. The transmitter must always be above any area you're working on. If the work area is higher than the beam, the transmitter must be reset to a higher location as well. If no surveyor's bench mark or grade is available for the new location, set a hub nearby and check the elevation of the hub with your grade rod. Mark it before moving the unit. Then when you move the laser unit, you can use that hub as your bench mark to reset the laser unit. You don't need a specific elevation for your bench mark, but the elevation you receive as level must be the elevation you set on your survey or direct-reading rod after the receiver has been reset.

Let's take a closer look at the direct-reading rod. Look at Figure 3-11. Notice that each black bar on the rod indicates 2 hundredths of a foot (0.02 foot). The bars (and the spaces between bars) are each 1 hundredth of a foot. So the top of the black bar is 0.01 and the bottom is 0.02 and the top of the next bar is 0.03, and so on. Every 5 hundredths of a foot, the bars are a little longer and have a diagonal tip. The tip indicates the 0.05 or 0.10 mark. If the tip of the black bar's on the top, it's at a 0.10 point on the rod. And if the tip of the black bar is at the bottom, it's at a 0.05 point on the rod.

Let's look at the readings called out in Figure 3-11. The top callout shows a rod reading at 0.48. That's the last three numbers for elevation 20.48. Under that is the reading for elevation 20.55 (0.55). The hundredths between these two readings are shown to help you understand the markings on the rod. The bottom callout shows 0.10 from one black tip to the next.

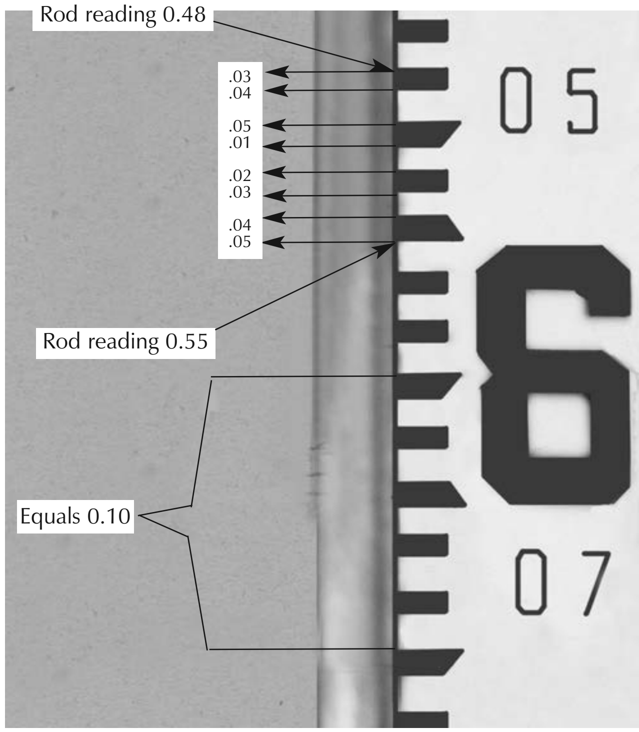


***Figure 3-11*** *Reading a rod*

Although laser levels are a big improvement over eye levels, they do have some limitations. Fog, dust and rain can deflect the laser beam, especially over longer distances. Reduce distances when there's moisture or dust in the air. On extremely hot days, the heat rays may cause the beam to jump around. Equipment working around the laser unit can disturb the laser beam. And equipment like a vibratory roller, working near the transmitter, can make it hard to get a steady signal at the receiver. Finally, be careful while checking grade on a job where there's more than one laser unit in use. It's easy to make a mistake if a second laser level is projecting a beam close to the same level as your laser. Your receiver can't tell the difference between one transmitter and another.

## *Types of Laser Levels*

There are several types and brands of laser levels on the market. The small laser level in Figure 3-8 only sends out a level beam. It has an on-off switch and three wheels for leveling. A transmitter that projects a beam in only one direction is sometimes called a *stationary level*.

***Figure 3-12*** *A laser level capable of sending a sloping beam*

Figures 3-12 and 3-13 show larger laser levels. They can project either a level, declining or inclined beam. A laser level that can project a beam sloping up or down is perfect for laying pipelines or grading large sloping parking areas. The beam is used for trenching, grading and checking each length of pipe at precisely the slope desired. Just punch in the percentage of slope. The laser unit should indicate the direction the unit must face to project an accurate beam. If you don't see an arrow or indication on the housing, check your instruction booklet. To project a level beam, it doesn't matter which direction the unit is facing. However, when the laser unit's projecting a sloping beam, it must be close to or on line with the trench, as shown in Figure 3-12. Notice in that figure that there's a shield at the back window. That's because a second crew is also trenching in that direction. By blocking the back window, it keeps them from accidentally picking up the wrong beam on the receiver unit.

The laser transmitter in Figure 3-13 is also projecting a sloping beam, but because no other crew is working nearby, all the windows are open. However, only the beam being projected down the trench is used. When projecting a level grade, all four windows are open and the laser beam is projected through 360 degrees. Leveling can be done in nearly any direction from the instrument at the same time. This is called a twirl-type laser level.


***Figure 3-13*** *Twirl-type laser level*

The twirl-type laser level has four small areas in 360 degrees where no beam will be received. The beam doesn't pass through the four posts that separate the windows. Try to set up a twirl-type laser so that a post isn't centered in the direction of your work. Also keep in mind that all these units (transmitters and receivers) are battery operated. Be sure you always have extra batteries available. Some transmitting units use car batteries.

## Marking Grade with Crows Feet

Grade setters usually don't use hubs to mark grade levels. You only need hubs when you stake a permanent point where many elevation shots will be taken, or when trimming to a close tolerance. Instead, grade setters use wood lath that they call *crows feet* to mark cuts and fills for equipment operators.

Setting up a line of lath and marking them is called *setting crows feet*. This method of setting grade is faster than setting hubs because if a hub were set, the grade setter would need one or two additional grade checks

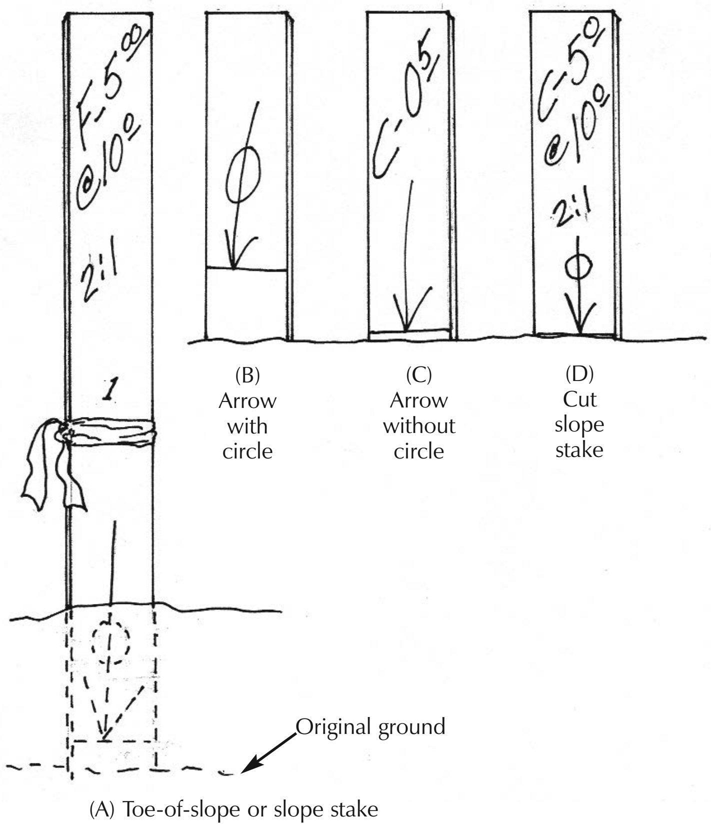


***Figure 3-14*** *Crows feet with markings*

to establish grade. To set a crows foot, he drives a lath into the ground until it's firm, places his ruler on the ground next to the lath and sights to the boot he's set. If a fill is needed, he measures up the lath to the fill needed and draws a line, then draws an arrow to the line with a circle over the tail, indicating that point is grade. If a cut is needed instead, he'll draw a line at ground level with an arrow pointing to the line, then write the cut needed at that point on the lath so the operators can see it. Only one sighting is required. This saves the time it would have taken to check a hub once or twice on a spot that's not on grade and doesn't need a hub. Figure 3-14 shows typical crows feet and their markings.

In most cases, if there's a large cut or fill, the grade setter might direct the equipment to cut or fill over his crows feet stakes. Then he'll check the grade and reset them as the grade gets closer to the level desired. Let's look at the markings on the crows feet in Figure 3-14.

**Toe-of-Slope or Slope Stake —** The first crows foot (A) in Figure 3-14 is a toe-of-slope or slope stake. The markings on this lath indicate the fill is the same (2:1) from the toe of the fill slope on up the fill slope. Notice that the horizontal mark and most of the arrow is covered over by fill in the drawing. That's because the equipment operator has overfilled the slope (as was expected). There's a ribbon showing above ground level with a 1 marked above it. The grade setter has a 1-foot boot ribbon tied (1 foot above the proposed finished grade) to the stake so he can use that as a boot for his next grade shot without digging down to his first grade mark.

The circle through the tail of the arrow indicated in Figure 3-14 (A) and more clearly in (B) always means that the point of the arrow is drawn to the finish grade. The operator seeing the arrow knows that's the elevation he must grade to.

The next crows foot (C) doesn't have a circle drawn through the tail of the arrow. Instead you see $C\text{-}0^{\underline{5}}$ above the arrow. This means that more cut is needed. A $^1/_2$-foot (0.5) cut must still be excavated below the line marked across the lath.

**Cut Slope Stake —** The crows foot in Figure 3-14 (D) is similar to (C) except the markings are for a cut slope. The arrow shows that the ground at the base of the lath is at grade, and there's a 5-foot cut needed 10 feet from the lath. The 2:1 slope was computed by dividing the 5 feet remaining to cut into the 10-foot distance from the stake.

Where an extremely accurate grade must be cut, the grade setter will replace the crows feet lath with hubs once the grade is nearly established. A hub marks a point on the ground, like a lath, but it also establishes a precise elevation at the top edge. After setting the hubs, the grade setter will drive a short lath next to each one so the equipment operators will see it. If the hub will be trimmed over, he'll use a plastic skirt (see Figure 3-15) instead of a lath. Plastic skirts are flexible and work well when trimming aggregate because they pop back up every time the grader passes over them. This eliminates the need for a guinea hopper (a worker who follows the grader and uncovers hubs after the grader passes over them).

## *Setting a Crows Foot Grade or Hub*

To set a crows foot grade or hub, you first need to establish the ground elevation at a given point in relation to the surveyor's hub. Let's assume the surveyor's information stake reads $C\text{-}3^{\underline{50}}$ ℄ $35^{\underline{0}}$ (cut 3.5 feet at centerline, 35 feet from hub). The grade setter measures the 35 feet from

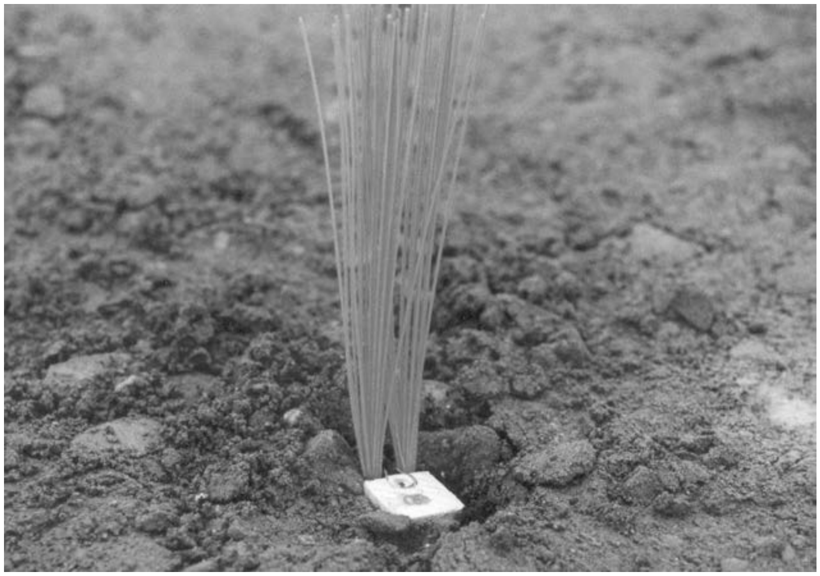

***Figure 3-15*** *Plastic skirt connected to hub*

the surveyor's hub or reference stake (RS), whichever is indicated, and drives a lath or hub. Then he sets his ruler (with small numbers down) on the hub or at the base of the lath. If he uses a hub, he'll only drive it part way into the ground at this time. Then, in his head he adds the road section thickness to the cut computed by the surveyor. If the road section is 0.5 foot thick, he'll add that to the 3.5 to get a total of 4 feet.

Next he shoots across to the surveyor's hub or the RS point until his eye level reads level. To get a level shot, the bubble must be centered and his eye level line and the top-of-hub or boot line must be level with each other. When he has a level shot, he looks to see where the eye level is in relation to his ruler. If the eye level's at 3.8 feet on the ruler, he drives the hub 0.20 foot lower so the level line intersects the ruler at the 4-foot mark on his next shot. If he uses a crows foot lath, he'll draw a horizontal line at ground level with an arrow pointing to the line. Above the arrow he'll mark $C\text{-}0^{\underline{20}}$ so the equipment operators will know a 0.20-foot cut is needed at that point.

## *Setting Boots*

Sometimes an obstruction will block the line of sight between the crows foot or hub to be set and the surveyor's hub or RS. When this occurs, the grade setter will set up *boots* before any work begins. To set a boot, the grade setter drives a 4-foot lath behind the hub the surveyor has set. Then he rounds the surveyor's cuts off to an even foot. For example, the C-3$^{\underline{50}}$ set by the surveyor in the example above would be rounded up to 4 feet. The grade setter measures from the hub up 0.50 foot and draws a horizontal line on the 4-foot lath at that point.

If he needs to measure up the lath farther to clear any obstacles in his line of sight, he may use a 5-foot boot. With a 5-foot boot, he would measure up 1.50 feet and draw a horizontal line. (A 6-foot boot is never used because it would be too high to shoot to unless the grade setter is very tall.)

For our example, however, we'll assume that 0.50 foot is enough to clear all obstacles, and there'll be a cut of 4 feet to the finished grade from the horizontal line marked on the 4-foot lath. The grade setter continues to round all the cuts off to 4 feet and mark the lath up the distance needed from the surveyor's hub. For example: C-2$^{\underline{60}}$ plus 1.40 equals 4 feet, and C-3$^{\underline{10}}$ plus 0.90 equals 4 feet.

If a fill rather than a cut is marked, he'll measure up the amount of fill marked by the surveyors, plus 4 feet. For example, if the surveyors have marked F-0$^{\underline{10}}$, he'll measure up 4.10 feet to equal a 4-foot boot. For F-0$^{\underline{40}}$, measuring up 4.40 feet equals a 4-foot boot. Doing this at every hub makes the grade setter's job easier and faster. Then adding the 0.50 foot road thickness to the ruler reading at each station will give a 4.50 cut at every station where he sets a 4-foot boot. This eliminates figuring hundredths. If the fill is 2.13, measure up 6.13 to make an even 4-foot boot again. If it were a 3.62 cut, measure up from the hub 0.38 and you have a 4-foot boot.

This is important for you to remember, so let's go over it again. On a fill, measure up the fill given, 2.45, *plus* the 4-foot boot for a 6.45 measurement. On a 2.45 cut, measure up 1.55 to *equal* the 4-foot boot. Both of these boots will be 4 feet above the finished surface the surveyors have staked. When the boot needed is higher than a single 4-foot lath, you can drop to a 3-foot boot and adjust the figures accordingly, or nail two lath together for more height.

Sometimes the grade setter can't set crows feet because there's no room for them. When that happens, he has to check the grade after each scraper or grader pass and let the operator know how much more cut or fill is needed. When the grade setter works this closely with the equipment, *he must make sure that all equipment operators have him in sight before stepping out in the work area.* I can't emphasize that enough.

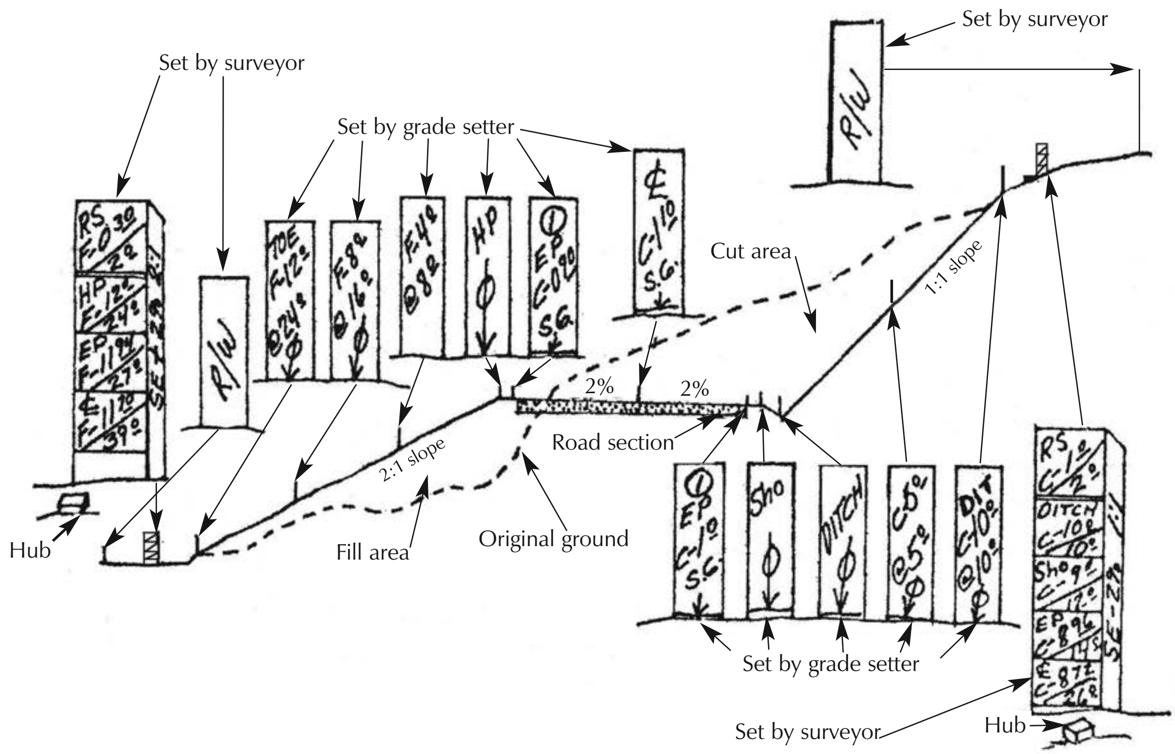


***Figure 3-16*** *Staking cut and fill sections*

## Staking for a Typical Cut and Fill Station

Figure 3-16 is a typical road section showing a cut section on the right and a fill section on the left. Only four stakes were set by the surveyors: two right-of-way stakes and two reference stakes. Notice that there's a hub at the base of each reference stake. These are the only hubs needed to complete the cut and fill and excavation for this road section. The surveyors have set right-of-way and RS information stakes on each side of the road every 50 feet the entire length of the project.

All the stakes, with the exception of the RS and R/W stakes, were set by the grade setter using information provided by the surveyor. On the fill side, the grade setter started by setting a lath marked *Toe* 2 feet out to the RS point. If you look at the top fills on his three stakes you'll notice he's set a fill lath every time the fill raised 4 feet, until reaching grade at the HP (hinge point). Looking at the distances on the bottom of the stakes, notice that for every 4 feet of rise each lath moved in 8 feet, creating a 2:1 slope, as indicated on the side of the RS stake. On the cut side, the grade setter has set a lath at the RS point marked *C-10.00 @ 10 feet.* This will create a 1:1 slope, as marked on the side of that surveyor's RS stake.

The grade setter has also set an optional stake, reading *C-5.0 @ 5.0 feet*, half-way down the slope on the cut side. The reason I say it's optional is because the grader won't be able to cut the remaining 5 feet of that slope without hitting that lath because of the short distance between the lath and ditch. It might be a better choice for the grade setter to spray-paint the grade on the slope. Or he could choose to bring his cut all the way down to the shoulder grade before cutting the slope. The grade setter should consult with the equipment operator on this decision. The operator may feel he can do a better job cutting a 6-foot slope than a 9-foot slope, depending on the material. A 1:1 slope is too steep to drive the equipment on to cut the slope, so the operator can't cut deeper than the equipment can reach from the bottom. Never run a dozer or grader horizontally on a slope steeper than 2:1.

Notice in Figure 3-16 that the grade setter hasn't set any hubs, only crows feet. Some grade setters might set hubs where the *Sho* (shoulder) and *HP* lath are located. The equipment operator doing the trimming may need or request hubs at those points to provide him with greater control and a closer cut. The shoulder and hinge point grades will be fine-trimmed after the road has been paved and will be left a little high until that time; 0.10 to 0.15 foot would be about right.

Once the area labeled *Road section* in Figure 3-16 has been cut out and the rough grading complete, the surveyors will return to set bank plugs for a string line to measure grade. If bank plugs aren't required, the subgrade will be compacted and then hubs set by the surveyors for fine trimming the subgrade so aggregate can be placed. The surveyors may also run a row of stakes down the shoulder with new grades.

## Location of Stakes

It's important to know when to use an offset and when to set the stake right on the point being cut or filled. Timing is an important factor in choosing whether an offset is needed for locating a stake. But no matter where or when stakes or hubs are set, make sure they're set on firm ground or aggregate. For example, suppose you need hubs in an area where fill has been brought up to the grade marked on the lath. The grade setter must be sure to pull the stakes, or offset them, so the area can be compacted before the hubs are set. In a deep fill area, the lath must be

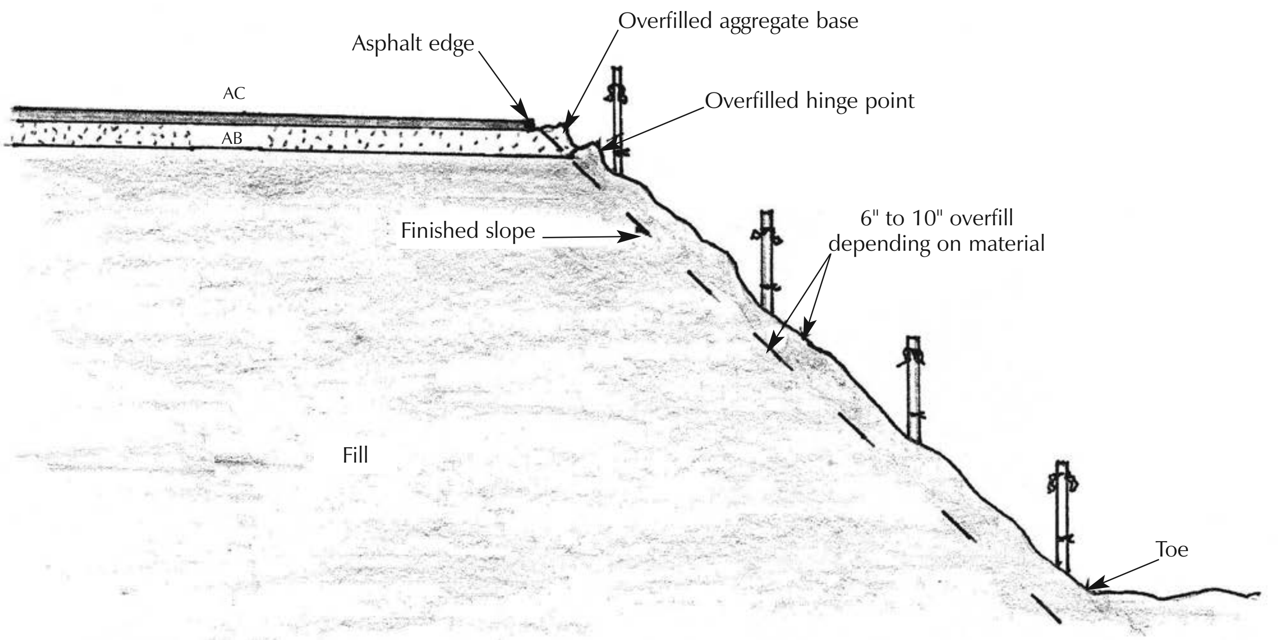


***Figure 3-17*** *Overfilled slope*

offset periodically so the area where the grade lath is placed can be filled and compacted. Then new lath is set with grades for the remaining fill (this is primarily for centerline stakes). In a deep fill where no structure will be built, such as a front lot pad corner that will be part of a yard, there's no need to keep offsetting the lath. Have the compactor operator carefully fill and compact around the lath after every couple of feet of fill while you hold the lath in place. It isn't necessary to pull the lath on this type of fill because the entire slope will be track-rolled when finished.

Never set stakes so close to the area being filled that the edge of a fill can't be compacted without covering up the stakes. Overfill all fill hinge points so that, when trimmed, the hinge point will be well compacted. If you're going to rock or pave the shoulder and the subgrade at the hinge point wasn't overfilled slightly, the rock or pavement will be lost over the edge of the slope. Figure 3-17 shows the correct way to overbuild a slope to provide a solid base for the aggregate.

If a dike — a raised section built to control water runoff or erosion — will be placed on the edge of the pavement, the grade setter or foreman must check the edge-of-pavement (EP) distance on the surveyor's stake.

The surveyor's stake may give the distance to the front or the back of the dike. There must be 3 or 4 inches of asphalt concrete behind the dike so the dike machine can function properly. The grade setter should adjust the stakes to give enough of an offset to allow for the extra 3 or 4 inches needed to place the dike. If the surveyor's stake is marked EP 3 feet, be sure that's the distance 3 inches in back of the dike and not in the front. Surveyors often give front- or back-of-dike distances without figuring in the extra needed for the dike machine to run on.

The grade setter must be very careful when setting lines and grades on all edges. Top-of-slopes, toe-of-slopes, hinge points, choker lines, and ditch lines must be set precisely, for line as well as grade.

The grade setter should never assume that the equipment operator made the correct cut or fill. When the equipment operator has completed a pass, the grade setter should recheck the grade and line. Both the grade setter and the foreman should watch closely as fills and cuts are made. It's easy for an operator to overlook a less-accessible area where cuts and fills are harder to make. Check these areas carefully before the equipment moves on to a new section of the job. Moving the equipment back later wastes time.

It's up to the grade setter to see that no small areas or edges are left half finished. He should also call the foreman's attention to any equipment operators who run over stakes unnecessarily. The grade setter is busy enough without having to replace stakes that have been carelessly run into the ground.

## Sewer Line Projects

On a sewer line project, when the locations of the sewer services are staked, the surveyor may not give a cut grade. That's because the project has usually already been rough graded and the existing ground is close enough to grade to be used. When the sewer service is dug, the trencher or hoe operator may want a grade line to follow. If so, you can do it without the surveyor's assistance. Offset a pin from the service "Y" or tee on the sewer main and also from the service location stake set at the property line by the surveyor. From the bottom of the pipe service "Y" at a 5-foot depth, measure up vertically 6 feet and then 5 feet horizontally to the side and place a grade pin.

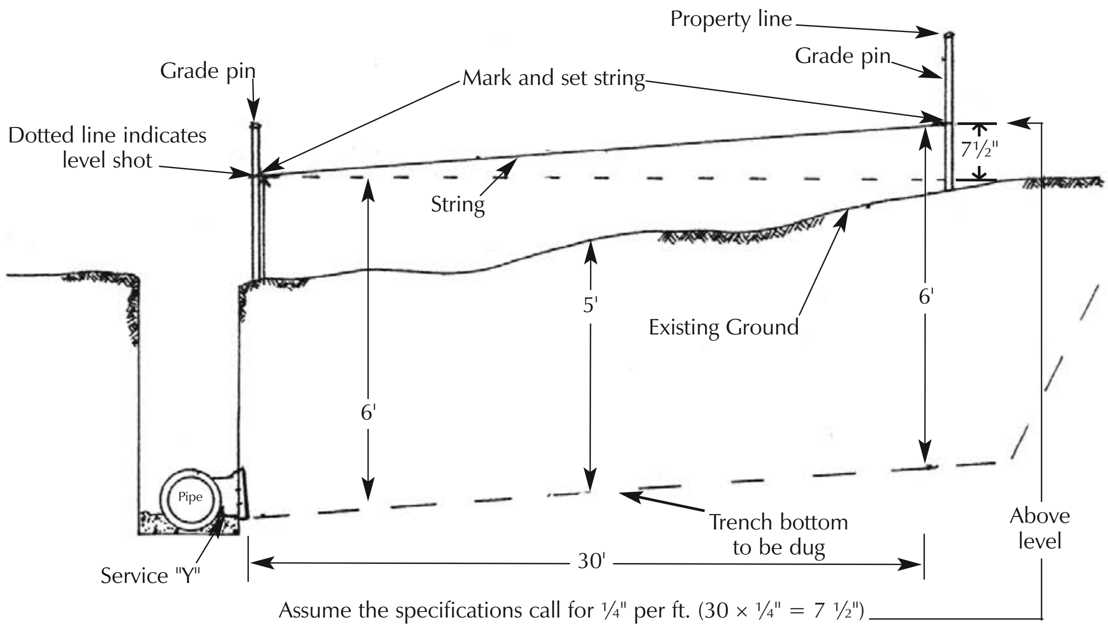


***Figure 3-18*** *Setting grade for a sewer line*

Look at Figure 3-18. Assume the trench is 5 feet deep and we've measured up 6 feet and over to the pin. Compute the amount of minimum fall required in the specifications and raise the string at the property line that amount. In this case, that's $7^1/2$ inches, because the specifications call for $^1/4$ inch per foot slope. If you multiply the 30 feet from the property line to the service "Y" by $^1/4$ inch, you get $7^1/2$ inches. So shoot level from the front pin at the "Y" or tee to the back pin at the property line. Then raise the back string above the level the amount of fall desired ($7^1/2$ inches) and mark it. If the ground rises sharply from the "Y" or tee to the property line, tie the string above the ground the same distance at both the back pin and the front pin. The service line will then have approximately the same fall as the ground slope and will have more slope than the minimum $^1/4$ inch per foot. This will only work with shallow trenches. If the trench is deep or the plans have a service detail or elevations, then the surveyor must set the service line grade.

When setting any grade line, be sure to check every figure. Avoid any distraction while figuring or marking grades. If you aren't quick with numbers, make it a practice to use a pencil and paper or a calculator to do the math. It's a common mistake to be figuring grades from a string of cuts and then come to a fill and figure it too as a cut. Look at each grade stake separately and read it for what it is.

# CHAPTER 3 QUESTIONS

**1. If you have a 4-foot swede and your finished grade at centerline is 0.30 higher, what should your ruler reading be?**

A) 2.70
B) 3.70
C) 3.90
D) 4.30

**2. What do you call a method of setting grade at a center point by sighting across three lath?**

A) Setting crows feet
B) Setting swedes
C) Setting swales
D) Setting boots

**3. To set an 8-foot string line for a 6.13-foot ditch cut, what must be added to the surveyor's grade in order to mark the grade pin correctly?**

A) 0.87 foot
B) 1.69 feet
C) 1.87 feet
D) 2.87 feet

**4. What will cause the laser unit to automatically shut off?**

A) The receiver is out of range
B) It's bumped off-level
C) Another unit is being operated nearby and the signal is confusing it
D) The beam is blocked by a metal object

5. **What is a bench mark?**

   A) The point at which you begin your cuts
   B) The northernmost point of the site, to be used as a beginning point for surveying
   C) The center point where you locate the laser level
   D) A point of known elevation

6. **What should you do if the receiver unit isn't receiving a signal from the laser level?**

   A) Turn the receiver off and on quickly
   B) Make sure the receiver is within 40 feet of the laser level
   C) Check the battery and replace it with the spare you should always have with you
   D) Slide the receiver up or down

7. **If the laser receiver unit shows a straight bar and the rod reading is 7.92, the bench mark *cannot* be at which elevation?**

   A) 127.92
   B) 717.92
   C) 876.92
   D) 1037.92

8. **When checking a grade, if your rod reading is 1.10 and the grade required at that point is 4.18, what would you mark on your lath?**

   A) F-3.08
   B) F-4.18
   C) F-5.28
   D) C-3.38

9. **What does it mean if a crows foot has a horizontal line drawn across it and there's an arrow with a circle through the tail pointing at that line?**

   A) The line indicates finish grade
   B) The line indicates original grade
   C) More cut is needed
   D) Overfill is needed

10. **If there's a cut of 3.50 and a 4-foot boot is needed, the grade setter measures up and marks the lath where?**

   A) 3.00
   B) 3.50
   C) 4.00
   D) 4.50

# SETTING GRADE STAKES USING A CONTOUR PLAN

# 4

Most of the plans we've looked at until now used profiles or cross-section views to indicate changes in the ground slope. For many jobs, all you'll need is a cross-section view of the finished grade. But on others you'll need a contour (or topographic) plan, which provides another dimension of the grading plan. Contour lines will completely control the grades on projects with large landscape areas or on a golf course project. A profile drawing or cross-section drawing isn't able to show all the changes in direction that a contour line will take.

The grading plan that we looked at back in Chapter 2 (Figure 2-2) is basically a contour plan overlaid with lots and streets. Grading plans help the estimator and foreman see what the contour of the project will look like before the grading begins. However, a project that consists primarily of open landscape won't need a grading plan with lot lines and streets. In that case, the plan may show just the finished elevations, or be an overlay of new contours over a very faint contour plan of the existing ground and elevations.

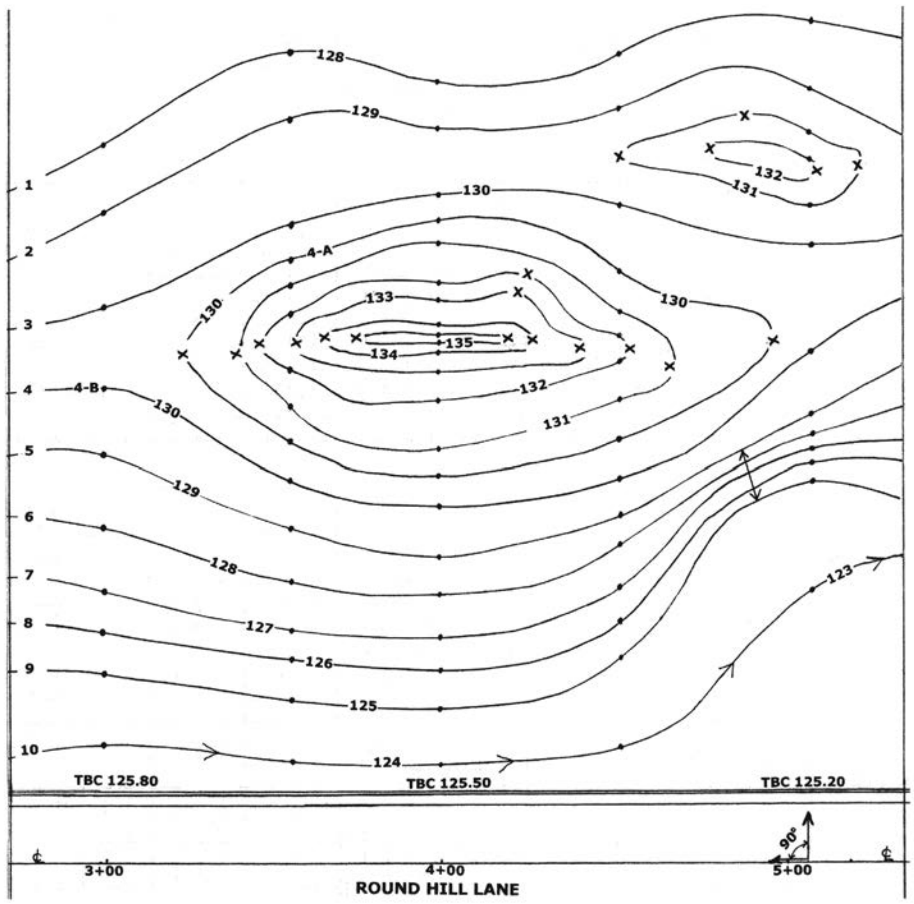


***Figure 4-1*** *Contour plan*

# Reading a Contour Plan

Figure 4-1 is a contour plan for a landscaped area in front of a new industrial building on Round Hill Lane. It shows finished elevations with contour lines. Each contour line on the plan connects points of equal elevation. Where the lines are closer together, the ground is to be steeper. Where the lines are farther apart, the slope is very gradual or flat. Try to visualize the ground this plan represents before we start discussing it.

## *The Contour Interval*

On this plan, each contour line shows a rise or fall of 1 foot of elevation. On some plans, the contour intervals are 5 feet or more. For our convenience, I've numbered these contour lines down the left side of the drawing. Look carefully and you'll see that there are two lines numbered 4 (one is 4-A and one is 4-B), both representing an elevation of 130 feet. Line 4-A is a closed loop, encircling the mound at the center of the plan. Line 4-B extends from the left edge of the drawing to the right.

Start at the top of the plan and follow the first four contour lines. You'll see elevations of 128, 129, 130 and again, 130. The first three lines are spaced further apart, showing a gradual rise toward the center of the drawing. The numbers go from 128 to 130, indicating a 2-foot rise in elevation. Remember, the larger the number, the higher the elevation.

### *Closed Loop Contour Lines*

Look at lines 3, 4-A, and 4-B. All three of these contour lines are at an elevation of 130, which tells us that this center area is flat — except where the five contour lines form irregular circles inside line 4-A. These lines, numbered 130 to 135, show a rise of 5 feet. From this figure you should be able to picture the shape of the ground when excavation is complete: an irregular-shaped mound 5 feet high rising out of the flat area. Line 4A will become the toe line for this fill mound.

Contour lines that form a closed loop always indicate a mound or a depression. If the closed contour lines went from elevation 130 to 125, instead of from 130 to 135, you would be looking at a 5-foot depression rather than a 5-foot mound.

Now look at the group of contour lines from 5 to 9. Following these lines to the right, they get closer together. This shows a slope that becomes steeper on the right side of the plan, dropping 4 feet from the top contour line of 129 to the bottom contour line of 125. If this plan were drawn to scale, you could find the slope by measuring the length of the arrow where the contours narrow. If the arrow represented a length on the ground of 8 feet, then we would know that it's a 2:1 slope (8 feet of horizontal distance in 4 feet of vertical distance). In any contour plan drawn to scale, you can measure a distance on the plan and compute the slope from one contour line to the next.

At the bottom of the plan you see elevations marked *TBC 125.80, TBC 125.50*, and *TBC 125.20*. These are the top-back-of-curb elevations on Round Hill Lane. Now look at the middle of the line marked 10. It's at elevation 124. Since all the top-back-of-curb elevations are higher, you know that the ground will slope gradually from the back of the curb to line 10. As you follow line 10 to the right, you'll see it change elevation from 124 to 123, dropping 1 foot. This line isn't a true contour line because contour lines never change elevations. Line 10 is actually a *contour swale*. It follows the contour of the land but is designed to drain the water runoff in the direction indicated by the arrows.

Again, if Figure 4-1 were a scale drawing, a grade setter and foreman could set stakes in the contour area for grading. The grade setter would mark the percentage of slope on his lath as it changes, allowing the grader operator, if he has slope control, to dial in that percentage, making grading much easier.

## Staking the Area

Let's look at how to set out grade stakes for the excavation work shown in Figure 4-1. We'll have to assume that we have a plan scale indicated somewhere that we can work from. Usually you'll see *1" = 40'* or something similar noted in the bottom corner of the plan. You'll need to have an engineer scale ruler (found at any office supply store) for this type of work.

The plan shows the centerline and the stations on Round Hill Lane numbered every 100 feet, starting at 3+00 and going to 5+00. Start by setting up a surveyor's transit level over the centerline mark at station 5+00. Sight up the centerline to station 4+00. This gives us an exact reference line for the other sighting we'll take. Set the transit at zero degrees along the centerline and turn 90 degrees toward the lot, as indicated in the figure on the bottom right. The grade setter would now scale from the plan the distance to each of the contour lines directly out along the 90-degree line. He would measure out and set a stake in the ground at each contour line, sighting through the transit for line, 90 degrees from centerline. This procedure would continue every 50 feet (plus or minus) down the centerline. The reason I say 50 feet plus or minus is because you might want to vary the distance a little to catch more of the contour in the most active areas of contours. This will help eliminate some of the intermediate staking. There should be a hub set in the ground at each stake as a reference for shooting elevations.

Once the stakes have been set as indicated by the small dots drawn on the contour lines in Figure 4-1, you may want to set intermediate stakes where contour lines make abrupt changes of direction. These stakes are indicated by the x's marked through contour lines. Set these intermediate stakes by measuring from the stakes (indicated by the dots) set along the 90-degree lines. Intermediate stakes will give better control once the grading has started. A grade setter using GPS will set fill or cut stakes for the scrapers if they're not equipped with GPS, but a grader with a GPS unit won't need any stakes to grade to.

If all your equipment uses GPS, it's possible to grade the entire area without putting a stake in the ground. In that case, the grade setter will spot check the grades with the GPS rover unit. When the grade setter sets grades with a GPS rover, he does't need to measure on a 90-degree line from the centerline. The screen on the rover unit will show all the contour lines and he can just set the rover on any line he needs a grade for, and the unit will supply the cut or fill needed.

### *Marking for Cut or Fill*

Without a GPS unit, the next step for the grade setter is to mark the amount of cut or fill needed at each stake to produce the finished grades shown in Figure 4-1. We must start from some known elevation on site. Use a bench mark if one is available. On this site we don't have a bench mark, so we'll use the top-back-of-curb elevation at 125.50 as our starting point.

Set the laser rod at TBC 125.50 at a 90-degree angle from the road centerline. Set and level the laser unit (Figure 4-2) anywhere in the contour area that's higher than the highest contour line by 3 feet. If you don't set the laser level high enough the first time, it must be reset if the readings on the rod become so low or high that the receiver is unable to get a signal. Make sure you locate it no further than 400 feet from the furthest shot for good accuracy. Slide the receiver up or down on the laser rod until you hear a steady signal (Figure 4-3). The top-back-of-curb elevation is 125.50, so loosen the clip that holds the rod tape and move the tape to read 5.50 at the point where the laser receiver indicator has a steady signal. Only the last three numbers of the elevation show on the rod, so 125.50 is set as 5.50. Once a 5.50 elevation is in place and level with the laser beam, lock the rod tape by screwing the clip tight again.

Now we can start marking cuts and fills at each of the hubs. Set the rod vertical on the first hub where the finish grade will be at 125 elevation. Without disturbing the laser unit, slide the receiver on the rod up or down until you receive a steady signal from the laser receiver.

***Figure 4-2*** *Set and level laser unit in the contour area*

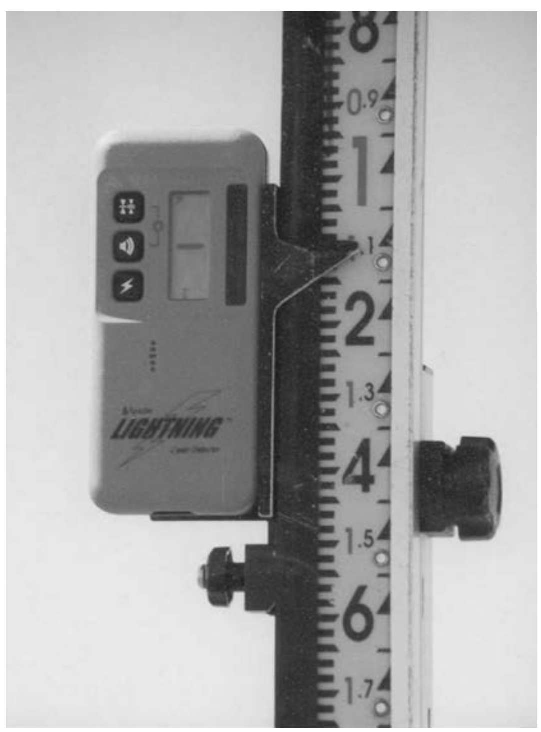


***Figure 4-3*** *Surveyor's rod with laser receiver unit*

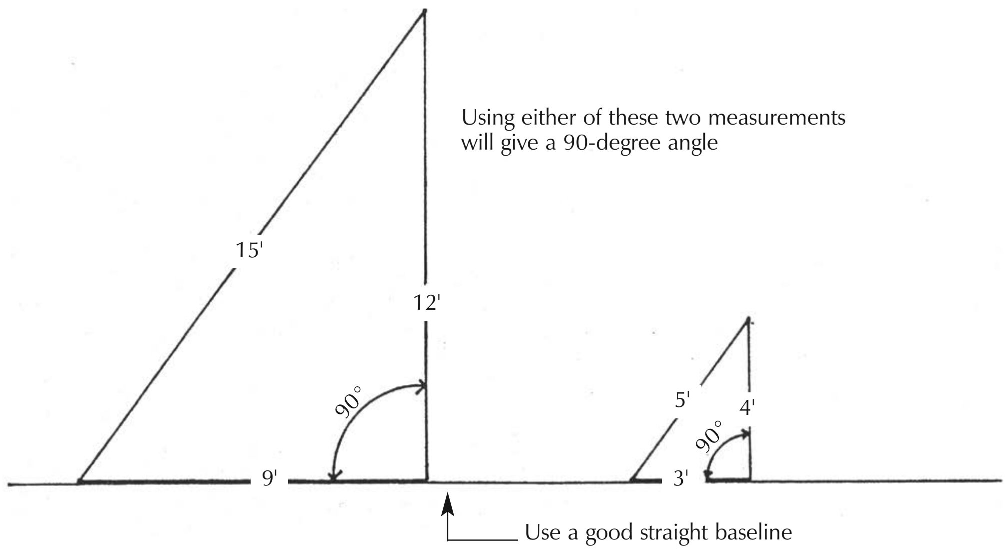


***Figure 4-4*** *Finding a 90-degree angle*

Suppose the rod reading is 1.10, with a level signal as in Figure 4-3. Since only the last three numbers of the elevation can be set on the rod, you know that 1.10 is 121.10. Calculate the grade by subtracting the grade shown on the rod (1.10) from the 5.00 (125.00) finished grade. Mark a fill of 3.90 feet on the stake by that hub. Keep in mind that if you're subtracting the rod reading from finish grade, it will be a fill. If you're subtracting the finish grade from the rod reading, it will be a cut. Continue taking readings and marking cuts and fills until the work to be done has been noted on every stake.

## *Making a 90-Degree Angle*

If no surveyor's transit is available, you can still set out the stakes indicated in Figure 4-1 with just a tape measure. First, find the centerline of the road. Run a string line down the centerline 50 feet. Make a 90-degree angle from that centerline by constructing a 9, 12, 15 right triangle. See Figure 4-4. Measure 9 feet along the centerline. Then measure 12 feet out from the baseline at approximately 90 degrees. Now connect the ends of the two lines. Adjust the perpendicular line until the line connecting them is exactly 15 feet. When you're at 15 feet, the angle is 90 degrees. I prefer running a string line 50 feet down both the 9-foot line and the 12-foot line. This gives a good line to sight down the 12-foot length of the angle (perpendicular). Then set out the stakes along the perpendicular by measuring to each contour line.

Set two 4-foot lath; one back-of-curb, then one 20 feet out on the perpendicular string line. These can be used to sight over for line to set the contour lath. Sight over the two lath as a helper moves a third lath right or left until it lines up with the two set on the 90-degree line. Once you have two lath placed, there's no need for a string line. Using two lath to sight over for line is very accurate.

When all the stakes set along the 90-degree line from the centerline have been marked at each contour line, and the intermediate stakes are placed with cuts and fills marked, the grading can begin.

If you look at all the dots and x's on Figure 4-1 indicating the grade stakes, you'll probably agree that heavy excavation equipment won't have room to work between them. The initial staking will give the operators an idea of what's needed. Then the operators should work around the stakes as long as possible. Eventually the equipment will have to work over the stakes. For final grading, the grade setter may have to check the grade and reset stakes. It's important to walk the operators through the area so they can picture in their minds what the final cuts and fills they're going to build should look like. Probably every stake in the circle area will need to be offset and reset at least once before the grading is finished.

Most contour plans show the existing contours in dashed or faded lines and the contours to be built in solid dark lines. Don't be confused when you see the extra lines and grades on a plan. I left the existing ground contour lines and grades off the drawing in Figure 4-1 so it would be easier to read. But the contour plan you get should show both existing and finished grades. The engineer and estimator need them to help determine the dirt quantity and distance the dirt must be hauled.

Generally, the accuracy of finish grading for apartment landscaping or industrial tract landscaping isn't that critical. Because of this, the excavation contractor's crew rather than the surveyor will often set the contour line grades. A hand-held eye level and a 90-degree prism or the 9-, 12-, 15-foot method in place of a transit and laser level may be good enough for setting contour grades on small jobs.

Also be aware that it's not unusual for the design engineer to change the contours somewhat if, when they're finished, they don't look the way he had visualized them. This would be calculated as extra work.

# CHAPTER 4 QUESTIONS

**1. What is another name for a contour plan?**

A) Profile plan
B) Topographic plan
C) Grading plan
D) Subdivision plan

**2. How can you tell when contour lines represent a steep slope?**

A) They are spread out evenly
B) They turn sharply
C) They connect in a circle
D) They are close together

**3. How many contour lines in Figure 4-1 are at elevation 130?**

A) 1
B) 2
C) 3
D) 4

**4. What is indicated when contour lines connect to form a loop or circle?**

A) A depression or a mound
B) A lake
C) A mound
D) A steep grade

**5. When do contour lines change grade?**

A) When making a loop
B) Never
C) In a depression
D) At the top-back-curb

**6. What line in Figure 4-1 does not represent a true contour line?**

A) 2
B) 4B
C) 7
D) 10

**7. In order to correctly mark the cut or fill to produce the finish grade, where must you start your measurements?**

A) At the first contour line stake
B) At the edge-of-pavement
C) At a known elevation
D) Only at a bench mark

**8. If an elevation is 125.50, which numbers will be set on the surveyor's rod?**

A) 5.50
B) 125
C) 125.5
D) 125.50

**9. Using 9 feet as a baseline, what combination of measurements will allow you to make a 90-degree angle?**

A) 3, 6 and 9 feet
B) 3, 9 and 12 feet
C) 9, 12 and 15 feet
D) 9, 12 and 18 feet

**10. Who, other than the surveyor, might set the grades for an industrial tract landscaping project?**

A) The architect
B) The general contractor
C) The equipment operator
D) The excavation contractor

# Grading with Lasers, GPS and Other Specialized Equipment

# 5

When setting grade stakes for large areas, such as large parking lots and industrial sites where an accurate finish grade is critical, it's best to use a laser level. With a laser level it's quick and easy to reset grade hubs that have been run over by the equipment or need to be offset and reset after an area has been excavated.

Think carefully about where to set up your laser. There are three main factors to consider. First, you want a safe place where it won't be run over by equipment. Second, the setup point should offer good coverage of the job site. Third, if the grades you'll be checking will continue to get lower, set the laser so the beam will hit the receiver low on the rod — say, knee high. This will give you more rod to work with as you work to lower grades. The receiver will keep rising on the rod. Do the reverse if you'll be working uphill from the receiver. If the only place available for a setup is in a high-traffic area, place lath and flagging around the laser so it's less likely to be accidentally run down. Keep in mind that wherever you set the laser unit, it must be higher than the area you want to grade.

## Using a Laser Level for Parking Lots

If you have a large parking area that drains to swales or curbs, your grading must be done precisely. Any low spots will collect water on the finished asphalt the first time the surface gets wet. Start by doing the rough grading, if needed. Where deep cuts are required, set a 2- or 4-foot lath with the cut or fill marked on it. This is faster and more practical than driving hubs that will be excavated or filled over later. Don't bother using the laser in areas where checking grade with a hand level or sweding the subgrade will be faster.

When rough grading is finished, you may want to establish a grid pattern on your parking lot plan. You'd only do this for very large parking areas, such as a football stadium parking lot with few islands. The grid lines should intersect about every 25 feet. Lay out the same grid lines on the site and drive a hub at each intersecting point of the grid. Don't bother setting the hubs at the right elevation yet. That will come later. Figure out what the elevation should be at each hub so that the entire area will drain evenly from the highest point to the lowest. Mark those elevations on the grid plan you've created.

When the entire grid is established, both on the ground and on your plan, begin driving hubs to grade. Use a laser to check the elevation at each hub. Drive each hub until the head is on grade — that's when the rod reads the elevation you've computed for that point, there's a solid line showing, and you hear a steady on-grade signal from the receiver. Once you have each hub set to the desired grade and there's a guard lath beside it, the grade is ready to be fine trimmed. This is the method you use for trimming subgrade and aggregate.

If the parking area has several ridges and swales for drainage, plus curbs and planters around the perimeter and throughout, it may be faster to swede the grades needed from the swales and ridges rather than laying out a grid. A combination of setting some grades with a laser and sweding some grades might work best. Remember the grid only works well on very large surfaces. If the grader is equipped with sonar and slope control, the grade setter must compute the percentage of fall for each area and let the grader operator know what slope to dial in. With GPS, very few intermediate stakes will be needed. Then you'd mainly check for accuracy behind the grader, and paint grades on the trimmed surface if more cut or fill is needed.

# Using a Laser Level for Apartment or Industrial Pads

On apartment or industrial pads, the surveyors usually set four corners and some perimeter stakes. You'll have to set all the remaining grades needed for excavation. On any building pad, the plans may show two grades: the finished floor of the building and the pad elevation. Be sure you always use the pad elevation.

Let's assume the pad is 300 feet long and 250 feet wide. The scraper operators can't be expected to hold a level grade over that distance unless they're using a laser-guided system or GPS. As a rule, you need to set grade control stakes across the pad until the cut or fill is within 3 or 4 tenths (0.30 or 0.40) of the finished grade.

With a laser level, you can check grade at any point on the pad from a single setup. When the excavation is getting close to finished grade, there are three ways to inform the operators of how much cut or fill is needed.

1. You can relay the information directly to the operators by hand signals.
2. You can paint cuts or fills on the ground.
3. You can set crows feet across the pad with the cuts or fills indicated on them.

If you have time to stay with the scrapers, you should look for areas that are on grade and paint an on-grade symbol on that spot. The on-grade symbol is a circle with a line through it. Setting lath is usually the best method when a fill is being made. The scrapers dump at a higher speed than they cut. They may not have time to read symbols painted on the ground. If you have other areas to check and can't stay with the scrapers, use crows feet to indicate the grades.

Once the pad is nearly on grade, it's ready to be trimmed with a grader. Work ahead of the grader, painting cut or fill symbols on the ground. After the grader has made a pass, check to be sure the trim or fill was made correctly. If the grader is using sonar and slope control, the first pass on the outside edge must be right on grade. If the first pass is off, the sonar will read it as correct and all the remaining passes will be off as well. Check the first pass very carefully. Figure 5-1 shows a grade setter

***Figure 5-1*** *Grade setter working ahead of grader*

checking ahead of the grader. On a large job, several grade setters can work at different elevations off the same laser level if the beam isn't too high or too low for their receivers.

With a laser rod, you don't use a boot as you do when checking grade with an eye level. Instead, mark the elevations you need with a pencil on the front of the information lath. For example, if you need 2 inches (0.17 foot) of asphalt and 6 inches (0.50 foot) of aggregate for a parking section, the three elevations marked on the lath might be *AC 135.00* (finished asphalt), *AB 134.83* (finished aggregate: 135 − 0.17 = 134.83), and *SG 134.33* (subgrade elevation: 135 − 0.17 − 0.50 = 134.33). During excavation, the subgrade elevation is all that's really needed on the lath.

## Using a Laser Level on a Road Project

On a road job, the elevations of ditch, shoulder, and centerline subgrade are marked on the lath. Each time the grade is checked at a station, the grade setter can see on the lath the elevation he should have on the survey rod. It helps if the finished elevations for each point are shown on the plans. That makes it easy for the grade setter to subtract the section he wants to cut from the finished grade shown.

If the surveyor sets a hub and information stake with a cut of 0.70 and you want to check subgrade with the laser rod, here's how to do it. Set your survey rod on the hub in question. Subtract the cut and the road section depth. Let's say the survey rod reading on the hub is 3.50. The surveyors have a 0.70 cut to finish AC and there's a 0.75 road section depth. Subtracting the cut and road section from 3.50 gives you an elevation of 2.05 ($3.50 - 0.70 - 0.75 = 2.05$) for subgrade at that point. Mark *SG 2.05* on the lath so you won't have to refigure it every time the station is checked.

If the surveyors have a fill rather than a cut to the finished grade, the fill must be added to the rod reading before the section is subtracted. For example, if we use the same rod reading, 3.50 elevation with a fill of 0.70 and a 0.75 road section depth, the rod reading for subgrade should be 3.45 ($3.50 + 0.70 - 0.75 = 3.45$). Mark that subgrade elevation on the lath to save calculations later. Remember, a road or parking lot section is the thickness of AC and aggregate between finished grade and subgrade. On a large road project where the laser unit must be moved several times, it's faster to just check grade with a hand level for rough and fine grading.

When excavation of the compacted earth is complete and the subgrade has been compacted and trimmed to the tolerance required, it's time to begin placing aggregate. To figure the correct elevation for aggregate at each station, add the thickness of the aggregate to be placed to all the subgrade elevations that the grade setter marked on the lath while excavating and trimming subgrade. If the subgrade marking says 3.45 and there's 0.50 foot of aggregate to be placed, then add 0.50 to 3.45 to get 3.95. That's the AB elevation that should be marked on the lath. This gives you two elevations on the lath: *SG 3.45* and *AB 3.95*.

Set the rod elevation from an accurate grade reference such as a bench mark. If a bench mark isn't available, use a point on the plans with an elevation indicated, such as an existing drain inlet, curb, concrete slab or wall. If they haven't been disturbed, survey hubs for pads, curbs, or pipe are also good reference points. Once the elevation is set, check the setting at a second and third known elevation point to be sure the setting is accurate.

If you're using a laser level for grade control on a subdivision, road or parking lot job, be sure to ask the surveyors to set an accurate bench mark somewhere on the site. This is a must if they haven't provided an elevation on each information stake.

# Using a Laser Level for Trench Work

Using a laser capable of sending a sloping beam is the fastest and most accurate method for setting grades for trenching and laying pipe. Set up the laser level at a location where it won't be bumped by the equipment, usually several feet from the work area, facing down the trench. At this location, both the hoe and grade checker can receive the beam from a twirl-type laser. A laser with a twirling beam needn't be positioned on the centerline of the trench because it's only used for grade and not line. The center of the transmitter, however, should be pointed in a line parallel with the trench to be excavated to insure grade accuracy. I don't suggest placing a laser with a sloping beam farther than 12 feet from the trench edge. For trenching, use a string or paint line to keep on line.

The advantage of using a laser with a twirling beam is that it can be used while laying or trenching on a radius (or curve). Also, because it's offset from the centerline of the trench, it can be used for trenching and laying simultaneously. The trench grading and pipe-laying operation can go on while the laser guides the work of the hoe doing the trenching.

## *Setting the Percentage of Slope on the Laser*

The job plans will have a profile sheet showing the amount of fall required for each pipeline. Assume the profile shows a slope of 0.0032 per foot. There are two ways to set the percentage of slope on a twirling-type laser. Some transmitters have a calculator-type keypad. Just punch in the slope you want with a plus or minus grade or use the up and down key to change the slope. The laser has a small window with figures that show what slope it's sending. On other transmitters, you dial the slope in with a knob on the side of the laser.

Keep the instruction manual you get with a new laser unit with you in the laser case at all times. Every laser model is a little different, and it takes time to learn. A mistake in surveying for grading work can have far-reaching repercussions.

## *Setting Up the Laser for Trenching*

Once you've dialed in the slope, you're ready to set up the grade rod. Be sure the survey rod you use is a direct-reading rod. Set the laser at a point behind the trench that's higher than the surveyor's hubs. Set the rod on a hub that's 25 to 50 feet away from the laser. Slide the receiver up and down until you pick up a steady signal from the laser level. Now measure up from the hub to the pointer on the receiver while the rod is receiving a steady signal tone. Let's say you measure up 2.60, and the cut the surveyors have marked on their stake is C-7.90. Add these two numbers together to get 10.50 (7.90 + 2.60 = 10.50). Without moving the receiver, loosen the tape clip and raise the tape until it reads 10.50 at the pointer on the receiver.

Next, walk 75 or 100 feet down the line and do the same thing, with the exception of moving the tape. Slide the receiver until you get a steady on-grade signal, then measure from the hub to the pointer on the receiver. If the surveyor's grade is marked C-7.58 and you've measured up 2.92 to the pointer, add those two numbers together to get 10.50 (7.58 + 2.92 = 10.50). As long as you continue to get the same reading at each hub when you add the ruler reading at the hub to the cut marked by the surveyors, the laser is sending the correct slope beam.

Once the rod has been set and the grade slope confirmed, the rod can be used for trenching, grading, and pipe laying. The 10.50 grade set on the rod is the flow line of the pipe only.

There are three grades that must be set to trench, grade and lay pipe. The first rod reading is the grade the hoe will dig to, including the undercut for placing the pipe bedding material. To determine the amount of undercut, you need two measurements: the amount of pipe bedding and the thickness of the pipe. You get the amount of bedding material required from the plans. We'll say the plans or job specifications call for 0.40 foot of bedding under our 10-inch clay sewer line. To get the pipe thickness, just measure the end of the pipe. We'll assume the pipe is 0.10-foot thick. Now we have both the measurements: 0.40 bedding plus 0.10 pipe thickness equals a 0.50-foot undercut.

Once you've determined a 0.50 undercut is needed, just slide the receiver and pointer to 10.00 and lock it again. With a direct-reading rod, 10.00 is lower than 10.50 by 0.50 of a foot. Be sure you don't loosen the tape clip. As long as the tape stays clipped you can move the receiver to read any elevation you want.

Now we want to start placing and grading our base material so we can lay pipe. We must set up a grade rod for the finished bedding grade by adding the thickness of the bedding material to the 10.00 rod elevation we used for trenching (10.00 + 0.40 =10.40). Just slide the receiver and pointer to read 10.40; don't loosen the survey rod tape. Remember, on a direct-

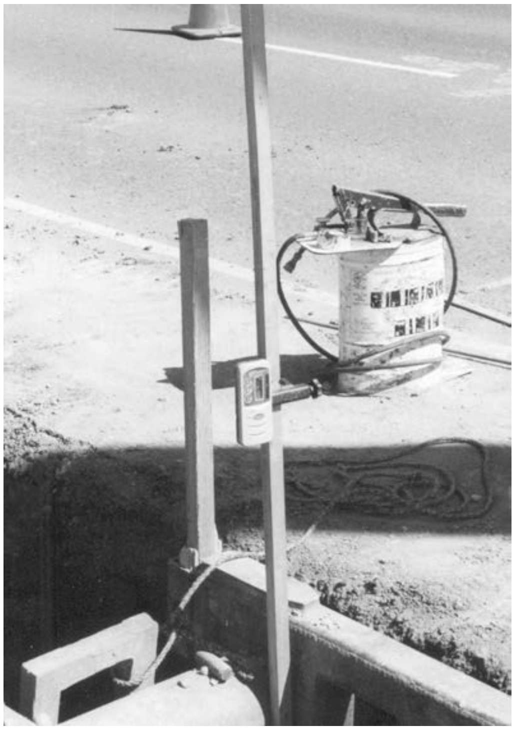

***Figure 5-2*** *1 × 2 pole with laser receiver*

reading rod, as you come up in elevation, the numbers get larger. Use the 10.40 rod reading to hand trim all the bedding material for the pipe.

Once the pipe laying starts, the rod must be adjusted once again to check the pipe flow line grade. If we add 0.10 to our rod reading of 10.40, that gives us the 10.50 flow line grade we want. There's one problem with this. You can't hold the rod perfectly vertical and set it on the flow line of the pipe because the top of the pipe interferes. The way to solve this problem without attaching a right angle bar at the bottom of the rod, is to check grade at the top of the pipe at the upstream end. To do this, add another 0.93 to the flow line elevation of 10.50. How did we come up with 0.93? We added the inside diameter of the pipe, which is 10 inches, or 0.83 foot, and the thickness of the top of the pipe, which is 0.10 foot (0.83 + 0.10 = 0.93). That gives us the rod reading of 11.43 (0.93 + 10.50 = 11.43) in order to check grade from the top of the pipe.

Remember to check the thickness of the pipe at the barrel end and not the bell end. Likewise, when checking the grade of the pipe, check just *behind* the bell, not *on* the bell.

You don't need a survey rod to check grade. A 1- × 2-inch pole will work. Take the measurement from the bottom of the rod to the pointer at 11.43 and transfer that to the 1 × 2 pole and mark it. Clamp the laser receiver firmly to the 1 × 2 so it can't move. Make sure the pointer on the receiver is level with the line just drawn on the pole. Now you can move the pole up or down until you get an on-grade signal without moving the receiver. Here's something to keep in mind when using a 1 × 2: to dig deeper, you raise the receiver; to dig shallower, you lower the receiver. It's a very common mistake to mark in the wrong direction. Figure 5-2 shows a 1 × 2 with a receiver clamped to it. Note: If the pole becomes cluttered with lines, use a piece of tape (duct or masking) to cover the old lines. You can draw new lines on the tape. Keep in mind that even though you don't need a survey rod for every procedure, you do need a receiver on every rod or pole used.


***Figure 5-3*** *Laser-controlled compactor*

## Laser Receivers Mounted on Equipment

Laser receivers are often mounted right on the equipment on larger projects. Consider this if you're grading farmland, large storage pads or even long levees or channels with a constant slope. Laser control is also useful for subdivision excavation. You can excavate lot pads by dialing the elevation required in each area.

Figure 5-3 shows a laser-controlled compactor. Equipment like this can save a lot of time. Hydraulically-controlled laser units can operate the equipment controls automatically. When using equipment-mounted receivers, the transmitter must be placed on a platform or mounting pole so it's high enough to reach the target on all equipment in use. No matter how many pieces of equipment or what size, the target arm on each must be long enough to intercept the laser beam. The target mast on the equipment telescopes up and down to receive the beam.

### *Using a Laser Mounted on a Scraper*

In Figure 5-4, the scraper is equipped with an on-board laser system. You can see the laser receiver extending above the paddles on the scraper bowl. In the cab there's a laser control box where the operator sets his

***Figure 5-4*** *Laser-controlled scraper*

elevation and gets his readings. On this particular unit, the operator dials in the elevation he wishes to cut, then manually operates the controls. The laser unit will read *Hi* or *Lo* until it's reached the grade dialed in. When the unit reads *On*, the operator knows he's on grade.

Here's how to set up for a laser mounted on a scraper. First, mount the transmitter on a platform in an area where it can cover the entire job. Next, set the cutting edge of the scraper on a bench mark or known surface elevation. Raise or lower the receiver pole until the laser unit aboard the scraper gives an on-grade signal. Then dial the elevation of the bench mark into the on-board laser. The on-board laser is now calibrated.

Procedures beyond this point will vary with the model or brand of laser unit you're using. As a rule, the elevation of each cut or fill must be dialed into the on-board laser unit. As the operator gets to the cut area, he sets the elevation to be cut. When he approaches a fill area, he sets the elevation to be filled. The on-board laser unit will adjust the bowl of the scraper up or down so the cutting edge will be at that elevation. If it isn't an automatically-controlled unit, the operator must manually operate the scraper bowl. Every system has an override so the operator can take over manually if the cut or fill is too large for the system to handle automatically.

***Figure 5-5*** *Grader with laser pole attached*

When you use on-board lasers, the equipment operators must have a small plan of the lots and their elevations so they'll know what elevation to dial into the laser unit. The laser may also be mounted on a grader for pad trimming and used in the same manner. Figure 5-5 shows a grader, with a laser pole attached, trimming a large commercial pad. Laser levels are like any other sophisticated equipment. If used properly in the right application, they speed up production. Used incorrectly, the results will be unpredictable.

## Other On-Board Control Systems

There are many grade control systems that aren't laser operated. Many graders are equipped with a system for slope control and a sonar unit that can follow curbs, wire, string or a precut grade. To prepare these units for work, the operator first levels the cutting edge of the blade and then sets the control box at zero percent and locks it in. Once this is done, the operator can dial in any slope percentage he wishes to cut. The unit automatically controls the cutting edge on the right, left or both sides for the slope dialed in. If too much material is being cut, the operator can override the system and take over manually. The setup never needs to be reset unless the unit starts cutting an inaccurate slope.

This system works well on road jobs where a crown or super-elevation is being trimmed. The operator can manually control the cutting edge over the guineas set by the grade setter along the road edge, or a string line can be set up along the edge of the road and sonar used to follow the string line grade. By dialing the percentage of slope needed for the opposite side cutting edge, the slope control automatically controls that side while the operator controls the guinea side, or the sonar follows the string line grade.

When the operator has finished his trim over the guineas on one side, the slope control has cut the opposite side to the exact dialed-in slope. The operator now moves over and manually holds the cutting edge to match the outside pass that was just cut, or locks onto that grade with his sonar unit. With the slope still dialed in, the cutting edge on the opposite side is again automatically controlled to cut the correct slope. A wide road section can be trimmed in this manner without intermittent stakes. The grade setter follows and checks the grade periodically to be sure the equipment is working accurately.

When the slope control is operating on one side and sonar on the other, the grader operator will override the system if the needed cut is larger than can be made with one pass. Again, the most important point in using slope control is to cut the first pass accurately because each succeeding pass will come out the same way. If the grader is equipped with sonar, it ensures a very accurate grade to work from, especially if a string line is used on the first pass. A concrete curb is also an excellent grade to run sonar from.

On-board slope control saves a lot of the time that would normally be spent setting hubs and retrimming. It can save hours or days on large building pads that are level or have slight slopes. One side can be set to grade with stakes or a string line and then the rest of the pad graded by dialing a slope or level, whichever is needed, into the control system.

## Grading with GPS

GPS (global positioning system) is a satellite navigation system consisting of approximately 30 satellites that orbit the earth, and receivers that convert their signals into position, velocity, and time estimates. The system is funded and controlled by the U.S. Department of Defense, though there are thousands of civilian uses worldwide. Among the civil applications are telecommunications, navigation, positioning, and surveying. The uses for GPS are expanding almost daily. In our business, we're interested in how we can apply it to surveying and grade control.

The main component for GPS grade control is the base station or receiver. Before you begin a project, the base unit needs to be set up. The ideal location for the unit would be adjacent to the site, on high ground with a clear view of the horizon. Buildings, walls, trees or hillsides will obstruct the satellite reception and may affect the performance and accuracy of the system. The satellite receiver has to be set up plumb, level and in precisely the same location each day.

***Figure 5-6*** *GPS receiver and antenna mounted on tripod stand*

There are two ways to set up the satellite receiver. The first is to attach it to a portable rod, as shown in Figure 5-6. Adjustable legs are attached to the rod so it can be set plumb and level. The second is to use a 4 × 4 post with a 2 × 4 top plate that forms a "T" (see Figure 5-7). The post is set plumb in concrete so it can't move. The 2 × 4 is placed perpendicular and level at the top of the post with the receiver bolted securely in place. This method is the one I prefer. It's less likely to move in a strong wind. Generally, the satellite receiver and radio antenna are bolted to the 2 × 4. However, in Figure 5-7, the radio antenna is mounted on a high pole to improve radio reception to all areas of the job. Unlike the receiver, the radio antenna doesn't have to be level or in the same location each day.

### *The Rover*

Once the base unit is connected and turned on, a hand-held rover unit is connected to the base to configure the radios and set the receiver height. If the rover and the base station aren't set to the same radio frequency and channel, they can't communicate with each other and the

***Figure 5-7*** *Stationary setup for GPS base station*

system won't work. After the base setup is complete, the rover is disconnected from the base and connected to a portable radio and satellite antenna.

The rover is used to enter survey control points (coordinates) to establish location and elevation. Depending on the software and system used, you need between two and five survey control points to establish vertical and horizontal control for the project. A job model with pad and street or parking lot elevations must be built for the job. The model should have all the appropriate limit lines for pads, sidewalks, curbs, paving sections, etc., to complete the job. Models are built on a personal computer using specialized software, and downloaded to the rover by link or from a memory card. With control points established and the necessary job model, you can begin work.

The rover is an excellent tool for rough grading projects. When beginning a job, the grade setter can establish limits of cut and fill areas for the initial prep work and ripping. If the job has heavy cut and deep fill areas, he can set daylight stakes to high pads (in the cut) before any pads, corners or streets are staked (see Figure 5-8).

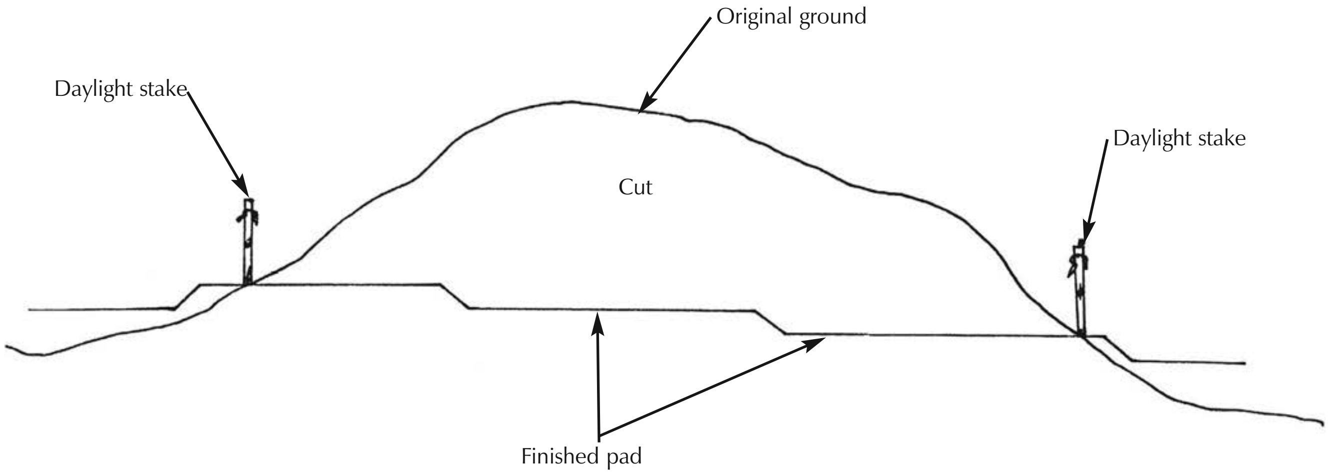


***Figure 5-8*** *Set daylight stakes for heavy cuts and fills*

Set toe stakes for deep fill areas so they can be built from the bottom up correctly. This saves a lot of time and money. Without a GPS, the grade setter spends a great deal of time offsetting stakes to save grade and location until the cut is made, then more time replacing the survey stakes to their original location. In large fill areas, a stake is hiked up and filled around until grade is reached. The problem with this system is that once grade is reached, the stake may be in 10 feet of fill and no longer perpendicular with the hub. It could be off by a couple of feet or more, as shown in Figure 5-9.

Using GPS, once the cut or fill is nearing finish elevation, you can use the rover to set pad corners, sidewalk, curb or centerline stakes. The amount of staking you need is determined by how much equipment on the job is GPS controlled. If the compactors, motor graders, and dozers building and finishing streets and pads all have GPS control, little or no staking is required. However, it's probably a good idea to set some pad corners and staking as a backup. That way, the job can continue with lasers and receivers in the event there's a problem with satellite or radio reception.

Depending on the type of GPS receiver you're using, you can pull up and check the number of satellites being accessed on the rover screen. There's also a graph that shows the best time of day for reception in your job area. Reception diminishes when you can access fewer than five satellites. However, as more satellites are added to the system, this problem is lessening.

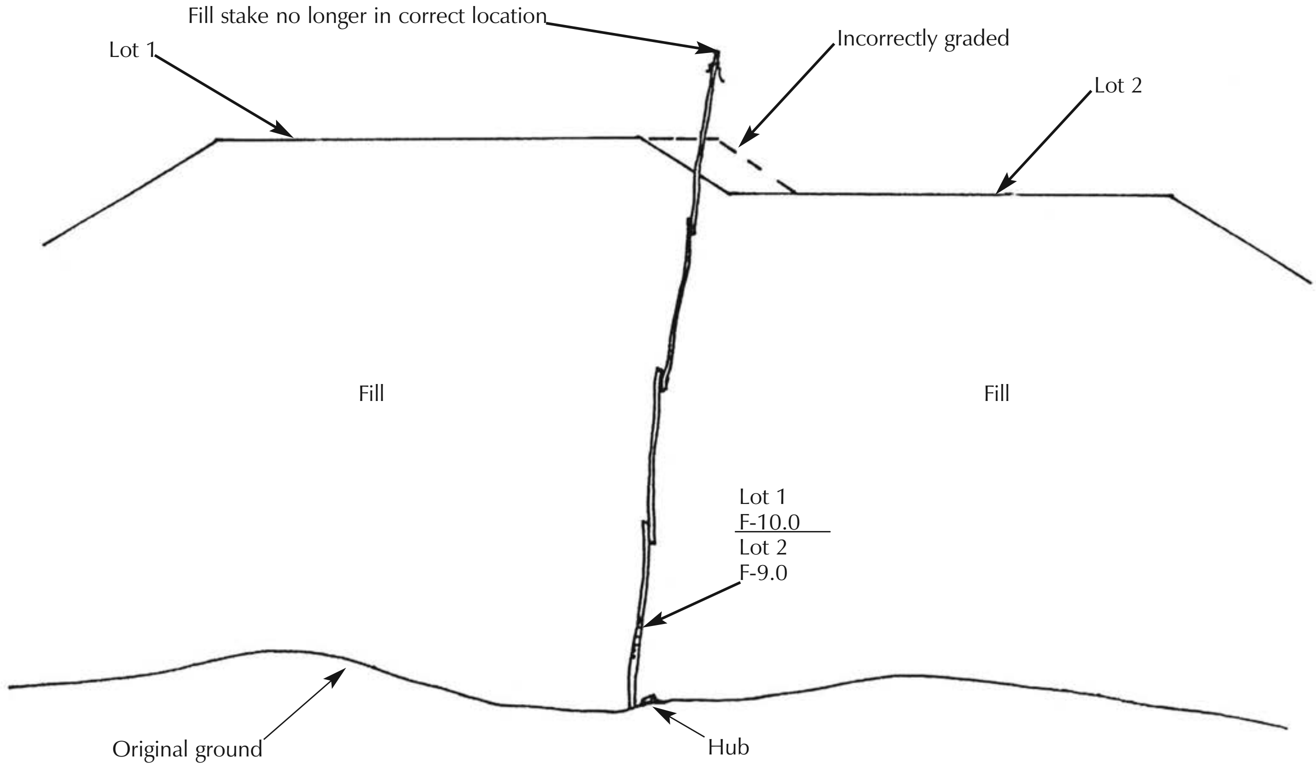


***Figure 5-9*** *Hub stake position is off after several fills*

The rover is a good tool for saving the locations of existing utilities. When beginning a subgrade job, you need to reference and tie out all water valves, manholes, sewer cleanouts and anything else in the grade that will get buried during grading and paving. There's sometimes considerable risk of losing the tieout from a temporary tie to a lath or survey stake. With the rover, you can establish a point file and save the objects to tie out one at a time into the file. The file can be named anything (i.e., Job 1 Underground). To save a manhole location, the rover rod is set on the top center of the manhole plate (Figure 5-10) and the option to measure point is selected. You're prompted to name the point (manhole 1). Make sure the rover is plumb and level so it's accurate, then measure the point. The process of calculating and saving the longitude, latitude and elevation position takes just a few seconds. If the option to show these saved points is selected, you'll see them on the design surface on the screen. Once the job is paved, you can use the rover to mark the utilities that need to be raised to finish grade. This saves the headache of trying to locate a utility in finished paving where the wood tieouts may have been knocked out.

***Figure 5-10*** *Grade setter holds GPS rover plumb while entering manhole location and elevation into the system*

You can use the same process that you use to tie out utilities to save survey stake locations. Let's say the job is completely staked for rough grade and there are some deep fill and cut areas. Instead of the grade setter offsetting the stakes to save location and grade, he can create a point file to save the survey location. Once the location has been saved, he can pull the stake until the deep fill or cut is brought close to grade. Then the stake, with a new cut or fill grade, can be placed in its original location using the rover. This process saves a great deal of time and lath.

You can also use the rover to verify the existing topography of a project before work starts. The easiest way to do this is with an auto record feature. Attach the rover to a vehicle like a small quad wheeler, set the auto record at an interval of 50 feet, and the rover will automatically save the job elevations every 50 feet as you drive. With the right software, this saved information can be compared with the existing contours on the engineer's drawings. If they differ, the dirt quantity can be quickly calculated.

It's not uncommon for there to be a significant difference between the engineer's topo map and the current condition of the property. The engineer may have used a 15-year-old aerial topographic survey of the


***Figure 5-11*** *Caterpillar D8 dozer with two GPS antennas*

land that doesn't take into account the height of the vegetation on the ground, which would cause the job to be short of dirt. A more common situation is that someone dumped dirt on the property after the topo was done, causing the job to have excess dirt. The job can be built more efficiently if these conditions are discovered before excavation begins and reengineering is necessary to achieve dirt balance. Reengineering can save the contractor money if the new dirt quantity is more than originally estimated. On the other hand, if the quantity of dirt is reduced and less grading is required, the customer saves money.

## *Equipment with GPS Control*

Dozers, compactors and motor graders can all be equipped with GPS machine control. All sizes of dozers can be set up with the system. There are systems with dual satellite antennas or a single antenna set in the center of the dozer. Figure 5-11 shows a D8 dozer with two antennae. With the system on a dozer or compactor, the operator follows grade manually by watching grade control lights (see Figure 5-12). He'll also have a plan view with cut, fill and elevation readings on a screen in front of him. He can choose the display shown on screen, such as plan view or cross section view, or split the screen and show both.

The low-profile GPS screen in Figure 5-13 is more compact. The screen shows a street running from the bottom to the top, a cul-de-sac on

***Figure 5-12*** *Dozer control panel and GPS screen with grade control lights*


***Figure 5-13*** *Low-profile GPS screen*

the bottom right and several lot pads. In the center of the screen is a small rectangular light that indicates the position of the dozer on the lot pad. The grade control lights are on each side of the screen. The three lights that are lit on the left side of the screen tell the operator that he must cut. If the oval below those lights were lit, it would mean that he was "on grade." If the three lights on the bottom of that side of the screen were lit, it would indicate a fill rather than a cut.

Across the bottom of the screen are two bars. The left bar says *+0.200',* indicating the operator has set the system to cut 0.20 foot high. Below that is a small arrow pointing down and *0.323*'. This tells the operator that there's a little over 0.32-foot cut still needed to reach the design grade. To the left of those figures are two symbols. The first symbol represents the radio antenna and the second the GPS antenna. A flashing x over either antenna symbol would indicate that it isn't working properly and the operator would know that there's a system failure. The right bar on the bottom of the screen has a rectangle and then *0.2%*. This tells the operator that the blade on the dozer is square, not angled, and it's cutting a 2 percent grade. The *3D* following indicates the system is on and a 3-D image is available.

Notice the lights on the upper right side of the screen. First you see an *N*, then + and –. By pushing the *N* and then the plus or minus button, the operator can change the screen image. The plus will zoom out, showing the entire project, and the minus will zoom in, showing only one lot pad, or less if needed. The two knobs on the left and right side of the screen image are adjustment knobs. The left adjusts the amount of cut above or below the desired finished grade and the right knob sets the slope needed.

A motor grader can be set up to be fully automatic. Just like sonar and laser control, the grader with GPS makes grade automatically. With a single satellite antenna, one side is controlled by GPS and the other side by setting the slope control on the blade to automatic. With dual antennas, the GPS can control both sides of the blade.

There are many uses for GPS machine control, from quick and simple rough grade to detailed finish grade. A dozer and compactor equipped with GPS can bring a 20-foot fill with a 2:1 slope up to finish grade without a grade setter's slope staking. The operators can see the fill and slope on the screen in the cab and know if the slope is fat or shy of material. In the cut area of the job, the push dozer or rip dozer with a GPS can control the grade. Once the pads and streets are excavated close to finish grade, they can be finish graded with a dozer or grader. All this work can be done with fewer grade checkers, as the grade setter becomes more of an inspector, checking the plans and comparing them to what's being built.

Looking again at Figure 5-12, you can see that the visibility from the cab of the GPS dozer is greatly reduced. The fewer people you have on the ground around large equipment, the safer and more productive the job. As mentioned earlier, however, the grade setter should set control stakes that can be used in case there are problems with the GPS reception. That way the job can remain productive.

***Figure 5-14*** *Motor grader using GPS to balance road grade and shoulders*

A grader using a GPS becomes more productive for several reasons. The grader can typically cut grade faster than the grade checker can check and give grade to the grader operator. With continuous grade and no one in front of him, the grader can move more quickly and more efficiently. The ability to have continuous grade instead of station-to-station grade increases the quality and accuracy of the final product. In Figure 5-14, the grader is rebuilding a choker and rebalancing a street after the wet and dry utilities have dug up the original rough grade. The grader has continuous grade control and is able to prepare the job for finish grade stakes. Once the aggregate base is placed, compacted and graded, a string line will be set to finish street or curb grade for the slip form curb machine. Since the grader can work without a grade checker, the grade checker can be marking and tying out utilities so they won't be hit and can be easily located after paving. The ability to clean up a job before finish grade stakes are set makes it easier and faster to sell, or get approval for, the job after it's paved.

The most difficult part of using GPS is the initial setup and model building. Once this is done, the machine control is relatively user-friendly and easy to apply, even for an operator who has never used a computer. The possibilities of GPS machine control are endless. We've only touched on a few useful applications of the rover and machine control. The more the system is used, the more applications are discovered. Operators have given feedback to product manufacturers that have resulted in product and software upgrades. Free upgrades are usually included in the purchase of a system. On large grading projects such as subdivisions, commercial sites, and road jobs, this technology has already become a necessity if a company wants to remain competitive in the work place.

In this chapter we've looked at a variety of new grade-control features designed to improve the quality and speed of the work being done. These systems are effective and efficient, but also expensive. A GPS is excellent for large excavating projects, but may not be required for the type of projects being done by your company. Examine every system carefully before deciding which is the one best suited to your needs.

# CHAPTER 5 QUESTIONS

**1. If checking a road section with a laser, how many elevations should be marked on the lath by the grade setter?**

A) One
B) Two
C) Three
D) Four

**2. If your rod reading on the hub is 3.50 and the stake shows a 0.70 fill with a road section depth of 0.75, what rod reading would you want to read for subgrade?**

A) 2.05
B) 2.75
C) 3.45
D) 3.55

**3. When using a laser with a sloping beam, what's the maximum distance from the trench centerline you'd want to set up to ensure accuracy?**

A) 6 feet
B) 8 feet
C) 10 feet
D) 12 feet

**4. When setting up a grade rod for trenching using a laser, if the cut is 7.58 and you measure up from the hub and get a steady signal on the receiver at 2.92, where on the rod do you place a mark for flow-line grade?**

A) 10.50
B) 10.58
C) 10.92
D) 11.84

**5. If the survey rod has a 10.50-foot measurement for flow line and you need a 0.50 undercut, where would you set the rod elevation?**

A) 9.50
B) 10.00
C) 11.00
D) 12.50

**6. How do you figure the undercut when determining trench depth for laying pipe?**

A) It's provided in the specifications or plans
B) Add the thickness of the pipe bedding to the trench cut
C) Add the thickness of the pipe bedding to the inside pipe diameter
D) Add the thickness of the pipe to the thickness of the pipe bedding

**7. What do you calibrate the cutting blade on a scraper to when using an on-board laser?**

A) The laser transmitter
B) The finish elevation
C) The system is automatically controlled
D) A bench mark or known elevation

**8. When setting a GPS base station, what must always be set up plumb, level and in the same location each day?**

A) The GPS screen
B) The GPS receiver unit
C) The radio antenna
D) The rover unit

**9. What is the minimum number of satellites you should be able to access to ensure the accuracy of a GPS signal?**

A) Eight
B) Seven
C) Six
D) Five

**10. What is the most difficult part of using GPS?**

A) Connecting the rover to a portable radio and satellite antenna
B) The initial base unit set up and model building
C) Training operators to use the equipment
D) Transferring information to the rover unit

# Road Building Equipment

# 6

In addition to new grading and surveying systems, there have also been advances in heavy equipment that can save you time and increase your productivity. In this chapter we'll look at machinery you can use that will both improve the quality of your work and reduce your manhours.

## Slip-Form Curb Machines

Slip-form curb machines are now used regularly for various shaped curbs and barriers. They're so efficient that they've replaced conventional form setting on all large jobs and most small ones. The slip-form machine in Figure 6-1 is pouring a 42-inch high K-rail with a concrete slump of zero. It's using concrete so dry it won't sag after leaving the slip form.

*Courtesy of GOMACO*

***Figure 6-1*** *Concrete machine pouring highway K-rail*

The machine straddles the steel rebar that has been set ahead to strengthen the K-rail. This machine doesn't need a trimmer, but it must operate on a pretrimmed grade.

Figure 6-2 shows a concrete curb machine pouring the curb and sidewalk simultaneously, and trimming as it pours. But because the grade was pretrimmed by a grader running off the same string line, there's very little trimmed aggregate being pushed out the side.

Sonar and slope control on a grader are a big advantage when pretrimming for slip form pavers or curb machines, especially those that need a precise grade because they don't have a trimmer.

Some smaller curb machines are actually propelled by the force of the concrete being pushed into the form. On these machines, the concrete is poured into a small hopper, then an auger drives the concrete into a slip form that shapes the curb. The force of the concrete being augered into the form moves the machine while the operator steers the machine by hand. This type of curb machine uses a special $^3/_8$ mix with a zero slump. An epoxy must be spread over the asphalt before the curb is placed so the curb won't slide if it's bumped once it's dry. Or, you can use rebar with rebar pins driven into the asphalt base to secure the curb.

***Figure 6-2*** *Concrete curb machine running grade from a string line*

These small auger-type machines are also used for asphalt dikes on small jobs using a special dike-designed asphalt mix that holds its form. The asphalt base must be sprayed with a tack coat of oil before the dike is placed. The asphalt base they run on is the grade they follow; they don't use a string line for grade, only a string or paint line for line.

## Slip-Form Pavers

All concrete roadways are now poured with concrete slip-form pavers. The machines are equipped with sonar and are guided for line and grade by a string line as they move forward. The slip-form paver can pave more than one mile of 24-foot-wide road in one shift and still get excellent profilograph readings. A profilograph is a straightedge on wheels. The inspector rolls it along the road surface to detect any areas that may be out of tolerance and must be ground down after the concrete has dried.

The operators and mechanics working with this kind of equipment usually get on-the-job training provided by the manufacturer. Trained factory personnel stay on the job site until the contractor's personnel are ready to take over.


Courtesy of GOMACO

***Figure 6-3*** *Spreader and paver work in tandem to produce a smooth concrete mat*

Figure 6-3 shows a spreader and a paver working in tandem to produce a smooth concrete mat. Having a spreader doing the initial spreading ahead of the paver increases its production rate. It's important for the person dumping the concrete in front of the spreader to know the exact yardage needed per foot so the spreader and paver can move along without being overloaded. A loader is usually working with the crew to add or remove concrete if the quantity of concrete is misjudged a little. This is especially important if a rebar mat isn't required. If there is a rebar mat, as in Figure 6-3, the concrete is poured onto a conveyor that spreads the concrete on the grade. You can see the rebar mat and the conveyor in the figure. The conveyor is in the raised position at the front of the spreader machine.

The paving machine has an auger, a primary strike-off bar, a row of vibrators, a secondary vibrating strike-off bar and one or more screeds for the initial finish. A large float device floats and edges the concrete mat, leaving it smooth and uniform. The concrete paver can be adjusted so it leaves a crown in the concrete mat if required. Figure 6-3 shows the finished concrete mat as it comes out the back of the concrete paving machine.

The concrete paver is followed by a texturizing/curing machine (Figure 6-4) that tines (scratches small grooves into) the surface, then sprays a curing compound for the final pass on the concrete mat.


*Courtesy of GOMACO*

***Figure 6-4*** *Texture/cure machine puts the final textured finish and cure on the concrete mat*

# Profilers

Profile machines are now available for resurfacing freeways, runways, secondary roads and parking lots. These machines are extremely cost-efficient in remote areas. A profile machine can mill off 4,000 tons of road surface a day to a specified tolerance. The profiler is so accurate it can trim as little as 0.05 foot off a concrete or asphalt road that's out of tolerance. Grade and slope are usually controlled by a wheel-type ski sensor, or sonar off the existing grade or string line. The old asphalt that's milled off can be loaded into trucks by the conveyor on the profiler and hauled to the asphalt plant for recycling. Recycling is usually done by crushing the asphalt, then mixing a percentage of milled asphalt with virgin aggregate, creating a good aggregate base. Concrete can also be milled by the profiler and recycled.

Figure 6-5 shows a profiler milling 2 inches of old asphalt off a highway and loading it onto a truck. Sonar sends readings back to the controls that automatically set the elevation being trimmed. Profilers are used regularly on overlay jobs when new asphalt is required without adding to the surface elevation.


*Reprinted courtesy of Caterpillar Inc.*

***Figure 6-5*** *Profiler starts first pass for new pavement overlay*

In Figure 6-6 you can see a roadway where the edge along the curb has been ground down 2 inches and then tapered out 14 feet to match the existing surface. This is a common practice on city streets to prevent the new asphalt from being built up higher than the curb. Sometimes fabric is placed before the paving. It adds extra strength to the new asphalt mat and helps to keep old surface cracks from coming to the surface of the new asphalt over time. If you look closely at Figure 6-6, you'll notice a 12-foot-wide strip of fabric has been placed the entire length. The fabric is 2 feet out from the curb and extends to the cone line. Note that the fabric isn't placed right up to the curb. There shouldn't be anything covering the tack coat within 2 feet of the curb that could prevent a good bond between the old and new asphalt surfaces.

Profilers are an excellent choice when the old road section must be removed and hauled off. The profiler in Figure 6-7 is cutting a 10-inch section in one pass. The profiler has rows of carbide teeth spinning at high speed that do the cutting. A spray system sprays water to keep the teeth cool and the dust down. The asphalt concrete and aggregate base are conveyed into trucks and hauled off; or in some instances, stockpiled on the job site and reused as subbase. The profiler also trims the subgrade to such a close tolerance that in many cases, if the moisture in the subgrade's right, it can be rolled, trimmed with a grader, rolled again, and the compaction test will be good enough to start placing aggregate.

***Figure 6-6*** *Profiler has cut 2 inches along curb so new asphalt can be placed*


***Figure 6-7*** *Profiler trims asphalt and aggregate 10 inches to subgrade for a new road section*

***Figure 6-8*** *Recycler-paver combination*

Figure 6-8 shows a unique process for reclaiming old road surfaces. The Wirtgen asphalt recycler is grinding 8 inches of old road surface. The first unit contains hot asphalt oil and cold water. The second unit is a reclaimer that does the grinding. As the pavement is ground, the hot oil and cold water are added, creating a foam that coats the aggregate. The reclaimer also has an asphalt paving screed attachment which enables it to grind the old surface, add oil, and pave cold mix to grade out the back of the machine. Using equipment like this, traffic can use the reprocessed pavement within one hour of completing the job. This process is often followed with a section of hot asphalt paved over the cold base for a final completed surface.

The main difference between a profiler and a reclaimer is that the profiler runs on tracks rather than tires, and it has a conveyor belt to load material into trucks. Wirtgen calls their machine a recycler. It runs on tracks like a profiler but doesn't have a conveyor. The tracks provide the stability of a profiler for very accurate grade tolerances. The recycler also has a grizzly unit that kicks large chunks of asphalt back to the grinding unit to be reground to size. The grizzly is a screen or several bars that only allow chunks of the correct size to pass through.

It's important, whether using a profiler, recycler or reclaimer, that all steel covers for manholes, water valves or sewer cleanouts be clearly


*Reprinted courtesy of Caterpillar Inc.*

***Figure 6-9*** *Reclaimer pulverizing and mixing old surface*

marked. If any of these machines hits a steel cover it will instantly damage the equipment's teeth and shanks. These machines also need a water source for grinding asphalt or concrete. Their water tanks only supply the water needed for the spray. If reclaiming, or doing a lime or cement treatment, you must have a water hose from a water truck attached to add the moisture needed for compaction.

## Reclaiming Machines

Reclaiming machines don't usually have the grade and slope control capabilities of a profiler. The reclaimer works like a large rototiller, although more than one pass is usually needed to pulverize the material well. As it rototills the asphalt or cold mix and aggregate together, it can also add a controlled amount of asphalt oil from an attached oil truck. When the road is graded, rolled and oiled, a surface course of asphalt concrete or cold mix is applied. Figure 6-9 shows a reclaimer mixing cement into a ground road base. A water truck will be attached to add water on its last two passes.

***Figure 6-10*** *Trencher with carbide teeth will cut through concrete, asphalt and rock*

A rural road with light traffic may not require a surface course if oil is added. The oiled base may be simply rolled and chip sealed. In many cases no oil will be added. Instead, the ground base is watered, mixed and rolled. Then it's trimmed with a grader, rolled again and chip sealed or paved. This reclaiming method saves the time that it would take to rip and pulverize with a grader and compactor. Making several passes with a compactor won't pulverize the asphalt surface as well as a reclaimer. As just mentioned, reclaimers can also be used for cement or lime treatment. Instead of adding oil, the attached truck adds water to the cement or lime. You must add the correct amount of water to ensure a good compaction test, and that may take more than one pass to achieve.

Many miles of primary and secondary roads in the U.S. need resurfacing or rehabilitation. If you're bidding on these jobs, consider using profilers and reclaimers for every application possible.

## Other Specialty Equipment

Trenchers equipped with carbide teeth (Figure 6-10) are now able to trench through concrete, asphalt and some rock. In many cases, this will eliminate hoe hammers and ripping or blasting. There are also improved


***Figure 6-11*** *Thumb attachment is ideal for loading chunks of asphalt and concrete*

hoe attachments, like *hoe rams* for breaking concrete or rock, or *hoe packs* for compacting narrow or restricted work areas, and compaction wheels for trenches. Single ripper-tooth hoe attachments and large toothless buckets for grading are other options available for this equipment. Figure 6-11 shows a hoe bucket with a thumb attachment that's excellent for loading chunks of concrete, asphalt or rocks. Figure 6-12 shows a clam attachment for setting rock walls and riprap. Staying current with new machinery and the attachments available will help you cut costs and make your work easier and safer.

## Communication Is Important

There are no secrets in the excavating and paving business. The work is done outside and anyone can watch if they want. If you're a foreman or superintendent, you should keep an eye on the competition. If a competitor is using new techniques or more productive equipment that gives them an edge in the market, consider making the same change in your company.

It's my opinion that every foreman should know the estimated cost of each major part of the job, for both labor and equipment. This lets him compare estimated productivity with actual productivity. If actual daily


***Figure 6-12*** *Clam bucket sets rocks into place*

costs are running more than estimated costs, something's wrong. The foreman should be able to catch this in time to make equipment or employee changes to lower daily costs before a loss becomes inevitable.

Many companies are hesitant to give the foreman this information — which I believe is a mistake. Human nature being what it is, most crews who know their estimated productivity rate will try to beat it.

I also feel a major cause of cost overruns is lack of communication between the estimator, superintendent, and foreman. If they would spend some time together walking the job and discussing how the job was bid and where potential problems might arise, the job could be done more efficiently.

Here's an example. Consider an excavation with excess dirt to be exported to a dump site. The superintendent and foreman may get the plans and set up a crew using scrapers to stockpile the excess dirt. Their plan is to load it into trucks with a loader and haul it to a dump site. Maybe the estimator figured the job entirely differently. Perhaps because of the depth of the excavation and the restricted work area, the estimator decided that using a large hoe to excavate directly into trucks would be more cost-efficient. He bid the job accordingly. He may have based his estimate on a haul to a nearby dump area that he has established instead of the one that's actually being used. If the foreman and superintendent aren't given this important information, all the research done by the estimator is wasted.

## *Safety Is Important Too*

Safety is an important part of every construction business, maybe even the most important part. Never compromise safety for production. Injuries caused by negligence can lead to fines and even jail terms, or both. A contractor who continues to have safety violations and accidents will soon be overwhelmed by his liability insurance costs, and probably end up losing his business.

Protecting the public passing through or around the project is just as important as protecting your crews. Be sure to take time during and after each work shift to check signs, barricades and arrow boards. On a highway job it's easy to disorient the public driving past or through a project, and this creates a potential hazard to both your crew and the drivers. Every state has a manual for traffic control. Follow the guidelines closely and make sure your crews are trained in traffic control. Your crew should be the only ones setting and removing detour signs each day.

The highway work zone consists of five areas. First is the warning area, where signs such as *Road Construction Ahead, Lane Closed Ahead* or an arrow board, tell motorists what to expect on the road ahead. Second is the transition area, where traffic is diverted from its normal lane. The third zone is a buffer area, with *Lane Closed* signs or an arrow board. This can also be an area where equipment not being used may be parked. The fourth zone is the work area, where work for the day is being performed. And the fifth is the termination area, where traffic resumes its normal path.

The best devices for controlling traffic in construction areas are flexible drums, delineators and traffic cones. Your state traffic control manual will have acceptable heights for these items. All lane delineators must have reflective tape so they're clearly visible at night. Using flashing lights to delineate traffic is a poor choice; too many flashing lights are distracting and confuse drivers. Only use flashing lights to draw attention to an important sign or some other significant item, but don't use too many. If a detour is to be in effect for an extended period of time, use K-rail, buttons and temporary striping.

Set a long gradual taper when closing a lane so that the traffic has plenty of time to react. Check your traffic manual for the suggested spacing distance between cones in the taper and how long the taper should be. The manual may give you a formula to use, such as multiplying the speed of traffic by the width of the lane being closed. For example: 65 mph × 14 feet wide equals a taper distance of 910 feet. Usually the taper cones are spaced 25 feet apart. If the taper is to be placed and removed every day at the end of the work shift, mark the pavement where each cone will sit so they can be placed quickly each day.

A subdivision job may not require as many signs or traffic detours, but you still have safety issues to deal with. A subdivision will usually have occupied houses nearby with curious children who may come into the area after your crews leave for the day. It's important that all trenches are safe so children can't fall in. You may need to backfill open trenches each night or cover them with steel plates. Be sure that equipment is parked on level ground where it won't roll if tampered with, and that all hydraulically-controlled features, such as hoe arms, scraper bowls, blades and ripper racks, are lowered. Watch out for any sharp objects sticking up that someone could fall on. If appropriate, put up temporary fencing to keep unwanted visitors out of the work area.

Following all the state and local safety guidelines may sometimes be time-consuming and costly, but it could save lives, as well as thousands or millions of dollars in damage awards. Any time you work, work safely! You can't afford not to.

# CHAPTER 6 QUESTIONS

**1. What is the primary cost-cutting feature of concrete curb machines?**

A) No form crew is needed
B) No finishers are needed
C) They cut their own grade
D) They pour the curb and road at the same time

**2. What is the primary use for a profilograph?**

A) Sloping concrete
B) Striking off concrete
C) Checking road grade
D) Cutting grooves in concrete

**3. What equipment is used to pour concrete roadways?**

A) Profiler
B) Slip-form paver
C) Concrete curb machine
D) Reclaiming machine

**4. What does an auger-driven curb machine use for grade?**

A) A string line
B) A laser beam
C) Sonar
D) The asphalt base

**5. The type of surface produced by a concrete slip-form paver is a smooth concrete mat that needs which of the following?**

A) No finishing
B) A tined finish
C) Hand finishing
D) Only a groove-cutting machine

**6. A profiler can mill which type of road surfacing material?**

A) Asphalt only
B) Concrete only
C) Both concrete and asphalt
D) Only aggregate within the size parameters of the profiler

**7. What is the function of a grizzly?**

A) Sizing material
B) Crushing rock
C) Trimming aggregate
D) Ripping asphalt

**8. Which of the following is *not* done by a reclaiming machine?**

A) Grind up asphalt
B) Mix dirt
C) Mix aggregate
D) Trim to grade

**9. What is the purpose of carbide teeth on a trencher?**

A) To dig more precisely
B) To dig through hard materials
C) To increase the trenching speed
D) To protect the edge of the trenching blade

**10. What is probably the most important element to consider in operating an excavation and grading business?**

A) Proper estimating and bidding techniques
B) Selecting the right equipment for each job
C) Communication among the foreman, superintendent, and estimator
D) Safety

# PLANNING FOR EXCAVATION

# 7

Planning is an essential part of excavation — and your first planning concern is choosing the right equipment. Study the plans and stakes carefully and analyze the type of equipment required for the job. This includes the correct type, number, and size of equipment you'll need to move the most material, the shortest distance, at the lowest possible cost.

Poor equipment balance will cost you dearly in lost production. Good planning means you'll never have equipment standing idle while you decide where to start the next cut or fill. Remember, you still have to pay the equipment operators while they stand by. The effects this will have on your profit margin should be enough to convince you of the benefits of proper planning.

Let's look at what determines your choice of equipment. First is the amount of excavation to be done, followed by the type of material to be excavated and the depth of cuts.

***Figure 7-1*** *Two Cat D10 dozers pushing to speed loading time*

## The Equipment

Let's assume you need to excavate (cut) 1 million cubic yards of material and also fill 1 million cubic yards of embankments. At this point in the planning, it makes no difference whether the job's a highway or subdivision; the number of scrapers you'll need is determined by the length of haul. For a two-mile haul, you might need a dozen scrapers; a one-mile haul may only require six scrapers. If there's a time limit on the job and a penalty clause if you exceed the allotted days, you may need two separate scraper spreads. This would double the number of scrapers required. This size job requires large scrapers (Cat 651s or push-pull scrapers of equivalent size), Cat D10 or D11 dozers, Cat 825 compactors for good compaction, and several water trucks or two or more water wagons, depending on the existing ground moisture.

Figure 7-1 shows two Cat D10s pushing a 651 scraper. This is called *double pushing*. Usually one dozer is equipped with a push block. Because the soil is very rocky, two Cat D11 dozers are ripping ahead to keep production up. Figure 7-2 shows one of the D11s at work. On this same job, there's a second dirt spread using push-pull scrapers loading preripped material with very little rock in it. The front scraper always loads first as the back scraper pushes. When the front scraper is loaded, it'll pull until the back scraper is loaded. Each scraper has two engines

***Figure 7-2*** *Cat D11 rips ahead to speed scraper loading time*

and all-wheel drive. When they're both loaded, they unhook and head to the fill together. See Figure 7-3.

At the fill site, the rocky soil is spread by a dozer with a Cat 825 compactor following. This is an efficient combination. The dozer handles the rocks so the compactor can work faster, thus eliminating the need for another compactor. Of course, this all depends on the soil conditions. If more than 8,000 cubic yards is hauled in a day, you may need a second compactor to get the 90 percent compaction required. For rocky fill, use a water wagon rather than a water truck (see Figure 7-4).

On a large job like this one, with many scrapers running, it takes organization so the scrapers can run as fast as possible from cut to fill without delays. A smooth haul road is very important. A Cat 16 grader can work full-time just keeping the haul road smooth. The haul road must also be wide enough for scrapers to pass safely at speeds of 30 miles an hour or more (see Figure 7-5). You need a water truck to control the dust on the road — it must be kept damp but not so wet that the scrapers could slide into each other, especially if they're empty. A water truck's better than a water wagon because it sprays a finer stream of water at a faster speed, and it's more maneuverable. A job with more than a million yards to move needs a good water source. When that much fill requiring 90 percent compaction is being worked each day, you go through a lot of water.

***Figure 7-3*** *Front scraper is loaded and pulling rear scraper*

***Figure 7-4*** *Cat D9 dozer and Cat 825 compactor work rocky fill with a water wagon*

***Figure 7-5*** *Wide haul road enables scrapers to pass easily*

The foreman should watch the cut areas to be sure he's using the best equipment balance. If the push dozers are waiting each time for a scraper to arrive, he should add another scraper or two. If the dozer ripping can't stay ahead of the scrapers, he should add another dozer to rip. If the fill's too dry, he should add another water truck. The same works in reverse. If the scrapers are waiting to be pushed, you may have too many. If the soil gets softer and easier to load, you may not need a dozer ripping. These are judgment calls based on experience, of course, but they're the kind of thing a good foreman will watch out for.

Most open-bowl scrapers being pushed take about 30 seconds to load under average conditions. If your scrapers are taking longer than that, you should do some investigating. This may be an indication that a larger dozer is needed to push, more ripping is needed, or the operator isn't experienced. It may also indicate the equipment's old and losing power. Paddle-wheel scrapers and push-pull scrapers take longer to load, but no push dozer is needed, so the cost should be pretty close to the same per yard.

A 4,000 cubic yard job will require smaller equipment than a 1 million cubic yard job. On the smaller job, a Cat 615 paddle-wheel scraper, a Cat D6 dozer if ripping is needed, and a Cat 815 compactor or a pad-drum roller may be sufficient. You may also need a Cat 12 or Cat 14 grader and a small water truck loading from a standpipe. It's even more important on a small job to have the correct balance of equipment because it's costly to start adding or changing equipment on a job that only takes three days to move the dirt. With a large job that will take two or more months, you've got time to make the adjustments you need.

The big debate among dirt foremen is which scrapers move dirt the quickest. My feeling is that if there are no rocks and the soil isn't extremely heavy clay or too sandy, push-pull scrapers have the edge over open-bowl scrapers. If the soil's heavy clay, rocky, or very sandy, then I prefer open-bowl scrapers. I like to have one paddle-wheel scraper to clean up the slobber left by the open bowls if the cut is moving along quickly. This isn't a must, but it *is* convenient.

Many dirt jobs of average size use all paddle-wheel scrapers, with a dozer ripping in firm soil. They work extremely well when there are shallow 2- to 4-foot cuts. When the soil doesn't need ripping, a paddle-wheel scraper is a good choice because the dozer cost is eliminated. Often, the equipment chosen depends on the equipment the contractor owns. If the contractor has a fleet of push-pull scrapers and a job with many shallow cuts, he'll make do rather than renting paddle-wheels while his scrapers sit idle. Likewise, if the job's very rocky or muddy, he'll use his push-pull scrapers as singles, and push-load them with a dozer.

There may be times when it's best to excavate with a dozer. The foreman for the job in Figure 7-6 decided to doze 4,000 cubic yards of excavation down this 3:1 slope rather than build a bench at the top and use scrapers. Notice the water truck at the top spraying water on the dirt to be dozed to the fill. As the Cat D10 dozes the dirt to the compactor working the fill below, it'll already have some moisture in it. That makes compacting easier. Excavating a slope in this manner works very well. The bottom is being filled by scrapers and kept smooth with a Cat 825 compactor.

In the figure, the dozer operator has mounded dirt at the bottom and hasn't pushed it out onto the fill yet. That's because the scrapers were hauling in the fill on that side. If the dozer pushed the dirt out in front of the scrapers, it would create windrows in front of them, slowing them down. The dozer operator will watch for the scrapers to move to the other side of the fill before shoving his dirt onto the fill. That means the compactor will have time to compact and smooth the fill before the scrapers return to that side again.

***Figure 7-6*** *Cat D10 dozing to fill below*

It's easier to bench and cut a 1:1 or 2:1 slope with scrapers than a 3:1 or 4:1 slope because usually the bench on a steep slope just generates more dirt. Figure 7-7 shows a dozer making the cut that's staked, and pushing the excess to a stockpile. It'll be loaded with a hoe on one end of the stockpile and with a loader at the other end, where the stockpile is more firm. This job calls for 45,000 cubic yards to be excavated and hauled by truck several miles to a waste dump. The site will be excavated 20 feet below the original ground. Once the hoe moves ahead on this stockpile, the dozers will start another stockpile in front of the hoe. Figure 7-8 shows the hoe loading a truck. Two buckets and the truck is loaded and on its way to the dump site. This works well if a truck haul is required.

It's important to have enough trucks to keep the hoe and loader going at all times. This isn't an easy task when there's a long off-site haul. Commuter traffic will be a factor in the haul time, and that's a problem not easily solved. Changing the starting time may help if traffic's heavier in one direction than the other at different times of the day. Adjust the starting time so the trucks haul out the loads before the traffic gets too bad, and return empty when peak traffic is traveling in the opposite direction.


***Figure 7-7*** *Dozer makes the cuts, pushing excess to a stockpile*


***Figure 7-8*** *The hoe rides the top of the stockpile and loads trucks as they arrive*

I've noticed truckers on a haul like this usually won't pass slower trucks. If you notice the same group of drivers showing up together every round, you can probably assume the first truck is the slow driver holding up the group. You must address this problem. On large projects it may be helpful to have a load counter if you can't be there every minute watching the trucks or scrapers. If one truck or scraper has fewer loads than the rest at the end of the day for two days, ask the driver or operator what's going on.

## Soil Conditions

In planning the equipment to use, it's always important to know the soil conditions. If the superintendent or foreman isn't familiar with the area, check with the estimator who bid the job. He should know. Soil conditions vary so greatly that there's no way to preset your equipment needs effectively without someone seeing the soil material and digging some test holes. The main thing to remember is that silty and loamy soils need no ripping, and load easier than heavy clay and rocky soils that *do* need to be ripped.

There's a variety of ways to excavate, and various types of equipment you can use. There's always going to be a debate among dirt movers as to which is best. One foreman may choose open-bowl scrapers and the other push-pull scrapers. My feeling is that if two foremen are working in the same soil conditions and each has the correct balance of water trucks, compactors and dozers, the cost will come out about the same regardless of which scrapers they choose.

My rule of thumb is this: Don't be underpowered. If you're having trouble deciding whether to use Cat 631s or Cat 651s on your dirt job, use the 651s. This is true for choosing a push dozer or a ripper dozer. When pushing 651 scrapers, use a push dozer no smaller than a D10. When push-loading 631 scrapers, use no smaller than a D9 dozer. If the soil is very heavy or rocky, choose D10 and D11 dozers. If there isn't a D11 available, double-push with D10s. Where equipment is concerned, more money is lost from being underpowered than overpowered.

> ***Note:*** *I've included operating tips for the most common types of equipment used in grading and excavation in the Appendix at the back of this book (page 467). These tips were provided by some of the best and most experienced equipment operators I know. Be sure to read through them — you'll find them very helpful.*

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# CHAPTER 7 QUESTIONS

**1. What determines the size of equipment you choose for a particular job?**

A) The amount of excavation
B) The length of haul
C) The amount of fill
D) The time allotted for the job

**2. What determines the number of scrapers needed for a job?**

A) The depth of cut
B) The amount of excavation
C) The length of haul
D) The size of the scrapers

**3. How should push-pull scrapers load?**

A) The rear scraper first
B) The front scraper first
C) Both scrapers at the same time
D) With a dozer pushing for a faster load

**4. How should a haul road be maintained?**

A) It must be kept moist to cool the tires
B) It must have a separate passing lane for fast-moving equipment
C) Any curves must be banked
D) It must be smooth, wide, and not dusty

**5. What is the typical loading time for an open-bowl scraper being pushed under average conditions?**

A) 30 seconds
B) 40 seconds
C) 60 seconds
D) 80 seconds

**6. Under what circumstances would you choose a paddle-wheel scraper?**

A) If all the cuts are short and deep
B) If the soil is very sandy
C) If all the cuts are shallow
D) If the soil is very muddy

**7. In which situation are you least likely to use a dozer?**

A) Excavating downhill to fill
B) Excavating on an all rock ripped slope
C) Excavating in good soil using a paddle-wheel scraper
D) Excavating muddy areas

**8. What might cause haul trucks to start bunching up?**

A) A slow driver who won't be passed
B) Not enough trucks on the haul
C) A traffic light near the fill site
D) Too many trucks on the haul

**9. Who would you check with to find out about soil conditions on your job?**

A) The equipment operator
B) The local building department
C) The property owner
D) The estimator who bid the job

**10. What situation do you *not* want to find yourself in on an excavation job?**

A) Working with underpowered equipment
B) Working with overpowered equipment
C) Working without a paddle-wheel scraper
D) Working without a Cat D11 dozer

# EXCAVATING ROCK

# 8

Rock is probably the most difficult material to excavate, and requires special skills, equipment and materials, including explosives. There's extensive drilling with air tracks, blasting, then loading the shot rocks into trucks with a large hoe, or a dozer feeding a loader, for the haul to a fill area. This isn't the type of work I do, and isn't what I'm going to discuss here. What we'll cover is the kind of job where the rock can be ripped with a dozer, and will break up enough to be hauled with a scraper. It takes its own special skills, practice and planning to efficiently operate excavation equipment under these circumstances.

An inexperienced operator can damage the equipment on this type of job. One spin of a tire can cause a blowout, ruining the tire — often an investment of several thousand dollars. The cutting edge or floor of the scraper can be damaged if the operator tries to cut through solid rock without lifting the bowl quickly once he feels the resistance.


***Figure 8-1*** *Cat D9R with slope bar attachment*

An experienced operator will work methodically in rocky areas. A good dozer operator studies the way the rocks lay and places the dozer blade or ripper exactly where he thinks he can gain the best leverage. He always tries to work from a level area he makes for himself. Trying to doze loose boulders from a rough and uneven surface is hard on the equipment and usually a waste of time. The operator must be thinking ahead at all times. He must pick out voids and then find the correct size rock to fill that void when possible. He can't just excavate and let the boulders fall where they may. This would be a very inefficient way of doing the work, because he'd have to move the same boulders two or three times.

## Cutting Slopes in Rocky Soil

The best way to cut slopes on a rocky job is with a slope bar on a dozer. The dozer and slope bar are also an excellent choice if you have to recut an existing slope. It can push scrapers and trim the slope, eliminating a grader. Figure 8-1 shows a dozer with a slope bar attachment. This is a very effective way to cut a rocky or wet slope where a grader can't get good traction.

Let's look at how you would cut back a slope in rocky soil. We'll assume that an existing 1:1 slope must be cut back 15 feet. The dozer will start at the top of the slope, back 14 feet, and make a 1-foot cut, pushing the rocky soil ahead and to the side. He'll continue moving in 1 foot and cutting 1 foot all the way to the bottom of the slope. As he keeps making the 1-foot cuts, he'll not only generate enough material for his outside track to run on, but will soon generate enough excess for a loader to start loading trucks at the bottom or a scraper to start cutting on the bench that the dozer has cut at the top. The dozer operator will use the slope bar once he's cut down enough to cut the 1:1 slope to grade. The grade setter must pay close attention to the slope grade and know the slope tolerance. He'll advise the dozer operator if there are boulders protruding from the slope that are out of tolerance.

On a rocky cut slope there's usually a 2-foot tolerance, plus or minus. In some cases, if there's a large rock cap sticking out farther than that, the inspector may allow it to stay. He may feel that blasting the cap of rock could damage the slope, making it unstable. If there are rocks on the slope that have to be blasted, the blasting must be done before the slope can continue down. The slope must be on grade before cutting any deeper because as it proceeds down, and a 40-foot 1:1 slope has been cut, you won't be able to get back up to do any trimming. If there's a 2-foot tolerance on a rocky slope, it'll change to a 0.5-foot tolerance or less once it gets to the shoulder grade. Always check the specifications for your job.

### *Safety Precautions*

Be careful working parallel on a rocky slope with a dozer. If both tracks get on a rock cap at the same time, the dozer may slide. Tracks will slide easily on rock and may cause the dozer to turn over. If this should start to happen, quickly turn the nose of the dozer uphill and put the dozer blade down. Usually this will swing the rear end downhill as the nose points uphill, stopping the slide. If you find yourself in a precarious position on a steep slope with any piece of equipment, lower the dozer blade, scraper bowl, bucket, or blade to the ground. This may keep the equipment stable until a choker line can be attached to keep it from rolling, while a second piece of equipment is brought in to pull it to a safe spot. A rocky slope is definitely no place for inexperienced operators.

When cutting a rocky slope or building a rocky fill, be very cautious. Rocks pushed to the edges could roll to the bottom of the slope. This can make for a very dangerous situation if there are houses or people working

***Figure 8-2*** *Dozer ripping rock to be excavated with scrapers*

below. Be sure there's a rock fence, a deep swale or a large berm, or a combination of these, to stop any rocks from rolling to the bottom. Also, a dozer working in a rocky area may cause sparks as tracks grind over rocks. If there's dry grass or leaves, those sparks may start a fire. Be prepared in case this happens. Always have a water truck working with the dozer in these conditions, or have a grader available that can push up a fire break.

## Ripping and Excavating Rock

When ripping boulders or rock layers with a dozer, it's best to work from north to south or south to north. The cracks in the rocks usually run in that direction, so it makes ripping easier. If this isn't the case in your area, study the rock layers to determine the best direction to rip. Before scrapers can begin excavation, the rock must be ripped small enough and deep enough to load. Figure 8-2 shows a dozer ripping rock that will be excavated by scrapers. Depending on the amount of resistance, the dozer may use one ripper or two.

***Figure 8-3*** *Scraper loading ripped rock*

When the scrapers begin their work, the operators must be careful not to cut too deep. They should apply little or no power while being pushed, letting the pushing dozer do the work. This avoids tire spin. If the scraper stops or nearly stops because it hits a hard spot, the operator should pull up the bowl just a little until it's past the boulder that's causing the trouble. Then let the bowl down slowly until the push dozer has to strain slightly to keep going. You can tell when the push dozer's engine is starting to strain by watching the exhaust stack. If the smoke starts to increase, lift the scraper bowl. When the push dozer's dark smoke stops, the dozer is no longer straining and the bowl can be lowered again. Notice in Figure 8-3 that no dark exhaust smoke is coming from the dozer stack as he pushes the scraper loading ripped rock. I don't recommend double-pushing with dozers when there are rock caps that are still solid. Too much power may damage the scraper floor.

When loading ripped rock, the operator must open the apron of the scraper wider than if he were loading dirt. Once the rock seems to have stopped loading and is starting to build up in front of the scraper bowl, the operator should raise the bowl slowly to let the apron close. When loading rock, the operator should let the dozer continue to push him after he's loaded to keep the wheels from spinning as he pulls away. The scraper operator shouldn't get frustrated if he can't get a full load. That's seldom possible when loading ripped rock.

If a scraper's loading 4-inch to 14-inch cobble that's rounded, not crushed or ripped, the loading is done pretty much the same way even though no ripping is usually needed. Again, getting a full load is very doubtful unless there are more fines than rock. Because there's no hard rock base in cobble, the operator must be careful not to cut so deep that he causes the push dozer to lose traction. As in loading ripped rock, the apron must be opened more than for cutting dirt.

Occasionally the scraper will load a boulder so large that it won't pass under the bowl when the load is dumped. The bowl can't be raised high enough. In this case, dump the boulder on the ground, back up slightly to give the scraper a little turning room, and then turn sharply 90 degrees. Reverse back until the bowl and cab pass beside the boulder instead of over it. Be careful to back up slowly so the boulder doesn't hit the transmission housing.

Larger rock chunks will sometimes keep the scraper's apron open slightly and smaller rocks will drop out onto the road as the scrapers haul the rock to the dump site. The grader working the haul road must keep the road clear of ripped rock and cobble dropped by the scrapers.

Anyone working on the ground must be careful not to work too close to rubber-tired equipment. The tires can cause a round rock to shoot out several feet, inflicting a potentially serious injury if someone was hit. Always work slowly and carefully in rock. Don't rush. No one can work fast enough to make up for the loss of a tire, damage to the equipment, or injury to a worker.

## Compacting Fill with Rock

Even though it's impossible to take a compaction test in a rock fill, in most cases a compactor is still needed. Only in solid rock with no fines at all can you just use a dozer. Each layer on a rock fill is much thicker than a dirt fill because of the thickness of the rocks. I use a dozer on the fill, working ahead of the compactor, to make the compactor's job much easier and faster. Figure 8-4 shows a scraper dumping off the end of the fill and a dozer spreading the previously-dumped load.

Running a compactor on rock fill without a dozer helping is a difficult job. It's the compactor operator's job to make sure that the fill doesn't become so rough that the scrapers can't move over it. If there are no fines to work with, he must go back and forth, smashing the rock and grinding

***Figure 8-4*** *Scraper dumps rock and dozer follows to spread the load*

down all the sharp edges to prevent tire damage on the scrapers. He must find low areas to push boulders into or dig a hole for the boulders so they can be covered quickly. Some can be pushed to the outside edge of the fill until they can be covered, but he must be careful that they're not left sticking too far out over the slope. If they slide over the edge of the slope, he may not be able to pull them back into the fill. In Figure 8-5, you can see several large rocks that the compactor operator has rolled ahead to a low spot in the fill so he can cover them over with dirt later.

Observe the same cautions when dozers are working on the fill area. Keep the fill as smooth as possible. Always keep the boulders pushed to the low spots so they can be covered with dirt or smaller rocks. On haul roads, use a grader to keep the sharp rocks pushed aside.

If there are areas where you need soil to cover rock grade, you can use a grizzly. Figure 8-6 shows a loader dumping a bucket load onto the grizzly. Notice that the grizzly has a sloping deck that vibrates. When a load is dumped onto the grizzly's deck, the fines fall through the small holes in the deck to the ground below, and the larger rocks fall off to the ground behind. Once the loader has dumped, it can scoop up a load of good soil under the grizzly to use as fill in a planter or wherever it's needed. The rocks on the back side can be returned to the fill or used for a rock wall or riprap in a ditch.


***Figure 8-5*** *Compactor works large rocks to the edge*

***Figure 8-6*** *Loader feeds material onto the grizzly to separate rocks from the dirt*

# CHAPTER 8 QUESTIONS

**1. What is the best equipment for cutting a rocky slope?**

A) Grader
B) Hoe
C) Dozer with a slope bar
D) Scraper with ripper teeth

**2. If an existing slope must be cut back 15 feet at a 1:1 slope, how far back will the first cut be made?**

A) 1 foot
B) 10 feet
C) 14 feet
D) 16 feet

**3. What is the usual slope tolerance of a rocky slope?**

A) 0.60 foot
B) 1.00 foot
C) 1.50 feet
D) 2.00 feet

**4. What should the operator on the scraper do when he's being pushed while loading rock?**

A) Turn slightly from side to side for better traction
B) Add little or no power while being pushed
C) Take a deep cut with the apron wide open
D) Apply more power than when loading dirt

**5. What position should the scraper apron be in when loading rock?**

A) Opened wider than if you were loading dirt
B) Opened as far as possible
C) Closed — the rock will force it open
D) Only slightly open

**6. If the scraper operator notices he only has a three-quarter load and it seems to have quit loading, what should he do?**

A) Move the bowl up and down until full
B) Lower the bowl for a deeper cut
C) Raise the apron
D) Not try to load any longer

**7. What should you do while dumping if you have a boulder so big it won't pass under the bowl?**

A) Pull forward slowly at a 90-degree turn angle
B) Back up slowly at a 90-degree turn angle
C) Pull ahead slowly until it rolls under the bowl
D) Have the dozer push it away

**8. What is the standard compaction percentage required for a compaction test on a rock fill?**

A) You can't do a compaction test on a rock fill
B) 80 percent
C) 90 percent
D) The standards vary according to the average size of rock in the fill

**9. What's the biggest advantage of using a compactor on rock fill?**

A) To help grind down sharp rock points
B) To get the percentage of compaction on the fill
C) To push boulders over the edge of the slope
D) To help the dozer cut the slope

**10. What is a grizzly used for?**

A) To compact fill
B) To separate fines from rock
C) To rip hard rock
D) To crush rock into smaller pieces

# EXCAVATING SUBDIVISIONS

9

Using experienced equipment operators is one of the best ways to keep your costs down. With a good, experienced crew, all areas of the excavation work like clockwork. If the crew isn't experienced, keeping everyone organized can be a nightmare for the foreman.

An experienced scraper operator knows how to cut stepped lots without undercutting at the property line. He also knows, with very few checks by the grade setter, when the grade being cut is on grade. He's aware if he's cutting up grade to a summit or down to a drain swale. He can also feel the softer areas and will hold the scraper bowl steady to keep from digging holes in soft areas or leaving humps in the hard areas. In the fill areas, a good scraper operator has the bowl at the right level as he comes into the fill so he can start a smooth dump pass without slowing down. But he'll know to slow down to fill an area like a corner where he'll have to make a sharp turn at the end.

An experienced compactor operator is equally important. He must keep the dozer blade down so he's always mixing moisture evenly across the fill. He'll know when more water should be added or when to wave the water truck off. If he receives a load so dry that he can't mix it without more water, he'll wait for water rather than compacting the soil dry so water won't penetrate when it does arrive. He'll also keep the fill area level and smooth so the scrapers have a good site to dump on.

An experienced grader operator will watch the cut area, fill area, and travel route. He'll grade the cut area as it gets close to grade so the scrapers will know the area has been cut enough, and they should move on to the next cut. And most importantly, he'll keep a smooth haul road and grade new haul roads as the cut moves from one area to the next. The grader operator will also help with lot grading when he has time. A savvy grader operator knows the capacity of the grader and won't try to cut so deep that the grader bogs down. Then he'd have to raise the blade quickly to keep going, leaving a bumpy grade. That's a sure sign of an inexperienced operator.

The water truck driver must know when he should spray water in the cut area for dust control and how much to spray on the fill for good compaction. He must be able to keep the haul road damp, but not so wet the scrapers will slide into each other.

## Selecting the Right Equipment for the Job

The sequence you follow for each subdivision excavation may vary greatly depending on lot size, elevation between lots, the topography of the terrain, and the plans. Some subdivided parcels only grade the front lot portion, just to match the street, with no lot pad grading at all. You must study the plans for each job carefully to make a determination on the type of equipment you need.

Let's look at a fairly simple project in a flat area. The lot sizes are 80 feet × 100 feet, and the soil is firm, with some clay but no hardpan or rock to contend with. When we look at the plans, we see by comparing the existing contour lines with the new elevations to be built that there are no lot cuts greater than 2 feet, and no street cuts greater than 5 feet. There are no elevation changes greater than 6 inches between lots. The engineer's bid quantities show 53,000 cubic yards of excavation and 53,000


***Figure 9-1*** *Paddle-wheel scraper*

cubic yards of embankment. This indicates it will be a balanced job — no dirt to be hauled off or to be hauled in — which is the easiest scenario for a subdivision excavation. Keep in mind, however, even when the engineer predicts the dirt quantities will balance, there's always an adjustment to make toward the end for raising or lowering lot pads. The foreman and grade setter will need to do some rough calculations and give the engineer a heads-up if it looks like there will be an excess or shortage of dirt. The engineer can then recalculate some lot pads so the dirt will balance.

## *Scrapers*

With this information in mind, let's talk about the equipment we'll need for this job. Most of the cut will be in the street, the entire fill will go to the lots, and no lot cuts are more than 2 feet. There will likely be lots with cuts on one side and fills on the other. I'd recommend using paddle-wheel scrapers with 20 cubic yard capacity or larger, like the one shown in Figure 9-1. Paddle-wheels are good for small lot cuts. It would be harder to cut these lots with a dozer pushing open-bowl scrapers and maintain good production. Another possibility would be to use two Cat 631 open-bowl scrapers pushed by a D9 dozer for the deeper street cuts, and one paddle-wheel scraper making the small lot cuts. Figure 9-2 shows a scraper/dozer combination like this making street cuts.

***Figure 9-2*** *Caterpillar 651 scraper being pushed by a D10 dozer making a street cut*

You could also use push-pull type scrapers that are connected to each other like those in Figure 9-3. They're held together with a U-shaped connector. These scrapers are capable of making deep cuts by pushing and pulling each other without a push dozer. They can also work independently, making small lot cuts. They have extra power with their two engines, one pulling and one pushing, and all-wheel drive. A drop center on the cutting edge of the scraper is best. They make a smooth cut (see Figure 9-4). In very compacted soil, ripper teeth may be added to the drop-center cutting edge to increase production.

The *number* of scrapers you need depends on the length of haul and the capacity of the scrapers. You must calculate the cut and haul time to determine how many scrapers to use to keep your equipment balanced so one piece of equipment never has to wait for another to complete their portion of the task.

As you can see, there are a variety of ways to approach the excavation. What's important is to use equipment that's right for the job, and even more important, not to use equipment that's too small for good production. If you have 90,000 cubic yards to move, you wouldn't use Cat 615 paddle-wheels. Likewise, if you have 5,000 cubic yards to move, you wouldn't want Cat 651 scrapers with a D10 pushing. It's important to know

***Figure 9-3*** *Scrapers connect and load in tandem*

***Figure 9-4*** *A drop-center cutting edge helps the scraper load faster*

the production capabilities of each piece of equipment you're considering. If you're not sure about the equipment, contact the equipment dealer in your area for a brochure that describes its capabilities. Some manufacturers supply this information on the Internet.

If there's a substantial amount of excavation to be done, I think open-bowl scrapers are the most economical way to move dirt. Under most circumstances, they load much faster than any other scraper. Of course, this is only true if you have a good operator on board. For instance, there are some conditions, including sand or rocky soil, when a bowl scraper may not be able to take on a full load each time. You may find that it takes 40 seconds to get three-quarters of a load and another 40 seconds to get the last quarter to fill the bowl. It's not cost-effective to double your load time for that last quarter-load. A good scraper operator will see this happening. So, when the loading slows substantially, he'll close the apron and pull away from the push Cat. This keeps production up and loading time down. If the foreman has an operator who isn't experienced enough to know when to pull out, he should signal to him for a few rounds until the operator catches on.

## *Compactors*

The next piece of equipment we need for this project is a compactor. My rule of thumb is that if the amount of fill being hauled to the compactor daily is 4,500 cubic yards or less, I use a Cat 815 compactor. For 4,500 to 8,000 cubic yards a day, I use a Cat 825 compactor.

The amount of fill a compactor can compact to 90 percent will drop if the fill being hauled in is bone dry and must be mixed more than usual. There may be instances when the fill must be mixed with a disc as it's being compacted. Generally, when you excavate deeper, the soil will have some moisture, making compaction easier. However, on the West Coast there are many areas where there isn't any rain at all during the summer months. If the entire job has shallow cuts, it may be powder dry by the end of summer, and you'll need more than one water truck. This creates a major problem if you use paddle-wheel scrapers. The dust may be too hard to control, making open-bowl scrapers your only option. If the fill being made is very wide and long, the amount of fill the compactors can handle will increase because the scrapers running down the fill to dump will also help to compact it.

In good, damp soil conditions, the compactor on a large fill is capable of compacting 12,000 yards in a day. If there are very dry conditions, this could drop to 5,000 a day. If the compaction tests are reading 93 to 95 percent, the compactor is capable of handling more scrapers. If the compaction readings are 90 to 92 percent, the balance of scrapers to compactor is just right.

Let's assume our job doesn't have any major soil problems. For our equipment, we select a Cat 14H or larger grader, two Cat 631 open-bowl scrapers, one Cat 623 paddle-wheel scraper, one Cat 815 compactor, and one 3,500-gallon water truck. Now that we have the equipment we need, what's the next step?

### *Other Concerns*

Before beginning the job, call USA (Underground Service Alert) and have all the underground lines marked, get a water permit, pay all fees, and make sure all the construction signs are up. The first day of work on the job is usually spent with the grade setter marking up fill stakes and placing and marking boots next to all the cut and fill stakes. He'll mark the height of the fill on his fill boot, and spray the amount of fill needed on the lath in orange paint so the equipment operators building the fill can easily see it. The foreman will make sure that a good water source is available, using a standpipe or a water tank (see Figures 9-5 and 9-6). A water tank cuts the fill time more than 50 percent over a standpipe. It has a larger fill pipe and more pressure, and is a must if you're using more than one water truck. Place a load of crushed rock under the fill spout so a mud hole won't develop.

## Planning the Excavation

It's very important that the foreman work out a good plan for excavating and filling so the equipment travels the shortest distance possible from the cut area to the fill area. He'll need to check all the survey stakes to determine where he wants to start the scrapers for the first cut and where to make the first fill. If possible, always start the first cut in the largest cut area. This gives the grade setter and operators more time to get familiar with the job before moving to a second cut area.

### *The Crew Meeting*

Before the equipment begins working, the foreman will meet with his crew to discuss the job and his excavation plan. He'll show them where he wants to start excavating and where the fill areas will be. He'll tell the

**Figure 9-5** *Water truck filling from a standpipe*

**Figure 9-6** *Water truck fills quickly at a water tank*

paddle-wheel operator what lot pads he should concentrate on first. And he'll brief the water truck driver on how much water he should use in the cut area for dust control without making it too muddy to work efficiently. The foreman will start the excavation on this job at the end of the existing street where the new subdivision ties into an older one. This is always a good choice, because by looking at the existing street, the operators can see the depth and width they'll be cutting to, and it helps them start with confidence. Soon they'll become familiar with the grades.

## *Preparation Work*

On the second day, the foreman has the water truck, grader and the paddle-wheel scraper begin work. The scraper does any stripping that's needed. The grader scrapes vegetation off the fill lots and rips them. The vegetation is hauled off or spread in the areas designated by the soils engineer. The water truck and compactor follow the grader, watering and compacting all the fill areas he rips up. It may take two or more days to get the fill areas prepped and ready for fill. On large jobs, a Cat D6 dozer may be needed to rip and fill areas for prepping. By the time the prep work is done, the grade setter will have all his fills painted up on the lath and boots set to start excavation. The foreman or grade setter will point out the staking pattern and offsets to the rest of the crew before excavation begins.

Usually the surveyors place one lath and hub at each back lot corner. If two lots meet at that point, they'll drive lath so a wide side of the lath faces each lot. The surveyor will mark a cut or fill on each side of the lath facing the corresponding lot. The front lot corners will have one lath on line offset 5 feet toward the street. The wide side will face the street, with the offset and grade for the finished sidewalk grade (top-back-of-walk) marked. On the back of the same lath, the surveyor will mark the grade of both lot corners.

Notice, on the front of the lath in Figure 9-7, the offset is 15 feet to top-back-of-walk (TBW). The plans for this job show that the R/W (right-of-way) and TBW (top-back-of-walk) are the same distance, and there's a cut of 4.80. On the back of the lath the surveyor has also marked a 5-foot offset to the lot corners, with a 2.00 cut for lot #7 and a 2.20 cut for lot #8. Usually the surveyor will put different-colored ribbon on the front and back lot stakes. Notice in the figure that the top line of the drawing is marked *Existing ground to be excavated*. The bottom grade line reads *Finished lot pad* and *Finished profile grade*. That's the finished profile after the sidewalk and curb are poured and the street is paved. The finished lot profile is our excavation grade. Assuming this is butting up to

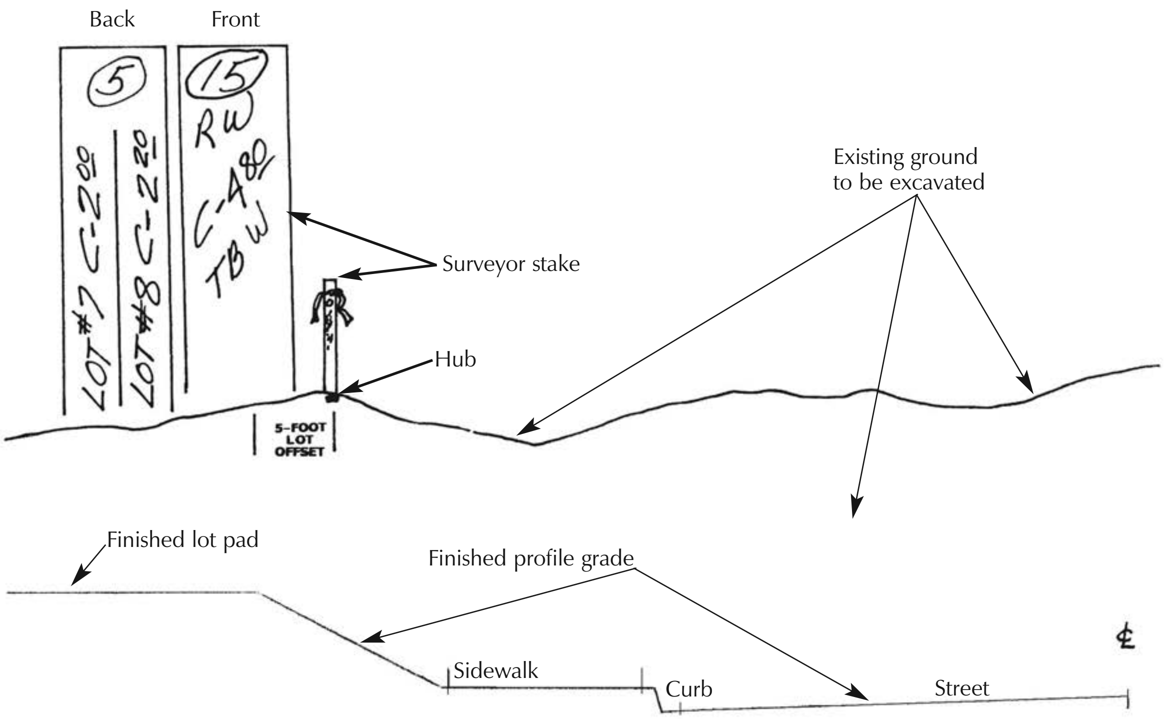


***Figure 9-7*** *Surveyor's stake set before rough excavation*

an existing subdivision, and we need a 2-foot lot cut to match the adjacent ground, the foreman will probably want to start the scrapers cutting perpendicular to the street and parallel to the existing yards. He'll have the operators cut the grade far enough away from the existing lots or fence so there's room for the scrapers to get turned and cut parallel to the streets.

## *Watching Haul Distance and Equipment Balance*

While the work is ongoing, the foreman must watch the excavation closely to be sure the scrapers have a good haul road and the fills are made in the right order to keep the haul distance to a minimum. A rough haul road will cut production, and any increase in the travel distance will add to the job costs.

He'll also watch the equipment balance. If he notices the push dozer is waiting for scrapers to return to the cut area each time, he should add another scraper. If the scraper is always waiting to be pushed, then there

***Figure 9-8*** *Scraper making a nice even dump*

are too many scrapers for a balanced spread. Of course, these conditions may be temporary. If you get into a cut area with a short haul to the fill area for 30 or 40 loads, the scrapers may be waiting to load. Once that cut is made and the haul gets longer at the next cut area, the equipment balance will be good again. In this case, it wouldn't be cost-effective to park a scraper. I like to start with fewer scrapers cutting all the short hauls, then when the short hauls are finished, put on more scrapers for the longer hauls. Of course, this isn't always feasible. It may require too much moving around. Balancing equipment is already a juggling act the foreman must perform daily. He has to constantly evaluate whether he has enough water trucks, scrapers, compactors, and graders, or if adding a ripper Cat dozer would increase production.

The foreman must also pay close attention to the compaction tests taken in the fill areas. If the optimum moisture starts going up and the test results start to read lower, he must tell the water truck driver not to water so heavy. On the other hand, if he notices the optimum moisture dropping and the test results doing the same, he must see that more water is applied.

Another important consideration is the way the scrapers dump in the fill area. If the scrapers don't dump an even layer each pass, it won't take long to overwork the compactor to the point where the compaction fails to meet the percentage needed. In Figure 9-8, the scraper is dumping a smooth pass to build up the front grade to match the fill on the crows feet. It may be necessary to dump in a pile to get a corner filled if directed by the compactor operator.

### *Checking Grade*

During the excavation, the grader should be finishing lot pads and occasionally grading haul roads. The lot pads are the only things cut to finished grade during the rough grading phase of the subdivision. You may need two graders and a second grade setter as the grading progresses. The grade setter with the dirt spread must check the grade as the scrapers make their cuts, and inform the operators when the correct grade is reached so they don't undercut. He should *give them line* for the front lot slope, and line for the back-of-sidewalk, curb step, and street subgrade step lines. This involves painting a 1-foot spray paint line every 25 feet or so where these cuts must be made.

The grade setter must also check grade in the fill area. The lot corner lath should still be up for line, with the height of the fill or amount of cut painted on the boot lath. Once the grade setter sees the fill is getting close, he'll put one or two crows feet in the center of the pad with the fill remaining at that spot. Or, if he has time, he may decide to hand-direct a few loads where he wants them and then wave the equipment to the next fill. Lot pads being filled should be left 0.05 to 0.10 foot high so the grader will have a small trim to make for finished lot grade. A good compactor operator will hand-direct the scrapers to the next fill if he feels that the fill they're working on is to grade, and the grade setter is too busy to check it. To excavate a subdivision properly takes a team effort from everyone on the job.

### *Excavating Streets and Lot Pads*

The street and lot pads are excavated simultaneously. This will get the lot grade close enough to finished grade so the front lot stake can be moved to the actual lot corner, eliminating the 5-foot offset. Notice the surveyor's offsets have been scratched out on the lath in Figure 9-9. The lot stakes are now on the corners and the R/W is 20 feet. The grade setter marked the new lot pad grades as on-grade where he drove his hubs. The top-back-of-walk grade is changed from a cut of 4.80 feet to a cut of 2.80 feet because the hub is now 2 feet lower. The grade setter must add the thickness of the sidewalk, curb, pavement and the aggregate under them to the 2.80 cut, plus each grade change from back-of-walk to street, as well

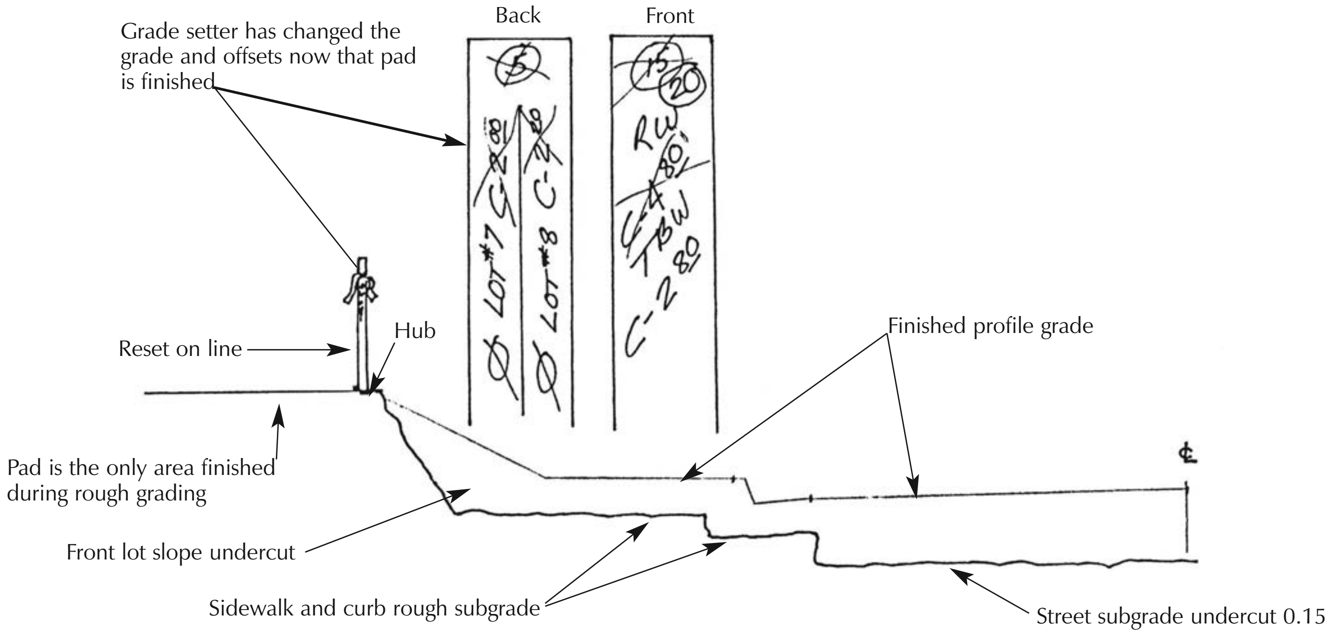


***Figure 9-9*** *Rough excavation is finished*

as the undercut in the street. The grade setter will need to check the plans to find the thickness of the road section.

If there's a row of several lots that don't vary in elevation more than 0.30 foot, and the grade tolerance is 0.20 foot, then it's a good idea to average them. By lowering one end of the row 0.15 and raising the other end 0.15, you may end up with several lots at the same grade. That makes grading go much faster, with no small steps to cut. The grade setter works ahead, painting grades on the ground. Once the lot stakes have been set back, there's nothing in the way and the scrapers can finish the remaining excavation to sidewalk curb and street subgrade. The site is now ready for utilities.

Look at the notes in Figure 9-9. Unless the plans show a specific undercut detail, this is the plan I recommend. The front lot cut shows about a 1:1 slope from the lot pad to the sidewalk subgrade. Remember, to get the sidewalk subgrade, the grade setter has to add the thickness of the sidewalk and aggregate under it to the top-of-walk grade.

Do the curb subgrade the same way. Cut the street subgrade by adding the section of asphalt and aggregate to the cut, plus a 0.15 undercut for underground spoil. I don't add an undercut to the sidewalk or curb

***Figure 9-10*** *Rough graded with a vertical cut at the front of the lot to back-of-curb*

subgrade. Before the grade setter can add the thickness of the road section and undercut to the 2.80 cut back-of-walk grade, he must first compute the sidewalk slope and the drop from the front-of-walk to the lip-of-curb, and add that to his road thickness cut. He must also know the distance to measure from the back-of-walk to the lip-of-curb. All that information can be found on the plans under the typical road section. It's common practice to cut from the front of sidewalk to the road subgrade, eliminating the extra cut for the curb. I prefer this method because it saves time. The grade setter doesn't have to spend time marking a second cut line, and the small difference in dirt quantity won't matter much in the rough grading phase. He'll run a line of crows feet or paint an orange line every 25 feet to mark this cut line. I prefer a painted line.

Figure 9-10 shows a subdivision where the rough grading is complete. Notice the lot pads are finished and the front lots, sidewalk grades and street subgrade have been bladed to the required grade. Also notice there isn't a front lot 1:1 slope; instead it has a vertical cut. The undercut of the front lot slope will be filled in with the spoil from the underground telephone, electrical, gas and cable lines. This should still leave some room for foundation dirt later. You must be careful when calculating how much undercut you'll need to accommodate the excess dirt from the underground utilities. When the grading crew returns to finish the

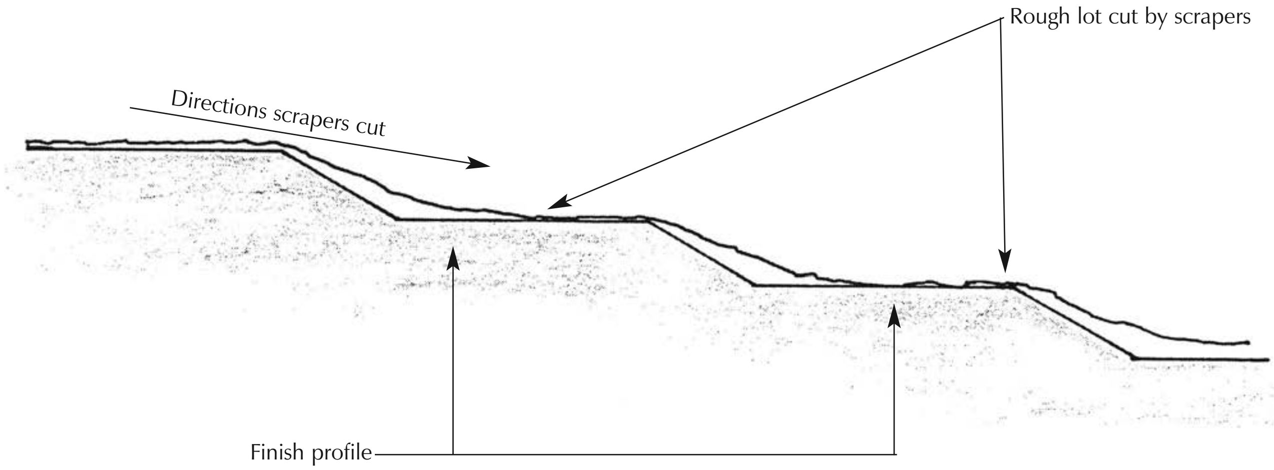


***Figure 9-11*** *Rough grade cut on stepped lots*

sidewalks, curbs and streets, it can be costly if there's a large excess or shortage of dirt. If the utilities are placed in a back lot easement, then the front lot undercut should be substantially less.

The subdivision job just outlined is the easiest type of job possible, with no large lot pad steps and no rock or hardpan to contend with. If rock or hardpan is encountered, you'll need dozers ripping ahead. Don't use paddle-wheel scrapers if the rocks are larger than cobble size.

## *Stepped Lot Pads*

A subdivision built in the hills may have lot steps that are 6 feet or more to contend with. Make the initial lot cut from the highest point on each lot, as shown in Figure 9-11. Once the lots have been excavated, use a dozer to cut the remaining slope and push the excess pad dirt out into the street where the scrapers can handle it. If the adjoining lot behind is several feet higher, a hoe rather than a dozer may be faster for excavating the corners. The top-of-slope usually starts down 1 foot or more past the property line of the top lot, and the entire slope is built on the lower lot.

The only time this doesn't apply is when the new lot pad butts up next to an existing subdivision pad or property where no right-of-way has been obtained. In that case, build the fill slope on the high side lot, not on the lower one.

As the lot pads are being trimmed, trim all the cut and fill slopes to grade with a grader or dozer. If the fill slopes are 8 feet or higher, you should track-walk them with a dozer. No trim is required unless the slope is slight, say 4:1, and then you might need a grader to trim. If a GPS is available to use for rough excavating the subdivision, it would be very cost-effective. A grader equipped with a laser mast and slope control will work well for lot trimming, though not for street grading.

Usually all fills must be compacted to 90 percent. Of course, there are always exceptions. Some extremely expansive, heavy clay soils are compacted to just 85 percent and then rolled very lightly. I've worked in areas where there were clay pockets under the building pads that the soils engineer directed to be removed before work could begin. That required extra work at extra expense. Read the job specifications carefully so you're familiar with any soils engineer directives before proceeding with the excavation. This will help you to determine what should be charged as *extra work*.

## Erosion Control

Once rough grading is complete, all slopes and dirt areas where water can run off and erode must be protected. Every project is required to have a plan to control dirty water runoff from the construction area. Erosion control, most commonly known *as storm water pollution prevention* (SWPP), has become an increasingly sensitive issue in the construction industry. This is a year-round concern, but during the rainy season it can be an especially serious problem. In the area where I work, that's from about the middle of October through April. However, any time during the grading operation, if there's a threat of rain, erosion control must be in place. You should have erosion-control materials on site at all times.

There are several different erosion control measures you can implement. Some projects may require straw bales, straw waddles, a silt fence and cobble or riprap to catch water or prevent erosion. In other areas, you may need to begin erosion control during the rough grading stage with temporary ditches and detention basins to catch silt and sediment before it can leave the site. If the area is large (several thousand square feet), the most cost-effective measure is to put down straw and hydroseed once grading is finished.

***Figure 9-12*** *Straw-filled waddles used for erosion control*

There are machines that chew up straw bales and blow the straw across the areas needing protection. You can then spray those areas with hydroseed using a truck designed specifically for this purpose. A biodegradable paper mulch, water and seed are mixed in the truck's holding tank and sprayed from a narrow-nozzle hose. This method of hydroseeding holds the straw in place, tacking it to the ground. For small unfinished areas that need quick protection from a predicted rain, you can just lay down plastic. When the rain passes, you can easily remove the plastic and finish grading the area. That'll work until you can put permanent erosion-control measures in place.

Rough-graded streets without drainage improvements will sheet-drain to the lowest area of the job. You can use rolls of straw, called *waddles* (see Figure 9-12), to slow the water flow. They'll help trap the silt carried by the water. If a section of dirt road is 400 feet long, stretch the straw rolls across the road every 50 to 100 feet. They'll act as check dams to control the water and stop the sediment from leaving the job site. Figure 9-13 shows an existing storm drain pipe with silt protection around the inlet. A berm was built around the storm drain to create a detention basin. With the silt barrier on the pipe, the water will pond in the basin and heavy sediment

***Figure 9-13*** *Berm surrounds drain inlet covered by filter tent*

will settle out before it reaches the silt barrier. If the berm weren't in place here, the water and eroding soil would bypass the inlet and run down onto an adjacent paved street. It might also clog the inlet pipe with mud.

You may wonder why the silt shouldn't just be channeled into the storm drain or be allowed to settle into undeveloped land next to the building site. The reason is that waste from chemicals and materials used in construction can be washed into arroyos or canyons that eventually empty into our rivers after a rainfall. Sediment and other debris clog fish gills, damage fish habitat and block the sunlight needed for plants to survive in our rivers, lakes and lagoons. We all need to be environmentally proactive or we'll pay a heavy price. In our industry, that includes some hefty fines.

## *Maintain Erosion Control Measures*

As the project evolves, you must continue to maintain your erosion-control measures. When improvements such as storm drains, concrete gutters, drop inlets and paved streets are finished, you must install silt barriers until the construction project is completed. Figure 9-14 shows a

***Figure 9-14*** *Filter bag set in drop inlet to catch silt*

filter bag set into a drop inlet. The bag allows water to flow through but traps the silt in the bag. You must make sure the bags are checked and emptied as silt builds up inside or they'll become plugged. Along with the drop inlet protection, you can lay fabric filter bags filled with crushed rock in the gutter flow line upstream from the drop inlet. These bags will help to slow the flow of water and trap sediment before it reaches the drop inlet. You can also place straw rolls behind finished concrete curbs where you expect rainwater might spill over into the gutter. Lay straw mats on small finished slopes to prevent erosion. All these measures will prevent silt and sediment from entering the drainage system.

SWPP is an ongoing process. The first measures you put in place may have trouble spots where the water flow is more than they can handle. You must address these problem areas immediately or you could face penalties and fines for violating your state's storm water pollution prevention regulations. When there's rain, erosion-control measures for your construction project must be in place. Keep them in good repair and check them after each storm. They must be maintained until vegetation begins to grow and the threat of erosion and runoff is over. The requirements, as well as the fines for violating them, are becoming more stringent every year. Don't take them lightly.

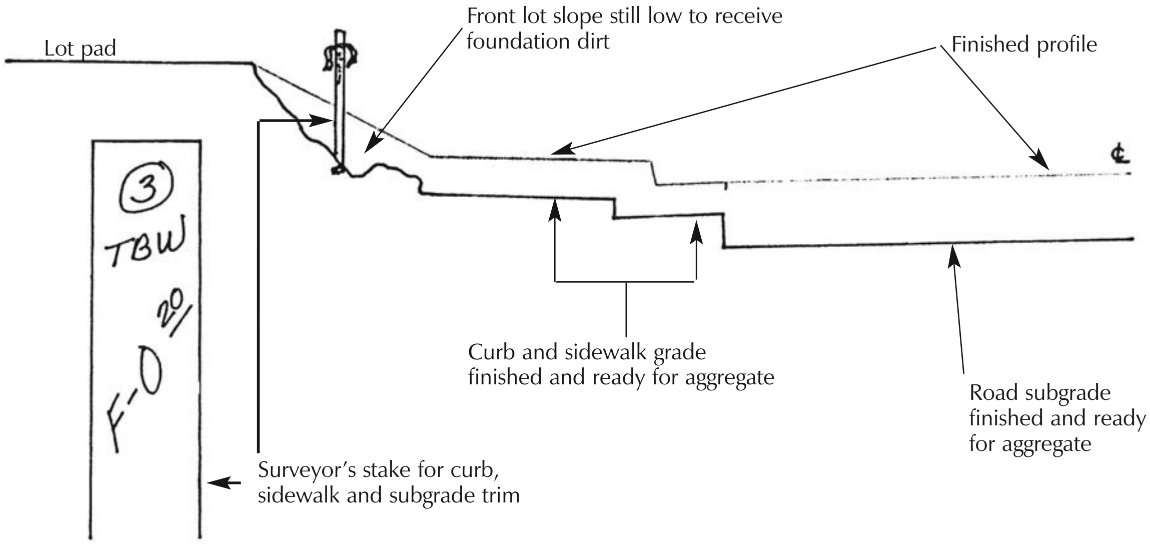


***Figure 9-15*** *Walk, curb, street and subgrade trimmed and ready for aggregate after all utilities are in*

## Grading and Compaction

Once the rough grading and underground are completed and all the trenches have been compacted, the grading crew can return to fine trim sidewalk, curb and street grades. The first order of work is to be sure the front lot easements are graded fairly level so the surveyor can set back-of-walk stakes. The surveyor's stake in Figure 9-15 shows an offset of 3 feet from where the top-back-of-walk (TBW) stake is set. The first order of work is for the grade setter to mark up every survey stake. If the survey stakes are too short for the boots he must set, then he'll drive his lath next to the surveyor's hub to mark his boot. The tall lath on the left in Figure 9-16 is the grade setter's lath and boot. All distances are measured from the nail on the top of the hub.

While the grade setter is marking his boots, someone should tie out all the water valve and manhole locations. This is done by driving two laths behind the back-of-walk stakes about 20 feet apart, then measuring from the manhole or water valve to the lath and marking the distance on the lath. Once this is done on each lath, the manhole or valve is tied out. This must be done for everything that you'll need to locate after the job is paved. If a GPS unit is available, it's the quickest and most accurate way to establish these locations. The big advantage to the GPS is that there are no stakes to be accidentally knocked out of place. All the elevations are saved in a digital file for easy retrieval.

When the grade setter has all his boots set, the rough trimming for walk, curb and street subgrade may begin. You'll need a grader, water truck, paddle-wheel scraper and later, a vibratory pad-drum roller or pad-food compactor. The size of paddle-wheel scraper depends on the distance to the waste area and how much excess dirt is left from the underground utilities. On a very small job, a Cat 615 paddle wheel will work, and for a large 130-lot subdivision, you might consider using a Cat 623 paddle. It's not uncommon to use two scrapers on a large job. The grade setter will walk ahead of the grader checking sidewalk subgrade and painting a line 1 foot back-of-walk. He'll give the grader operator a hand signal to let him know how much cut or fill is needed at that station. This procedure will continue until the back-of-walk grade is 0.05 foot high. If the grader doesn't have slope control, the front-of-walk grade also needs to be checked. Use the same procedure for cutting curb and subgrade. If the subgrade of the curb and the subgrade of the street are within 0.20 of each other, you could just make one cut to road subgrade at this time.

***Figure 9-16*** *Surveyor's hub with tack and grade setter's 2-foot boot on left*

If the grader is equipped with sonar and slope control, the grader operator can use the sidewalk subgrade for his sonar reading. The grade setter will go ahead to mark the line for cutting curb and won't be required to check grade on this pass, with or without sonar, because this cut will be too deep to cut in one pass and still hold a good line. On the second pass, the grade setter will follow behind, checking curb subgrade or street subgrade, depending on which one the foreman has decided to cut to at this time. If sonar isn't used, the grade setter will shoot grade ahead of the grader, not behind. The grader operator must be told what percentage of slope to dial in for each step when cutting sidewalk, curb and street subgrade.

While the grader is cutting subgrade to the plus side of 0.05 or 0.10, the scraper follows, picking up the excess dirt to fill lots that are still low

***Figure 9-17*** *Rough-trimmed subgrade before ripping and compacting*

or to haul to a designated waste area. The water truck should be busy watering the grade for dust control or the fill area for compaction. If the fills being made on the lot pads are more than 0.20, you may need a compactor or a pad-drum vibratory roller. If the grader is equipped with a GPS, the grade setter will just check grade now and then to be sure the system is working correctly. No line is needed because the operator has the line on his screen and knows exactly where he's cutting at all times. Once the subgrade of the walk, curb and street are trimmed 0.05 or 0.10 foot to the high side, the grade is ready to be compacted. Figure 9-17 shows what the subgrade should look like at this stage.

Now the entire street from back-of-walk to back-of-walk should be ripped. If the soil has good moisture with no dry streaks, it just needs a light watering before compaction. If the ground is dry, it may need ripping and watering several times before there's moisture for good compaction. The compactor shouldn't sit idle until the grade has enough moisture. Running a pad-drum roller or Cat 815 compactor after the water truck has watered the grade and the grader has ripped helps distribute the moisture as the grader keeps ripping. This ripping, watering and rolling will continue until the foreman and crew feel the soil has enough moisture to compact properly.

The compaction under the road is usually required to be 95 percent. Some agencies only require 90 percent compaction under sidewalk and curb.

## Fine Trimming the Subgrade

When the compaction looks right and the moisture is good, you should start trimming subgrade, assuming the rolling for finish subgrade will bring the tests up to 95 percent. For fine trimming subgrade, we'll still use the grader, scraper and water truck. But we'll need a smooth-drum vibrating roller rather than the pad-drum roller or 815 compactor we used for the preliminary compaction.

To start fine trimming subgrade, the grader may need to push some dirt back up to the sidewalk grade that was probably displaced from the ripping and compacting. Take the precaution of overfilling the sidewalk grade by 0.10 and make sure there are no low areas. That's because once the sidewalk trim starts, it would disrupt the trim to stop and make a fill. As the grader is building the sidewalk grade back up, the smooth-drum roller should be continuously rolling every pass the grader makes. The water truck should be adding water ahead of the grader so it'll be mixed as the grader trims, and won't stick to the roller drum. Once the grade setter is confident that there's enough overfill, the grader will start fine trimming sidewalk subgrade.

On the first pass, the grader operator will dial in the percentage of sidewalk slope called for in the specifications, which is usually 2 percent. The grade setter will paint a line 1 foot behind the walk and let the grader operator know what the cut is at that station. It may take the grader three passes to get the walk to grade, usually plus or minus 0.05, with the roller close behind on each pass. The foreman must be confident the sidewalk grade has enough rolling before directing the grader operator to make the curb cut. The grade setter will again paint a line for the grader to follow for the curb cut. Let's say a 0.50 cut is needed for curb subgrade. The grader operator shouldn't attempt to make the cut to subgrade in one pass. He should keep his attention on the line. The grade setter will mark every 25 feet as the grader takes a cut of approximately 3 inches with the curb slope dialed in to the slope control unit — usually 8 percent. Again, the roller should be close behind on each pass.

On the second pass, the grade setter should check the line that was just cut and signal the cut remaining to curb subgrade to the grader operator. The grader operator will try to cut as close to subgrade as possible this time without undercutting the grade. On the third pass, the grader should make the final trim to curb subgrade, with the roller still right behind him.

This is how the walk and curb grade would be cut using a grader with slope control only. If the grader is also equipped with sonar, the curb crew should set their string line for the concrete machine before the sidewalk and curb grading starts. Then the grader operator can use the same string line to run his sonar unit for trimming. This makes a more precise trim. The grader operator can use sonar on the walk grade to cut the curb grade and then use sonar on the curb grade to cut the street grade. By using sonar, you'll get a very accurate grade.

Even if the grader operator is using sonar, he still shouldn't cut to grade in one pass. Usually too much dirt will build up and the line he's cutting will be hard to hold. If there's an aggregate base under the walk and curb, and a concrete machine is pouring the concrete, the back-of-curb cut should be a couple of feet behind the back-of-walk so dirt won't be pulled into the aggregate while trimming the aggregate under the walk. Once the curb subgrade has been trimmed and rolled enough, the road subgrade is ready to trim.

The road and curb subgrade seldom match, so a notch line must be painted at the lip-of-curb every 25 feet for the grader to follow. On a subdivision, the road slopes 2 percent or more. The plans will have a street cross section that shows the slope required. The grader operator will dial in the slope (let's say it's 2 percent) then start cutting on the trim line the grade setter has marked for him. Once the first pass has been made, the grader operator will have a feel for the amount of dirt the scraper must start picking up, and he'll direct the scraper operator to begin. If the scraper operator is experienced with subgrade trimming, he'll be able to tell when the grader is starting to generate more dirt than he needs. Again, the water truck should water ahead of the grader and the roller operator should keep rolling nonstop, as close to the grader as possible without getting in the way. The roller operator should pay close attention to the water truck and not try to roll a watered surface until the water has had time to evaporate a little, or the drum will pick the dirt up, making a mess of the finished trimmed grade. If the water truck always stays ahead of the grader, this problem won't occur.

While the grader is trimming the road subgrade, the foreman should order a compaction test for the finished sidewalk and curb grade. The grade setter will carefully check centerline grade and quarter crown. He may also elect to set centerline hubs. The grader will make several trimming passes on the road subgrade, with the scraper picking up any excess and the roller rolling, until the road grade is trimmed within a tolerance of plus or minus 0.05 foot. Be sure you check your job

***Figure 9-18*** *Trimmed and compacted sidewalk, curb and street grade ready for aggregate base*

specifications. On some jobs the road grade may have a tolerance of 0.08 foot. Figure 9-18 shows how the finished trim for the sidewalk, curb and road will look when it's completed, compacted and ready for aggregate.

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# CHAPTER 9 QUESTIONS

**1. What is one of the best ways to keep your excavating costs down?**

A) Use only the smallest equipment that can handle the job
B) Use one large water truck instead of several smaller ones
C) Use several grade setters on each job
D) Use experienced equipment operators

**2. Why is it important for the compactor operator to keep dozing dirt as he works?**

A) To break up large chunks
B) To mix the moisture evenly
C) To keep from getting ahead of the grader
D) To keep the soil from compacting too soon

**3. What is the grader's most important job when rough excavation starts?**

A) Grade haul roads
B) Start lot pad grading
C) Outline street cuts
D) Cut sidewalk grade

**4. Why would you choose to use a water tank rather than a standpipe?**

A) To keep an accurate load count
B) To decrease loading time
C) To have extra water on hand
D) To load two trucks in tandem

5. **What is the most efficient equipment for stripping?**

A) A grader
B) A compactor
C) An open-bowl scraper
D) A paddle-wheel scraper

6. **What is the only area trimmed to finish grade during rough excavation?**

A) Sidewalk grade
B) Curb grade
C) Lot pad
D) Street grade

7. **Fill lots should be overfilled by how much for trim?**

A) 0.05 to 0.10 foot
B) 0.10 to 0.20 foot
C) 0.20 to 0.30 foot
D) 0.30 to 0.40 foot

8. **When must you have erosion control measures in place?**

A) Any time you're excavating in developed areas
B) Always
C) Any time there's a threat of rain
D) Any time there are steep slopes

9. **What are the usual compaction requirements for sidewalk and curb subgrade?**

A) 85%
B) 90%
C) 95%
D) 100%

10. **What are the usual compaction requirements for street subgrade?**

A) 85%
B) 90%
C) 95%
D) 100%

# Excavating Commercial Sites

# 10

Since there's a big difference in job size between a shopping mall and a fast-food site, there will also be a big difference in the equipment you use. For example, on a fast-food site you might use a small Cat 615 paddle-wheel scraper, a Cat 12 grader, a pad-drum vibratory compactor and a small single-axle water truck. With 1,800 cubic yards of excavation to embankment, that would be all the equipment needed for rough grading. You might also want a smooth-drum roller for compacting the pad while it's being trimmed.

But for a large shopping mall, with 110,000 cubic yards of excavation to embankment, you may need a full dirt spread of two Cat D10 dozers, five Cat 651 open-bowl scrapers, a Cat 825 compactor and probably two Cat 14 graders. You may also need a water tank setup, possibly two water trucks, and a smooth-drum roller for rolling the pads after they're trimmed.

Excavating for commercial buildings and apartment houses is different from road jobs and subdivisions. For one thing, you'll notice that there are many more stakes. The parking areas have islands to delineate traffic and to create parking stalls, and each one must be staked. Commercial sites always have at least one parking area adjacent to the building pad. The grading usually includes excavating these parking and swale areas as well as landscape mounds in contour areas. Parking areas also have many drain inlets, so there are multiple summits and swale lines to drains that must be excavated. It's important that the grade setter let the operators know where the grade breaks are, and this requires staking each one.

## Take Time for Planning

Take time to study the job specifications and soils engineer's report before you begin work. Here are some of the things to consider:

- Do you have the contract to fill all the planters with topsoil?
- How much contour grading is expected?
- Is there any topsoil to be stripped and stockpiled before excavation begins?
- How much are the building pads to be overbuilt and what compaction is required?

Also, how much offset is there to the lot corners? Each building pad corner should have an offset stake from each side. The grades marked on them should be pad grade, not finish floor.

Try to arrange a job conference to share information and plan the work. The foreman, superintendent, and estimator should discuss how the job was bid. Let's look at a typical situation. Suppose the plans show an 8-inch parking section (aggregate base plus paving thickness) interrupted by landscaped islands that are surrounded by concrete curbs. Do you grade and pave the entire area and then cut out the islands? Or is it better to work around the islands when grading, laying down the base and paving?

Many estimators feel that it's cost-effective to rock and pave through the islands and then cut them out after the paving is done, especially if there's no grade change between the back and front side of the island. Grading, installing aggregate, trimming and paving go faster if there are

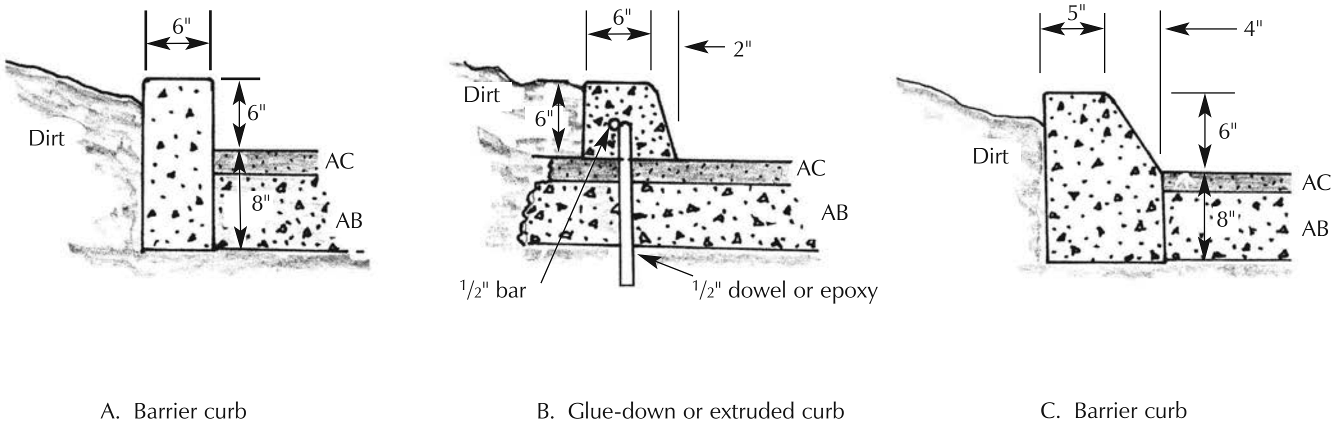


***Figure 10-1*** *Three types of curbs used around island planters*

no islands to maneuver around. However, you can only use this method if the plans specify a glue-down curb that sits on top of the finished asphalt. If the islands are 14- or 18-inch barrier curbs that sit on or below subgrade, you must place them before the aggregate and paving.

Figure 10-1 shows three types of curb commonly used around planters. Type B is a glue-down curb. Before bidding the job, the estimator should decide if the time saved working and paving through the islands justifies the cost of the extra time and materials needed to cut and remove paving material from each island. Of course, you'll always need to excavate through the islands during rough grading if there's a large cut to be made.

## Excavating an Apartment or Office Complex

The first step in excavating an apartment or office complex is usually stripping the grass or brush. The soils report should tell you how to handle this. Before stripping begins, the foreman should find the excavation pattern that minimizes travel time for the equipment. Usually debris is hauled off or placed at the edge of larger landscape areas. The soils engineer may require that the job site be disked and allowed to sit until the grass is dry. Once the grass is dry it can be disked again and then

***Figure 10-2*** *Grass being disked and left to dry*

used in any fill that's made. In some cases, if the grass is already dry, just one disking may be required. Green vegetation is *never* allowed in a fill area. Figure 10-2 shows a field that's being disked and left to dry.

After the grass or brush is stripped or disked, the next step is to remove topsoil to a designated stockpile area. The soils engineer determines the depth of the topsoil to be excavated. If all the soil is good enough for planter fill, you won't have to stockpile any topsoil.

## *Setting the Boots*

While the stripping or topsoil removal is going on, the grade setter should be marking all his boots next to the cut and fill stakes the surveyor has set. He'll drive a lath next to the surveyor's information lath, which usually shows the top-of-curb or finished asphalt cuts or fills. Then he'll place a mark on the lath (boot). This mark should be 3, 4, or 5 feet above the finished grade. A 2-foot boot is hard to shoot because it's so low. Unless the grade setter is very tall, a 6-foot boot is too high to shoot with an eye level. It may take two lath nailed or glued together to get enough height for the grade mark.

The grade setter should set boots based on the finished grade, then add the curb or road section subgrade depth when checking grade from these boots. After marking the boot, he'll mark the cut needed to reach subgrade on all the cut stakes. That way, the equipment operators can see what cut is needed directly, without having to add the curb height and road section to the surveyor's cuts. Figure 10-3 shows the lath set by the grade setter for a cut area. He's added 0.60 to the 1.20 cut on the surveyor's stake. The parking lot has an 8-inch section, which is 0.66 foot. By adding only 0.60 to the cut, he's leaving the grade 0.06 high for compacting.

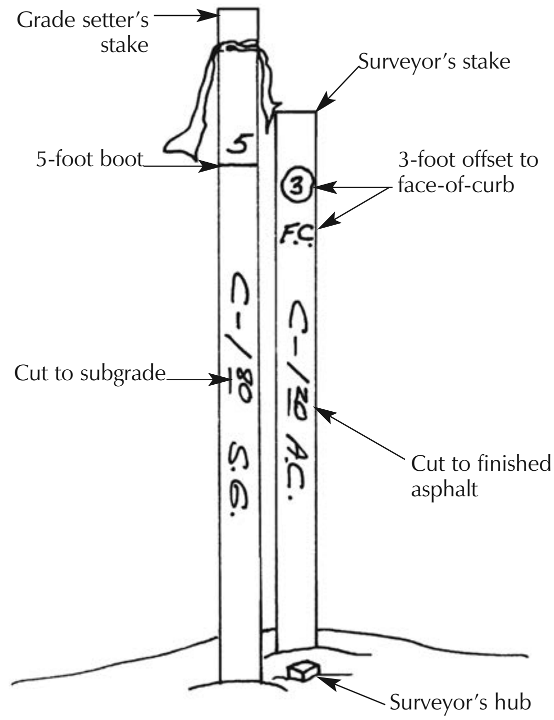


***Figure 10-3*** *5-foot boot next to surveyor's information stake*

The grade setter will mark the height of all subgrade fills on the lath, using the finished grade symbol and arrow, with the fill part of the lath painted orange so it's easily distinguished from a cut stake.

## The Excavation Begins

Once the grade setter has finished marking the stakes, excavation can begin. The fill areas must be ripped, watered and compacted before any excavation can be placed there. This step is usually done while the grade setter's marking his boots. Other than planning for the convenience of the equipment, there's no set rule that dictates where to start the excavation. Beginning at either a building pad or parking area is fine. If the site is fairly level, usually the building pads are the fills and the parking lots are the cuts. In that case, you'd want the scrapers to begin the excavation in the parking areas, starting on the largest cut first.

If possible, build the pads first. Apartment and office site pads are so large that pad grading can begin before rough excavation of the site is

***Figure 10-4*** *Scraper works parking lot fill while grader and roller trim pad*

finished. Then, if more dirt's needed or there's excess to be removed, the scrapers are available to make quick adjustments. Figure 10-4 shows a scraper making a cut in the back parking lot and the grader and roller finishing the pad trim.

Apartment and office pads usually extend 5 feet beyond the building line in both width and length. This makes the pad overlap into planter and walk areas. The pad is the most important part of the job at this point. If it overlaps into the parking area, there's no problem; the parking area near the pad won't be cut for a while. That's also true for narrow swale areas between buildings. Overbuild the pad 5 feet even if it temporarily covers some swale areas.

Notice the tripod between the grader and roller at the rear in Figure 10-4. A receiver on the grader receives the laser beam and controls the grade being trimmed. By setting the laser high on the tripod, the receiver on the grader can also be set high, allowing the grader's receiver to pick up the laser beam over the top of the cab without interference. The grade setter checks each pass the grader makes and paints an on-grade symbol (circle with a line through it) or the cut still needed on the ground (Figure 10-5). After the initial pad compaction with a pad-foot roller, a smooth-drum vibratory roller working with the grader is my choice for good compaction (Figure 10-6).

***Figure 10-5*** *Grade setter paints on-grade symbol for grader*


***Figure 10-6*** *Smooth-drum vibratory roller*

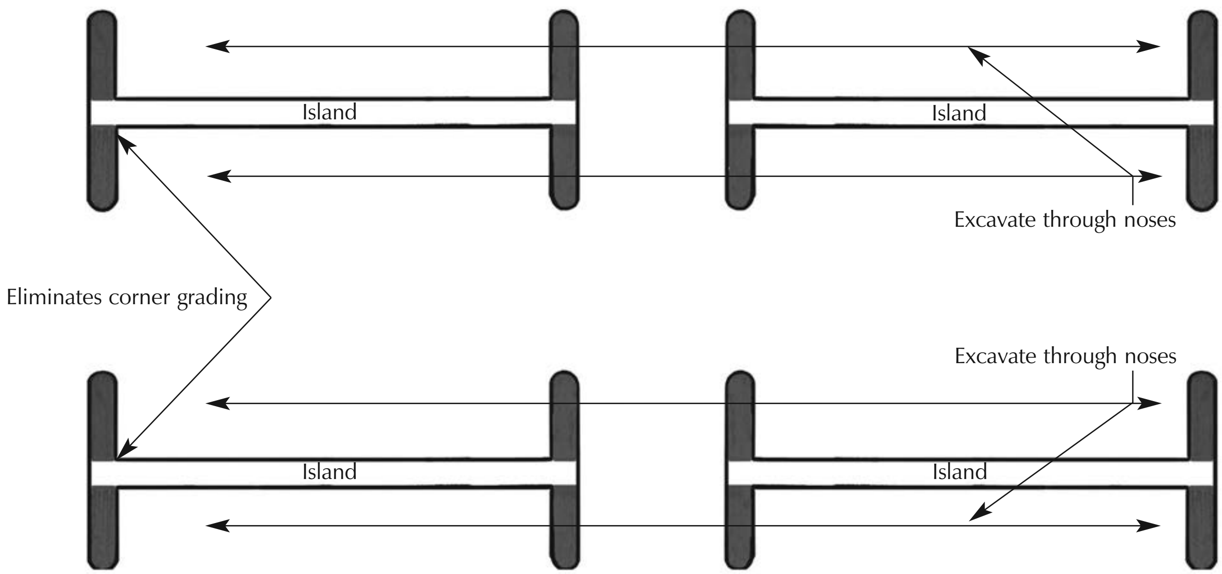


***Figure 10-7*** *Rough-excavate through shaded noses*

If there are ramps to excavate for loading docks, be sure to excavate to the back of the concrete structures, *not* to the front. When making vertical cuts, you'll need a hoe to complete the loading ramp. Don't leave a slope less than approximately 2:1, from the top of the building pad down to the planters or parking areas. This provides access to the pad for both equipment and materials once the building contractor starts construction.

## Excavating Islands

The parking lot islands are the most troublesome part of an apartment or office complex excavation. As I mentioned earlier, the parking lots and the islands are usually cut areas. At some time during the excavating process, the island stakes must be offset so the islands can be excavated to the grade necessary to receive topsoil later. If the island is narrow and just a small cut is needed, the grader can make the cut without the stakes being offset. If a small fill is needed for an island, the grader can do that during the excavation, or it can be left for the final trim.

The island noses are usually cut through during the rough grading so the scrapers won't be hindered while making their cuts. Figure 10-7 shows how removing the island noses will make the excavation easier. The foreman may decide the cuts are small enough to run the grader parallel

***Figure 10-8*** *Grade setter offsets surveyor's lath and hub*

with the nose, pushing the excess out of the corners to the scrapers, rather than offsetting all the nose stakes. On the other hand, if deep fills are needed, the foreman may have to reconsider the nose removal. These decisions should be made in the field after starting the cuts. Be sure all stakes are offset carefully so the island line and location aren't lost. Resetting the grades isn't a problem, but resetting island locations is time-consuming unless you're using GPS. Excavating a parking lot usually requires the grade setter to do a lot of sweding to check all the summits and swale areas.

When small island fills are needed, I prefer to leave the islands a little low. That way, the grader will have a place to move the excess trim material to later. Small islands are often ignored during the initial excavation. They're cut to parking lot subgrade and built up later.

The grade setter must offset each stake he removes, and then reset it after the area is excavated or filled to the desired grade. In Figure 10-8 a grade setter is taking a grade from the surveyor's hub before setting the new hub behind him. When this hub is offset, the area over the surveyor's hub can be excavated. Notice how well-equipped the grade setter is. He has job plans in his back pouch, ribbon, paint, feathers for hubs, 50-foot tape, knee pads in case he has to kneel down to take shots with his eye level, a hatchet and a survey rod with a laser receiver.

There's a variety of methods for doing this work, depending on the soil and what's included in the grading contract. It's important to always be planning ahead. If, for example, during the rough grading you look ahead to the finish grading, you'll know where you want to place any remaining excess dirt. This kind of foresight will save a lot of time and money.

## Balancing the Site

If soil in the area will be used in planters and landscape mounds, a small dozer or loader can push or dump the soil into small islands. Use scrapers to fill the larger landscape areas. On most sites, the planters and mounds are left low so foundation dirt can be placed in them later. If a site is balanced and you shouldn't have to haul any dirt in or out, keep a close watch on the grades. If it looks like there will be too much or not enough dirt to reach grade in all areas, contact the engineer. Let the engineer make the grade changes while the equipment is still working. Otherwise, you may have to stop work while corrections are being made. Overbuild the building pads 0.05 to 0.10 for trim excess.

Remember that some soil will be displaced during construction, especially from the 5-foot overbuild on the pads. You'll need some place to dispose of this dirt in order to save the cost of hauling it away. Many excavation contractors undercut the parking area enough so it can handle excess dirt from underground spoil. In most cases, you won't be responsible for disposing of the foundation dirt. That's usually an extra expense and is charged as such, so be careful about undercutting parking areas. I prefer to leave the islands low while rough grading to receive any excess dirt while trimming.

When the initial excavation is completed, have the surveyor check the pads and parking areas to certify that they're excavated properly. That way, any excess dirt problems that develop later won't be your responsibility. Remember, the initial surveyor's grade stakes may need to be offset or pulled out and then reset while the area is cut or filled to grade. It's important to leave these stakes in place long enough to keep control of distances and grades. The job will be restaked for fine grading and curbs after the underground work and foundations are in.

After the rough grading is done, you might not be called back until all the buildings are up. When you return to the site, all the underground drains, sewer, and water should be in. If electrical and irrigation lines aren't placed yet, you'll have to coordinate the work of these contractors with your grading to avoid any conflict. The landscape contractor usually can't run his line until the area has been cut to grade. The surveyor doesn't set the grade for his sprinkler line. Instead, he uses the subgrade for his grade, so it must be accurate to within plus or minus 0.10 foot. Sprinkler lines crossing the parking lot must go in after the subgrade has been ripped, compacted and trimmed or they'll be damaged.

## Curbs and Paving

Now the site is prepared for curbs and paving. If extruded curb (a glue-down curb placed on top of the pavement) is called for, you may decide to grade and pave through the smaller islands. Be very careful to check the survey stakes and the offsets provided. Surveyors follow several different conventions when marking their stakes. Every firm is different. For example, they may give the offset to the top-back-of-curb, face-of-curb finished asphalt, or edge-of-pavement finished grade. If it's to top-back-of-curb, the grade setter needs to look at the plan and find the distance from top-of-curb to finished asphalt. Then he'll add that figure to his grades, plus the parking section of aggregate and asphalt for his subgrade elevation.

On the other two markings (face-of-curb finished asphalt, or edge-of-pavement finished grade), he'll only figure the parking section of aggregate and asphalt into the grades. Then you must decide how far behind the curb to excavate on all the offsets. On a barrier curb (refer back to Figure 10-1), it's good practice to cut 2 feet behind to give the curb crew enough room for setting forms or for the curb machine to work. For an extruded curb poured on top of the pavement, leave enough space behind the curb for the curb machine to work. Usually 2 or 3 inches is enough pavement behind the curb to run the machine on. That means you must place aggregate 6 inches behind the curb to give the paving crew enough room to pave their 3 inches.

Do some planning before cutting grade where curbs will be placed. Some concrete curb machines need more space behind the curb for machine overhang and string line. In that case, the soil beyond the finished asphalt surface should be cut back. But don't go too far. Don't waste more aggregate than necessary. Most small curb machines don't trim, so it's better if the string line for curb is set before trimming. Sonar on the grader can run on that string line, cutting a much closer grade for the curb machines.

Once you've decided on the distance to overcut, there's just one more decision: Will the subgrade be processed, compacted and fine trimmed now, or after the curb is placed? If the curb will be placed on the finished asphalt, the subgrade must be processed, trimmed, rocked, and paved first. If it's a barrier curb, the depth of the curb and the section of aggregate and pavement will determine when to trim subgrade. If the bottom of the curb and the subgrade of the parking section are the same elevation, you may choose to trim the subgrade and curb grade at the same time. However, if for some reason you decide not to trim subgrade at the same time as the curb grade, I strongly suggest you go ahead and process and compact the subgrade of the entire parking lot before the curb is trimmed, even though the subgrade will be trimmed again later. That's because it's very difficult to do this *after* the curbs are in.

Try to get some dirt backing behind the barrier curbs before placing the aggregate. They'll break easily if bumped, especially if they're the same grade as subgrade. The electrical and irrigation contractors should place their lines deep enough so ripping and processing won't damage them, or they should wait until the processing is finished. Let me emphasize again, it's much faster to process and compact subgrade *before* you place the curbs. Even if the bottoms of the curbs don't match subgrade, you can still compact and trim the entire area all at one time. Then, after the curbs are placed, you'll only have to trim or fill slightly along the curbs before placing the aggregate.

## Items to Watch Out For

If compaction tests are required under the curb, it's much more cost-effective to compact and trim the entire area at one time. Once the curbs are placed, measure all the sewer cleanouts, water valves and manholes under the paved section from fixed locations so you can find them after they're paved over. Be sure any object you measure from will remain in the same place so it will be there when you need to measure from it again. Otherwise, you may have problems locating the valves and manholes after paving. This process is called "tying out." If you have a GPS, use that instead of tieouts to identify and locate items.

After the curbs are in, any grading that's needed should be done with a small tractor and a drag box. The operator, working with the grader, can also grade the corners and dump excess trim in the planters.

Any area that has unsuitable soil, such as soft or muddy soil or pockets of vegetation, must be brought to the attention of the soils engineer. He'll determine how much soil has to be excavated and the material you should use to refill the excavated area. Areas in the building pad with unsuitable soil must be excavated before any pad fill is placed. If the engineer feels that any unsuitable soil in the parking lot or street will dry out before the grading contractor returns for final grading, he may decide to leave it there to dry. If soft dirt goes so deep that it hinders excavating or placement of underground utilities, it should be removed during the rough grading operation.

It's important that the foreman keep close track of the time spent and the amount of material moved or used when dealing with unsuitable soil. Excavation of unsuitable material is usually charged under the contract as extra work. Be sure you get a written agreement regarding how the extra work involved in removing any unsuitable materials will be paid for *before* starting the excavation. Unsuitable soil in landscape or planter areas is usually left undisturbed because it poses no problem unless a concrete walkway will be placed over it.

## *Special Care Areas*

You'll nearly always excavate for swale areas around building pads for apartments and offices. Make sure that all swale areas that aren't overlapped by building pads are excavated early. You don't want to generate a lot of excess dirt when the final landscape grading is done. Pay special attention to this potential problem and to all excavation for swales, planters, pool areas and sidewalk subgrade around buildings. Be sure to cut all sidewalk or concrete patio areas to subgrade, not to the finish elevation shown on the grading plan.

Excavation is always more difficult when the working area is limited. That's a common problem when apartment and office sites are designed for high-density use. Where land values are high and buildings are close together, there may not be enough space to stake the swales between buildings. These are important areas and should be excavated accurately during rough excavation.

If they're not staked, the grade setter should check the plan for the elevation difference between the swale and the two building pads it runs between. Use the pad elevation for control of the swale cut. These areas may be too narrow for a scraper once the buildings are up.

If there's a large amount of stockpiled topsoil to be placed in planters, place it after the curbs are in, but before doing the fine trimming for the aggregate. Planters could be filled after the project is paved, but that may cause some asphalt damage or tracking on the new pavement.

If the engineer or building superintendent makes any grade or design changes while the project is under construction, be sure the change is in writing and signed. This is very important, even for minor changes where no extra charge will be involved in the change. Otherwise, you're accepting the responsibility for making the change without anyone's authority. Any repercussions from that change could come back to you — and that's never a happy prospect.

# Chapter 10 Questions

**1. What's the biggest difference between staking a commercial site and staking a road project?**

A) The stakes are set every 100 feet
B) There are fewer stakes
C) There are more stakes
D) The surveyor will mark the boots

**2. Which item listed below will *not* be found in the job specifications or soils report?**

A) What to do with stripped topsoil
B) The amount of contour grading required
C) How much to overbuild the pads
D) The staking diagram

**3. What type of island curb is placed on finished asphalt?**

A) 6-inch glue-down curb
B) 10-inch asphalt dike
C) 14-inch barrier curb
D) None of these

**4. What must be done to a fill area before any excavation can be placed on it?**

A) It must be leveled for dumping
B) It must be disked under and the vegetation burned off
C) It must be ripped, watered and compacted
D) It must be undercut with a grader

**5. How much are commercial building pads overbuilt?**

A) 2 feet
B) 3 feet
C) 5 feet
D) 10 feet

**6. How can you make the rough grading of parking areas easier?**

A) Excavate through the island noses
B) Rip the entire area first
C) Cut the islands with a grader
D) Use a dozer to shape the islands

**7. How much should you overbuild pad elevations during rough grading?**

A) 0.03 to 0.04
B) 0.05 to 0.10
C) 0.10 to 0.25
D) 0.15 to 0.30

**8. What should you have the surveyor do when the initial excavation is completed?**

A) Set a benchmark to be used for finished grading
B) Stake for curbs
C) Stake for underground work
D) Verify the parking area and pad grades

**9. When is it best to rip and compact the subgrade for parking areas?**

A) Before the curbs are poured
B) Before the aggregate is placed
C) After watering has partly evaporated
D) Before the rough trim

**10. What must be done about any unsuitable soil discovered during excavation?**

A) It should be brought to the attention of the soils engineer
B) It should be brought to the attention of the owner
C) It should be removed and replaced with dry dirt
D) It should be removed and replaced with rock

# HIGHWAY GRADING AND EXCAVATION

# 11

In this chapter we'll look at staking a road job and then follow through the steps needed to complete the job. We'll also cover excavating procedures. Just be aware that problems that crop up on your jobs may change the order of work slightly from what's shown here. Compaction, subgrade preparation and aggregate grading are covered in later chapters.

Highway construction is one of the more difficult excavation jobs because of the many changes in grade that occur between the right-of-way line and the road centerline, island or median. And, in most cases, there's no concrete curb to aid the final grading.

## Beginning the Job

Begin by walking the job with the grade setter to review the plans and staking before you start the excavation. Place or order all construction signs, temporary striping, barricades or K-rail. Plan for traffic detours.

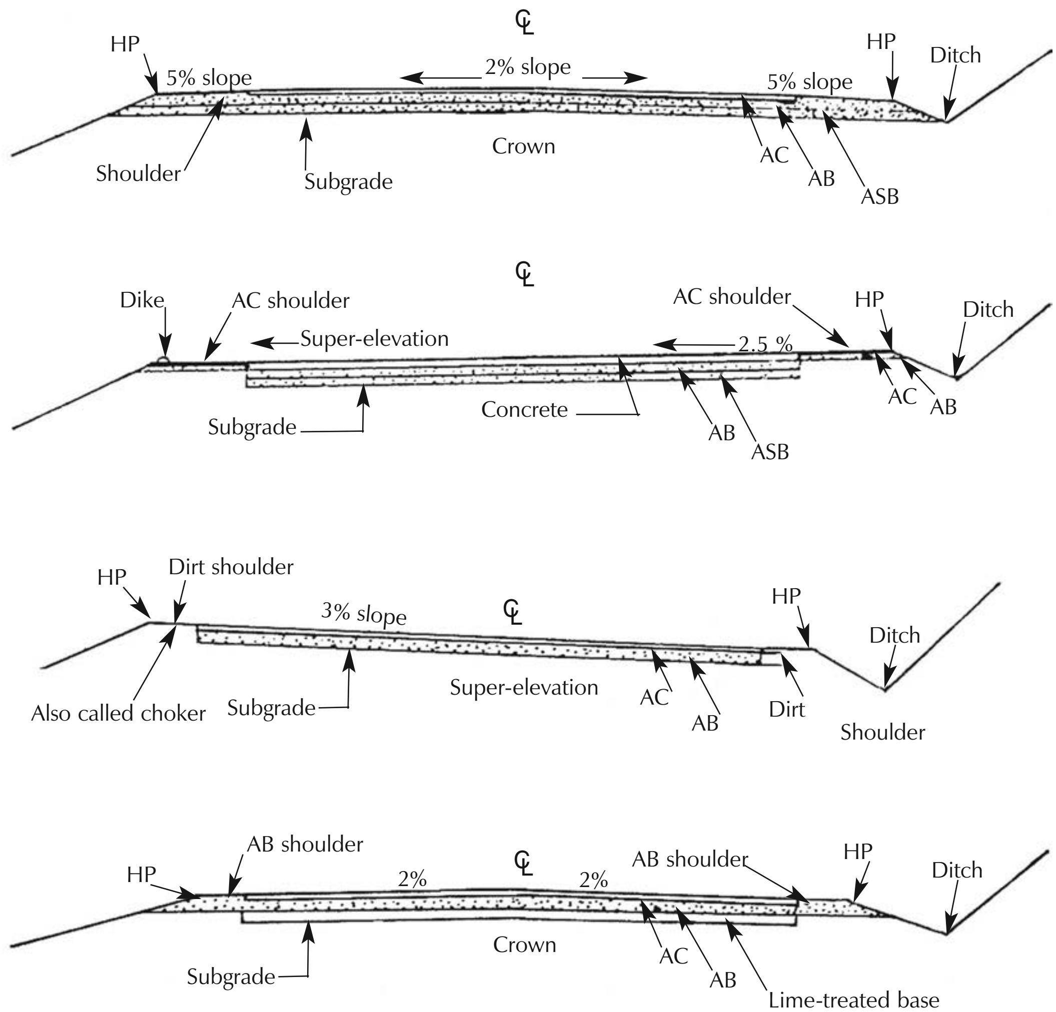


***Figure 11-1*** *Road cross sections*

You may need arrow boards to alert traffic of problems ahead. When working adjacent to traffic, be sure you have all your safety equipment in place before any construction begins. Have a trained crew who will set out the detour signs, and make sure the same crew will be responsible for setting them out each day. You may also need waddles or tree fencing. If any trees need to be removed, that must be done before you can begin. Any power poles, signs, fencing or other obstacles that must be relocated or removed must be taken care of before the equipment can start excavating. Check for any necessary dewatering. Figure out how many water trucks you'll need and set up any pumps, standpipe, or water tanks they'll use.

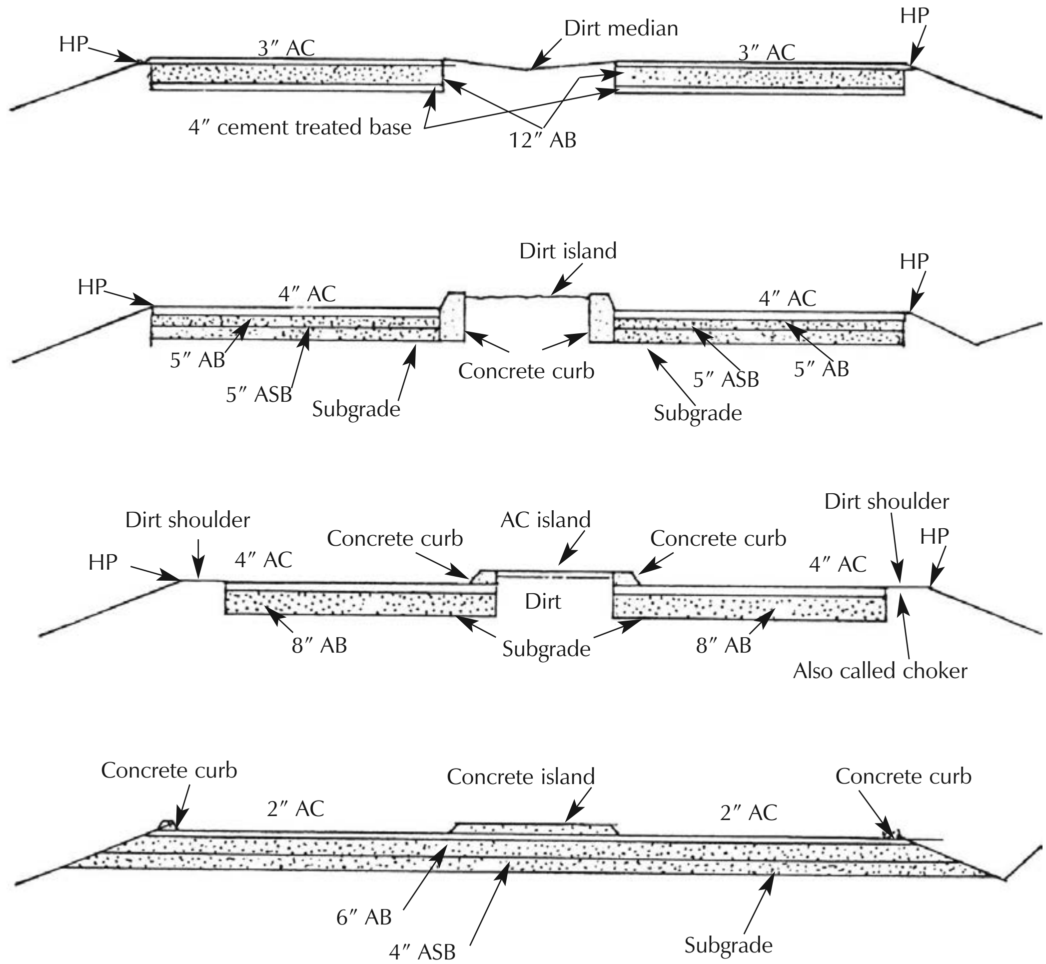


***Figure 11-1*** *Road cross sections (Continued)*

Look at the typical road cross sections in Figure 11-1. You can see the variations in grade you may encounter. Grade changes are easier to handle if you can visualize the finished grade ahead of time. It will also help you interpret the stakes set by the grade setter.

As with any other excavation, the grade setter must have time to set his boots for cuts and fills. He'll also place toe-of-fill stakes and top-of-slope stakes. Fill areas must be stripped of vegetation, ripped and compacted before excavation starts. While this is being done, a grade setter and grader should start cutting any roadside ditches indicated on the plans before the cuts or fills hinder the order of this work. There could be a ditch at the top of the slope, followed by a slope cut to another ditch at the bottom of a 30- to 70-foot-or-more slope. It's not unusual on large slopes to have a bench every 30 feet or so for erosion control. From the bottom ditch, there'll be a fill to the shoulder grade and then a slope to the centerline of the road. If there's an island or median between lanes, those grades will usually be shown on the information stakes.

The foreman and grade setter should watch the excavation equipment carefully on highway work until the operators become familiar with the fill and cut areas. It's important that the operators are always clear about the percentage of slope for cut and fill slopes.

## Staking a Highway Job

When staking out a highway job, the surveyor usually runs a row of information stakes and hubs. At the right-of-way line on each side of the road, there may be only a lath and no hub. The right-of-way line is usually the limit of the construction area. No work should be done and no equipment should travel beyond the right-of-way stakes without a property owner's written permission. If the grade stakes aren't on the right-of-way line, the right-of-way line will be staked separately at 100-foot intervals.

### *Stake Placement*

The stakes on each side of the road show the grades for every change in elevation from the stake to the centerline of the road. These stakes are set parallel to the road, at intervals of 50 feet or less. The cuts and fills start from the given reference stake (RS) point grade. If the road is wide and has a median down the center, you'll probably need a row of stakes there as well. If the ground level at the RS point was lowered during clearing, start the fill closer to the information stake to compensate for the cut that was made.

Let's assume you have a fill with a 2:1 slope starting from the reference point given on the stake. When the grass was cleared, 1 foot of dirt was removed, leaving the RS point 1 foot lower. Compensate for this by setting a stake 2 feet back of the RS point toward the information stake. With a 2:1 slope, this yields the grade and distance given by the surveyors when the fill is 1 foot higher at the original RS point. Use the same procedure in reverse if the RS point is undercut and there's a slope to cut. The RS point must be moved out, away from the information stake.

### *The Surveyor's Stakes*

On the front of the survey stake, the surveyor lists all the cuts, fills and distances needed to build the road to the centerline, including the distance from RS to the centerline. The stake on the opposite side of the road gives the information needed for the other half of the road. The back of the stake has the station number where the stake is set, and the distance from the hub to the center of the road. The sides of the stakes show the percentage the road slopes from the centerline to the HP or the shoulder, the elevation above sea level at the hub, the fill or cut, and the slope, such as 2:1 or 1:1.

If the road grade from the centerline to the shoulder is rising at 2 percent, the stakes will read +2 percent. If the road slopes down from the centerline to the shoulder of the road, the stake will read −2 percent. In some cases, the survey stakes won't have this much information. It depends on the surveyor and local practices. When the grade stakes don't have all the percentages or information you need, go to the plans for the missing information. If you can read the grade stakes, you should have little trouble completing the necessary grading as described in the remainder of this chapter.

### *Setting the Cut and Fill Stakes*

Remember first to clear all the vegetation, trees and debris from the road area and dispose of it according to the specifications. Using the grades and distances supplied by the surveyor's information stake, the grade setter can set out his stakes. Then the operators will know where the cut and fill areas will start without stopping to read the surveyor's stakes.

If the grade setter places the cut stakes first, this means that he puts a stake where the slope starts downward to the road grade. He writes on this stake the cut to be made, and the rate of the slope to the bottom of the cut. Some grade setters indicate the vertical feet of cut and the horizontal distance to the cut bottom. If a grade setter has experienced operators on the equipment, he can give them the rate of slope and they'll know how much to move out with each pass.

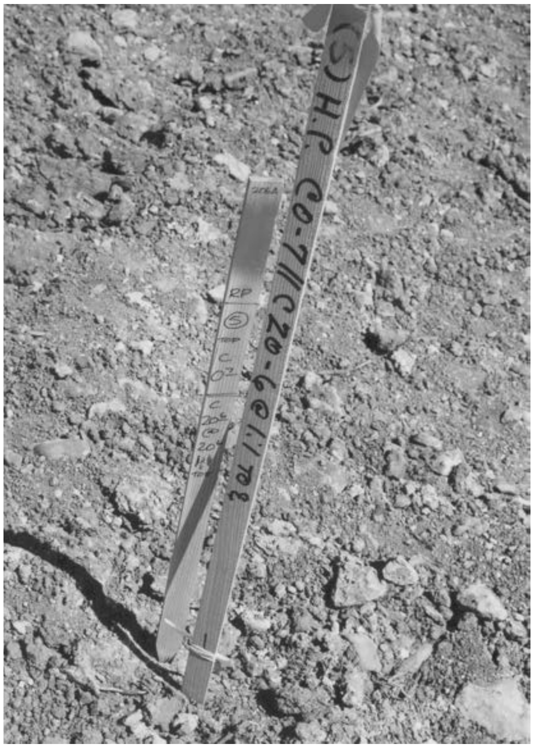

***Figure 11-2*** *Surveyor and grade setter cut-slope stakes*

Figure 11-2 shows a typical grade setter's cut stake. The grade setter has elected to set his lath to the right of the surveyor's stake and not out 5 feet at the RS. The stake indicates a 5-foot off-set to hinge point (HP) and a cut of 0.70 foot at HP. Then you see two double lines (indicating "and then"), followed by a 20.6 foot cut at a 1:1 slope to toe. He didn't give the distance to toe.

Notice the surveyor's stake on the left is marked a little differently. It starts with RP (or RS), not HP. That stake says 5 feet to RP top, then $C\text{-}0^{\underline{7}}$, double lines, $C\text{-}20^{\underline{6}}$ *at* $20^{\underline{6}}$, *1:1 Toe*. The grade setter didn't mark top because 5 feet out he's marked top-of-slope with a red paint line for the operators to see. He didn't mark the distance of 20.6 feet on his lath, just the 1:1 slope. His operators are experienced enough to know a 20.6 foot cut at 1:1 will be 20.6 feet out once the slope reaches the toe.

The grade setter didn't place his lath at HP 5 feet out because when the grader starts trimming the slope, he would likely hit it if it were right on the top-of-slope line. The grade setter's lath has a white ribbon tied at the bottom with a 1 marked above it. This is a 1-foot boot above the 5-foot RS. You might be thinking that's too low to shoot grade from. Only a 1-foot boot is needed here because the first time the grade setter shoots to it, he'll be standing on the cut slope shooting back to the 1-foot boot at eye level.

After all the cut boots are marked, the grade setter moves to the fill area and sets a stake at the toe of the fill to be built up. This is the *toe-of-slope* and is the given RS point on the stake. He includes the same information as on the cut slope: the number of feet of fill, the distance to the top of the fill, and the rate of slope. If there are any ditches to be cut at the top of the cut slopes or bottom of the fill slopes, these must be staked and cut before cutting or filling the main slope. Refer back to Chapter 3 for more information on setting stakes.

***Figure 11-3*** *Fill stakes set to build the fill*

# Beginning Earthwork

Once the vegetation is stripped from the job and all the outer ditches are cut, the main earthwork can begin. The equipment operators must know the rate of slope for all the fills or cuts being made. It's very important not to undercut a cut slope or underfill a fill slope. On fill slopes, the scraper operator mustn't dump so close to the top of the fill that the dirt runs over the edge and down the slope. The compactor must run the dirt out further to the top-of-slope edge, if needed. Poorly cut or filled slopes will have to be repaired, wasting manhours and equipment time.

## *Restaking Fill Areas*

Each time the fill slope rises about 4 or 5 feet, the grade setter should set another row of stakes along the full length of the top edge of the fill. Figure 11-3 shows slope stakes set every 10 feet horizontally for every 5 feet of rise on a fill slope. These stakes should have new fills and distances written on them to indicate what's needed from that point to the top of the fill. It's very important when building a large slope that the fill slope stakes are kept straight and set at 90 degrees to the surveyor's stakes. Letting the slope stakes wander off at an angle will affect the vertical accuracy of the fill. It's best to line them up with the same station stake on the opposite side of the fill or road. Once the fill obscures that station stake, you should have enough fill slope stakes set to line up the remainder of the stakes. On many large jobs, the surveyor will set an offset stake to the information stake in case it's lost or buried. Then you can use the two stakes for line.

To set a new row of stakes on a fill with a 2:1 slope, the grade setter measures out 10 feet horizontally and drives a lath. Then he measures up 5 feet from the previous lath's grade mark and shoots level with an eye level to the lath 10 feet away. At that level point, he draws a horizontal line, and a boot line 1 foot above. The fill must reach the horizontal line, plus some overfill. If the fill is overbuilt, he'll just mark the 1-foot boot grade.

Setting these fill stakes in the slope periodically helps both the grade setter and equipment operators track the progress of the fill. Figure 11-4 illustrates the markings these progressive fill stakes might carry. If the grade setter finds the fill slope is getting too steep, he can tell the operators to move into the slope more. Or, if the fill is coming up too flat, the operators note the stakes and fill more to cover the line marked by the grade setter. If the grade setter finds an isolated area that needs filling before his stake can be placed, he'll direct the compactor operator to push material in and compact it before he sets his stake. The compactor operator must keep the fill coming up correctly and keep the edge compacted. The grader working the haul road should make a pass at the fill edge periodically to help the compactor operator build a smooth slope.

It's good practice to overfill the fill slope about 6 to 8 inches so that it's about right after it's track-walked. Usually a 0.50-foot (plus or minus) tolerance is allowed on a fill slope. If you overfill the slope 6 or 8 inches, it should be well inside the 0.50-foot (plus or minus) tolerance after track-walking. When building a fill in very sandy or loamy soils, you may need even more overfill. On fills over 6 feet, be sure to lay any cross culverts before filling higher. It's obviously not cost-effective to build a 15-foot fill and then trench through it 15 feet to lay a 36-inch culvert line.

Always notify the surveyors if the information on one of the stakes doesn't seem to match the others. Surveyors make mistakes occasionally. The sooner they're notified of an error, the sooner it can be corrected and your work finished.

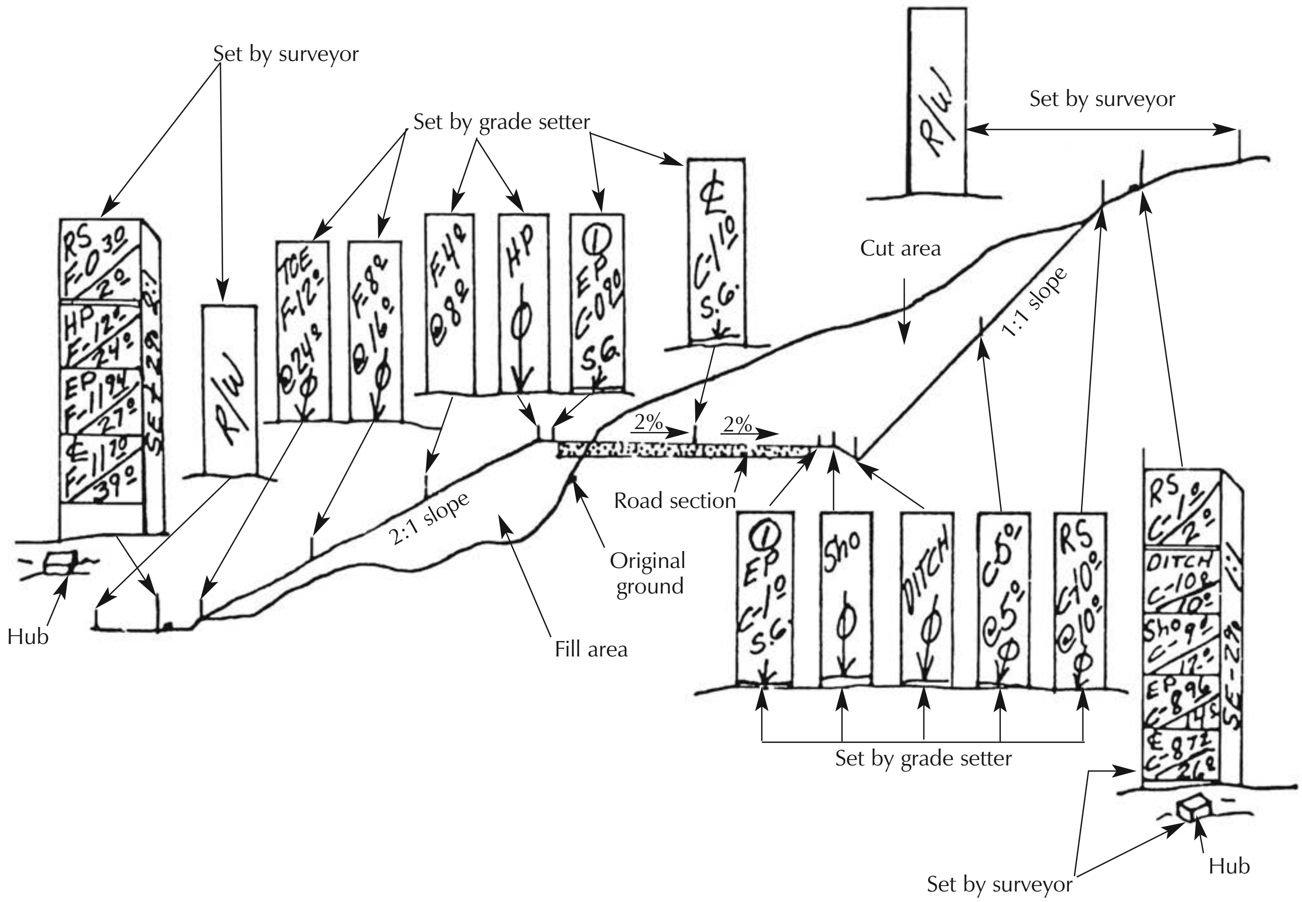


***Figure 11-4*** *Staking for a typical cut and fill*

## *Cut Areas*

In the cut area, keep the vertical cut on the slopes shallow enough so the grader can reach the top. The cut slopes must be trimmed to grade as the cut proceeds downward. If a grader is used, the cut can be taken down about 8 feet before being trimmed by the grader. Figure 11-5 shows a grader making a final trim pass on a 10-foot-high 2:1 slope. Notice his back wheels are at the base of the slope for stability while the grader is articulated so the front wheels are up towards the top of the slope. The base of the slope is kept smooth so the rear wheels will run evenly, making it easier for the operator to hold a steady grade. It's very important that the grade setter give the grader operator a good top-of-slope line on the first slope-cut pass. If the first top-of-slope pass isn't true, the entire slope will reflect the error.


***Figure 11-5*** *Grader trimming a 2:1 slope*

Figure 11-6 shows another slope operation. This is a 4:1 slope and is much easier to cut because the grader can run parallel on the slope without sliding off. A slope this flat doesn't need to be trimmed at any specific vertical distance because the grader can run on it any time without a problem. When cutting a 1:1 slope, it's a much different story. That's too steep for the grader to run on. A 1:1 slope must be cut before it gets out of reach for the grader because the grader must run all six wheels on the ground level at the toe, and reach up.

## Checking the Grade

The grade setter should check the grade ahead of the grader operator and let him know how much to trim. On a 1:1 slope, measure out 5 feet from the top of the slope or previous stake to check grade. Hold the ruler


***Figure 11-6*** *Grader cuts a 4:1 slope*

horizontal and drop a plumb bob to check large slopes. On small slopes, it's easier to drop a pebble from the 5-foot mark. At the point the plumb bob or pebble hits the slope below, set the ruler vertical and shoot level back to the top-of-slope or previous stake. If the ruler reading at that point is less than 5 feet, more cut is needed. If it's more than 5 feet, too much has been trimmed off. If the slope is a little high or low, but within tolerance, you may want to call it good. In this case, be sure to mark the cut or fill on the slope stake you set so you'll know on the next level cut what the actual grade should be. Otherwise, you might compound the problem.

## *Slopes*

Most jobs use a tolerance of 0.50 foot on slopes. When the slope has been trimmed to grade, the grade setter sets the stakes on the slope with a line indicating *at grade.* He'll also indicate the cut distance remaining. Figure 11-7 shows a slope stake indicating that the slope has been slightly undercut. A cut of 25.9 feet remains at a 1.75:1 slope from the horizontal line. The horizontal line has an arrow drawn to it. I'd much rather have the grade setter keep the slope slightly undercut than too high. It's easier

***Figure 11-7*** *Slope stake showing an undercut*

to work the slope at the bottom when there's a ditch. If the slope is too fat, the toe-of-slope will encroach on the ditch flow line. There's no tolerance at the toe; the toe-of-slope must exactly meet the ditch flow line, as shown in Figure 11-8.

The grade setter continues to set stakes on the slope again and again until the cut is at the toe-of-slope called for on the surveyor's grade stake. The grade setter doesn't need to take his grades from the original survey stake each time. He can take the grade from his slope stakes and change the elevation and distance accordingly, but he must be accurate. Look again at the stakes in Figure 11-3. Just as on a fill slope, the cut slope stakes must stay on a straight line, at 90 degrees from the surveyor's stake, all the way down.

Sometimes, in the cut area, there's a ditch on each side of the road that must be cut lower than the finished shoulder of the road. In this case, make the initial cut to the finished shoulder grade. After the dirt has been removed to this point, cut all the lower grade elevations, such as ditches. Any ditches at the bottom of fills or top of slopes should have already been cut.

## *Chokers*

If there are shoulders that should remain higher than the subgrade (these are usually called *chokers*), this vertical cut should be trimmed. The choker must be cut on a straight, even line. If it's overcut, you'll waste excess base material to fill the overcut choker. That's expensive. It's important to trim the shoulder grade 0.05 high and compact it before cutting the choker.

Remember this: It's the *finish grade* the surveyors are staking. The road section thickness must be added or subtracted when staking subgrade for cuts and fills. It's important to leave dirt shoulders or chokers 0.05 foot high so they'll be easier to finish after the road has been paved.

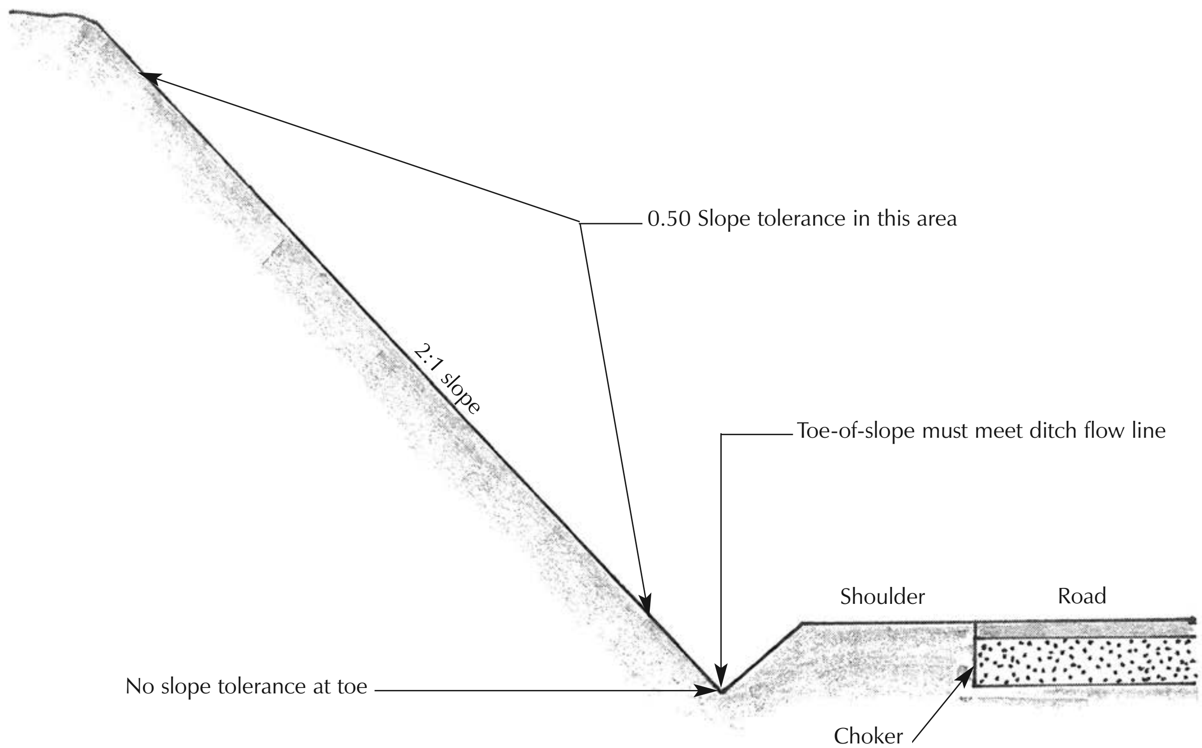


***Figure 11-8*** *Toe-of-slope must meet ditch flow line*

Many of the roads you work on will have dirt shoulders with the shoulder finish grade higher than the road subgrade. During excavation, once the highest grade has been reached in a cut area (which should be the shoulder grade), move the equipment to the inside of the shoulders and continue cutting until the road subgrade is reached. Be sure to leave the choker face full by a couple of tenths until the subgrade is fine trimmed. Then fine trim the choker face. Figure 11-9 shows a choker in the rough grade stage. You can see the stakes set by the grade setter for line and grade, but the surveyor hasn't set the bank plugs yet. Sometimes the surveyor may elect to set stakes rather than bank plugs for the final subgrade and aggregate trimming.

In fill areas, bring the fill up to near the road subgrade and then build up and trim the shoulders to the width and elevation specified. Leave the road subgrade low enough so that when the chokers are trimmed, the excess dirt brings the subgrade up to the correct finished grade. This eliminates both extra trimming work on the subgrade and excess dirt to deal with. If the road has a dirt-filled island or median, handle it just like

***Figure 11-9*** *Choker with grade stakes for control*

a shoulder choker. In a fill, it's important to build the shoulder 1 to 2 feet wider than needed, so when the choker is cut, there'll be good compaction at the choker face. This is more than you need overbuilt in a cut area, because a cut slope is undisturbed soil and should already be compacted. During the rough excavation cut or fill, always leave the choker a little high and wide for final trimming. It's too time-consuming to make fills during the finished trim stage.

The grade setter must be especially alert when the cut operation is approaching the shoulder or island grade and the fill operation is nearing the subgrade elevation. The operators need plenty of stakes and guidance so they don't cut or fill too much, or in the wrong areas.

Make sure each operator has a good picture in his mind of what he's building. This could save the grade setter and the foreman a lot of trouble. Usually, the fill slopes are track-walked once they're up to grade. If you use a pad-drum compactor while the fill is built, often track-walking with a dozer is all that's required. Then, if needed, a dozer can trim the slope to the required grade to remove any blemish that shows up. If a more uniform, smoother grade is required, drag the slope with a large chain or cable that's hooked to a dozer or grader from the top and weighted at the bottom. That will remove all equipment tracks and lumps.

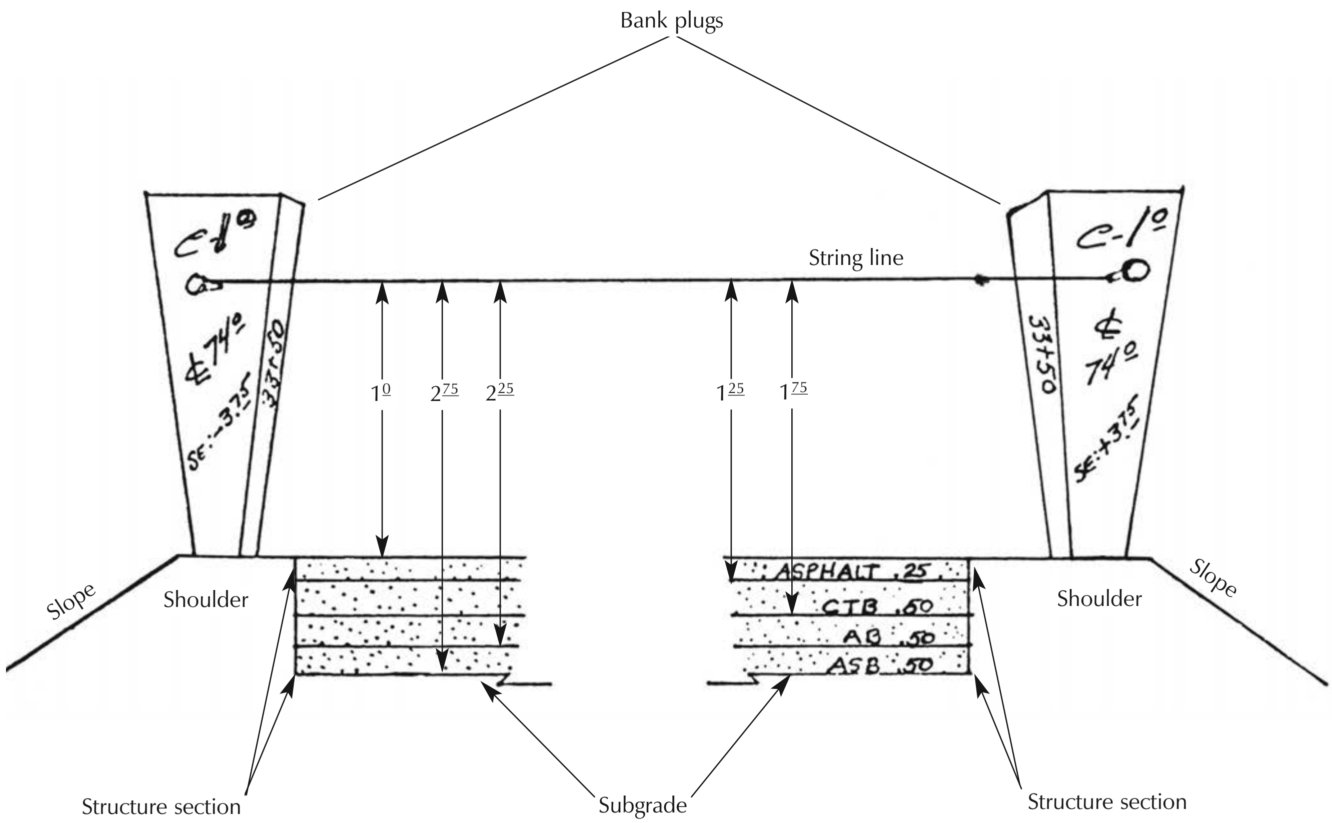


***Figure 11-10*** *Bank plugs*

## Subgrade Work

The road is ready for subgrade work when the slopes have been compacted and trimmed, and the shoulders are built and cut off vertically on the roadside. You can track-walk fill slopes before or after the shoulder grade is rough trimmed. The surveyors may then set bank plugs for the final grading operation. Figure 11-10 shows a string line stretched between bank plugs 1 foot above finished grade. Notice the five measurement readings from 1.00 at finished asphalt grade to 2.75 at finished subgrade. The nails on the bank plugs are exactly 1 foot above finished asphalt grade. The *SE: +3.75* on the right bank plug indicates the road slopes from centerline up 3.75 percent to that bank plug. The bank plug on the left indicates the slope is sloping down 3.75 percent to that bank plug. If the road was crowned, each bank plug would have two nails, one for +3.75 and one for –3.75 percent. By rotating the string to the lower nail, it would establish grade for one half of the crowned road.

For the other half of the road, you would then rotate the string line to the high nail on that side and to the low nail on the other side.

When bank plugs are set, no other grades are needed for subgrade, rock, or pavement grade. If the surveyors don't set bank plugs, they'll set grade hubs in the subgrade after it's been rough graded, and once again when the aggregate base is ready for fine grading. Or, they may elect to set stakes and hubs on the shoulder, as mentioned earlier.

You usually need 95 percent compaction on a road base subgrade. The fastest way to achieve this is to rip the entire road base several times while it's being watered. Once enough water is added, use a sheepsfoot or pad-foot self-propelled compactor for the initial compaction. If you're compacting subgrade on a fill area, it may be compacted to 90 percent already, so it won't require ripping. If it still has moisture, it may just need more rolling. Once the initial compaction has been completed, use a grader and a vibratory smooth-drum roller for the final trim and compacting.

Trim the subgrade of the road in the cut area to approximately 0.10 foot high before you begin ripping and compacting. After compaction, trim the subgrade again, this time to the tolerance of the job specifications, usually 0.05 or 0.08 foot, plus or minus. Be sure the entire width needed for base or pavement has been trimmed and compacted. Never let chokers encroach into the base area.

If there are any underdrains to be placed to divert water that seeps through the rock grade, they usually go in after the subgrade is trimmed, compaction tests are passed, and it's ready for the aggregate base. They're usually too shallow to place at any other time.

Many times there are underdrains placed after the aggregate base has been trimmed, to divert water that penetrates the concrete or asphalt road surface. These are placed just before paving is done. When the underdrain is placed in the aggregate, a concrete rock aggregate is used as a cap over the filter fabric. Figure 11-11 shows an underdrain being placed in a shoulder with filter fabric surrounding the pipe and a crushed rock cap that allows the water flow to the pipe. When the aggregate is hauled in, it's important to keep trucks and equipment off the drain until it has enough aggregate over it to hold the weight of the equipment. If the drain will be under the road section, you'll need to use hard PVC pipe.

When the paving is complete (we'll cover paving in later chapters), a final fine grading is required. Trim the shoulders, islands, and ditches of

***Figure 11-11*** *Roadside underdrain with filter fabric*

any excess dirt. Roll the shoulders and shape the ditches. The hydroseeding can be done at this time, but leave the waddles until the seed begins to grow. Once that's finished, the road can be cleaned.

It's now time to place any necessary dikes and down drains. Dikes are installed to prevent slope erosion due to water runoff. If open-grade asphalt is called for on the top lift (road surface), be sure the dikes are in place before the open-grade asphalt is applied. Open-grade asphalt concrete (sometimes referred to as popcorn) is coarse asphalt concrete, usually having 3/4-inch aggregate with very little fine material added. If a dike like the one in Figure 11-12 is placed on it, water will seep under the dike and out the back, defeating its purpose. If you place the dike before open-grade asphalt is put down, the base of the dike will be sealed and it'll collect the water as it runs off the road, and carry it to a drain.

The final steps in a highway job are the placing of road signs, roadside reflector paddles and a fog seal of oil, if required. Road striping and reflector buttons are last. When that's done, take down the construction signs and remove the barricades — the job is finished.

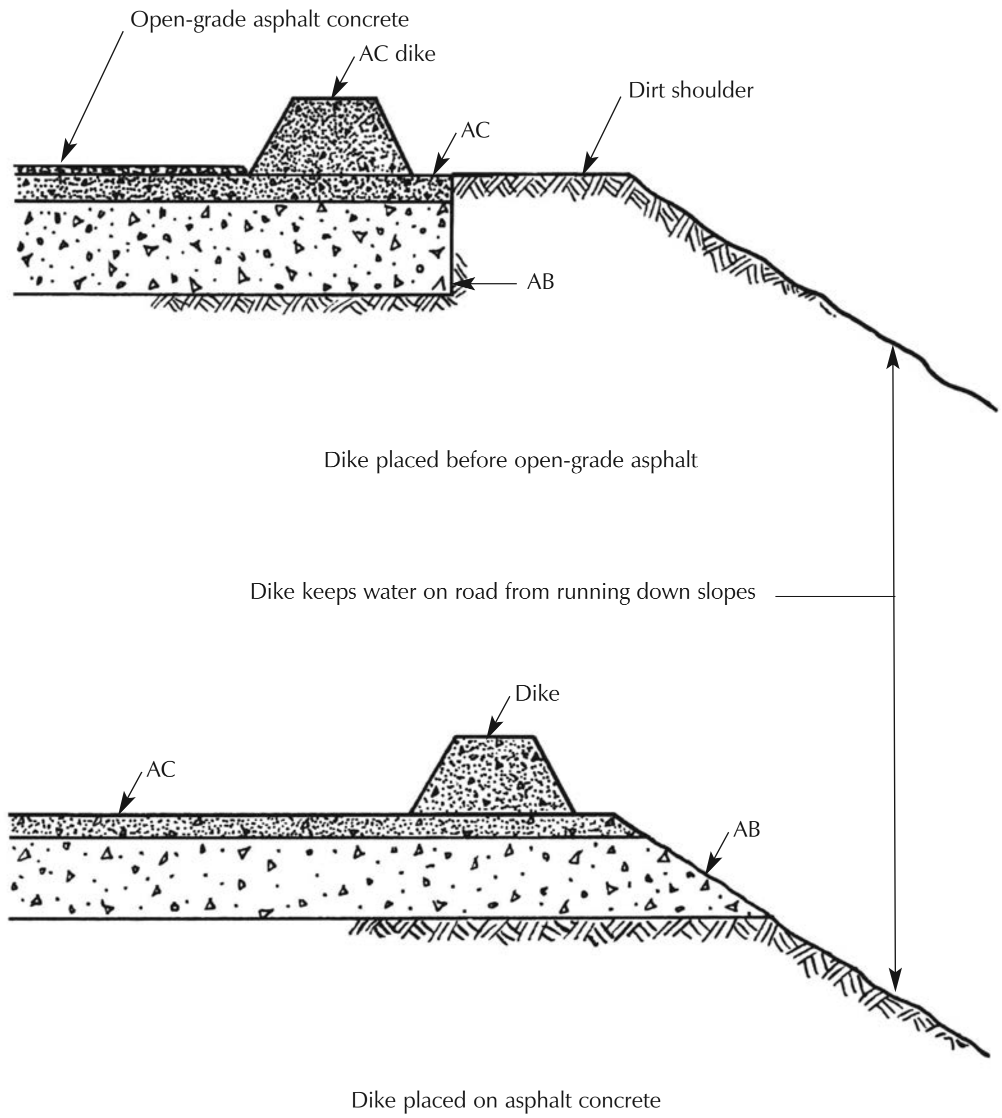


***Figure 11-12*** *Placing dikes*

# CHAPTER 11 QUESTIONS

**1. What should be done first before any work begins on a highway project?**

A) The crew and equipment should be directed to the largest cut area
B) The foreman and grade setter should go over the plans and staking
C) The surveyor should run three rows of stakes for the grade setter
D) The traffic should be detoured so the work area is clear

**2. Why are right-of-way stakes set?**

A) For the surveyors' use
B) For the grade setters' use
C) To indicate limits of the work area
D) For centerline control

**3. Where do you start the fill on a 2:1 fill slope if the RS point is a foot low after clearing?**

A) 1 foot back of the RS point
B) 2 feet back of the RS point
C) 4 feet back of the RS point
D) None of these

**4. What do double horizontal lines marked on a survey stake mean?**

A) Information above the lines is for the surveyors' use only
B) "And then"
C) The grade setter must double the distance to ditch
D) The plus or minus amount tolerance allowed for the grader

5. **How does the grade setter set the fill slope lath on a large fill slope?**

   A) At 90 degrees from the surveyor's stake
   B) Exactly plumb with the slope
   C) In even rows 10 feet apart
   D) At a uniform height

6. **What is the usual tolerance on a fill slope?**

   A) 0.05 foot
   B) 0.10 foot
   C) 0.20 foot
   D) 0.50 foot

7. **It's good practice to overbuild a fill slope by how much?**

   A) 2 to 4 inches
   B) 4 to 6 inches
   C) 6 to 8 inches
   D) 8 to 10 inches

8. **Which slope angle is the most difficult to cut with a grader?**

   A) 1:1 slope
   B) 2:1 slope
   C) 3:1 slope
   D) 4:1 slope

9. **When cutting a slope that has a ditch at toe-of-slope, to what elevation must the initial cut be made?**

   A) The road subgrade
   B) The bottom of the ditch
   C) The shoulder subgrade
   D) The centerline of road

10. **What must be done with the road subgrade when building a road fill that has chokers?**

    A) It should be ripped for compacting
    B) It should be left low for the choker excess
    C) It should be built to choker level
    D) It should be compacted to 95 percent

# WIDENING RURAL ROADS

# 12

Traffic and a limited work area make widening rural and residential roads more difficult than highway roadwork. If you look back at Chapter 2 (Figures 2-7 through 2-9), you can review plan drawings and road cross sections for a highway-widening project with driveways and a culvert to be removed. The job we'll be discussing here will be much the same, except the work area for a residential or rural road is usually more confined.

To begin this kind of job, first contact the Underground Service Alert (USA) so they can come out and mark any underground lines on the project. It's not unusual to have to lower sewer, gas and water services on a road-widening job where there are houses on each side of the road. There may also be telephone and power poles to be moved.

After all the utilities are clear of the work area, set out all road construction signs that the agencies controlling the work require you to place. Then you can begin the grading.

## Minimize the Inconvenience to Residents

The first order of work is to mark and saw-cut all the driveways and walks to be removed. You may also need to remove shrubs, fences, planters and sprinkler lines. The plans or job specifications will indicate if these items must be relocated or replaced with new. Sometimes they're removed and no replacement is necessary. If you have to cut any sprinkler lines, be sure that they're replaced or capped quickly, so when the water is turned on it won't run out onto the project.

Good public relations are important. Residents may resent a contractor ripping up their yards, even though they know it's required. Talk with all the residents before you start work to prepare them for what's to come. That'll help alleviate problems. Explain that there may be dust, noise or other inconveniences. Tell them that you'll do everything possible to minimize these problems and ask for their patience and understanding. Be courteous to anyone who complains about the disruption, follow through on what you say you're going to do, and don't make any promises you can't keep. Keep the road free of dust — wash or sweep it at the end of each shift. Be sure you don't work beyond the right-of-way stakes, unless a note on the plans says a driveway or a walkway must be cut past the right-of-way line to make a smooth transition to the new work. Use extra barricades to assure the safety of the residents.

You must also be concerned with the safety of your crew when they're working adjacent to the traffic. Make sure that flagmen and delineators provide for safe traffic flow through the project as the job proceeds. Some mornings you may find flooded areas where runoff from lawn sprinklers has accumulated. Most people will cooperate if you explain the damage they can cause by allowing surface water to run into the cut and fill areas. If the problem persists, have the inspector intervene to help solve the problem. As a last resort, you may need to get the water district to threaten to shut off the water. Usually, it doesn't need to go that far.

If there's enough room, and not many driveways, set K-rail to isolate the work area from the adjacent traffic (as shown in Figure 12-1). If you don't use K-rail, you'll usually need to slope the edge of pavement adjacent to the traffic at the end of each day so a vertical cut isn't left overnight. Public agencies should address this problem in their specifications. Some agencies will allow a vertical cut if it's 6 feet or more from the traffic lane. And sometimes, in areas where traffic is light, vertical cuts are allowed if they're well delineated and barricaded.

***Figure 12-1*** *Set K-rail to separate the work area from traffic*

Read the specifications closely so you're aware of all the requirements. Some agencies require that only a few barricades have flasher lights on road and highway work. Usually delineators or cones with reflective tape are preferred. They claim, and I agree, that too many flashers at night tend to confuse traffic. Review the information on traffic control and detour plans at the end of Chapter 2.

## Preparing the Work Area

The surveyors will set a line of grade stakes down each side of the road every 50 feet or so, usually inside the right-of-way line. Each stake gives the information needed, such as station number, grades and distances, to build the road section to the centerline. If you're only adding one lane, the surveyors may not stake the centerline. Instead, the last information on the shoulder stake may read 20 feet to *match line*. The match line is where the new lane section being built will meet and match the elevation of the existing road lane. The plans may show the existing pavement to be saw cut, and give a distance for the match line and the existing grade to be matched.

Once the job has been staked, the clearing can begin. A small rubber-tired hoe with a front-loader 4-in-1 bucket is excellent for removing driveway pavement, brush, culverts and planters. The hoe operator will load all the strippings into a dump truck to be hauled away to a dump site. Be sure to smooth any driveways after clearing so residents can drive in and out without damaging their cars.

You must tie out items such as water valves, manholes, and cleanouts that will be paved over, so they can be located and raised later. There are two time-honored methods used, and a third, relatively new method that seems to be the way of the future.

The first method of tying out the item is by measuring from the item to two points that won't be moved, such as a tree or power pole. Use a spot of paint to mark each stationary object at the measured point. Enter both measurements in a notebook or on the plans. The second method is to measure the exact distance of the item from the stake line at the station where the item is located. Measure out, on a 90-degree angle, from the stake line at that point to the item. Again, enter the distance at that station on the plan. If using the survey stakes for tie outs, be sure to tie out on the new work before the survey stakes are pulled up. The third tie-out method is to use a GPS rover and enter the location points of each item into the GPS memory and save them so you can retrieve them later.

If you need to remove shoulder asphalt, it should be saw-cut and then removed. If traffic, trucks, or scrapers will be running over the saw-cut edge, it's good practice to make two saw cuts at the edge of the pavement. Make one cut on the designated cut line and another 6 inches out. Remove the asphalt to the outside line when clearing, leaving the 6-inch strip of asphalt at the inside cut. This will protect the edge that you'll be paving to while traffic is still running over it during excavation. Then, just before subgrade is processed, you can remove the 6-inch strip of asphalt, leaving a clean unbroken edge.

During the clearing operation, cut mailbox posts and place them in 5-gallon buckets filled with gravel so you can easily move them out of the way as excavation begins. Relocate speed limit signs, stop signs and any other important signs. If relocating them in the new right-of-way puts them too far from the existing traffic to be heeded, then you'll need to attach a wooden base to them to keep them up and portable. Weight the bases with sandbags to keep the signs from blowing over.

***Figure 12-2*** *Use a smooth-edge grading bucket to finish ditch*

## The Excavation

Be sure you or your foreman checks the electrical plans before you begin work to see if any new power lines will be placed under the road section. If you're going to place new traffic lights, the main electrical lines will usually be dug through the existing pavement with a 4-inch-wide trench bucket, then backfilled with cement. If the plans call for 4 inches of new asphalt, make a 2-inch deep saw-cut and place the intersection traffic light loops in the existing asphalt base. Once that has been completed, you can place the top lift of new asphalt over them. If you need to place culverts that cross the road, now's the time to lay them as well, unless they're very shallow and will interfere with the subgrade. If the culverts *are* too shallow, you may want to place them after the subgrade trim is finished to keep the pipe from being damaged by the equipment.

Let's say we're starting excavation on a 12- to 15-foot-wide road section. The roadside ditch must be cut first. If the ditch gets so deep that the grader can't pull the dirt up the slope, you can use a hoe with a 5-foot-wide smooth-edge bucket to finish the ditch (see Figure 12-2). If the soil is too hard, you'll need a conventional bucket with teeth.

***Figure 12-3*** *Cover the ditch with steel plates to allow access to driveways*

As soon as the ditch is cut to grade, lay the driveway culverts and backfill them so the property owners can get in and out. Because you need to ensure that the owners have access to their property, the grader shouldn't cut through more driveways than the pipe crew can lay in one day. But just in case more ditch is dug than culvert can be laid, the contractor should have steel plates on hand, like the ones shown in Figure 12-3, to cover any ditch remaining in front of a driveway at the end of the shift.

To keep the grader moving along, the driveway culverts should be positioned out of the way at each driveway, but close enough to be available for the pipe crew. If the culverts are large pipe, say 18 inches, a hoe will be needed to widen the bottom of the ditch so the pipe will match the flow line of ditch. In most cases, unless the ground is extremely hard, it'll just require shovel work for a 10- or 12-inch culvert. Most agencies will have you cover the pipe with some type of rock, and contain the rock at each end with a dirt plug (see Figure 12-4). The specifications may call for rock all the way to the surface, or just a foot of rock with dirt to subgrade.

With shallow ditches, less than 4 feet, I prefer to use aggregate to the top. It saves time (if the aggregate is on hand so the pipe crew doesn't have to wait for trucks). I like to rent an empty lot and store the aggregate near the site. That way, the hoe or scraper can get the material

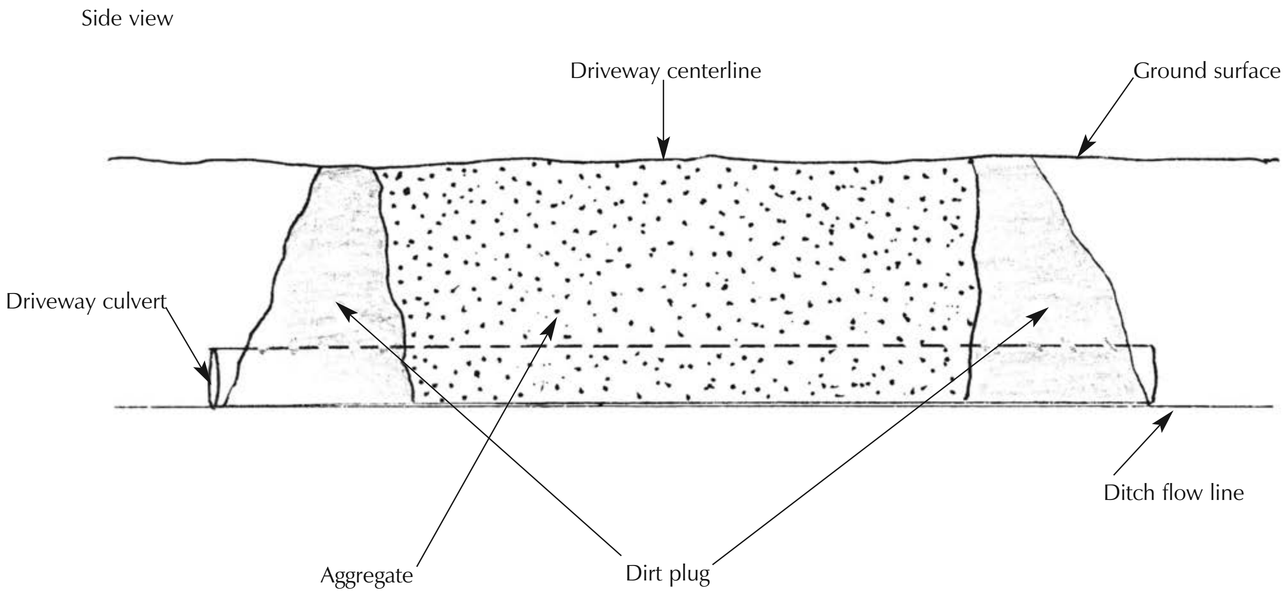


***Figure 12-4*** *Dirt plugs contain the rock laid over culvert*

to the pipe crew as soon as they're ready for fill. The scraper can dump a pile of aggregate at each driveway once the grader has finished, then a rubber-tired hoe can do the backfilling. The aggregate and the dirt plug must be compacted with a mechanical tamper or a hoe compaction wheel. If there's a shoulder (choker) indicated for the street section, you can use the ditch dirt to build the shoulder.

When the ditch is cut, the driveway pipe laid and the choker built and trimmed, the street section is ready for excavation. The equipment you use will depend on where the excess dirt must be hauled. If there are many waste areas, such as adjacent lots that can be built up, you can use a paddle-wheel scraper. However, in order to build up an adjacent lot you must get an agreement signed with the property owner and, in some cases, a fill permit with the agency controlling the job. If there aren't any dump sites on the job and you need a truck to haul the excess dirt away, a hoe or profiler is an option. A track loader or scraper is a good choice if you just want to haul the dirt to a stockpile, and then dispose of the excess when the excavation is finished. You should make these decisions based on the width and depth of the section excavation and the amount of dirt to be moved.

It's now time to remove the 6-inch strip of asphalt that was cut and left, and pull the excess into, and mix it with, the subgrade. If you're

***Figure 12-5*** *Pad-drum roller compacts subgrade to 95 percent*

working a 12- or 15-foot-wide road section, the subgrade should be ripped and watered after you complete the rough trim. I recommend rolling the section with a pad-drum roller, which has a small dozer blade so it can do some mixing. See Figure 12-5. I like a pad-drum roller, not a pad-foot compactor, because a pad-foot compactor doesn't have a compaction wheel in the center. In a narrow section, it doesn't have enough room to move over so the center can be rolled. The pad-drum roller has pads the entire width, so coverage isn't a problem.

Once the soil has the correct moisture and has been thoroughly compacted with the pad drum, the grader and a smooth-drum roller can start fine trimming subgrade. When it's trimmed to a 0.05 tolerance and the section has passed compaction tests, it's ready for rock. Some agencies require only a 0.08 tolerance when base rock is the next lift. Check the specifications and know your tolerances.

For narrow sections of road — 10 feet or less with no choker, it may be better to cut the outside edge twice as deep as needed for the asphalt section while trimming the aggregate, then match the top inside edge to the existing pavement. By doing this, after the aggregate has been well-rolled and watered, the grader can make the cut needed for asphalt along the inside edge of the existing pavement. The excess aggregate he cuts out

***Figure 12-6*** *Grader controls aggregate by adjusting wing angle*

from the high inside edge should be enough to make the fill on the outside edge. This job is much easier if the grader has slope control, and a wing attachment to control the aggregate along the outside edge so it doesn't get lost in the ditch. The wing on the grader in Figure 12-6 can be flared out or sucked in by sliding the mold board on the grader. This lets the grader control the aggregate.

If the road section is only 6 or 8 feet wide, a hoe or a profiler may be your only option for excavation. Figure 12-7 shows a profiler excavating a shoulder area with a curb on one side. On that job, the county agency called for 2 inches of asphalt and 6 inches of aggregate to be excavated. The contractor made two 5-foot passes to excavate the 10-foot sections. A bobcat cleaned up the crumbs, followed by a roller. Then a paver placed a 4-inch asphalt base. The next day, after the base cooled, the section was paved with two 2-inch lifts of asphalt to finish the shoulder repair.

Don't get into a habit of excavating every job the same way. Study the plans and look at each job with a creative eye. Learn the capabilities of all the excavating equipment you have available before you choose the equipment for your job. If the road section is very narrow, you may need to pull the ditch dirt up onto the existing road as it's trimmed, and load from there. If that's the case, you'll need to set up traffic control so the

***Figure 12-7*** *Profiler excavates shoulder section*

lane can be closed off to traffic while you do the work. This usually requires a flag person with a walkie-talkie on each end of the job, or a pilot car for the traffic to follow. Don't forget that if you have flagmen, you'll need to relieve them for lunches and restroom breaks. It's also useful to put arrow boards out at each end of the work area, warning the traffic of what to expect ahead. Be sure to read the traffic control specifications so the correct warning signs are in place.

If you're making small fills, say 3 or 4 feet, be sure to overbuild the slope by 8 to 10 inches. On rural road jobs there usually isn't room for track-walking slopes, so a hoe must cut the ditch (if a ditch is required) and trim the slope. By overbuilding the slope, you'll have a compacted smooth surface on the fill slope when the excess is removed.

There are situations where one side of the road must be widened 24 feet and the opposite side only 3 feet. If this is the case, it may be cost-effective to complete the wide side first. When it's done, it can be temporarily striped and traffic moved over enough so the 3-foot section can be worked without the cost of traffic control. If the section is so narrow that good compaction tests are a problem, the county or city agencies will usually allow the contractor to overexcavate at his expense. Then they'll drop the compaction requirements from 95 to 90 percent because of the added aggregate section. The cost for additional aggregate usually works out to be less than the cost of trying to get a 95 percent compaction test on a 3-foot-wide road section.

We'll cover road paving in the chapter on asphalt paving later in the book. On road jobs where the old pavement is removed, there are usually areas with unsuitable material. We'll discuss unsuitable materials and how to contend with them in a later chapter as well.

The cleanup on a road job involves completing several tasks. The most important are paving all the driveways, cleaning up any excess aggregate or dirt that was lost in the ditch during grading and aggregate placement, and trimming shoulders as needed. You should do this after the pavement has cooled for a few days so the equipment tires won't mark up the new pavement. You must also set all the mailboxes on new posts, replace old road signs, and set up new signs as required. Clean up any loose dirt and clear any construction debris out of yards. You may need to replace shrubs that were taken out, and rebuild fences. If there are centerline islands, they must be finished as well. When these items are done, the new road is ready for striping and the placement of any permanent barricades.

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# CHAPTER 12 QUESTIONS

1. **What should be quickly repaired if cut or damaged during the road-widening preparation process?**

   A) Fences
   B) Walks
   C) Shrubs
   D) Sprinkler lines

2. **When is it acceptable to work beyond the right-of-way line?**

   A) When you find, after beginning work on the job, that it's necessary
   B) When a note on the plans instructs you to do so
   C) When the property owner asks you to do a little extra paving
   D) When the inspector thinks it will look better

3. **Some agencies don't approve of using too many of which road safety device?**

   A) K-rail
   B) Delineators
   C) Barricades with flashers
   D) Cones

4. **How many methods are generally used to tie out manholes, water valves, and cleanouts?**

   A) Two
   B) Three
   C) Four
   D) Five

**5. How can you protect a saw cut in the shoulder pavement that will be run over by trucks and scrapers?**

A) Back it with aggregate
B) Make the cut only half-way through the asphalt
C) Make two cuts, 6 inches apart, and leave the pavement between them
D) Don't make the saw cut until the equipment has finished excavating

**6. What should be done with mailboxes on posts that are in the work area?**

A) They should be returned to the post office
B) They should be given to the property owner until the work is complete
C) They should be cut off and placed in portable 5-gallon buckets
D) They should be hauled away and then replaced later

**7. When the preparations are complete, which of these work items is the first to be done?**

A) Cut roadside ditches
B) Lay driveway culverts
C) Pour walks
D) Repair fences

**8. What determines your choice of excavating equipment for a 15-foot road section?**

A) Where you must haul the excess dirt
B) The depth of the road section
C) The equipment the estimator assumed would be used
D) The length of the job

**9. Why should you overfill a fill slope even though it can't be track-walked?**

A) Because it will help prevent slope erosion
B) So a compacted surface is left after trimming
C) So there will be excess dirt for the shoulder fill
D) So the landscaper will have topsoil for planters

**10. If a road section is so narrow that 95 percent compaction is difficult to achieve, how might you reduce the required compaction rate to 90 percent?**

A) Deepen the aggregate section
B) Use a hoe compaction wheel
C) Use only asphalt and no aggregate
D) Use crushed rock in place of aggregate

# Building Narrow Embankments

# 13

Building a narrow fill on a highway overpass, abutment or a rural county road is more costly than a large fill. That's because there isn't enough room on a 12-foot-wide fill for the scrapers, grader, compactor and water truck to pass with ease. Usually someone has to wait to gain access, which slows down production.

Let's assume you're building a new lane on a highway through a fill area that's 18 feet high and 900 feet long. The surveyors will stake the road section the same as if you were building a 75-foot-wide road bed, and the grade setter will set out toe-of-slope stakes. If needed, the existing slope must be cleared of brush, trees and heavy grass with a hoe or dozer. After the clearing is done, the grader or dozer rips the original ground where the new fill will be placed so it can be watered and compacted. The grader then cuts into the existing slope about 6 feet, leaving a vertical slope that's approximately 3 feet high. You must always cut a 5- or 6-foot bench into the existing slope for a good tie in. The grader spreads the

***Figure 13-1*** *Grader cutting bench in existing slope*

material from the bench cut across the fill area for the compactor, and it becomes the first part of the fill. In Figure 13-1, the grader has started to cut a bench and has pulled the material out to be compacted, keeping the fill level.

## Making Space for the Equipment

The grader and pad-drum roller can pass each other, even on a 12-foot-wide fill, because the grader can run his wheels far enough up onto a 2:1 slope to let the roller pass. That's something that scrapers and water trucks can't do well. If a road section is being widened 12 feet and the grader cuts a 6-foot bench into the slope, that leaves an 18-foot-wide area. That's wide enough for scrapers to pass on the inside of the compactor and grader working the fill. It's much harder for them to pass if the fill is only 8 feet wide because, even with a 6-foot bench cut, there's only 14 feet of fill width. In this case, the roller and grader would leave the fill for the scrapers to move on one end of the work area. If the fill is extremely long, working it in this manner can get very expensive.

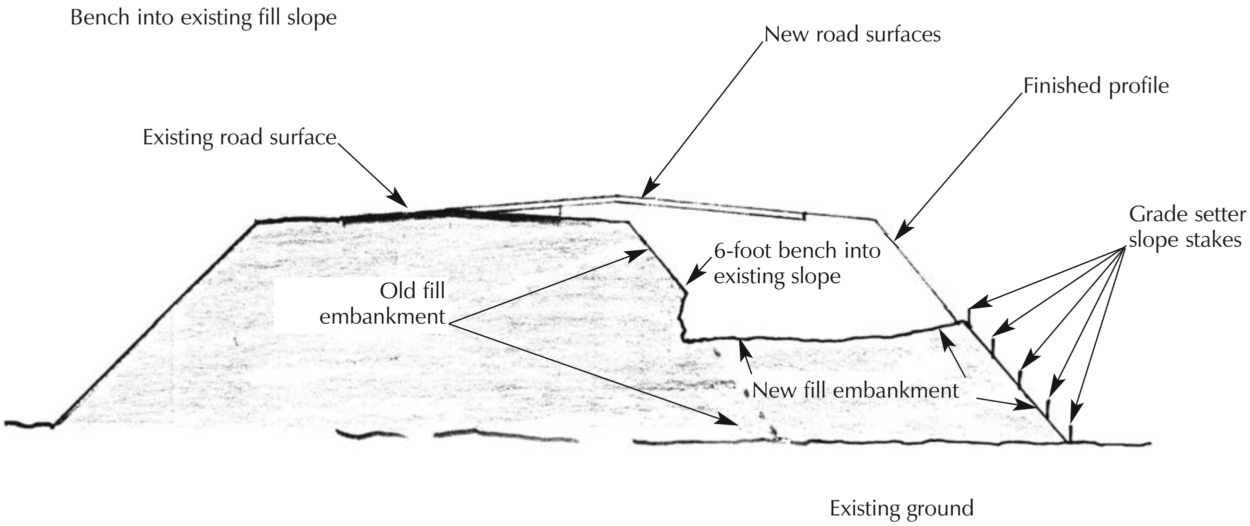


***Figure 13-2*** *New fill with bench cut*

It might be more cost-effective to have a hoe cut two turnouts into the existing fill. If you're working a 2:1 fill slope that's 18 feet high, have the hoe reach up 10 feet and cut a $^3/_4$:1 slope, 30 feet wide. Use the material removed in the fill. Cutting a $^3/_4$:1 slope will add an extra $12^1/_2$ feet to the fill width. This will give the equipment room to pass each other until the fill rises 5 feet. When it becomes too narrow again, the hoe can cut into the slope again. This method works well until the fill gets up towards the top of the existing fill. Then, if the existing road or shoulder is so close the extra slope cut will infringe on it, you may be able to make a vertical cut instead. If you're 5 feet or less from the top of the fill, you can make a vertical cut without shoring or sloping.

You can also gain width by cutting a 10-foot bench into the existing slope, rather than a 6-foot bench. This method requires no less than a Cat 14 grader. The extra 4 feet will give you 8 feet of width and leave a 5-foot vertical in the existing slope. I prefer this method to cutting turnouts with a hoe. It saves you the cost of having the hoe on the job. Regardless of the fill width, you must always cut a 5- to 6-foot bench into the existing slope for a good tie in. Figure 13-2 shows the profile of an existing fill and the new fill with the required 6-foot bench cut.

For safety, you should always build the fill with the outside edge higher than the inside edge. That makes it much less likely that equipment will

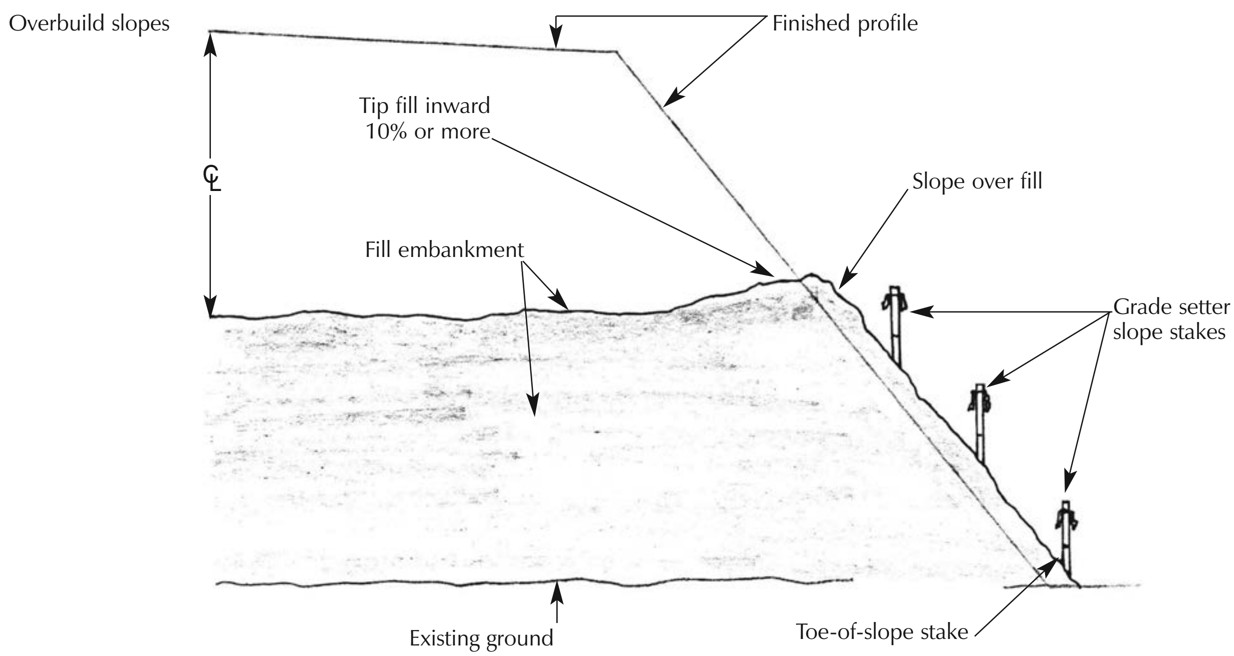


***Figure 13-3*** *Correct fill slope profile*

slide off the fill. Figure 13-3 shows a profile of the proper way to build a fill. You can see the fill stakes set by the grade setter with the outside edge higher than the rest of the fill and the slope overbuilt for track-walking.

There should be someone at the equipment entrance to control the equipment entering the fill. If scrapers are used to build the fill, push-pull type scrapers are a good choice because they work in tandem and will arrive and leave the fill together. That way the grader and roller will only have to pull into a turnout area and stop once for both scrapers. When working a limited space like a narrow fill slope, don't expect the same production from equipment that you'd get in a wide, open fill.

If there are too many scrapers hauling fill, the compactor will end up spending time waiting for the equipment rather than compacting, and the compaction tests will fail. This is a problem you want to avoid when working on a narrow fill. If you use trucks to haul in the fill, bottom dumps are best because the trucks can dump on the go without stopping. However, if the fill being hauled in is heavy clay and big chunks, it can get hung up in bottom dumps, slowing down the work and eliminating any savings. In this case, use side- or end-dump trucks.

## Bringing in Fill From Above

Another method for building a narrow fill is to close one lane of the highway and have the fill dumped from above. Trucks can dump the fill on the roadbed, and you can use a Cat 16 grader to blade it over the edge. This works well because you don't have to worry about equipment passing in the limited work area below. The grader and roller can work the fill dumped from above without worrying about trucks or scrapers. With this method, you'll need to use a Cat D6 dozer working below to feed the fill pushed over by the grader down to the fill area. If you're working off a two-lane road, you'll need to set up traffic control signs, arrow boards, delineators or cones, and have flag persons on each end directing traffic around the work area. Be sure to scrape and sweep the roadbed clean each night before the lane is reopened. You might also need a water truck to wash the remaining dust away. As in any other dirt job, have a good water source for the water truck to load quickly. In most cases, a fill can't proceed without water.

## Compacting and Finishing the Embankment

When selecting equipment to compact the fill, the dozer blade on a pad-drum roller isn't as effective for heavy dozing as a pad-foot compactor, like a Cat 815. However, the pad-foot compactor has pads on each side but not the center, so it's a poor choice on a narrow fill where it can't move over enough to compact the center strip. There are some pad-foot compactors with a center wheel. If you find one available, it would be faster to use than the pad-drum roller.

A small dozer, in place of the grader, cutting the bench is also an option if you're using a pad-drum roller. I prefer the grader because it can mix faster if you run into dry fill areas. However, with very rocky fill material, I'd probably lean toward using a dozer. Once the fill reaches the top, it's like any other fill. The shoulders (chokers) need to be built and compacted, then trimmed horizontally across and cut on line vertically before you begin rough-trimming the subgrade. And finally, the slopes must be track-walked.

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# CHAPTER 13 QUESTIONS

**1. Why are narrow embankments more difficult to build than wide embankments?**

A) The compaction requirements are greater
B) The confined area makes passing difficult for the equipment
C) Compaction water applied tends to flow off the area
D) The slopes must be kept to a closer tolerance

**2. After the stripping and clearing is done, what is the next order of work?**

A) Rip and compact the original ground
B) Have the grader set slope stakes
C) Track-walk the original slope
D) Have the scrapers start hauling fill

**3. Cutting a 3-foot vertical bench into an existing 2:1 slope adds how much horizontal space?**

A) 4 feet
B) 6 feet
C) 8 feet
D) 12 feet

**4. Where does the first fill on a narrow road widening come from?**

A) It's hauled in from the closest cut area
B) It's usually dumped from the road above
C) It's generated from the bench cut
D) It's generated from the stripping operation

**5. What method should you *not* use to gain extra fill width for your equipment?**

A) Cut turnouts
B) Cut a 10-foot bench cut
C) Make a 5-foot vertical cut
D) Overfill the shoulder

**6. Why do you need to cut a bench into the existing slope?**

A) To make room for the equipment to work
B) To properly tie into the existing fill
C) To generate more fill
D) To provide a mark for the scrapers to fill to

**7. What important safety factor should you remember while building any fill?**

A) Make sure the fill is compacted with a vibratory compactor
B) Never make a vertical cut into the existing slope
C) Always keep the fill area level
D) Always build the outside edge higher

**8. What is the possible disadvantage of using bottom dump trucks?**

A) Heavy clay and large chunks may not dump
B) They need a 60-foot turning radius
C) They are slower than graders
D) The truck must stop for a bottom dump

**9. If you're dumping fill from the road above, what must you do before the lane is reopened for traffic each night?**

A) Advise the local agency of your progress
B) Remove all signs related to the road work
C) Scrape and clean the roadbed
D) Post a guard at the edge of the work area

**10. What type of compactor works fastest on a narrow fill?**

A) A pad-drum roller
B) A pad-foot compactor with a center wheel
C) A Cat 815 pad-foot compactor
D) A sheepsfoot compactor

# DRAINAGE CHANNELS

# 14

Drainage channels come in various sizes with a variety of challenges depending on the area where you'll be working. For instance, you may need to make repairs on a suburban channel due to erosion from high water, or rebuild a channel in a suburban area to handle more water as new streets and parking lots are piped into it. Not only will you have to deal with water, but grass, tulles, trash and erosion as well. And, channel work in existing subdivisions usually doesn't allow much right-of-way room for construction. There may be only room for the survey stakes and a dewater pipe along the top of the channel. Some channels have sharp turns following property lines that make it impossible for scrapers to maneuver. A hoe may be the only equipment you can use to excavate, with dump trucks loading behind it.

These are just a few reasons why existing channels are much more difficult to excavate than new channels. In this chapter we'll discuss the excavation methods for both types of projects, but the emphasis will be on existing channels. Excavating a slope for a new channel is no different than excavating a slope on a highway or subdivision job. All slopes are cut and staked in a similar fashion. A large channel, 200 feet wide, is cut the same as an excavation for a roadbed through a 20-foot cut area. The only variation may be a closer tolerance on the slope. For this reason, GPS is especially helpful in excavating large channels.

Many problems can be avoided at the beginning of a project by selecting the right equipment for the job. Water and width are the cause of most channel excavation difficulties, whether you're diverting an active stream or water runoff. So, the type of equipment you choose will depend on the amount of water you have to divert or contain, the soil conditions, the width and length of the channel, yardage of fill required, if any, and the haul distance to bring that fill to the job. Equipment too big for the work, or too much equipment, always results in lower productivity. Plan your equipment needs carefully on a channel excavation job. And remember to check for underground utilities before any excavation begins.

Whether you're working on an existing channel or a new alignment (cutting a new channel in an area away from the old channel), it will usually be staked on both sides of the channel. The stakes should be offset far enough from the top edge of the channel slope so they don't interfere with the equipment. The surveyor's information stake will give the cuts needed, and the following distances: the distance out from the stake where the cut begins (top-of-slope), the distance to the bottom of the cut (toe-of-slope), and the distance to the center of the channel. The stake on the opposite side will give the information needed for the other half of the channel. The stakes are usually set every 50 feet, with station numbers and possibly elevations on the back of the stake. On wide-bottom channels, there may be a shoulder on each side with a narrow channel cut down the center that's one foot deep or more. These smaller channels are designed to contain the summer flow only, and the plans may call for them to have a concrete bottom. Information for these smaller channels will also be on the stakes.

## Controlling Water in an Existing Channel

The first order of work when excavating an existing channel is dealing with the water and mud. The method you use for dewatering depends on the amount of water and the space you have available to divert that water.

You'll have to build a dam at each end of the project. For a small channel with little water flow, sand bags and plastic tarps may be sufficient to hold the water. For larger channels you may need to use dozers and scrapers to build a large dam. The height of the dam will depend on the amount of water you need to hold back, and the capacity of the pumps to handle any unexpected water surge.

### *Digging a Diversion Trench*

If there's enough room to detour the water around the work area, you can use a hoe to dig a trench large enough to carry the water from the upstream dam to below the downstream dam. That's the easiest and best way to divert the water, and it usually doesn't require maintenance. Begin your trench at the downstream end, and excavate to the upstream end. That way there won't be any water in the detour trench until you break through to the existing channel on the upstream end. Figure 14-1 shows a hoe digging a diversion channel or trench. The temporary channel has sloped sides so it won't cave in when water flows through it.

**Figure 14-1** *Hoe with tapered bucket cuts a sloped channel*

Keep in mind that there may be downstream effects of any silt or sediment carried in the initial flow of water through the diversion channel. You may have to place some type of erosion control to prevent the sediment from entering the existing channel downstream.

If you need to dig a long detour trench, the grade setter should set grades every 50 feet, and run a string line to check grades from. This will help you create an even flow through the diversion channel. To set the flow line of the diversion trench, the grade setter will set up a laser level and check the grade at both points where you want to tie into the existing channel. Let's say the upstream end of the channel is 2 feet higher than the downstream end 500 feet away. The grade setter will need to set a hub every 50 feet, for a total of ten hubs over the 500 feet. He'll divide the ten stations into the 2-foot fall from the high end of the channel to the low end, to get a fall of 0.20-foot at each station. Then he'll place one more hub at the beginning of the trench with the beginning elevation. At first, the grade setter will set his lath down the center of the diversion channel to be dug. After he's decided how much offset he needs, and which side of the trench the offset should be on, he'll measure from his centerline lath out to that offset, and drive a hub. He'll do this at every station he's established, until all eleven have a hub. Remember, the eleventh hub is at the beginning on the upstream end. This is the only hub where the 0.20-foot fall per station doesn't apply.

Now let's compute the cuts needed to dig the diversion trench. The grade setter will get an elevation from the new channel excavation surveyors' stakes. Let's say the surveyors have marked an elevation of 19.38 on their lath. The grade setter will set his survey rod on the surveyors' hub and set 9.38 on his grade rod, then check the elevation on the hub he set for the diversion trench. If the elevation on the rod reads 9.87, the hub is at 19.87 feet. He should mark that on his lath for a reference. Now the grade setter will take a reading at the existing channel bottom, where it was previously shot, to check the elevation at each end. We'll say he gets a rod reading of 2.36, which he computes to be 12.36 feet. Now he has the hub elevation on top (19.87), and the channel bottom elevation (12.36). He'll subtract the bottom elevation from the top elevation to get 7.51, and write *Cut 7.51 flow line* on his lath.

Remember, at each of the next 10 stations, the elevation of the top hub and flow line will change. The top hub will change up or down depending on the ground level. The bottom flow line elevation will drop 0.20 foot at each station. The first channel flow line elevation we used was 12.36, so the next will be 12.16, and the next 11.96, and so on. The last channel elevation where the diversion channel enters the existing channel downstream will be 10.36, two feet lower than the beginning reading. Setting trench grade is fairly easy if you put some thought into what you want to achieve, and stay focused.

## *Pumping Water*

If you're working in an existing easement, through back yards or where no room is available for rerouting water by trench excavating, you may need to pump the water to a nearby storm manhole, or along the channel through a pipe to the downstream side of the project. You can use gas or diesel pumps, or a generator with submersible electric pumps. For 24-hour pumping, a diesel generator with submersible electric pumps, and enough fuel capacity to run all night will work well. However, there may be some objections to a diesel generator running all night in a residential area. In that case, you can either make arrangements to buy power from a resident, or ask the power company to supply temporary electric power to run the submersible pumps.

Build a temporary fence around the power supply to both ensure the safety of the residents and to guard against vandalism. Consider having a security service make periodic checks of the pump site during the night as well. The cost of a security service is minimal compared to the cost of cleanup if the dam overflows because of vandalism or a breakdown in the pumping system.

Protect the pump intakes from floating debris by placing the pumps in 55-gallon drums with slots cut in them. Water can enter through the slots, but trash is blocked. As an alternative, you can use a screen around the intakes. Both methods must be maintained to ensure that the pumps don't get stopped up. Install a float switch system, so the pumps will turn on when water reaches the height you wish pumping to begin, and turn off when it drops below the height you wish them to stop. If you have a small flow where only one pump would normally be needed, you might want to use two pumps, so you have a backup in case one gets plugged up or breaks down when no one is around.

### *Running a Pipe*

Here's another option you can consider if your working space is limited. You can run a pipe deep below the channel floor to transport the water through the work area. The work area must be dewatered first, and the pipe must be placed deep enough so it won't be damaged by the excavation work. Running a drain pipe works best when there's only a small stream of water, and you only need a 10-inch pipe or smaller to carry it.

This method requires building two dams on the upper end of the stream. Build the first dam far enough upstream so there's room to place the pipe. Build the second dam between the work area and the pipe end, after the pipe has been laid. After the second upper dam is in place, and the dam on the downstream end of the work area is in, remove the first

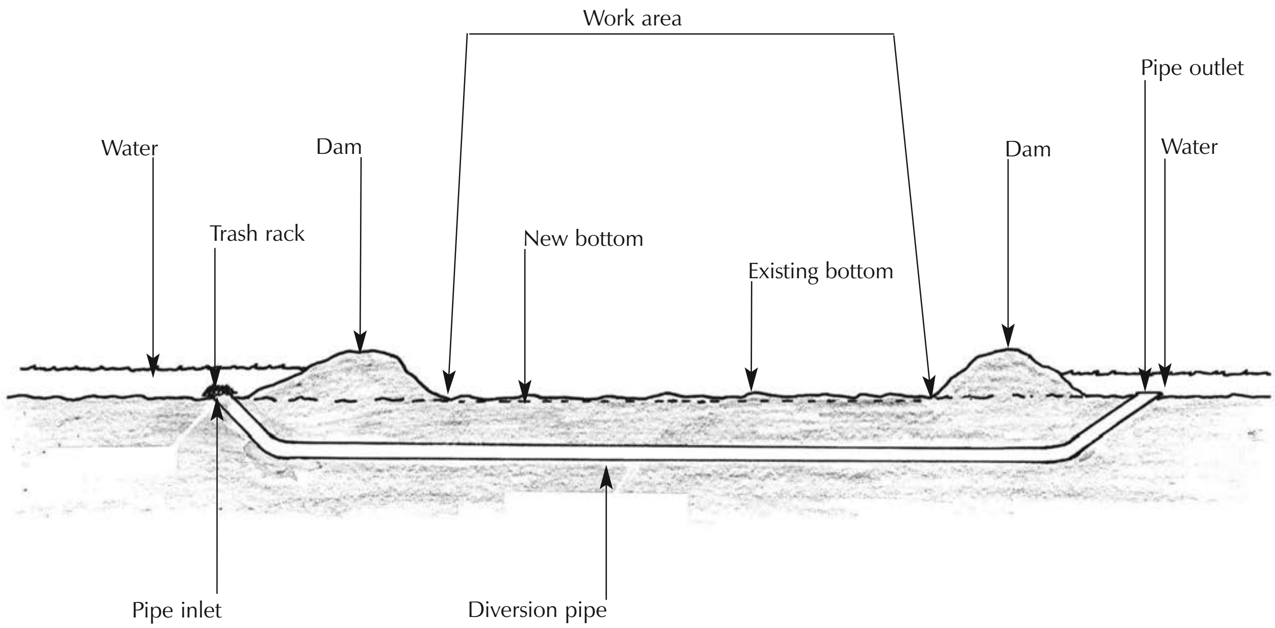


***Figure 14-2*** *Diversion pipe under work area*

upstream dam to allow the water to run through the pipe. See Figure 14-2. Use good firm dirt or crushed rock to backfill over the pipe so equipment running over it won't damage the pipe. You can just plug the pipe and leave it when the job is finished. This system should only be used if the agency doing the inspection agrees the pipe can be left in place.

## Widening or Rebuilding an Existing Channel

When widening an existing channel, the width of the channel will determine the equipment you'll use. If a wide channel with a firm bottom is to be cut wider and deeper, then scrapers may be a good choice. If the channel bottom is too narrow for scrapers and dozers, you've got to use a hoe. The hoe can work from the top to cut the bottom and sides. Or, if there isn't enough room on top, it can work from the bottom using a tapered bucket for the slope and a standard bucket for the bottom. You'll need a grade setter to mark line for toe, bottom, top, and grades.

Let's assume you're widening a channel 10 feet on one side only. A good method would be to start a Cat D6 dozer, equipped with a slope bar, tiltable dozer blade and ripper rack, at the top of slope. Let's say the new slope is $1^3/4$:1. This means that for each foot cut vertically, the slope will move out $1^3/4$ (1.75) feet horizontally. To start the bench, the grade setter will paint a line 1.75 feet out from top-of-slope. Once the dozer has cut 1 foot deep along that line, another line will be painted 1.75 feet out from the first cut (or 3.50 feet from the top-of-slope), and cut in the same manner. The grade setter and dozer operator will follow this procedure until there's enough width for the scrapers to work safely. As the dozer makes the cuts, the operator will tilt the dozer blade up on the outside edge, so when the scrapers start work they won't slide off the pad being built for them.

The dozer operator must also build an access ramp for the scrapers to enter and exit the channel as the slope work proceeds down. If the dozer is equipped with a ripper rack and a slope bar, you can use it to rip for the scrapers, and trim the slope to grade as the excavation moves along. It's important to cut the slope within tolerance before digging past the reach of the slope bar on the dozer. If this should happen, the dozer operator won't be able to reach the slope, and a hoe will have to be brought in to reach the untrimmed slope.

In good soil, the dozer may be able to make the cut to the bottom with a hoe loading the dirt into trucks, eliminating the need for scrapers.

### *Rebuilding Channel Slopes*

Excavating a channel is usually faster and easier than rebuilding washed out channel slopes. Let's assume you have a rebuild job. The channel is 10 feet deep, and the slopes have eroded through the years and must be rebuilt and trimmed. While walking the channel, you see by the surveyors' stakes that the channel bottom is 8 feet wide, and the eroded slopes must be filled from 5 feet to 8 feet in several areas.

This is the type of job where you'd want to use hoes. You'd want one hoe with a compaction wheel building the fills on the slope, and a second hoe with a 5-foot grading bucket to trim the bottom and slope excess. The hoe with the compaction wheel should also have a bucket along to place the fill supplied to him by the trucks dumping fill. With quick-coupler buckets and wheels, you can change from a wheel to a bucket quickly, eliminating the need for a small dozer to push the fill to the hoe. When you use a hoe to make a fill, be sure the fill being supplied has enough moisture in it to meet compaction requirements. It's much faster to mix moisture into the dirt before it's loaded into the trucks than to have the hoe operator stop and mix it. If the hoe must mix the material, it'll significantly slow down the project.

That same hoe must also strip any vegetation and mud from the slope sides and bottom, cut a small bench, and rough up the slope being filled. The grade setter will give the hoe operator line for toe-of-slope and top-of-slope, as well as grade shots on the slope being built. The grade setter must ensure that the slope is overbuilt 0.30 to 0.50 feet, so the second hoe will have enough excess to trim a good compacted slope. The second hoe will trim the bottom of the channel. You may need to have a dump truck working with the second hoe to take the excess dirt being trimmed to the first hoe to use for fill, if it's suitable. If the bottom needs to be undercut to remove mud, the first hoe will do it, and then refill the bottom so the second hoe does nothing but trim. Or, you could have a small dozer with mud tracks grading the bottom and pushing the excess ahead to the first hoe, so both hoes can just work the slopes. You'll need a grade setter working full time with each hoe to be sure the channel is kept on grade.

Let's look at another channel where you need to rebuild several hundred feet of eroded slopes. This one has a 20-foot-wide firm bottom, and 8 feet or more to be filled to repair the slopes. Depending on where the fill material is located, you may be able to build the slopes using scrapers. Start with a bench cut into the existing slope, and make the fill starting with toe-of-slope stakes. The difference in using scrapers, rather than hoes, is that when the fill is finished and track-walked, it must still be trimmed so no loose material is left on the slope. You can do the trimming with a hoe, grader or dozer, depending on the depth and steepness of the slope. This is a good method only if you have several hundred feet of slope to fill. You must maintain a bench cut all the way to the top of the slope, and build a ramp on each end of the work area for the equipment.

## New Channel Excavation

To dig a new channel that's only 7 feet deep with a 4-foot bottom, you'd use a hoe with a tapered bucket (also called a *trapezoid bucket*). It's fast and does an excellent job. I've also had good production using a hoe like this on channels with 8- to 10-foot bottoms, with a small dozer on the bottom trimming the bottom grade. You can also use a scraper and a grader on a deep channel with a narrow bottom. When the excavation becomes narrower than the scraper width, change to a hoe for the remaining excavation.

### *Working with a High Water Table*

If you're working on a new alignment for a large drainage channel where the water table is a problem, you may have to excavate in two stages. Use scrapers for the first stage, until the bottom becomes too wet and soft. Trim the slopes of the first stage with a grader. Then use a hoe with a tapered bucket to finish the remaining excavation to the bottom. If the bottom of the channel is deep mud that must be excavated with a hoe, you might need planking or sheeting under the tracks of the hoe to keep it from getting stuck. You can use a small Cat D4 dozer with mud tracks to trim wide bottoms and push excess dirt to the hoe.

When ground water is a problem, consider using a wellpoint pumping system to control the water level. This helps in two ways. First, it allows the scrapers to work longer before the hoe is needed. And second, when the hoe is finally required, the wellpoints reduce the amount of water that will seep into the channel, making excavation and grade checking easier. Figure 14-3 shows a wellpoint pumping system set up. Notice at every vertical 10-inch casing there's a submersible pump inserted to pump ground water. A generator supplies the electrical power to each panel and wellpoint pump. This is an expensive procedure and is usually only cost-effective for excavating large channels like the one shown in the figure.

If you don't have water problems, excavating a new alignment is much easier. Start the first cut, with the scrapers, in from the top-of-slope the distance the slope falls. For example, if the slope is 1:1, start 1 foot out and cut 1 foot. For a $1^3/_4$:1 slope, move out 1.75 feet and cut 1 foot. For a 2:1 slope, move out 2 feet and cut 1 foot, and so on. The grade setter should see that the equipment moves out the amount of the slope every time they make the 1-foot cut, so the slope won't be undercut. By cutting the slope this way, the grader will have a small amount of trim for a good firm slope finish. But if the channel bottom is so narrow that equipment can't pass, this will slow production. Then you might want to consider excavating with a hoe. If the plans call for pouring a concrete lining on the slope and bottom (as required on many suburban channels), ask the surveyors if their cuts are to finished grade or subgrade. More than likely they've staked finished grade. In that case, the grade setter must add an undercut the thickness of the lining.

***Figure 14-3*** *Wellpoint dewatering system*

Remember, for any channel, unless all the excavation is done with a hoe from the top, you must cut a ramp on each end so equipment can enter and exit the channel. You may need several ramps for a very long channel. There must be enough excavated or imported material available to fill the ramps after the channel grading is complete. Use a hoe and compaction wheel with a quick-coupler grading bucket to fill the ramps. If the fill is piled close enough to the ramp, you won't need equipment to feed material to the hoe. If you have to haul the material in, have the trucks dump close enough so one hoe and grade setter is all you'll need to fill, compact and grade the ramps.

There's usually very little cleanup left to do when the channel excavation is completed. After you've removed the ramps and dewatering system, just reset existing fences, or construct new fences if needed, to finish the job.

# CHAPTER 14 QUESTIONS

**1. How are channels usually staked?**

A) Every 50 feet on both sides
B) Every 50 feet on the right, looking downstream
C) Every 100 feet on each side
D) Every 25 feet down the center of the channel

**2. How should a diversion trench be dug?**

A) From upstream to downstream
B) From downstream to upstream
C) At least 1 foot deeper than the existing channel
D) At least 6 feet deeper than the existing channel

**3. How can you ensure an even flow through a long detour channel?**

A) Use a trencher to excavate the detour channel
B) Make sure the detour channel is at least 6 feet deep its entire length
C) Set hubs and cuts for grade
D) Use scrapers equipped with a laser to excavate the detour channel

**4. What type of pumping setup is best to use in a residential area?**

A) Gas water pumps
B) Diesel water pumps
C) A diesel generator and submersible electric pumps
D) Utility-supplied power and submersible electric pumps

**5. How can you be sure the water is maintained at the proper level if you're using a pumping setup?**

A) Install a float switch system
B) Have a maintenance person to control the pumps
C) Set the pumps on timers
D) Make sure there's an adequate fuel supply to maintain the pumps

**6. Where will the grade setter paint the line for the first cut of a bench cut at top-of-slope on a $1^3/_4$:1 slope?**

A) 1 foot out from the top of slope
B) 1.50 feet out from the top of slope
C) 1.75 feet out from the top of slope
D) 2 feet out from the top of slope

**7. What equipment would you use to fill in a narrow, washed-out slope?**

A) A hoe with a grading bucket
B) A hoe with a compaction wheel
C) A small dozer
D) A dump truck

**8. Never fill against what type of slope?**

A) A slope that has been benched
B) An undisturbed slope
C) A 1:1 slope
D) A slope less than 3 feet high

**9. How do you finish a channel slope?**

A) Track roll it two times
B) Hydroseed it
C) Trim it to a firm surface
D) Back-drag it with a dozer blade

**10. What can you do to eliminate most ground water during a channel excavation?**

A) Sink wellpoint pumps
B) Pump lime into the soil
C) Set up a sump pump
D) Dig a small drainage ditch

# UNSUITABLE MATERIAL

# 15

Unsuitable material is any soil or aggregate that has absorbed enough water so that it won't give adequate support for a road section. You can usually recognize it by the rolling movement of the ground as the equipment runs over it. It's similar to the way a waterbed ripples. A surface that moves this way is said to be *pumping*.

Before any excavation begins, always call Underground Service Alert so all underground utilities can be properly located and marked. You should also be sure to read the specifications regarding the removal of any unsuitable material and discuss it with the inspector, engineer or owner prior to the excavation. If the specifications or bid items don't cover unsuitable material, and you discover some, *don't remove any until you've reached an agreement on payment.* Unsuitable material removed below subgrade level is usually allowed as an extra charge. It's unlikely that the project specifications will require the contractor to remove unsuitable material at his own expense, because the extent of the problem is usually never known until the excavation is finished. No estimator would have been able to come up with an accurate estimate. Whenever you remove unsuitable material, be sure to keep an accurate record of the quantity of material removed and replaced.

When you must remove unsuitable material at your own expense, it will save money if you can accurately tell unsuitable material from suitable material. Distinguishing the two soil conditions takes a great deal of experience. Don't entrust the decision to an inexperienced foreman or superintendent. When in doubt, seek advice from a soils engineer or a superintendent or foreman with several years of experience under his belt.

## Testing for Unsuitable Soil

It's possible that soil with a slight movement at the surface will still be suitable to fill over. Earth with heavy clay content may move under the weight of rollers as though it were unsuitable material. It may actually be quite stable for most purposes. Here's how to test for unsuitable soil: Take a grader, scraper, or water truck and wheel-roll the area in doubt. If the area rolls in front of or behind the tire, then it's too soft. If no rolling occurs, just a slight settlement from the tire, then it's usually stable enough to support a road section. Don't use a steel drum roller to check for unsuitable areas, as it won't give a good indication of the soil stability. Equipment with rubber tires work best. I've always felt that if a grader running over an area doesn't cause movement, it's stable enough, even if a loaded water truck does cause some movement.

## Excavating Unsuitable Material

When excavating any road or parking area, try to excavate to the subgrade level before removing the unsuitable material. If the unsuitable soil is so soft that the equipment can't get through, you may have to remove it before the subgrade level is reached. If the area needing excavation is too soft, too deep, or too small for scrapers, use a hoe, track loader, or dozer. To excavate large areas that are too soft for scrapers, a

***Figure 15-1*** *Cat D10 dozes unsuitable soil to a stable area for removal*

***Figure 15-2*** *Track loader will load unsuitable soil into trucks*

dozer works well. The dozer will start dozing down one edge to get a solid bottom to work from. In Figure 15-1, a dozer is pushing a large pile of unsuitable material to a firm area where it can be loaded on stable ground. Figure 15-2 shows a track loader that will be used to load the trucks.

If unsuitable areas are large enough for scrapers and there's a waste disposal area close by, open-bowl scrapers with a dozer pushing can handle the job. If the unsuitable material area is long enough, you can use either


***Figure 15-3*** *Dozer helps a paddle-wheel scraper get a load in a soft area*


***Figure 15-4*** *Dozer pushes a twin-engine scraper loading mud in a lake bottom*

paddle-wheel or open-bowl scrapers with a dozer pushing. A paddle-wheel scraper can't cut deep enough to get a full load in a short area. Figure 15-3 shows a dozer helping a paddle-wheel scraper get a load through a soft area. You can use open-bowl scrapers in small areas because they have the ability to take a deeper cut when pushed by a dozer. Figure 15-4 shows a dozer pushing an open-bowl twin-engine (push-pull) scraper in a large unsuitable area. The double engines on the scraper really help with power and traction pulling through the mud.

Avoid running dirt-moving equipment over unsuitable soil areas. This slows the equipment and cuts down production. If there's no convenient way around unsuitable soil, it may be more practical to just remove it as you meet it. Then the scrapers can haul over firm ground.

### *Determining the Amount of Fill Needed*

If you're using aggregate to fill an unsuitable area, and the area is irregular and hard to measure accurately, you can generally figure one cubic yard of dirt excavated for every two tons of aggregate used. This rule-of-thumb is accepted by most contractors, inspectors and owners. So, if you dump 4,000 tons of aggregate in the void left by the unsuitable material, you can assume you excavated 2,000 cubic yards.

## Plugging Small Unsuitable Areas

Never try to build a road section over an area that's rolling under the weight of your equipment. Invariably, the unsuitable material will cause the finished surface to break up under the load of traffic. Occasionally, you'll discover small soft areas after the aggregate base has been trimmed and the road or parking area is ready to pave. Use a plug of asphalt 4 to 6 inches deep to bridge these small areas. Asphalt will bridge even a very soft area, if it's thick enough. But remember that the asphalt plug must be placed well ahead of the paving, usually the day before. That way, the plug is hard by the time you're ready for the equipment to put down the top surface. Keep heavy loads from traveling over the plugs until at least the day after they've been paved.

A few small unsuitable areas may appear when you're trimming subgrade. If they seem to be shallow, the grader operator can roll the unsuitable material across the subgrade far enough to mix it with dry dirt. After it's mixed, blade and roll it back into the same area. Or, if it can be done in one pass, you can have the scraper trimming subgrade cut the small areas out, and return with stable fill from a borrow area.

## Bridging Unsuitable Material

When removing unsuitable material, make sure you remove enough to expose good firm soil. When you can't reach a firm bottom, let the inspector or owner make the decision about what should be done next. If you've removed 5 feet of unsuitable material without reaching a stable base, here's a method you can recommend that, in most cases, will bridge the unsuitable area.

Fill the excavated area with large cobbles or pit-run gravel. Push the full 5-foot lift back into the depression. Don't do any rolling until the depression is filled to the top. If it's placed and rolled in layers, the gravel will usually continue to roll or pump even at the finished grade level. About 2 feet of 8- to l0-inch size cobbles, with 6 inches of base over the cobbles, is usually enough to bridge an unsuitable area for cars and light trucks, like a parking lot. If the inspector insists on rolling layers 18 inches or so deep, then I would suggest placing filter fabric before dumping the rock. Of course, the inspector, engineer, or property owner should agree on which method to use. If the method doesn't provide a suitable base, you don't want to be held responsible. It's always best if a soils engineer decides what's needed to stabilize the area, and what results are adequate.

### Working in Bridged Areas

Occasionally you'll find an area of unsuitable material under a layer of firm earth. This earth usually bridges the unsuitable material, except for a few isolated areas where the equipment has broken through. This is a troublesome situation for any contractor. Usually, if you use scrapers to remove the material, the loaded scrapers pulling out of the unsuitable area will break off more of the bridging layer and increase the problem. The unsuitable area will get larger at each end of the run as the scrapers enter and leave the area, breaking down the bridge. There are two ways to resolve this situation.

***For a sizeable bridged area —*** If most of the unsuitable soil can be removed without breaking through too much of the bridged area and increasing the problem, use scrapers or a track loader to remove it. Remove all unsuitable material except for where the bridged area on the ends has collapsed from the equipment weight. Then let a hoe take over. The hoe can remove the remainder of the unsuitable material without additional deterioration of the bridged area by heavy equipment.

***For a thin brid\ged area —*** If the bridged area is thin, you can't use scrapers to remove the isolated unsuitable area. The weight of the scrapers would cause the thin bridging to collapse, resulting in a larger unsuitable area. In this case, use a hoe to remove the isolated unsuitable area. The hoe should load the unsuitable material into small dump trucks with a weight capacity less than the scrapers. This lets you remove unsuitable material without breaking through the thin bridging. It reduces the chance of increasing the size of the unsuitable area before the base can be placed. Once the base is placed, it will add enough strength to keep the grade stable.

This hoe method works well in parking lots where only car traffic will travel over the finished asphalt — not truck traffic. I don't recommend trying to work over a thin-bridged area on a road job that will carry heavy traffic. It may eventually fail.

Sometimes the ground is firm enough to hold a track loader even though scrapers are breaking through in the bridged area. If this is the case, use a track loader rather than a hoe to increase production. But a word of caution: Only use this method of removing unsuitable material if the surface bridging is thick enough to hold up during the rocking and paving operation. Even though a parking area is designed for cars only, the subgrade must be firm enough to hold the weight of the gravel and asphalt trucks delivering to the job site. If it holds up under the weight of the grading equipment, water truck and roller running over it, then it should be stable enough to hold while aggregate is placed.

When filling the area after removing unsuitable soil, use equipment that's light so it doesn't break the bridged area around the edges. A small dozer or backhoe with a front loader bucket is ideal for this work.

## The Fill

The inspector may direct the contractor to incorporate the unsuitable material removed into the fill area. If so, the scraper operators must dump only thin layers of soil. Spread the unsuitable material in a thin, even layer and then add a layer of good material. Good material draws moisture from the unsuitable material when the two are mixed. No water truck is generally needed. The moisture from the unsuitable material should provide plenty of moisture for good compaction.

Sometimes the unsuitable material is so wet that you'll disrupt the filling operation if you try to incorporate it in the fill. In that case, you should be compensated for the production loss. If there's more unsuitable material being directed to the fill than you can incorporate without causing the fill to become unsuitable as well, point this out to the authority involved. An inspector or authority that insists on dumping unsuitable material into a fill does so at his own risk. If the entire fill becomes unsuitable because of the inspector's error, you're not to blame. Be sure to get the directive in writing if you anticipate a problem.

During hot and dry weather, shallow areas that are pumping slightly should dry out enough in one day, especially if they've been ripped. Rip them before end of shift and rework them the following day.

## Remedies for Unsuitable Soil Problems

During winter months or early spring, when unsuitable areas are most prevalent, some county and state agencies will shut a job down until dryer conditions prevail. They often don't have the funds to deal with the extra cost of removing unsuitable material. Developers, on the other hand, may prefer to pay that cost to keep a large project on schedule. There are some solutions for unsuitable soil problems. Time and cost would be the two most crucial issues to look at to determine which option is the best for the job. Let's look at some examples.

### *Using Construction Fabric with Fill*

You can use construction fabrics (often called *filter fabric*), available in woven and nonwoven material, to improve unstable soils. Their technical name is geotextile fabrics. Check with a soils engineer to find the correct weight or type of construction fabric to use for your project. For maximum subgrade stability, a woven fabric is usually required.

Earth that's almost unsuitable on the top surface will form slight grooves or ruts as the trucks haul aggregate or pavement over it. Roll these ruts flat before spreading aggregate or pavement. It's good practice to place construction fabric over these areas to help stabilize them. If an unstable area has 5 feet of fill remaining, cover the area with fabric, then doze about 18 inches of good fill over the fabric before hauling over it with small scrapers to finish the fill. This should stabilize the fill at the top. Figure 15-5 shows a cul-de-sac being covered with construction fabric before filling.

Construction fabric keeps mud from coming up through the material you place over it, yet allows water to seep down through it. It also works well behind rock walls, as shown in Figure 15-6. Here the fabric covers the

***Figure 15-5*** *Construction fabric is placed under fill*


***Figure 15-6*** *Construction fabric covers fill behind rock wall*

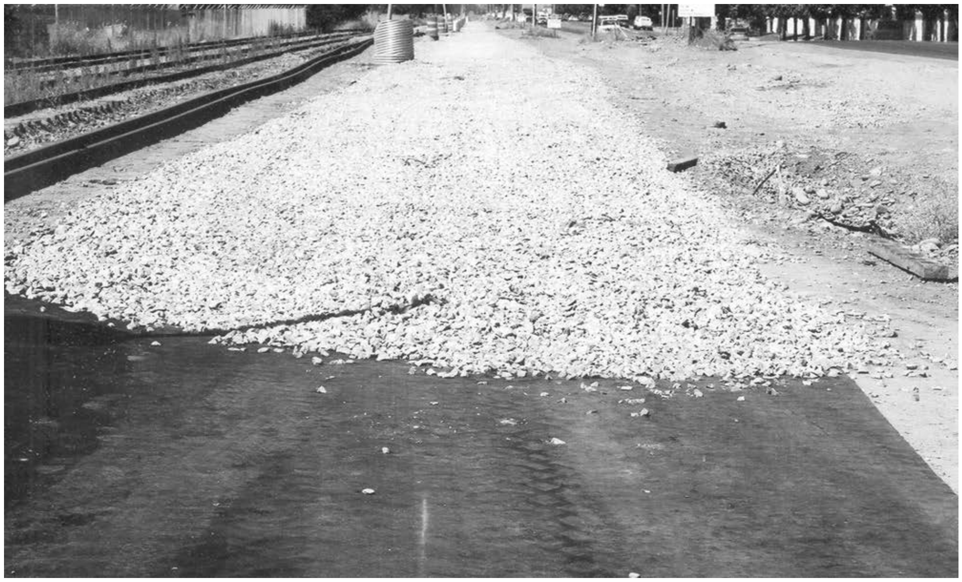

**Figure 15-7** *Construction fabric is placed under light-rail bed to prevent mud penetration*

fill behind the wall. Construction fabric may also be used on a stable subgrade to prevent mud penetration over the years. In Figure 15-7, fabric has been laid under a crushed-rock bed for a railroad. (We'll cover fabric placement under asphalt in the chapter on asphalt paving.)

What if, when you're trimming the subgrade for aggregate, a large amount of the grade is too soft for aggregate and there's no dry fill available? You still have some options. Let's assume the subgrade is only soft on the surface, but won't dry because the weather isn't warm enough. Excavate a small amount, perhaps 3 inches, and haul it off. Then place construction fabric and fill the excavated 3 inches with aggregate. If the original section called for 8 inches of aggregate, it will have 11 inches of aggregate instead. In this case, the fabric plus the extra 3 inches of aggregate would be enough to stabilize the grade so it could be paved.

## *Using Lime Treatment*

Now let's assume we have those same weather conditions, but the unsuitable material runs 1 or 2 feet deep. In this case the best method would be to lime-treat the soil to at least a 1-foot depth. Lime works extremely well in clay materials. It pulls the moisture out of the unsuitable material. Once it's mixed in several times, roll it with a pad-foot compactor. In cool weather, it can be trimmed the next day and should stabilize the subgrade enough so you can place aggregate. (For more information on this subject, see Chapter 20, Lime-Treated base.)

### *Increase the Thickness of the Pavement*

What if the subgrade has been covered with 8 inches of aggregate and then it rains for several days? When the rain stops, the developer wants to get the project paved before more rain shuts it down for the winter. After several days of rain, the gravel along the edges of the curbs is pumping as well as several other spots where the rain has penetrated. Let's say the original road section was 3 inches of asphalt and 8 inches of aggregate. There are a couple of things you can do to get the project paved. One would be to remove 2 inches of the 8 inches of aggregate already placed, leaving 6 inches of aggregate. Then, trim the grade again and place construction fabric and 3 inches of asphalt. Once the pavement hardens, say the next morning, pave the road with another 2 inches of asphalt. The soft areas of the road section now have 6 inches of aggregate and 5 inches of pavement, instead of the 8- and 3-inch section in the original plan. The extra asphalt will usually be enough to give a good road base.

### *Using Cement Treatment*

Your second option may be to cement-treat the 8 inches of base rock, retrim, and then place 3 inches of asphalt. The soils engineer will determine the percentage of cement to add into the aggregate for stabilization. Usually it's about a 2 to 4 percent ratio of cement to aggregate (dry weight of cement to dry weight of aggregate). The aggregate plant personnel will supply you with the dry weight of their aggregate per cubic foot, if needed.

Spread the cement over the 8 inches of saturated aggregate base and mix it in using a lime-mixing machine. Don't add any water until you've mixed it twice — you may not need additional water. Once the final mixing is complete, begin rolling and trimming immediately. For best results, you should finish the rolling and trimming within 3 hours — the cement begins to set up quickly. Check the specifications or consult with the soils engineer to find the recommended cure time of cement-treated base in your area. Keep all traffic off the treated base during the specified cure time. When the cement is cured, place the 3 inches of asphalt. If the cement-treated base develops small soft areas that break-up under the weight of the asphalt truck traffic, remove the soft areas and plug them with asphalt before the paver gets to them. Place the asphalt in two $1^1/_2$-inch lifts. By the time you're ready to place the second lift, the plugs should be healed up. Note: This type of treatment can't be used if the atmospheric temperature is below 35 degrees Fahrenheit.

### *If Nothing Works*

If none of these methods will produce a good base, you're left with one option: don't finish the top layer of asphalt. Leave off at least $1^1/_2$ inches of asphalt. If you do this, the developer will be able to start the homes he needs to build through the winter. Then in the spring, he can pay for the pavement to be cleaned, and all the areas that didn't hold up through the winter dug out and repaired. Once all the broken areas are repaired, he can get the final $1^1/_2$ inches of asphalt placed, producing a good smooth firm job.

All of these methods should be paid as extra work and billed at time and materials. Or, you might need to establish a new bid price before proceeding with the work.

## Unsuitable Soil Around Utility Lines

When replacing old pavement, you'll often find unsuitable material around water, gas, sewer, telephone, electrical or drain lines. The asphalt or concrete in the existing road tends to trap water and saturate the soil underneath.

If there are utility lines under the existing pavement and the ground below is soft, there's a real danger that heavy equipment will break the lines. A loaded scraper can compress the soil enough to break a water main that's 4 feet below the surface. This is probably one of the most aggravating excavation problems. Water from the broken main quickly floods the area to be excavated, stopping work for hours. You can avoid these problems by locating all the utility lines before starting the job. Know both where they are and how deep they are. This is doubly important when there's unsuitable material involved.

## *Use the Right Equipment*

The best piece of equipment for removing unsuitable material above and around utility lines is a backhoe. Sometimes you can use a small dozer to push the unsuitable material out to where scrapers can pick it up. You may encounter soils so sloppy that only a small Cat D4 or D5 dozer with wide mud tracks can travel through it. It's important that the operator makes very small cuts when dozing mud. If he tries to doze too much at one time, the tracks will spin in the mud and the dozer may get high-centered and stuck.

The equipment you choose will depend on which utilities are involved and how much weight they can take without damage. A reinforced drain line can take much more abuse than a vitrified-clay sewer line or plastic water main. A cast iron water main is a sturdy pipe, but will snap in the center with excessive weight or a sudden jar, especially if the grade below it is soft. Telephone ducts are as fragile as a clay sewer line. A gas main will probably take more weight without damage than any other utility line, but they present their own special problems. The service lines coming off the main can snap off easily, so someone with a shovel must uncover the main as the hoe or dozer gets within 8 to 10 inches. The service connections must then be located and uncovered so the operator can visually work around them.

If you need to remove unsuitable material below the utility lines or very close to the top, always place a crew member on the ground with a shovel and prod rod to direct the hoe operator. Using the prod ahead of the work will keep the hoe operator from damaging service lines attached to the main line. Water main services usually come from the top half of the main, and you can easily hit them if you're not careful. Sewer services may rise quickly after leaving the main. The prod should have rubber handle covers in case a power line is prodded too hard and the steel prod makes contact with the wire. Prodding too hard can also puncture a plastic gas service. Be sure the person prodding doesn't shove the prod rod so hard that he puts himself in danger.

## *Notify the Utility Companies*

Again, always notify the utility companies before starting an excavation. They're very helpful in locating the lines and service connections. Some utility companies do the locating for you, while others will supply you with a utility plan of the construction area. Most utility companies require 24 to 48 hours notice before construction begins.

Some states have an underground alert number to call that informs all utility companies that belong to the service that construction excavation work is beginning. If there's an Underground Service Alert (USA) number in your area, call it, but be aware that not all utility companies belong to the service. USA requires that the work area be marked with white paint so that it's visible and well-defined, especially if no one will be at the job site when they come out.

Removing unsuitable material around utility lines is a slow process. This is especially true if you must excavate under them, because that involves handwork and planking. It's an expensive way to excavate. Don't rush it. It's much cheaper to take the time to work carefully around the utilities than to damage them. The cost of repairing a telephone cable or sewer main is high. Cutting a gas main or an electrical line is both expensive *and* dangerous.

The best way to protect yourself is to have the utility companies mark their own lines. The contractor still has the responsibility of working carefully up to the marked area, but he's protected if the lines are marked wrong and one is hit. It's not unusual for the marks to be 2 or 3 feet off, but the utility company will usually bear the cost if the contractor is being careful, and the marks are 3 feet or more off from the actual location of the line. Here's what I recommend. Make a clean cut perpendicular to the line you're trying to find. If you cut down through undisturbed soil well above the utility line, you'll be able to detect a difference in soil gradation where the utility trench was excavated and compacted when the line was installed. Always look for this telltale sign. It's a simple method to avoid big trouble.

### Backfilling Around Utilities

The contractor is responsible for compacting stable material around the utility lines once the unsuitable material is removed. I suggest using crushed rock under all utility lines — $^1/_2$- to $^3/_4$-inch crushed rock won't settle and makes an excellent base. Gas, electrical and telephone lines usually require a 6 inches to 1 foot of sand placed around them. Be sure the sand is watered down well for compaction, then fill at least 1 foot more above the utilities with crushed rock before bringing in fill that must be compacted. Be very careful compacting over utilities until you have at least 2 feet of cover over them. I suggest using a compaction wheel or small plate tamper. Don't use a vibratory roller until the full 2 feet or more of cover has been reached.

If a line is extremely shallow, the utility company may decide to lower the line or pour a concrete cap over it for protection. You shouldn't be charged for lowering the lines unless the specifications require it as part of the job.

After all the unsuitable material has been removed, the inspector decides on the kind of fill material to use to bring the road back up to the subgrade level. Generally, it will be aggregate. Soil isn't usually used because it requires more compaction than aggregate, and that may involve more risk of damage to the utility lines. When the unsuitable material has been replaced, you can build and trim the area to finished subgrade. Remember: All unsuitable work below subgrade, until normal grading operations can resume, should be billed as extra work — time and materials.

Unsuitable soil is one of the most troublesome areas of construction. Always think the job through thoroughly before beginning, and get the advice of a soils engineer whenever possible.

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# CHAPTER 15 QUESTIONS

**1. What do you call an area that's too soft to cover with base rock or asphalt?**

A) Muddy
B) Pumped
C) Unsuitable
D) Saturated

**2. Who covers the cost for removing unsuitable material below subgrade during excavation?**

A) It's billed as extra work
B) It's the contractor's responsibility
C) The cost is shared by the contractor and owner
D) No one; it should be allowed to sit until it dries and firms up

**3. What should you *not* use to test roll movement on subgrade?**

A) A water truck
B) A grader
C) A scraper
D) A steel drum roller

**4. How much soft soil was excavated if 4,000 tons of aggregate is needed to fill the hole?**

A) l,800 cubic yards
B) 2,000 cubic yards
C) 2,400 cubic yards
D) 4,000 cubic yards

**5. How long should you wait to place the top lift when plugging soft areas with asphalt?**

A) 8 hours
B) 12 hours
C) 24 hours
D) 36 hours

**6. What is the best equipment choice for removing unsuitable soil in a thin bridged area?**

A) Hoe and small dump trucks
B) Cat 613 scraper
C) Grader
D) Dozer

**7. What is the main reason for using filter fabric?**

A) Stabilize mud
B) Keep mud from penetrating the aggregate
C) Keep water from penetrating the aggregate
D) Eliminate trimming

**8. Which of the following will *not* help stabilize an unsuitable subgrade?**

A) Cement
B) Filter fabric
C) Lime
D) Rolling

**9. Which type of utility line is less likely to break in unsuitable areas?**

A) Telephone ducts
B) Steel water mains
C) Plastic or steel gas mains
D) Clay sewer lines

**10. How much sand or light gravel backfill do most utility agencies require you to place around excavated utility lines?**

A) 4 to 6 inches
B) 6 to 12 inches
C) 12 to 18 inches
D) 18 to 24 inches

# COMPACTION

# 16

Good compaction requires more experience than any other type of excavation work. It's difficult because there are so many types of soil, each needing a different compaction technique. It's your job to learn what each soil type requires for proper compaction. For example, sandy soil needs much more water than heavy clay before it reaches maximum density.

Water acts as a lubricant and helps the particles of soil slide into place. If too much water is added, the particles of soil tend to float, lowering the soil density. Conversely, if the soil is too dry, the particles won't slide into the small voids, also reducing the density. If the soil doesn't contain the correct amount of water, it won't pass compaction testing regardless of how much you roll it. If soil fails the test because it's too wet, it can be rolled again after it dries a little. It'll probably pass then. If the soil didn't pass because it was too dry, you'll have to rip it up again, add more water, and reroll it. A fill that's mostly ripped rock or cobbles can't be tested accurately.

With experience, you'll be able to look at a particular soil and know whether or not it has enough water to compact well. Grab a handful of soil and squeeze it. That's a quick and easy test of the soil's moisture content. Soil that crumbles when you open your hand is too dry. If it holds solid, it should be good. If you can squeeze moisture out of the soil, or if it feels sticky, it's too wet.

This chapter highlights the various methods you can use to achieve the required compaction for earth fills, aggregate and subgrade. There are many opinions about which type of equipment to use for the best compaction. Since there's a wide variety of compaction equipment to choose from, we'll look at some of the options and suggest the type and size to use. Most contractors agree, however, that good compaction is the result of controlling the amount of compaction effort, along with water, used on each layer before it's covered with another layer. We'll also look at some common problems that occur when your work requires compaction testing.

## Compaction Testing

The amount of compaction is a measure of the density of the soil. The more dense the soil, the greater the load it will support. Most roads and buildings are designed on the assumption that the soil has a certain density or load-bearing capacity. The job specifications usually require the excavation contractor to compact the soil to the density specified by a soils engineer. Soil tests will confirm if the soil has been compacted adequately, and whether it'll support the planned road or building.

The two most common types of compaction tests are *nuclear* and *sand cone*. While sand cone tests haven't been in general use for about 20 years, some testing firms say the sand cone method is still the more accurate of the two. We'll cover it here in case it's still used in your area. However, the nuclear test has generally replaced the sand cone test because it's much faster.

### *Sand Cone Test*

To perform a sand cone test, the soils engineer will dig a round hole with a volume of $^1/_{10}$ of a cubic foot. He'll weigh the dirt extracted from the hole. Then he'll pour sand from a cylinder of sand with a known weight into the hole until the hole is full. The remaining sand is weighed

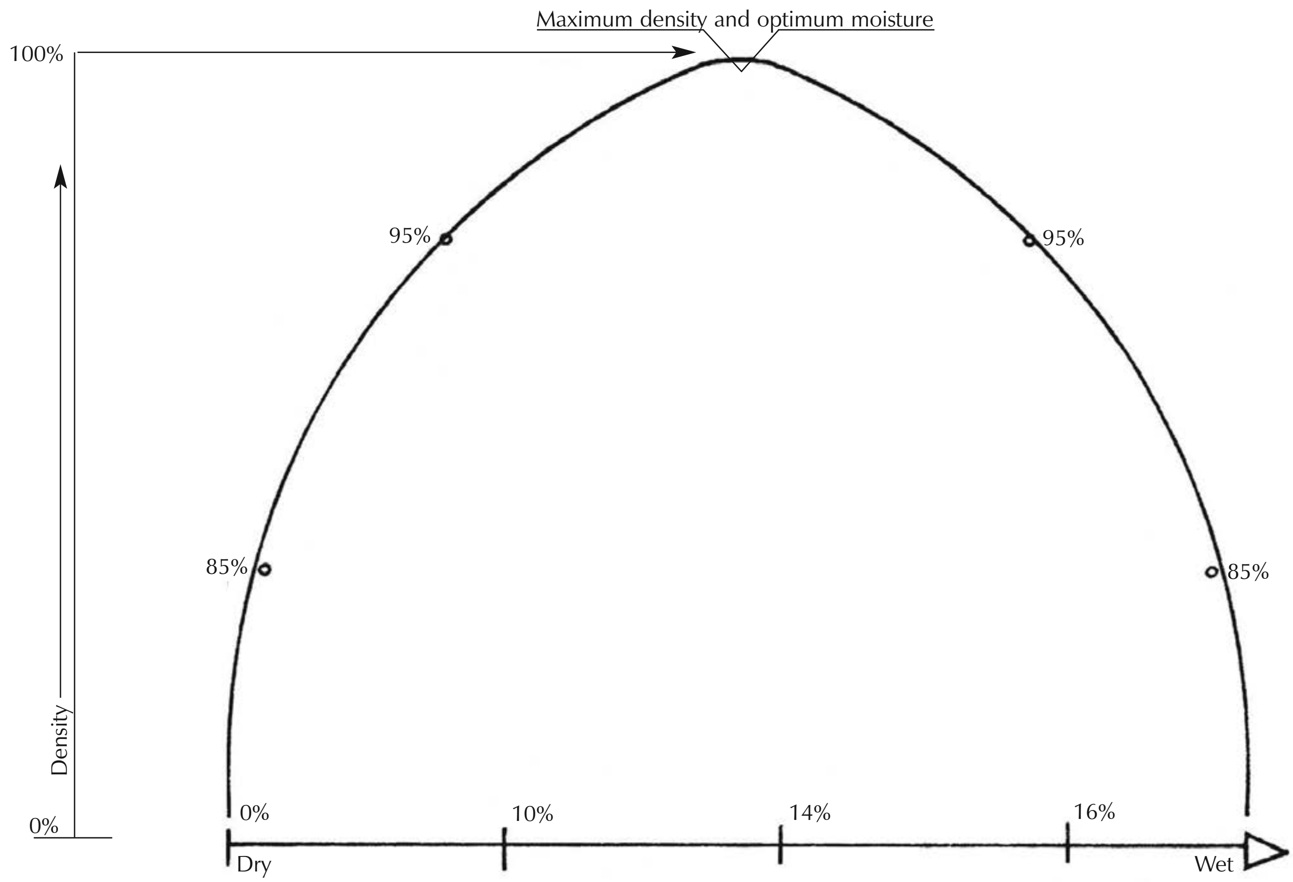



***Figure 16-1*** *Moisture-density curve*

to determine how much sand was poured into the hole. That gives him the precise volume of the hole. He'll seal the soil removed from the hole so it won't lose moisture, and take it to a soil-testing laboratory. There it'll be dried and weighed again to determine how much of its weight was water. An additional sample of soil from the same spot is taken to the lab so they can plot a moisture-density curve for the soil.

The lab will add known amounts of water to samples of dry soil. Then they'll place the soil in a tube, tamp it a given number of times, and weigh it. Each time a sample with a given moisture content is tamped down, a certain soil density will result. The percentage of moisture and density is plotted as a point on a graph, as shown in Figure 16-1. Adding water to the dry soil and compacting it increases the density until it reaches an optimum density at a certain percentage of moisture. After several samples are plotted, they're connected with a curving line. That's the

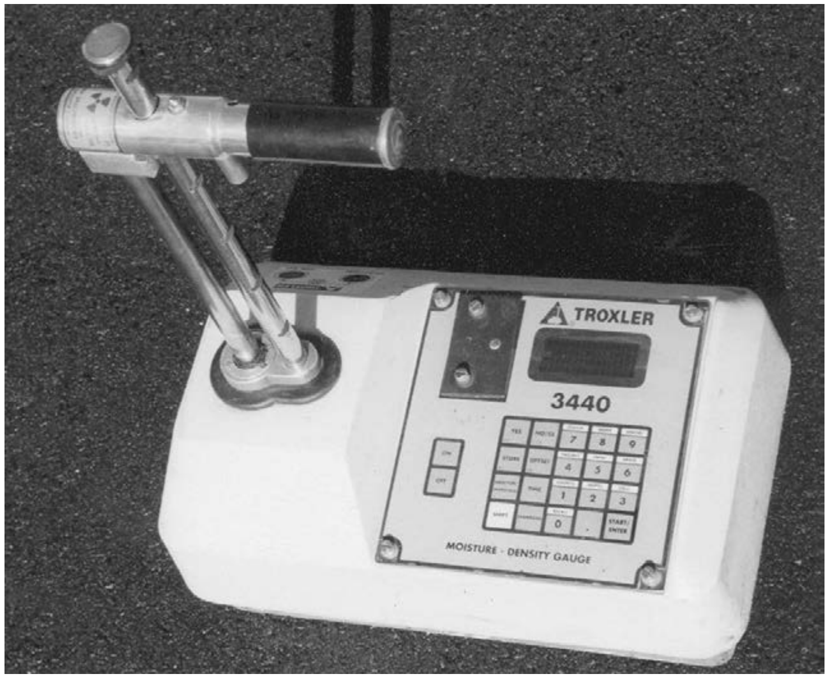



***Figure 16-2*** *Nuclear density tester on smooth surface with testing rods up*

moisture-density curve. The best moisture level is the volume of water the soil sample contains at the highest point on the curve. This is called the point of *maximum density and optimum moisture*, and is considered 100 percent, or optimum compaction. You may see it called 100 percent AASHO (American Association of State Highway Officials).

If the lab sample maximum weight is 150 pounds at maximum density, and the field sample weight was 145 pounds, then the test result would show 96 percent compaction. (150 pounds divided into the 145 pounds field weight, rounded down to the next whole number, equals .96 or 96 percent.) In an area of dense soil, it's possible to get a test result of 100 percent. You could even get a compaction test result over 100 percent if you're working in soil with good aggregate material.

## *Nuclear Testing*

There are two ways to take a nuclear test. With the first method, you simply set the tester on a smooth surface and read the instrument. Figure 16-2 shows this method, called a *back-scatter test*. Notice that the rod arm


***Figure 16-3*** *Rod inserted into soil for below-surface nuclear density test*

on the instrument is up. The second type of test requires that you drill a 1-inch hole slightly deeper than the section being tested, and stick the test rod attached to the instrument into the hole. In Figure 16-3, you can see that the test rod handle is in the down position, extended into the soil being tested. The devices shown in Figures 16-2 and 16-3 can both be used either way, with the rods up or down.

During the tests, nuclear impulses are sent into the soil or aggregate base. A gauge on the tester records the impulses reflected by the soil and returned to the machine. The better the soil is compacted, the fewer impulses are received and the lower the reading on the gauge. In tightly-compressed soil, fewer nuclear pulses return to be counted.

In less than five minutes, the nuclear gauge will display the numbers the technician needs to compute density and moisture content. For example, if the soil is compacted to 95 percent, the reading might be 22,000. If the soil is compacted to 90 percent, you might get a reading of 26,000. Lab personnel know the density of the material from the reading. They have a chart that gives the particular characteristics of that nuclear gauge tester based on controlled readings of a material of known density, such as a plastic block. The soils tester working in the field usually carries a polyurethane block to check his gauge in the field. A nuclear tester should be checked occasionally to be sure it's operating properly.

The soil technician gets a sample of soil at each nuclear test location, takes them to the lab and mixes them together. The lab can use the soil to create a moisture-density curve like the one in the sand cone test. From this curve, the lab establishes the weight of that soil at its maximum density. Once the maximum density weight is known, the lab can then determine what the nuclear gauge reading should be at the density required by the specifications.

## Meeting Embankment Compaction Standards

Most embankment fills must be compacted to 90 percent. Generally 90 percent isn't difficult to get. On a large job, a greater depth of soil may be put down at one time than the compactor can compact. However, the soil may still pass the density test if the spread was done correctly. Have the scrapers hauling the fill run over the fill they dumped on the previous pass so each run helps compact the fill. Even the water truck can do some compacting. Anything running on the fill adds to the compaction. That's why it's much easier to get good compaction in a large fill area than in a small confined area. For example, assume an area 200 feet long and 30 feet wide can receive 3,500 cubic yards of compacted fill during one shift. An area 800 feet long and 300 feet wide could easily receive 7,500 cubic yards of fill using the same compactor, if you use the scrapers and other equipment running through the area to compact as well. That will give the compactor operator more time to spend compacting areas out of the traffic pattern, thus cutting the total compaction time.

When a compaction test is taken in a fill before it reaches grade, the area where the test is to be taken should be cut down about 8 inches with a grader or compactor. This will give the person doing the test a smooth, firm area for the test. This is important, because any fill above that level will not be totally compacted yet.

Some expansive clay soils may just need 86 percent compaction, using only a disc and dozer. This is usually when the soils engineer requires a high optimum moisture content.

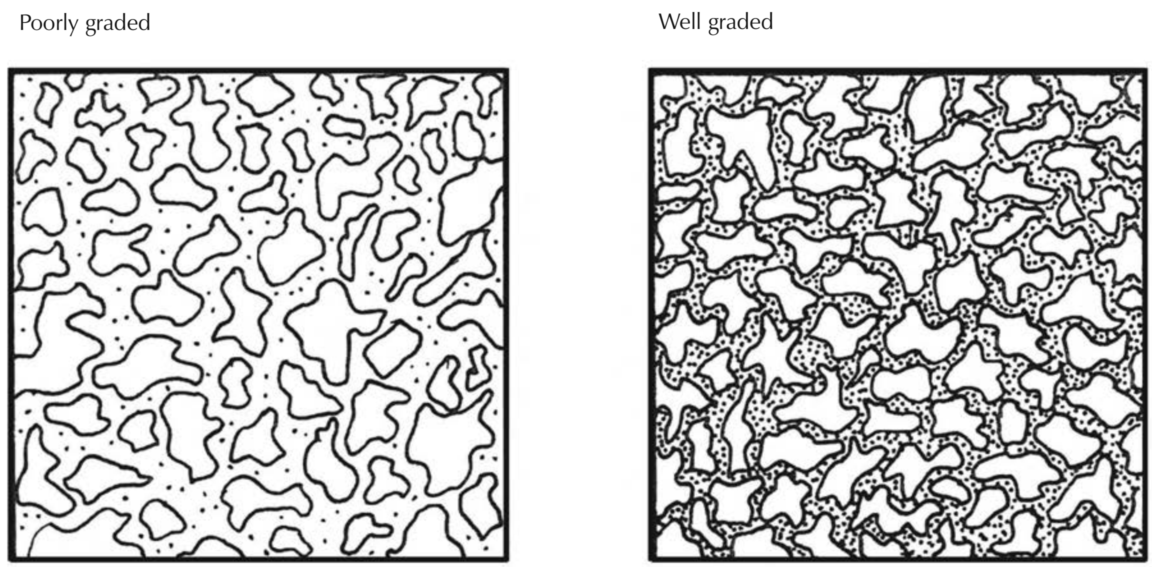



***Figure 16-4*** *Material gradation*

## Meeting Subgrade Compaction Standards

You'll have more trouble with density tests during subgrade preparation than embankment fills because the standard is usually 95 percent density. It's much more difficult to get 95 percent than 90 percent. For 95 percent compaction, the soil must be mixed very well. If there are several types of soil in the same fill, as is usually the case, it takes even more work to get the proper compaction.

For example, the same fill might have hardpan chips, clay, and sand combined. A few chips of hardpan or a small sand pocket at the point tested can cause the soil to fail. If you're working in a combination of these materials, mix them thoroughly. All the chips of hardpan and sand layers must be mixed with the clay, and the hardpan chips must be crushed. Figure 16-4 shows how a well-graded soil mixture will look with all the voids filled.

Clay and sand together is a bad combination for compacting because clay needs only a little water and sand requires a great deal of water. It's difficult to get the two mixed together without getting too much water in the clay (causing it to pump) or not enough water in the sand. You may need a tractor pulling a disc to get the correct mixture.

For 95 percent compaction, the water content must be just right. If you notice any movement in the soil while compacting, you've added too much water. Going over optimum moisture by a few percent may still pass a 90 percent compaction test. But that 95 percent requirement gives you a narrower leeway. You might not pass a 95 percent test until the excess moisture dries out.

What does it take to consistently pass compaction tests at 95 percent? The correct compaction equipment and enough experience to be able to achieve a good soil mixture with the right amount of water added. However, sometimes even experience isn't enough — you may have to call on the services of a soils engineer to help you get the job done.

Recently, while widening a section of interstate highway, we encountered a one-mile stretch of very light-colored silty material that just wouldn't compact to 95 percent. After several attempts of mixing and rolling, and several meetings with the soils engineer and the state job engineer, everyone agreed that this soil could not be compacted to 95 percent under normal field conditions. The state engineer wrote an extra work order to lime-treat the entire area 10 inches deep. That did the trick. Don't hesitate to ask for help. No matter how much experience you may have, there's always something you can run into that you've never seen before or will ever see again.

Always supervise your crews carefully any time they're compacting soil. That's the only way for them to learn and benefit from your experience.

The top 6 inches of subgrade for the road surface, aggregate grade and asphalt usually requires 95 percent compaction. Fill around some structures also requires 95 percent compaction. Most earth fills for roads, subdivision lots and commercial projects require 90 percent compaction.

## *Problem Aggregates*

A vibratory roller is excellent for compacting nearly any aggregate in up to 6-inch layers. In most cases, aggregate base material or road rock is easy to compact. However, you may have a problem with aggregate material that doesn't have enough sand or rock dust in it. Aggregate that contains less than 6 percent of particles passing a number 200 sieve is considered very "clean." It probably has too much washed rock and not enough crushed rock to bind well. When this is the case, saturate the aggregate with water and roll it vigorously to reach 95 percent compaction.

With some aggregates, the subgrade or base will be so soft after achieving 95 percent that you'll have to leave it idle to dry out before it can be paved. This may not seem logical, but it can be perfectly acceptable from a soils engineering standpoint.

When you're trying to compact soil or aggregate material to 95 percent, avoid putting down more than 6 inches on any one lift. Sometimes, you'll have to compact layers only 3 inches deep to achieve 95 percent. If you do this, be sure the bottom layer isn't softer than the top, or the top layer, if dryer, will crumble when rolled repeatedly. You should use the same amount of moisture in every layer.

Use a pad-drum vibratory self-propelled roller or pad-wheeled compactor to roll the subgrade first on any large job. This ensures that there are no dry pockets and that the hardpan chips have been crushed to a size that allows easy mixing. Use a vibratory smooth-steel drum roller when you begin the fine trimming on most soils. In clay soils, a rubber-tired roller works better because clay won't stick to the rubber as much as it does to a steel-drum roller. However, a vibratory steel roller will get compaction much faster, so it should be your first choice — until clay sticking to the drum forces you to switch to a rubber-tired roller.

If the job is large enough for two rollers, it's not unusual for the contractor to use a pad-wheeled compactor dozing the aggregate windrow as it's dumped from the trucks. It will do the initial compacting, followed by a grader and a smooth-drum vibratory roller. This works well when several inches of aggregate are required. The trucks may have traction problems if you only use a pad-wheeled roller, though not so much with dirt as with aggregate. If your trucks have traction problems, the grader must go out ahead of the compactor and spread a thinner layer of aggregate.

On a large dirt fill, you should only use a pad-foot wheel compactor, never a smooth-drum vibratory roller or a pad-drum roller. You can add water to dry material and work it in with a pad-drum or pad-wheeled roller — they both have dozer blades for mixing — but I would only use a pad-drum roller on small fills. If you use a multi-tired pneumatic roller or smooth-drum vibratory steel roller on a very small job, mix the necessary moisture in the soil before rolling because these rollers will seal the surface. When you use a smooth-drum vibratory roller to finish dirt subgrade, the dirt must have the correct moisture and be bladed smooth so no bridging will occur. Very little water penetrates after the first pass over the soil. Aggregate, however, will still accept some water below the surface.

## *Ripping and Rolling Soils*

You'll need to rip some soils before compacting them. Ripping is needed to loosen the soil so you can mix water into it. The grader may need to rip several times to get moisture down the necessary 6 inches. The compactor should keep rolling while the grader is ripping. If the soil is very dry, the grader should roll the soil from side to side until the water penetrates. When compacting subgrade, ripping usually isn't necessary if moisture is already present in the soil on a new fill. Rolling alone should get the required compaction if you start with a pad-type roller and follow up with a vibratory steel-drum roller.

**Working in Hardpan —** One exception is undisturbed hardpan. Even though it's very hard, you'll have to rip it and recompact it to get a compaction density of 95 percent or more. If you've made a good compaction effort at the right moisture level but the tests still don't pass, check with the soils engineer taking the tests. He may not be using the current soil curve. What does that mean? The soils engineering firm usually computes the soil compaction curve from a sample taken at the beginning of the job. But as the job progresses, the soil composition may change, even though it looks the same. If the soils firm doesn't take another sample, the compaction test results could be wrong. If the tests begin to fail even though you're following the same procedure, ask the soils firm to take a new sample. The soil that's failing may now be a lighter weight than the sample they started with.

**Over-Rolling —** It's possible to over-roll some soils and aggregates. After three or four passes with a vibrating roller, the area being rolled may feel firm and look tight. If you keep rolling after that, it may cause separation of the top layer. If this starts to happen, turn off the vibrator and give the soil a shot of water. After the water has set, flat roll it with the vibrator off, and don't run the roller too fast. This should restore the firmness. Lack of moisture in the top layer will also cause the top layer to ravel and look over-rolled.

If you suspect over-rolling, dig up a small section of the top layer with a shovel and check the moisture content. If the soil seems moist, the problem may be too much rolling. If the soil is dry, add water and roll again. If most of the tests are good but a few are low even though the moisture's right, try rolling once more at a right angle to the first passes, if there's room. With vibrating steel-drum rollers, hard sections of soil can create a bridge, sheltering some areas from full compaction. The entire area under the drum may not get full roller pressure. Cross-rolling should eliminate this problem.


***Figure 16-5*** *Cat 825 compactor mixing and compacting fill*

## Selecting the Right Equipment

Selecting the right equipment is very important. The job size will determine the type and size of compaction equipment you'll use. If you're working on a large earth fill job where there are several types of soil, consider using a disc to fully mix the soil, followed by a pad-foot compactor. With other soil types, a large pad-wheeled compactor can doze, mix and compact at the same time (Figure 16-5). On smaller fills, you may only need a small compactor to mix and compact. For a small fill job of 1000 cubic yards or less, it isn't practical to bring in equipment to mix the soil. You can generally get by with just a grader and pad-drum vibrating roller with a small dozer blade. The grader can do some mixing as it levels the soil for rolling.

I don't recommend using a smooth-drum vibratory roller for building a fill. It can be done, but it's slow. The main problem is that the fill must first be graded very smooth. The smooth-drum roller has a tendency to bridge high spots, and with no pads to reach the low spots, the low areas don't get compacted quite as well as they should, which may cause compaction problems.

Here's something to remember. You can achieve 95 percent compaction using a small plate tamper, but you must place thinner layers. A small 2-ton vibratory sidewalk roller will compact aggregate to 95 percent as well as a large 12-ton roller — but will take much longer. The larger the equipment, the more cubic yards per hour you'll be able to compact. The important thing is to have equipment that fits the job so your work gets done quickly and efficiently.

### *Utilizing Equipment Efficiently*

When working on narrow fills, where either the water truck or compactor periodically holds up the scrapers, work more than one fill at a time if possible. Let's assume there are three narrow fills to make. Rip and water the first fill area so the original ground can be compacted. When that's done, have the scrapers start spreading a fill over the area. Then have the grader, water truck and compactor move to the second fill area and repeat the process. Once the second area is compacted, they'll move to the third fill site and start working there. When the original ground has been compacted at all three fill sites, the water truck and compactor will return to the first fill site after the scrapers place the first layer of fill, and begin watering and compacting that. The grader is no longer needed on the fill, so it can grade haul roads, outline cuts or start grading finished areas. The scrapers will spread a layer of fill over the second area, move on to the third, and then back to the first once each area has a layer of fill. The water truck and compactor will move to the second fill and then to the third and back to the first as they finish compacting in each area. By working this pattern in a narrow area, the scrapers and compaction crews aren't getting in each other's way . For this to work smoothly, however, the scraper operators must spread thin layers of fill each time, so the water can penetrate easily as the compactor works it.

When starting a project in an area where you've never worked, it's wise to talk to a soils engineering firm located in that area. They'll be happy to tell you about local soil characteristics, and having that information will help you plan your project — ultimately saving you time and money.

# CHAPTER 16 QUESTIONS

**1. What is the most important element for achieving good soil compaction?**

A) The weight of the compaction equipment
B) The type of drum used
C) The amount of mixing done
D) The amount of water used

**2. What does the amount of compaction actually measure?**

A) The water in the soil
B) The weight of the soil
C) The density of the soil
D) The volume of the soil

**3. Why has nuclear testing replaced sand cone testing?**

A) It's more accurate
B) It's faster
C) It tests much deeper
D) No compaction curve is needed

**4. How will a nuclear test gauge indicate tightly-compacted soil?**

A) A low reading on the gauge
B) A high reading on the gauge
C) The impulses will return almost instantly
D) There will be a delay as the impulses slow due to the compression in the soil

**5. What is the compaction requirement for most embankments?**

A) 80 percent
B) 85 percent
C) 90 percent
D) 95 percent

**6. Before taking a compaction test on an embankment fill in progress, the grader or compactor should cut down how many inches to a level spot for testing?**

A) 4 inches
B) 6 inches
C) 8 inches
D) 10 inches

**7. What are the compaction requirements for a road subgrade?**

A) 80 percent
B) 85 percent
C) 90 percent
D) 95 percent

**8. Which of the following materials compacts most readily to 95 percent?**

A) Aggregate
B) Clay
C) Hardpan
D) Sand

**9. What equipment should you use first to roll subgrade on a large job?**

A) A smooth-drum vibratory roller
B) A pad-drum vibratory roller
C) A disc
D) A rubber-tired roller

**10. What would be the last choice for rolling a large fill being built?**

A) A pad-drum vibratory roller
B) A pad-foot self-propelled roller
C) A sheepsfoot self-propelled roller
D) A smooth-drum vibratory roller

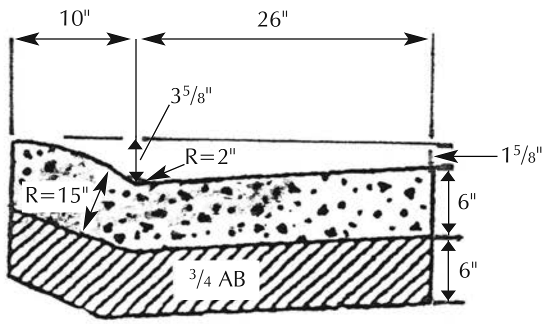
# Curb and Sidewalk Grading

# 17

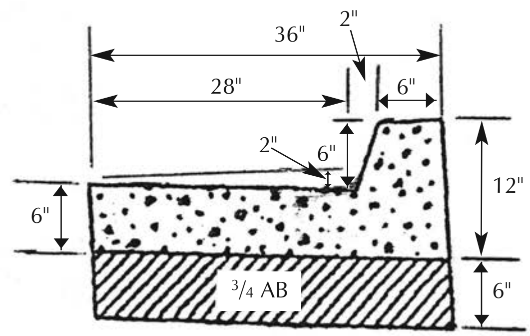
Curb designs vary greatly in different parts of the country. The curb from flow line to lip may tilt a little steeper in some areas, or the face might slope more or be higher in others. But whatever the design, the main purpose is to carry water to the nearest gutter drain. Figure 17-1 shows five types of curb you might encounter on plans. Type 1, Type 1-A and Type 2 are curbs you would likely see at the edge of a road. Types 3 and 5 are usually seen in parking lots around planters. As we talk about grading or pouring curbs in this chapter, you'll want to refer back to Figure 17-1 to see these curb types.

## Curb Stakes

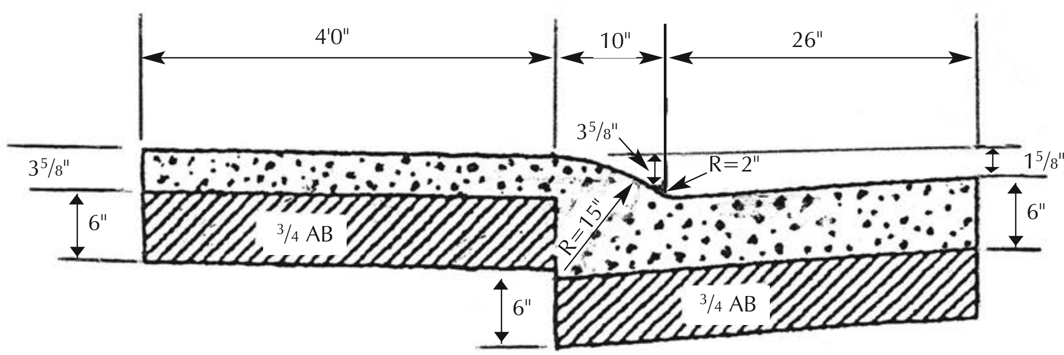
The surveyors must set all the grade stakes before you can begin work on the curb. There should be at least a 2-foot offset from each hub to the back of the curb or sidewalk for forming. The stations set by the surveyors



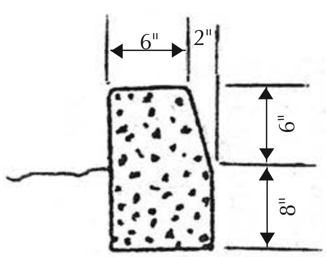

Type 1



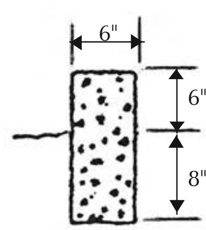

Type 2




Type 1-A and typical sidewalk




Type 5




Type 3

***Figure 17-1*** *Curb types*

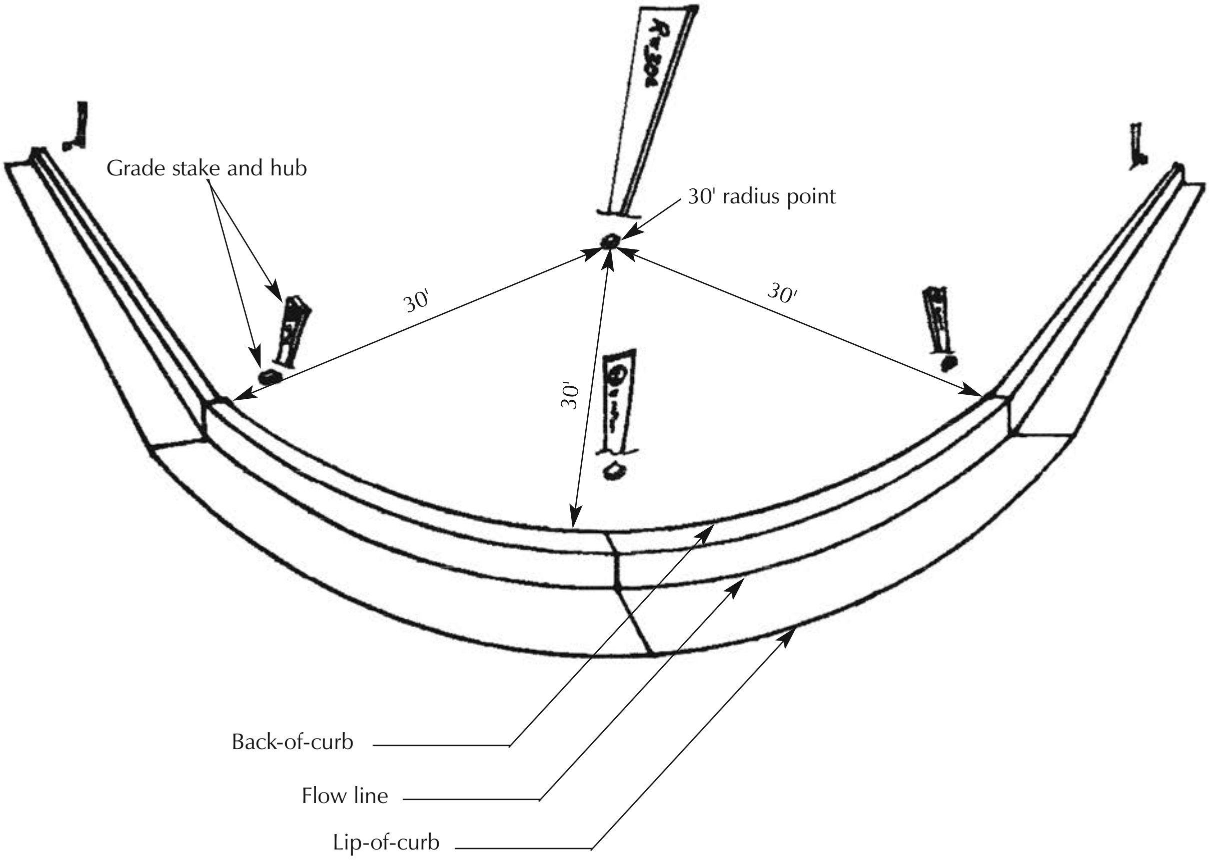



***Figure 17-2*** *Radius point staking*

should be no more than 50 feet apart. All the gutter drains and summits (the highest point on the road or street cross section) should be indicated on the stakes. Water flows from the summit, in two directions, to low areas where the gutter drains are located. Parking lots generally have many summits running in various directions. For that reason, it's not unusual for parking lot curbs to be within 5 feet of each other, or for curb grades to be marked on each side of a stake for curbs on each side of an island.

The surveyors will place grade stakes at all the corners. There should be a grade stake at the beginning and the end of the radius, as well as one or more stakes between those two points, depending on the size of the radius. There should be a radius point away from the corner so you can use a tape measure to check the distance to the curb or walk at any point along the radius. Figure 17-2 shows a properly-staked curb at a corner with a 30-foot radius.

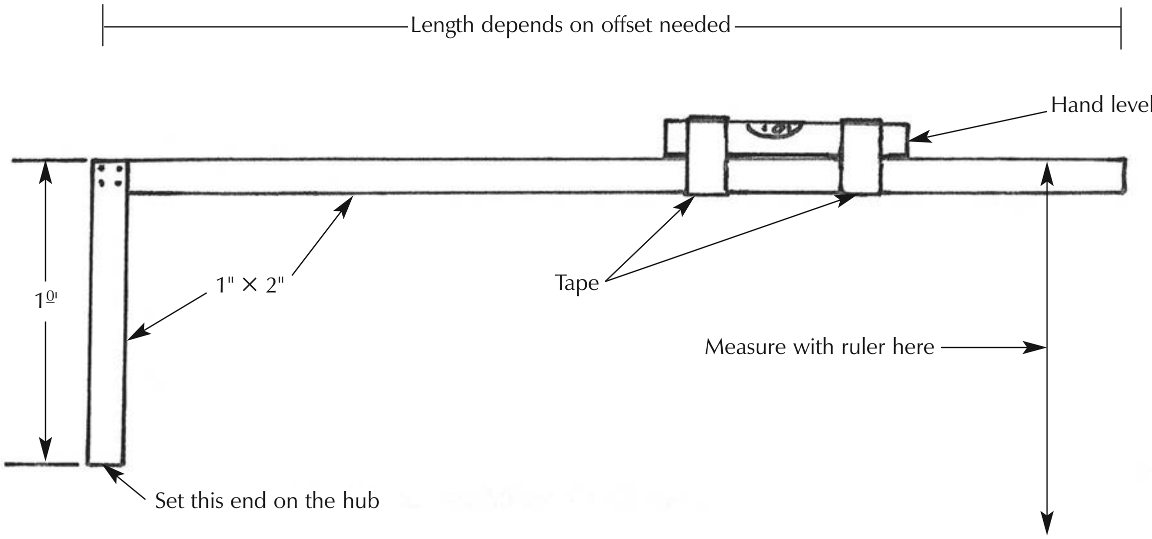



***Figure 17-3*** *Straightedge with 1-foot vertical extension*

## *Checking Grade*

Let's assume we're cutting grade for a Type 5 curb in a parking lot and the grader doesn't have sonar. The grade setter should check the curb grade with a straightedge and a hand level if the string line is up for the curb machine. The straightedge method is slightly faster than shooting with an eye level. If you use an eye level to check grade, you must first set boots at each surveyor's hub if no string line has been set. (Refer back to Chapter 3 for information on setting boots.) The straightedge should have a 1-foot or longer vertical extension on one end if you're checking grade from a hub. A small level should be taped to the other end of the straightedge, about 1 foot short of the offset that the surveyor has set. (See the example in Figure 17-3.) The length of the straightedge you need depends on the offset needed. If the area in front of the grade stake is rough, have the grader make a pass along the front of the stake line to smooth off the area so nothing will interfere with your straightedge. Once the grader makes a rough pass, start the first cut. The grade setter will keep setting the 1-foot extension on his straightedge on the hub, and checking the ground level against the grade given for the curb by the surveyors (and remembering to add 1 foot because of the 1-foot extension on his straightedge). Or, if he's using an eye level, he'll shoot the grade back to his boot. The grader will continue making passes until the soil or aggregate is at the correct level. Since the Type 5 curb is level at the bottom, the grader operator should hold the blade as level as possible.

When checking grade from a string line, you can use a 4-foot carpenter's level in place of the 1- × 2-inch wood straightedge. If a 3-foot boot is set at each station, all you need to do is add the distance from top-of-curb to subgrade to shoot grade with an eye level. (Again, refer back to Chapter 3 for more information on checking grade with an eye level.)

Let's say that the first stake set by the surveyors reads *(2) TBC C-1º*. This means that the hub is offset 2 feet from the top-back-of-curb and the top back of the curb is 1 foot below the level of his hub. The grade setter measures out 2 feet from the hub and down 3.17 feet from the top of the straightedge to the ground level. The 3.17-foot grade allows for the 1-foot vertical extension on the straightedge and the 1-foot cut to top of curb, plus the 1.17-foot curb depth to subgrade. If you look back at Figure 17-1, you'll see that a Type 5 curb is 14 inches from the top to the bottom of the curb. That equals 1.17 feet. Any inches shown on the detail drawings or plans must be converted to tenths and hundredths of a foot, because that's what the engineers use. Remember also that the surveyors always indicate the finished curb level at the top back edge. The flow line of the curb is usually given only for "V" gutters. When cutting sidewalk or curb grade, my suggestion is to undercut slightly (3 to 5 hundredths of a foot) when forming, and leave a slight trim of 0.03 or 0.05 foot for the machine.

## Cutting Curb Grade

The grade setter establishes the grade 2 feet out from the hub, but the grader operator will cut to within 1 foot of the hub. This allows 1 foot of working room for the forming crew or the concrete machine. The grade setter holds the end of his ruler on the spot and signals to the grader operator the amount of cut or fill remaining at that station. He repeats this method at each station until the required grade has been cut. For a Type 5 barrier curb that's only 0.67 foot (8 inches) wide, once the back of the curb grade is cut, there's no need to check the front of curb grade. For such a short distance, the grade shouldn't be off enough to waste time on, unless the grader operator fails to keep the blade fairly level and you see an obvious grade change.

This isn't the case when cutting a wider curb. When you use a concrete machine for a Type 2 or Type 1-A curb, the surveyors must set a 3-foot offset to back-of-curb. This allows room for the men and machine to work


***Figure 17-4*** *Offset provides room for curb machine and crew*

properly. In Figure 17-4 you can see the working clearance provided by the 3-foot offset. When grading for a Type 2 curb like the one shown in Figure 17-1, you'll need to cut another 0.50 for the 6 inches of aggregate required under the curb. The front lip of this curb is 28 inches out and 2 inches higher than the flow line at lip-of-curb. The grade setter has some calculating to do. He must find the rise from the back-of-curb subgrade to lip-of-curb subgrade. The 28 inches from the face-of-curb to the lip equals 2.33 feet. The 2-inch depth at the flow line equals 0.17 foot. The grade setter will divide 0.17 by 2.33 to find the percentage of slope, which is 7 percent. If you multiply 2.33 by 7 percent (0.07), you get a slope of 0.1631 foot. That's within $^1/_{16}$ inch of 2 inches (0.17 foot). We now know the curb rises 7 percent, or 0.1631 foot, from face-of-curb to lip.

Because there are no grade breaks from the back-of-curb to lip, we know the bottom of the curb also slopes 7 percent from back to lip. The Type 2 curb in Figure 17-1 has a width of 36 inches, or 3.00 feet. The grade setter multiplies 3.00 feet by 7 percent to find the grade at the lip, which is 0.21 higher than the back-of-curb subgrade. He'll subtract 0.21 from the ruler reading at back-of-curb to get the right grade at the lip, and tell the grader operator to cut the slope to 7 percent. If the grader has slope control, the grader operator can dial in 7 percent as he cuts the back-of-curb grade, and the lip grade will be cut as well. Even without slope control, the front edge should be very close to grade already, if the grader operator is experienced enough to hold a slight sloping angle while cutting the back grade. He must be very careful not to undercut the curb grade. It would be better for him to cut too little than too much, because it takes more time to fill and recompact than to make a second pass.

If you're placing forms, a windrow of dirt should be bladed up close to the front lip of the curb. If no aggregate is called for, the curb crew can use this loose material for regrading or backing the forms after they've been set. If aggregate is called for, then a small windrow of aggregate should be left. On Type 1, 1A or 2 curbs, I recommend a 0.03 to 0.08 undercut when forms are to be set. It's much easier for the forming crew to add fill after the forms are in, than to hand-cut to place the forms.

## *Trimming Curb Grade*

Again, when cutting curb grade for a concrete machine, leave the grade high so the machine will have a slight trim to make. This is true whether the subgrade is dirt or aggregate. You must leave a slight trim because the concrete machine can't make fills or compact the grade. It only trims and pours the concrete through a mold. If the grade is left low, it will fill the undercut with concrete, which would be an expensive waste of concrete.

Every crew trims the curb grade a little different. Here's the method I use when the sidewalk and curb are attached. It works well for me. Leave the sidewalk grade 0.03 to 0.05 high. After the sidewalk grade is trimmed, make the vertical cut at the back-of-curb right on line and grade. This will leave the curb flow line on grade. Cut from there to the lip, and cut the lip grade 0.05 high for trim. If it's a 3-foot-wide curb only, cut the grade 0.03 to 0.08 high. The concrete machine can handle the extra trim with no problem on a 3-foot curb when no sidewalk is attached. If aggregate isn't required under the curb, be sure to rip and compact any hardpan under the sidewalk and curb. Even though the machine will trim 0.05 of hardpan, it will cause the machine to rise up slightly, causing a hump in the grade and concrete. When aggregate is required under the sidewalk and curb, or just under the curb, compact and trim the sidewalk, curb and street grade at the same time.

If the grader is equipped with slope control and sonar, set the string line the concrete machine will use first, then the grader and concrete machine will work off the same string line. If the grader doesn't have the automatic equipment, it's still wise to set the string first so the grade setter can use it to check the grade between stations, as shown in Figure 17-5.

***Figure 17-5*** *Grade setter checking grade between stations*

# Cutting a Type 1 Curb

Notice in Figure 17-1 that Type 1-A and Type 2 curbs are flat bottom curbs. These are much easier to cut than a Type 1 curb, which has a small slope that must be cut. When cutting a Type 1 curb for a concrete machine, the first cut is made to the top grade at the back-of-curb subgrade. Remember, the grader must still cut 1 foot beyond the back-of-curb to give the concrete machine or forming crew room to work. The Type 1 curb is 6 inches thick, as are Types 2 and 1-A, so the grade setter must add 0.50 to the surveyor's cut shown on the grade stake. He must also add 1 foot for the 1-foot vertical extension on the straightedge he's using. Once the top-back-curb grade is cut, the grade setter should mark a line 10 inches in from back-of-curb every 30 feet, so the grader operator knows where to make the second cut. The grade setter must figure the cut and percent of slope to cut. The Type 1 curb in Figure 17-1 shows the top of curb to be $3^5/_8$ inches higher than the flow line of the curb. $3^5/_8$ inches converts to 0.30 foot. That's what the grade setter must add to his figures for the flow-line cut.

Now he must compute the grade for lip-of-curb. Looking at the Type 1 curb drawing again, notice the lip-of-curb is $1^5/_8$ inches lower than top-of-curb. Subtract $1^5/_8$ inches from $3^5/_8$ inches and you have a difference of 2 inches, or 0.17 foot. The lip is 0.17 foot higher than the flow-line grade. The grade setter will subtract 0.17 from his flow line figures to get the lip grade he needs. Because the Type 1 curb shows 6 inches of aggregate under the curb, the grade setter must add another 0.50 foot to his three calculations for back-of-curb, flow line and lip-of-curb. By doing this, he'll cut subgrade for the aggregate.

If the grader has slope control, he also needs the percentage of slope from flow line to the lip-of-curb so the grader operator can dial it in. The grade setter already knows the lip-of-curb is 0.17 foot higher than flow line, so to compute the percentage of slope, all he needs is the distance from flow line to the lip. We can see from the drawing that it's 26 inches, or 2.17 feet. He'll divide 0.17 by 2.17 to get the percentage of slope, which is 8 percent. 8 percent of 2.17 is 0.1736 foot — just a little more than 2 inches. The grade setter will tell the grader operator to dial in 8 percent for the slope. Once the grader makes a few passes and has the flow line and lip on grade, he still has to make a vertical cut at flow line below the back-of-curb grade. The Type 1 curb subgrade also shows a slope from top-of-curb to flow line. If a curb machine is pouring the curb, it will trim that amount in the short 10-inch section shown in the drawing. Be sure the back-of-curb, flow line and lip are cut *on grade* and not left high.

When trimming for a Type 1 curb subgrade that'll have aggregate placed on it, or will be formed and hand-graded, you should use a curb shoe to cut the back slope. Figure 17-6 shows how the slope on a Type 1 curb is trimmed using a curb shoe. The curb shoe, made from a 5/8-inch steel plate, is bolted to the cutting edge of the grader blade. The bottom of the shoe is shaped to match the slope needed, and trims the slope neatly. I've seen a grader operator take the tip of the blade and make several passes until he gets a slope, but this method is too slow for a large job. Sometimes companies have a small backhoe trim the slope, but again, this is an expensive method. The curb shoe is the best and least-expensive method to use. Remember, always undercut slightly when using forms, and leave a slight trim when a machine will pour. If placing aggregate on the curb grade, your trimming should be cut plus or minus 0.05 before the aggregate is placed.

The grade setter must always figure in the section of aggregate required under the curb, adding it to his cut. If the grades are all cuts, and you're adding a 0.50 undercut, you must recompute the undercut if you run into a section of stakes with fills. For example, if you have a 1.10 cut with the 0.50 undercut, the grade you're cutting is 1.60 below the surveyor's hub. If the grade stake reads *Fill 1.10*, you must subtract the 0.50 undercut from the fill. This leaves a 0.60 fill above the surveyor's

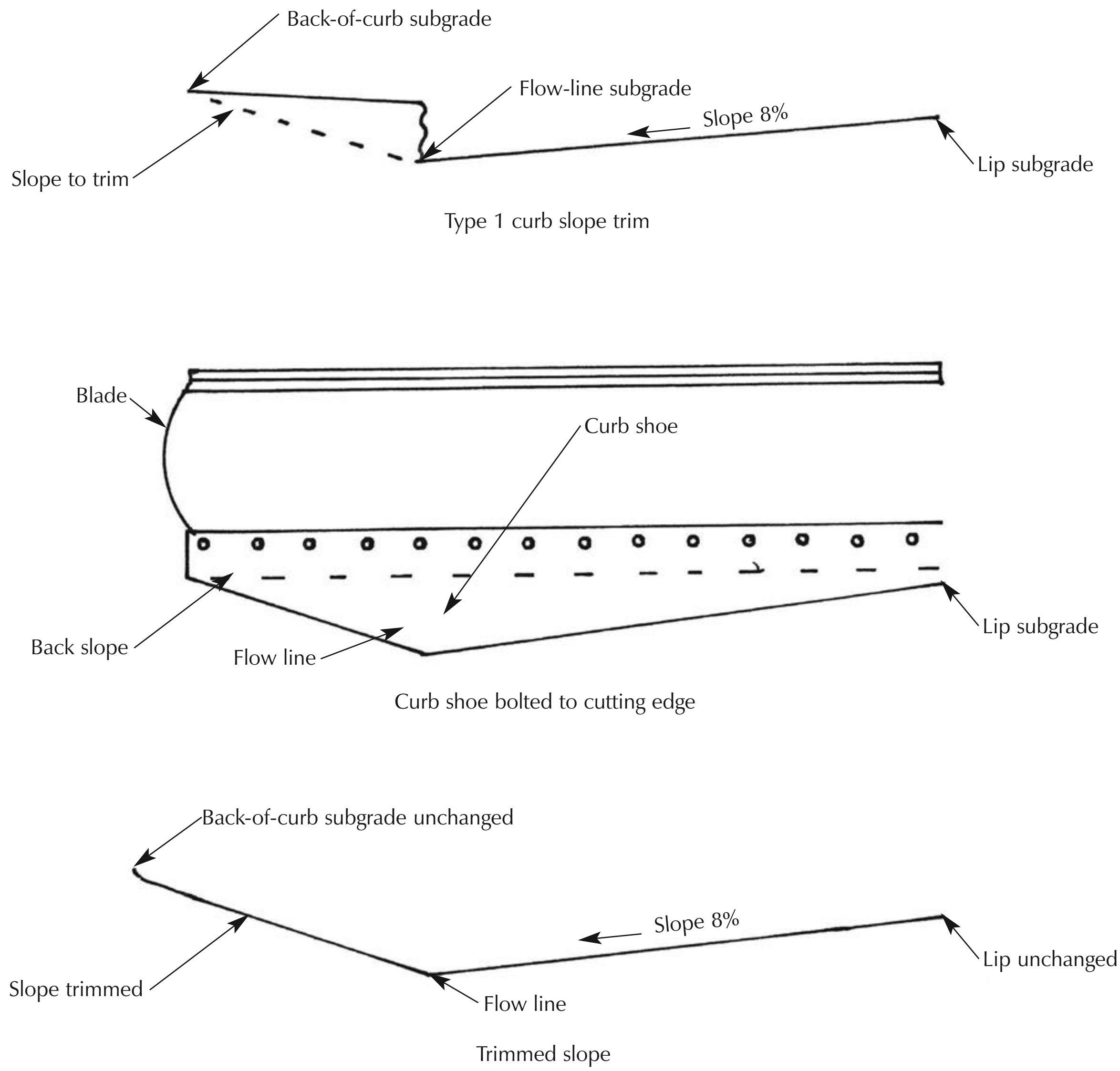



***Figure 17-6*** *Type 1 curb slope trimmed with a curb shoe*

hub. If the surveyor's stake shows *Fill 0.30*, when you subtract the 0.50 undercut, it becomes a 0.20 cut to the subgrade. The grade setter must have a good knowledge of the cuts and fills and be able to figure in the undercut needed to cut to the correct subgrade. Not all workers are good grade setters. It takes a person with good math skills who can visualize what the finished work will look like. Chapter 3 covered grade setting in more detail.

# CHAPTER 17 QUESTIONS

**1. What must the grade setter do before he can check grade with an eye level?**

A) Set a string line
B) Set boots
C) Offset the grades 2 feet
D) Set a swede at flow line

**2. How much offset is needed when a barrier curb is staked for forming?**

A) 1 foot
B) 2 feet
C) 3 feet
D) 4 feet

**3. What is the minimum the grader should cut behind the curb?**

A) 0.35 foot
B) 0.50 foot
C) 0.75 foot
D) 1.00 foot

**4. How much offset is needed when a concrete machine is used for a Type 2 or Type1-A curb?**

A) 1 foot
B) 2 feet
C) 3 feet
D) 4 feet

5. **If the curb is 3.00 feet wide and the slope is 7 percent, what is the rise?**

   A) 0.17
   B) 0.18
   C) 0.20
   D) 0.21

6. **What happens if the concrete machine pours over an undercut subgrade?**

   A) It will fill the undercut with concrete
   B) The concrete will crack
   C) The concrete will sag
   D) The concrete machine will not hold on the string line

7. **How should the sidewalk grade be left when using a concrete machine?**

   A) 0.03 to 0.05 low
   B) 0.03 to 0.05 high
   C) 0.05 to 0.08 high
   D) 0.08 to 0.10 high

8. **How should the grade be left if the concrete machine is cutting a 3-foot-wide curb only?**

   A) 0.03 to 0.08 low
   B) 0.08 to 0.015 low
   C) 0.03 to 0.08 high
   D) 0.08 to 0.15 high

9. **What is the slope if the grade is 8 percent in 2.17 feet?**

   A) 0.1227
   B) 0.1340
   C) 0.1736
   D) 0.1825

10. **If you're adding a 0.50 undercut to all the surveyor's cuts and one stake has a fill of 0.30, what would be the correct distance above or below the surveyor's hub?**

    A) 0.20 below
    B) 0.60 below
    C) 0.20 above
    D) 0.60 above

# PREPARING SUBGRADE FOR AGGREGATE

# 18

In this chapter we'll look at trimming subgrade on a subdivision road job or highway work. The subgrade and curb grade can be trimmed at the same time to cut costs, if a curb machine is used. This is covered in Chapter 9 under *Fine Trimming the Subgrade,* starting on page 177.

Our first item of work, whether we're dealing with a highway or subdivision streets, is to locate and tie out all the utilities under the subgrade, such as manholes, water valves, cleanouts and any other objects that must be raised after the road is paved. You must check their depth, so when the subgrade is ripped for compaction, they won't be hit. If there are any that are too high to rip over, leave them exposed until the ripping is finished. We discussed the best methods for tying out utilities in the roadway under *Preparing the Work Area,* in Chapter 12 (page 221).

# Rough Trimming a Subdivision Street Subgrade

Let’s assume we've tied out all the utilities and are ready to start rough-trimming subgrade on a subdivision road with curbs poured down both sides. The grade setter will check the grade along the curb, letting the grader operator know how deep the road section is and how much cut is needed. At this time, the grade should be left 0.05 to 0.10 high because there’ll be some shrinkage when it’s compacted.

The grader will start generating dirt, so you’ll need a paddle scraper and water truck to work with him. A laborer should be available to help the grade setter, if needed, and to clean the curbs. The water truck will spray to control the dust, and also to supply moisture to the road subgrade for compaction. If the scraper dumps the excess dirt on lots that are being filled, the water truck must supply water to the lots for compaction. If the excess is dumped in a waste area, the water truck is still needed for dust control.

When the grade along the curb gets close to being *on grade* and the scraper has picked up most of the excess dirt, the grade setter will start checking the centerline grade. To do this for rough subgrade, he sets a swede on the curb lip and shoots back to it from the centerline. Then he either paints the cut or fill needed on the ground, or sets a crows foot. If the grader is equipped with slope control, the operator should be able to carry the grade he’s cut along the curb to the centerline very easily by dialing in the slope needed. Once the foreman feels the grade is close enough to begin compacting, he’ll have the grader operator start ripping the road from curb to curb (or from shoulder to shoulder on a road job). As the grader rips, the water truck follows, spraying water. A vibratory pad-drum roller or pad-foot compactor follows the water truck.

Even though the subgrade will be ripped again, possibly several times, the compactor will keep rolling to help the water penetrate and improve the mix. The number of times you'll have to rip the subgrade depends on the dryness of the soil. In extremely dry soil, it may be necessary for the grader to blade the soil over several times. If the soil is moist 6 inches down, ripping may not be needed at all. You might get by with only rolling during the grading. The subgrade must be compacted to 95 percent a minimum of 6 inches deep, in order to support the section of a subdivision road or highway. Be sure you always check the specifications — some jobs may call for more than 6 inches at 95 percent compaction.

***Figure 18-1*** *Scraper with slobber bits to contain material*

## Fine Trimming the Subgrade

The foreman will decide to start trimming the subgrade when it has the right moisture content 6 inches deep (or more) and it's been rolled enough. If the pads on the compaction equipment only slightly penetrate the soil, or they're *riding high*, as they say, the compaction should be good.

For fine trimming, you'll need to exchange the pad-type compactor for a smooth-drum vibratory roller. You'll also need a paddle-wheel scraper and a water truck. Have a laborer on hand for cleaning curbs, shoveling edges, spotting hubs for the grader, or helping the grade setter. It's important that the grader have a good cutting edge with no worn ends. The water truck should be set up so that it covers the grade with a fine, even spray, and the paddle-wheel scraper should have extended slobber bits to aid in picking up small windrows without losing material out the sides. Figure 18-1 shows a scraper set up for fine trimming.

There are three different ways the grade setter can mark the fine trim:

- If the grader isn't equipped with slope control, he must set hubs at centerline so the grader operator has something to sight to while making his first trim pass along the curb.
- If the grader *is* equipped with slope control, the grade setter will start by checking the grade along the curb as the grader operator trims with his slope control set at 2 percent (which we'll assume is the percent called for). The grade setter will set centerline hubs after the edge is on grade. Or, he may elect to just paint a line at centerline every 50 feet, so the grader operator will know how far to carry the 2 percent cut on that side of the road.
- If the grader is equipped with slope control *and sonar*, the grade setter will have the grader make a few short passes (of about 20 feet) along the curb until he's on grade, then he'll set the sonar to read the lip-of-curb grade. Once the sonar is set, the grader will make another short pass as the grade setter checks to see if it's dialed in correctly. If not, they'll continue to adjust it until it's cutting at the desired grade. Once this is done, the grade setter will check the edge along the curb periodically. When a grader is equipped with slope control and sonar, some grade setters won't set hubs at centerline unless the grader operator prefers them. Again, he may just paint an orange line every 50 feet or so after the grader has carried his second pass across centerline. That shows the operator where to start the 2 percent slope for the second half of the street. Figure 18-2 shows a grader using sonar off the previously-trimmed grade to make his second pass across centerline.

### Computing the Centerline Grade

Let's look at how the grade setter computes the centerline grade. If the road is 30 feet wide, then it's 15 feet to centerline from each curb. We'll say the road cross section on the plans shows a 9-inch section, with 6 inches of aggregate and 3 inches of asphalt. The grade setter will set a swede on the


***Figure 18-2*** *Grader running sonar off a pretrimmed subgrade*

lip-of-curb, using it as a boot, 4 feet high, at the lip. Figure 18-3 shows a typical swede with adjustable stem. The grade setter will measure 15 feet out from lip-of-curb to centerline and drive a hub, leaving it sticking up higher than he thinks the grade will be. Now he'll compute the distance down from the 4-foot boot at the curb, shooting level from the centerline to boot. First he needs to find the 2 percent rise from the lip-of-curb to road centerline: 15 feet $\times$ 0.02 = 0.30 foot. The 0.30-foot rise from the lip-of-curb to the centerline must be subtracted from the 4-foot boot height, so he now has a centerline ruler reading of 3.70 for finished grade. To get the correct reading for subgrade, he must add the road section to the ruler reading of 3.70. The road section is 3 inches (0.25 foot) of asphalt and 6 inches (0.50 foot) of aggregate. 3.70 + 0.75 = 4.45, which is the ruler reading he needs to shoot level back to the 4-foot boot at lip-of-curb to give him subgrade at centerline.

Remember, to deepen the cut, you need to *add* to the ruler reading. To raise the grade, you must *subtract* from the ruler reading. The grade setter can now use the same reading every 50 feet along centerline, unless the figures change (the road gets narrower, the percentage of slope changes, or the boot height changes). If any of these three changes occurs, the grade setter will have to recompute the centerline grade.

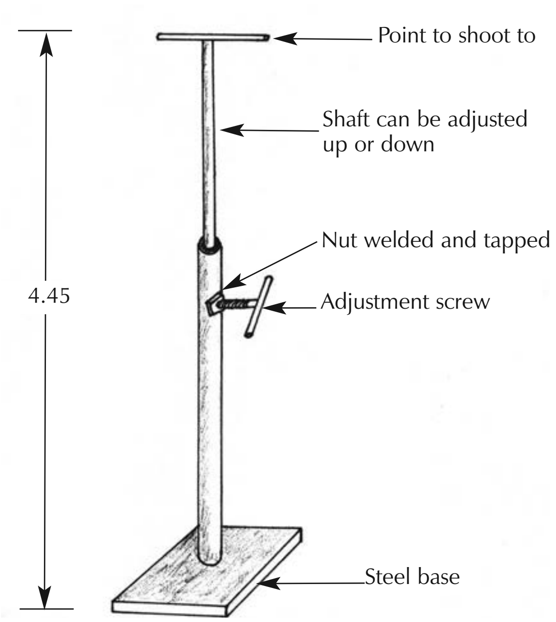



***Figure 18-3*** *Adjustable swede*

### Checking Grade

Now that the grade setter knows the centerline reading is 4.45 feet, he'll set his ruler (small numbers down) on the ground next to the hub and shoot level back to the 4-foot boot. He'll hold his eye level firm against the ruler and check the reading on the ruler where the side of the eye level touches the ruler. If he gets a reading of 4.35, he'll know that the grade must be cut 0.10 to get the 4.45 reading he needs. So, he'll drive the hub 0.10 foot down at the spot he just checked. However, if the ruler reading is 4.55, he'll have to raise the hub 0.10 for a fill.

Don't get confused by the ruler reading. If the small end of the ruler is down (starting at 1 foot), then the larger the ruler reading, the *deeper* the section; and the smaller the ruler reading, the *higher* the section. If the grade setter sets centerline hubs, he should put skirts on the tops so they can be located easily after the grader passes over them.

The grade setter must work closely with the grader to check grade along the lip-of-curb and centerline. It'll take several passes to get the grade fine-trimmed. While the grader is trimming, the roller should be following closely behind. That way, when the grader makes his next pass, the grade will already be compacted for a good trim. Be sure the equipment doesn't run or roll over fill hubs sticking up until they're filled over. If it does, the hubs may break off or be pushed down below grade.

If the grader builds up a large windrow of dirt, the scraper should pick it up quickly. The operator must pay close attention, and take care not to undercut the grade. The water truck should spray lightly during the trimming operation to keep the grade damp, but not wet. The water truck must work ahead of the grader, so the grader can trim after the grade has been watered. The roller follows the grader, which allows time for the water to soak in, reducing the amount of dirt that's picked up on the roller drum. If the grade is watered *behind* the grader, the roller operator usually must wait until the water soaks in before he can continue. So, the practical order of work is: the water truck, the grader, the scraper (if needed), the roller, the water truck, the grader, and so on, until the fine-trim operation is complete.

Here's something that you need to watch for: the grade setter must check the curbs from one side to the other for level. Even though the plan elevation shows them level, they may not be. To be of concern, the level would have to be over 0.05 foot off. If this is the case, the setter should shoot the centerline crown from the *highest* curb. If the grader is using slope control, the grade setter must mark those areas and let the grader operator know what percentage to dial in when he reaches the sections that are no longer 2 percent. The grade setter shouldn't swede through areas where the curbs aren't level from one side to the other, because the grade on one side will then be less than 2 percent.

Remember, there are many ways to approach a job. If the job requires aggregate under the concrete curbs, you may need to grade the subgrade under the concrete at the same time the road section subgrade is graded. In this case, the grade would be made using the survey stakes, but the processing and compaction would remain the same.

## Trimming Highway Subgrade

Highway subgrade trim and compaction are done exactly the same as a subdivision street. You use the same type of equipment, except on a highway job you might use a larger grader and scraper for trimming large jobs. The main difference between the two is that on most highway jobs, there won't be a curb to grade or to shoot grade from. The exception to this would be the curbs on some highway on and off ramps. There'll be a hub set at edge-of-shoulder or edge-of-pavement, or both, because the shoulder and road may have different slope percentages. Figure 18-4 shows the variety of road sections you may encounter.

### *Bank Plugs*

Surveyors stake highways differently in different regions of the country. Some agencies set hubs in the subgrade when trimming is to begin. Others set new hubs and information stakes to work from down each side of the road. Some set bank plugs.

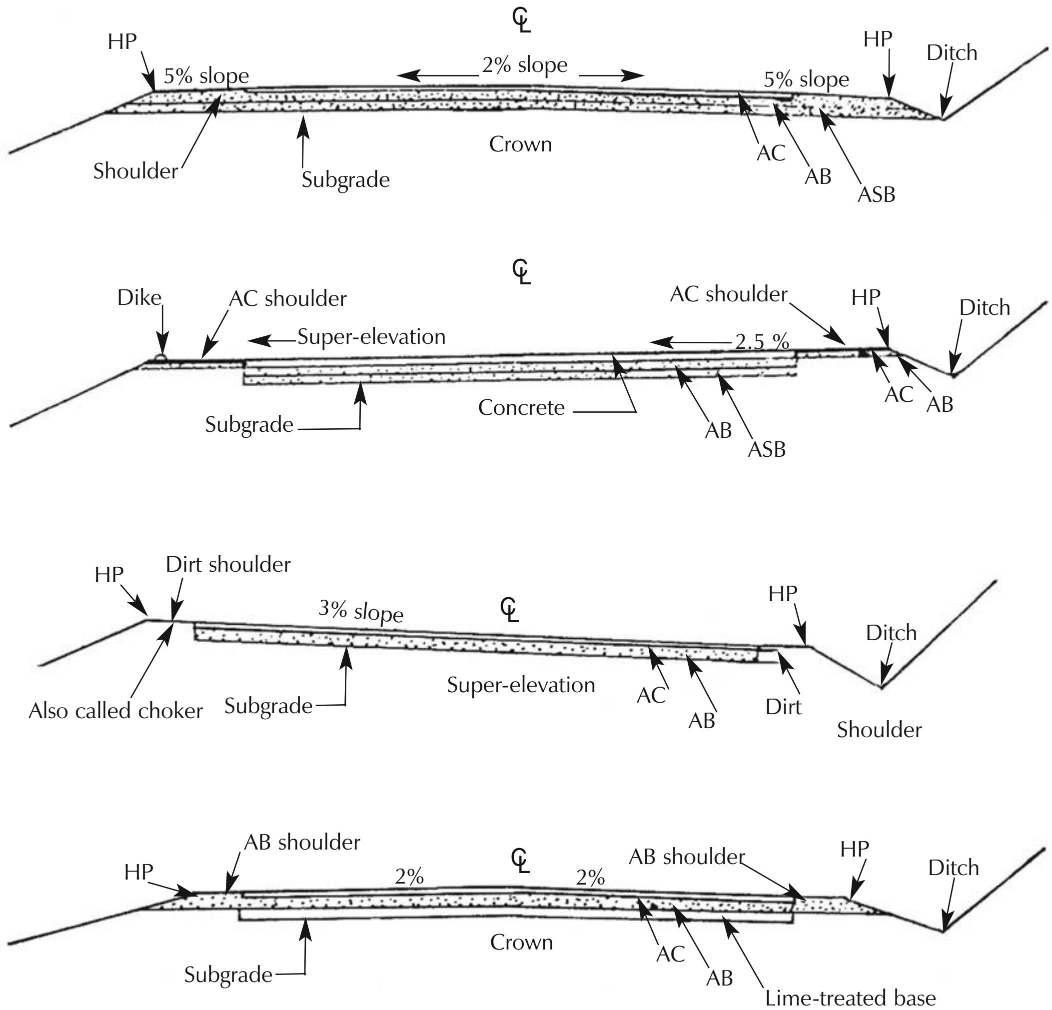



***Figure 18-4*** *Road cross sections*

A bank plug is a wedge-shaped 2 × 4 driven into the ground, with about 24 inches showing above ground level. Bank plugs are set on both sides of the road. The surveyors write the required information on the bank plug. They drive a nail in each plug, on opposite sides of the street, at a given distance above the finished roadway (Figure 18-5). If the road has a crown rather than sloping in one direction, the surveyors will set two nails in the bank plug. To set the grade for one-half of the road, stretch a string from the top nail on one side to the bottom nail on the other side. Then rotate the string to the other nails to establish the other half of the road.

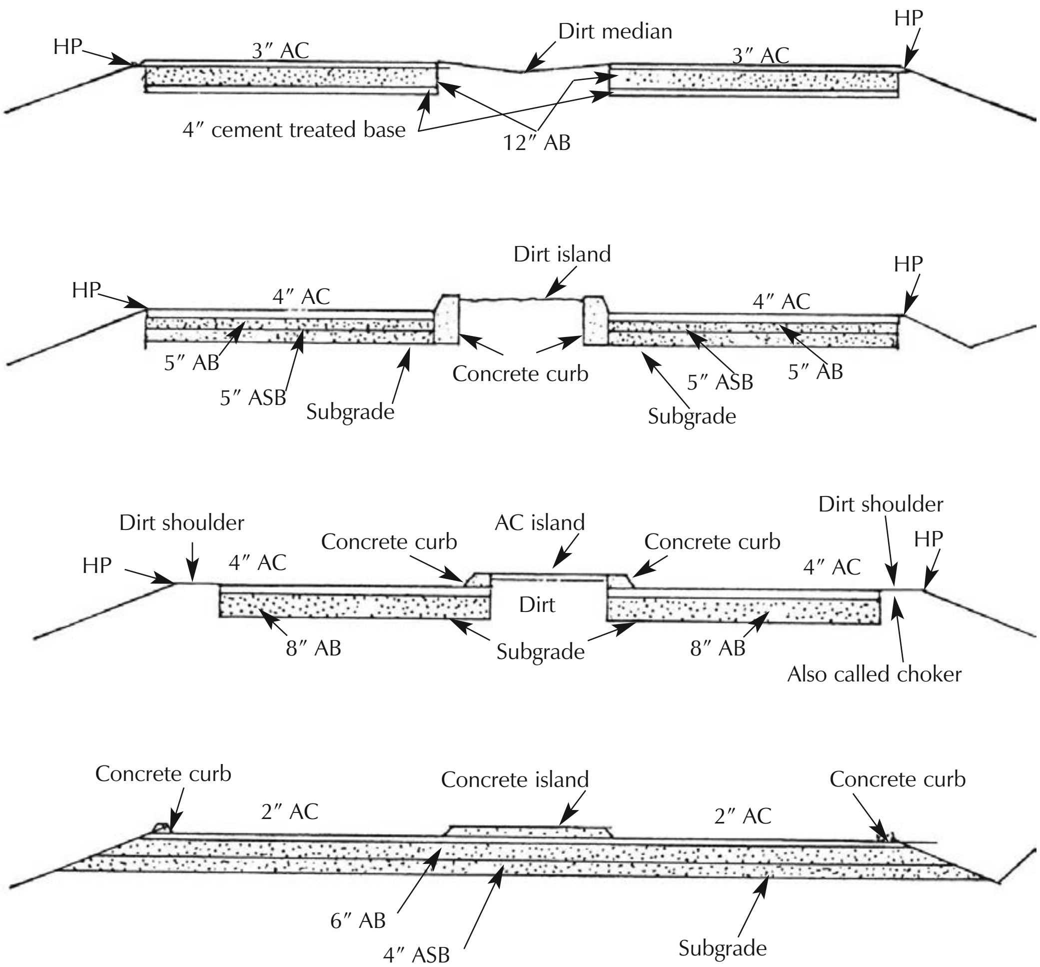



***Figure 18-4*** *Road cross sections (Continued)*

If the road has a continuous slope in one direction, it's called a *super*, short for super-elevation. A super only needs one nail in the bank plug on each side. Stretch a string from one nail to the other, and set the hubs by measuring down from the string. It's best to use colored nylon fishing line because it's light and strong and won't sag or break when stretched.

In some cases, the super in the road will change. One side may slope 2 percent from the east edge to centerline, but from centerline to the west edge, it may drop 3 percent. If so, each bank plug will then have two nails,

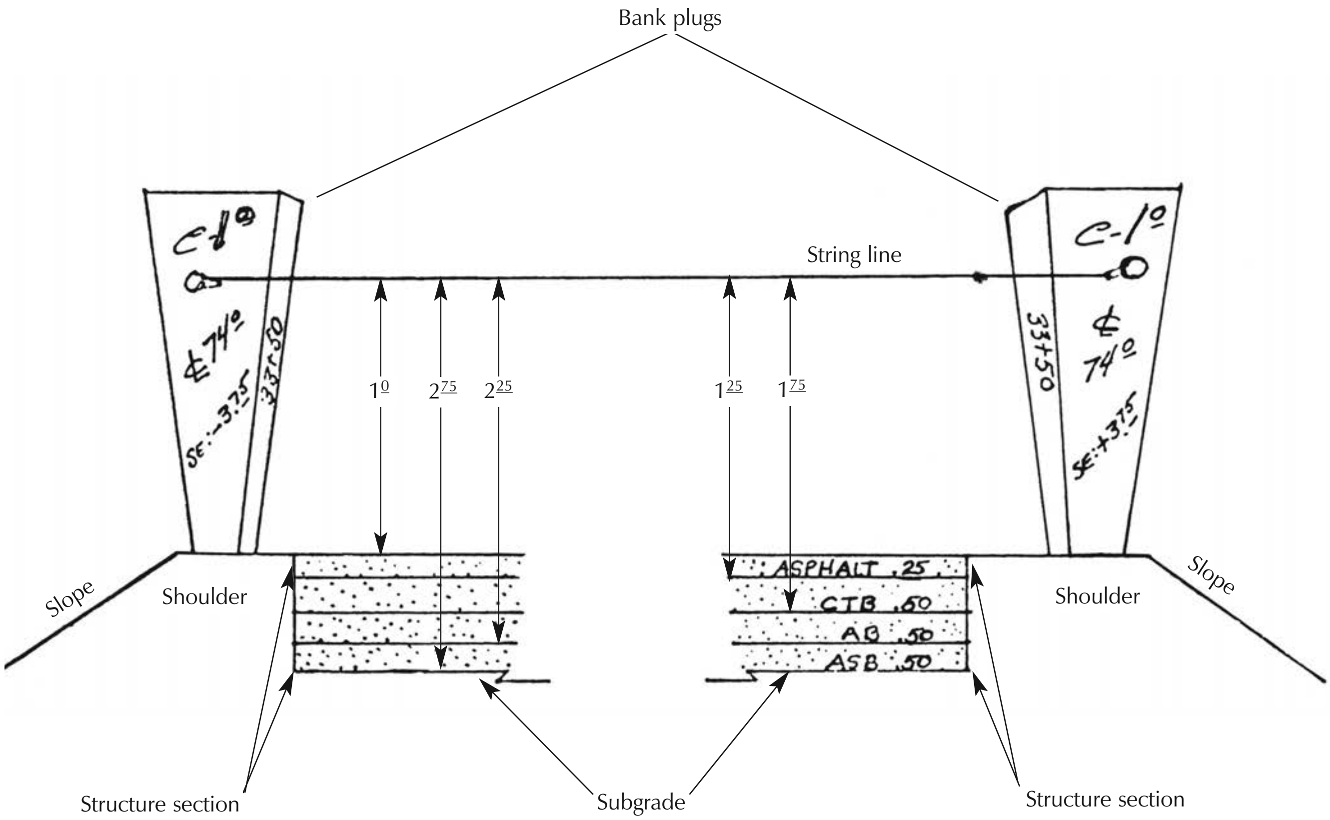



***Figure 18-5*** *Bank plugs*

so the string can be rotated to catch the extra 1 percent fall on the second half of the road.

The surveyors will write all the information necessary for finishing the road on the bank plug. It'll have the station number, the percentage of slope for the road, and a plus or minus sign to indicate the direction of the slope from centerline to shoulder. After the bank plugs are set, the grade setter stretches his string line and sets up his grade hubs by measuring down from the string.

Some engineering firms don't set bank plugs. Instead, they'll set finish subgrade hubs. These will either be in the subgrade to trim to, or on the choker with the grades and offsets to edge-of-pavement on an information lath. In any case, after the grade hubs have been set, the fine trimming can begin and finish in the same manner as on a subdivision street. With no curb to run the sonar from, it's a good idea to run a string line down each side. That'll provide better control than hubs, when using trimmed subgrade to run the sonar from on the second pass. A string line parallel to the centerline will eliminate humps between hubs.

Most highways are super-elevations, meaning there's no grade change from centerline. The road will slope in one direction, usually toward the shoulder. Supers make it easy for the grade setter to swede across, since there are no grade breaks to contend with. If the surveyors set finish grade hubs every 50 feet, the grade setter doesn't have a road section to figure in, because the hubs are subgrade and not finished grade. Looking back at Figure 18-4, you can see that some of the roads have chokers with dirt shoulders, some have shallow chokers with rock and pavement, and on some the road grade extends through the shoulder. The plans will always show the road section to be built and the thickness of aggregate and asphalt, along with any chip seals, open grade asphalt or dikes that may be required. Remember, when trimming chokers, make sure they meet the compaction requirements before cutting them on line. If they're not compacted well, they'll crumble off, requiring more aggregate.

The subgrade tolerances on highways and subdivisions are usually the same, 0.05 or 0.08. Be sure to grade islands (medians) between lanes fairly close before fine trimming the subgrade. If the island has barrier curbs, they should be poured after the subgrade trimming is completed.

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# CHAPTER 18 QUESTIONS

**1. How should the rough subgrade be cut before compacting?**

A) 0.00 to 0.05 high
B) 0.05 to 0.10 high
C) 0.10 to 0.20 high
D) On grade

**2. What may need to be done when processing subgrade with extremely dry soil?**

A) The grader may need to turn the soil over several times
B) The water truck may need to flood the subgrade so the water will penetrate
C) The compactor may need to do the mixing with his dozer
D) The scraper may need to remove the top layer and replace it with better material

**3. To what depth is the subgrade of a road section usually required to be 95 percent compacted?**

A) 4 inches
B) 6 inches
C) 8 inches
D) 10 inches

**4. What must you ensure that your grader has before beginning fine trimming?**

A) Equal pressure in all tires
B) Sonar set to maximum sensitivity
C) A good cutting edge with no worn ends
D) GPS

**5. What must the grade setter do if the grader is not equipped with slope control or sonar?**

A) Paint a line at centerline
B) Set centerline crows feet
C) Set centerline hubs
D) Paint grades at centerline

**6. If a road that's 15 feet to the centerline has a 2 percent slope and a 0.75-foot road section, what would the centerline reading be to get the correct subgrade when shooting to a 4-foot boot at lip-of-curb?**

A) 0.75
B) 3.75
C) 4.00
D) 4.45

**7. If the grade you require at centerline is 3.75 and you shoot 3.90, what is needed to shoot 3.75?**

A) A fill of 0.15
B) A fill of 0.30
C) A cut of 0.15
D) A cut of 0.30

**8. What must the roller operator do if the water truck sprays the grade just ahead of the roller?**

A) Roll quickly before it dries
B) Turn the vibrator off
C) Re-roll the grade
D) Wait until the water soaks in

**9. What is indicated when each bank plug has only one nail?**

A) The road has a crown
B) The road is level
C) The road has a constant super
D) The road has a curb on only one side

**10. What's the most accurate way to carry grade if you're running sonar on a road job with no curbs?**

A) Trim one side over the hubs then use that grade to run the sonar on
B) Set a string line on each side to run sonar on
C) Don't use sonar, just slope control
D) Start at centerline first

# AGGREGATE BASE

# 19

In this chapter we'll discuss methods for placing, compacting and trimming aggregate base in parking lots, highways and streets. But before you can do any of these, ordering the correct amount of aggregate is your first concern, regardless of the job type or size.

Aggregate suppliers sell their aggregate by the ton, so you'll have to calculate how many tons you'll need. First, calculate the area of the parking lot or roadway where you'll be placing the aggregate. Let's say that you're going to cover an area 200 feet long by 60 feet wide, and the specifications call for a 6-inch-deep (0.5 foot) aggregate base.

$$200 \text{ feet} \times 60 \text{ feet} = 12{,}000 \text{ square feet}$$

Once you know the area, you can find the volume of aggregate in cubic feet by multiplying the area by the depth of aggregate required — in this case 0.5 feet.

12,000 sq. ft. × 0.5 foot = 6,000 cubic feet

If you need the volume in cubic yards, divide the cubic feet by 27 (27 cubic feet equal 1 cubic yard):

6,000 cu. ft. ÷ 27 = 222.22 cubic yards

The next step is to find out how much the aggregate weighs per cubic foot or cubic yard. For this, you'll have to call the quality control division or scale house at the aggregate plant that will be supplying the material and ask how much their material weighs per cubic foot or cubic yard. It isn't uncommon for aggregates from different areas to vary in weight by as much as 5 pounds per cubic foot, or 135 pounds per cubic yard, so it can be significant. Be sure to make this call.

Let's assume that your plant's aggregate weighs 145 pounds per cubic foot. First calculate how many pounds you'll need by multiplying 6,000 cubic feet by 145 pounds. Then divide by 2,000 (2000 pounds = 1 ton) to find the number of tons to order:

6,000 cu. ft. × 145 lbs = 870,000 lbs
870,000 lbs ÷ 2,000 = 435 tons

Subgrade tolerances can be off plus or minus 0.08 foot — and that'll affect the total quantity of aggregate that you'll actually use. It's better to be short aggregate than to have too much. Adding a couple more truck loads is easy, but if you order more aggregate than you can use — it's very expensive to haul it away. I generally order about 8 percent less aggregate than I need to start, and make adjustments to my order as trimming proceeds. So, in this instance, instead of 435 tons, I'd reduce it by about 8 percent and order 400 tons of aggregate.

Since I was never much of a mathematician, I stuck with a simple formula I was taught back in the Stone Ages for figuring aggregate quantities. It saves me from having to convert inches into decimals of a foot, or working with decimals at all. It's much easier to work with whole numbers.

Here's the formula: Figure the square footage of the area by multiplying the length by the width. Then multiply that by the depth, *in inches,* of the gravel you need to place. Then divide the result by 160 and you have the approximate number of tons you need.

This formula assumes an aggregate weight of 150 pounds per cubic foot — which, of course, isn't always the case. But it's quick and easy and gives you a good ballpark estimate. Let's use this formula to calculate the tons needed for the example above. You have an area 200 feet long by 60 feet wide, and you need to place gravel 6 inches deep. Here's your calculation:

200 feet × 60 feet = 12,000 square feet
12,000 × 6 = 72,000
72,000 ÷ 160 = 450 tons

When I use this method, I cut my order back by 10 percent, and that comes out very close to the number of tons ordered using the longer method:

450 × 0.10 = 45
450 – 45 = 405 tons

Most large jobs are bid from an engineer's estimate of the quantity in tons of aggregate needed. The engineer may have an estimate of 30,000 tons on a road project. However, when the road project is finished and all the scale tickets computed, it may show that only 29,000 tons were placed. That will be what the contractor will get paid for. Or, if the scale tickets show 31,000 tons were placed, the contractor would get paid for *that* quantity.

Small jobs are often bid on estimated quantities only, so if the contractor goes over the quantity of aggregate he bid, he won't get paid for it. When bidding a job with a set quantity, it's important to measure the job yourself and do your own quantity take off. I used to add 3 percent to my quantity take off to ensure I'd bid enough to cover my costs. That way, if the subgrade was left on the low side when it was trimmed, I wouldn't get burned on the extra aggregate costs. I'd still order a little less aggregate than my estimate to start — and increase my order *only* when I was sure I'd need more.

## Placing Aggregate in Parking Lots

Now that you know how to figure the aggregate tonnage you need for a whole job, let's see how you might use this information to make aggregate dumps in a parking area. The parking lot is divided by islands into several sections, each measuring 60 feet by 12 feet and requiring 6 inches of gravel. You want to know how much aggregate to dump in each section.

Here's your calculation using my shortcut method:

> 60 feet × 12 feet = 720 square feet
> 720 × 6 = 4,320
> 4,320 ÷ 160 = 27 tons

Paint *27 tons* on the ground in each section, so the person dumping the trucks will dump the proper amount in that section. Every truck driver will give the dump person a ticket or weight slip that shows the exact amount of aggregate in tons that he has on board. The dump person will know by looking at the weight slip how much of the load should be dumped, all or part. Having the aggregate dumped in measured amounts will make it much easier for the operator spreading the gravel. He won't have excess in one area or be short in another, or need to have more dumped before the spreading is finished. This method speeds up the spreading and initial rolling of the base rock. Only use end dumps to haul in the aggregate, because bottom dumps can't maneuver in small areas. If the area is long enough, the truck driver can hook a chain on each side of the dump gate to control the dump and spread his load 6 inches thick while traveling.

Use the same method for the travel lanes in the parking lot. Every 50 or 100 feet, paint a line and compute the amount of gravel for that area. Paint the amount needed on the ground and tell the dump truck driver not to dump past your line until the correct amount is spread in that area. This is a good method to use regardless of the size of the parking area. The grade setter adds the curb face plus the thickness of asphalt, measures down from the top of curb and marks it. He paints a line 2 to 4 inches long every 20 feet or less, so the crew knows that's the grade to fill the gravel to. The paint mark will be about 1 inch wide, so the grade setter must let the crew know whether to fill to the bottom or top of the line. When a more-defined line is needed, use a short lath against the curb as an overspray shield. This will leave a nice, straight paint line at finished grade to indicate the level of the aggregate.

## *Selecting the Right Equipment for the Job*

You may elect to use one or two small tractors with a drag box to spread and trim the gravel in a small parking area, if you feel it's too confined for a grader to maneuver easily. In this case, you might also need a scaled-down smooth-drum vibratory roller and water truck. You could use a 66-inch drum roller in place of the larger 84-inch drum, and a small single-axle water truck rather than a large double-axle truck.

***Figure 19-1*** *Tractor with a drag box grades corner that the grader can't reach*

In a large parking lot for a shopping mall, the trucking requirements will be different. You can use bottom dumps as well as end dumps. The bottom dumps will spread gravel in all the large areas, and a few end dumps will dump in the corners or other confined areas. A small tractor with a spreader box, like the one shown in Figure 19-1, can grade the areas that the grader isn't able to reach. You'll need a variety of rolling equipment in a large parking area. A smooth-drum vibratory roller will do the major portion of the rolling, with a small 2-ton vibratory roller (Figure 19-2) rolling the tight areas. A large parking lot usually requires a four-man labor crew: One man dumping trucks, two working with the grading tractor raking the ridges that the tractor misses, and one tamping the edges along the curbs with a plate tamper (Figure 19-3). The labor crew is in addition to the regular crew, consisting of the foreman, the grade setter, two roller operators, a tractor operator, a grader operator and a water truck driver.

## *Balancing and Trimming*

If the rock is controlled correctly while it's being dumped, there'll be very little balancing needed once the trucks are cut off. This is important because the more aggregate is worked, the more fines it will lose, leaving what's called a *bony grade*. In other words, the more the rock is dragged


***Figure 19-2*** *A small vibratory double-drum roller compacts the edge-of-curb*

***Figure 19-3*** *Worker uses plate tamper to compact edges of island curb*

and bladed, the worse it looks. That's why the water truck must keep the aggregate wet all the time it's being spread, rolled, or trimmed. The water keeps the fines attached to the rocks so they won't separate as easily.

Once the gravel has been balanced and rolled, it's time to start trimming it to a 0.05 tolerance. The grade setter must set hubs on all the summits to trim down the swale lines. (The swale line allows water to drain naturally from the summit to the drop inlet.) He must also set a row of hubs at the nose line across all the parking stalls, from nose to nose, parallel to the swale line. You must pay close attention to any parking stalls near the summit lines because there's very little slope from the curb to the swale at that point. As the swale travels from the summit to the drop inlet grate, it gets deeper, creating a steeper slope for the stalls across from the drop inlet. At the summit end, the parking stalls may have only a 1 percent slope to the swale line. The stalls across from the drop inlet may have as much as a 3 percent slope. For this reason, the grade setter should shoot the grade after he's sweded it to be sure there's enough fall to get the water from the curb to the swale.

The grade setter primarily uses swedes to set grade in a parking lot. He'll first swede the summit by setting a swede on the curbs on each side. If the summit is level from curb to curb, he may elect to shoot the summit hub in with an eye level by setting the swede on just one side. Once the summit hub is set, he'll set a 3-foot-high swede there. The summit swede is 3 feet high because it's sitting on rock grade, not finished grade. Then he'll set a swede on the drop inlet grate at the end of the swale. The drop inlet grate is at finished grade, so the grade setter must subtract the thickness of the pavement from that swede because the swede at the summit is sitting on finished rock grade. Let's say the pavement section is 3 inches, or 0.25 foot. Then the grade setter will set the swede height for the drop inlet at 2.75. Now he'll swede a row of hubs down the swale line every 25 feet, using another 3-foot swede to sight across from summit to drop inlet.

Once the swale line is staked, the grade setter will swede from the top-of-curb in the parking stall to the swale. The swede he sets at the top-of-curb must be adjusted to account for the height of the curb face and the thickness of the asphalt. Let's say the face of curb is 6 inches and the asphalt is 3 inches, for a total of 9 inches, or 0.75 foot. He must adjust the swede on the top-of-curb to a height of 2.25, with the swede at the swale line at 3 feet. The swede in between them should be set at 3 feet.

The tractor and labor crew should trim all the corners ahead of the grader, dragging any excess gravel out to where the grader can get to it as he grades the larger areas. A small roller can roll the areas not easily accessed by the large roller, and a laborer with a plate tamper will tamp all the corners the small roller misses, as well as the island noses. As the grader and tractor are trimming, the grade setter continues to set hubs at any point he feels the equipment operators need to carry a good grade.

It's very important that the scraper operator has experience picking up a windrow of gravel from a trimmed grade. If the operator only gets half the windrow because he cuts too high, the grader must make another pass to windrow the gravel up again. On the other hand, if he undercuts the windrow, the grade material must be hauled back, spread, rolled and retrimmed. Any scraper used for finish work should have a good straight cutting edge and extended slobber bit. Remember, there should be an area at the end of the project that's left low, where the scraper working with the grader picking up excess trim can haul the aggregate.

## *Extruded Curb Parking Lots*

The curb grade stakes set by the surveyor are the same for an extruded curb as a barrier curb. Looking at the stake, you can't tell the difference — you have to check the plans to see what type of curb is called for. The grade setter will mark boots and shoot from them with an eye level. However, the grade setter must pay close attention to the distance to curb marked by the surveyors. Even though you're working with extruded curb, the grades marked may not be asphalt grade. The surveyor may mark one of three distances — top back-of-curb, top face-of-curb, or asphalt grade at face-of-curb. The grade setter must determine from the surveyor information where he should measure to for his cut. For example, if an extruded curb is called for, and *face of curb AC* is indicated on the survey stake, he'll subtract the width of the curb and some extra distance behind the curb so the curb machine will have a level pad of asphalt for the concrete pour. Figure 19-4 shows a surveyor's hub that indicates a 3-foot offset to asphalt grade face-of-curb. Notice that the grade setter excavated $1^1/_2$ feet behind the face-of-curb. This provides room behind the curb for excess aggregate and asphalt so the curb can be poured on a firm base.

When an extruded curb is called for, the parking lot must be compacted, trimmed and aggregate placed, then trimmed again and paved before the curb is poured. When a barrier curb is called for, the parking lot can be compacted and trimmed, but all the aggregate can't be placed and trimmed until the curb is poured.

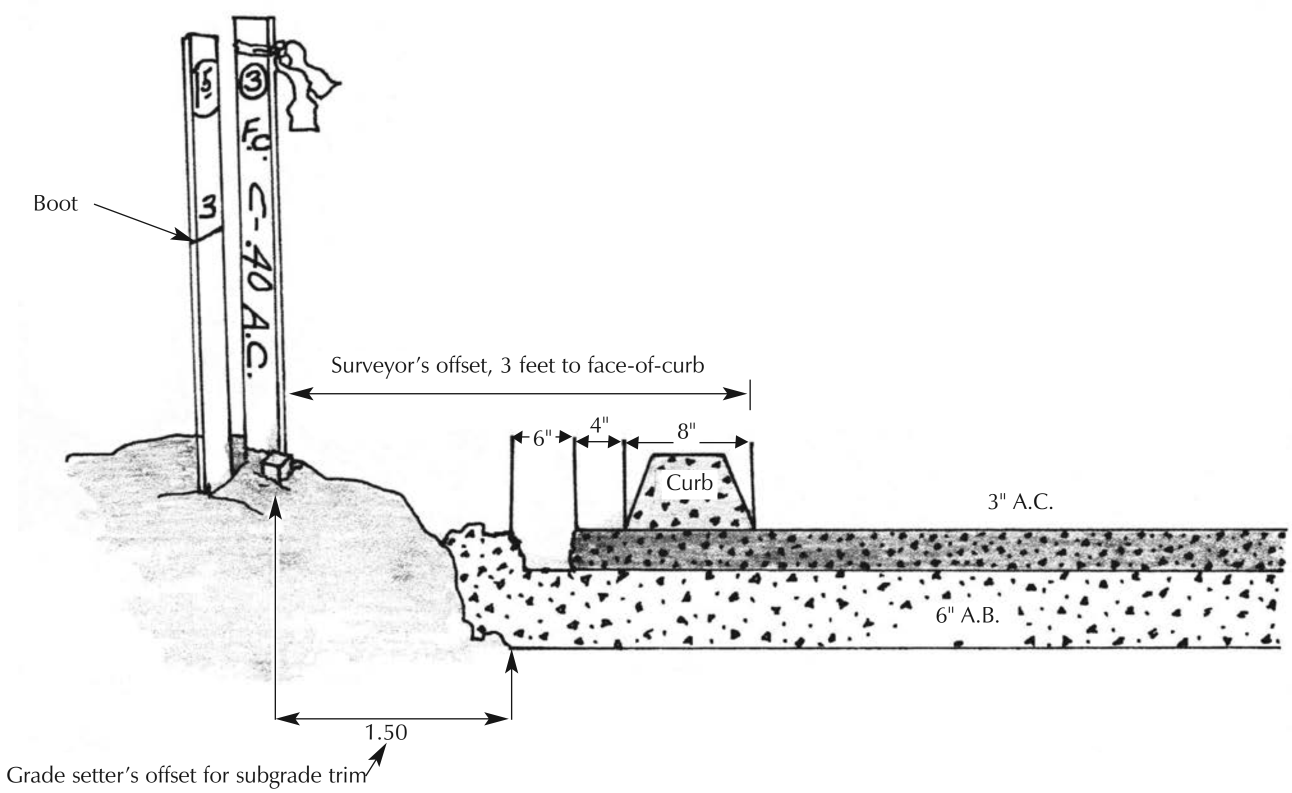


***Figure 19-4*** *Surveyor's hub indicates 3-foot offset*

For an extruded curb, the grade setter should carefully spraypaint a line at the edge-of-pavement for the paving crew to follow after the aggregate is fine trimmed. That way they'll be sure to pave far enough out so the curb won't be short of asphalt to sit on. The grade setter must check grade carefully when the aggregate is trimmed to be sure the grader operator hasn't left any humps between stations, or they'll show when it's paved and the curb is poured on the asphalt. Here's something else to watch for: Check the job specifications carefully — often, parking lots require weed killer before the paving is done.

We've covered the most common method used for placing and trimming aggregate in a parking lot. Using sonar or slope control isn't very effective for this type of work because there are usually so many islands. It would be too time-consuming for the grade setter. For a huge parking area, such as a football stadium or airport parking lot where there are very few or no islands, sonar and slope control is worthwhile. For that type of job, running grade using a laser is also a good option. The laser could be set to control two slopes at once. The parking area may slope 2 percent from east to west and 1 percent from north to south. The laser can be set on the baseline of a swale or summit to control the grader blade, and both slopes can be cut simultaneously. Another option is using GPS (GPS is covered in Chapter 5).

## Placing Aggregate Base on Highways

There are two main shoulder designs on highways, a choker shoulder or open shoulder. You don't need to set hubs or crows feet to start dumping aggregate on a road with a choker, because the choker is the line, and the grader will push the gravel against it. The first lift of gravel will be well below the finished gravel grade, so you won't need a grade stake. The grade setter may elect to put a paint line on the face of the choker every 50 feet for the grade of each lift of gravel, or just a paint mark at the finished gravel grade, depending on how many lifts there'll be. If there isn't a choker at centerline, you'll need a row of crows feet there with grade and line for the finished gravel grade.

With an open shoulder, the grade setter must place one row of crows feet for shoulder grade and line and another row for grade and line at centerline. An open shoulder should have a nice smooth slope on the aggregate. This isn't possible to achieve while dumping, spreading and compacting. To get line on an open shoulder, the grade setter should move out from edge of the AB (aggregate base) finished grade half the distance of the aggregate thickness. For example, if the section of aggregate is 8 inches, set the crows foot lath out 4 inches; if the section is 12 inches, set the crows foot lath out 6 inches; and if the section is 18 inches, move the crows foot lath out 9 inches. This will accomplish three things: It will give the paving crew the room they need, it will give the roller room to roll the edge correctly, and it will create enough excess aggregate on the edge to build a smooth slope of AB after the job has been paved.

### *Dumping the Aggregate*

The fastest way to dump aggregate is to use bottom dump trucks with either double trailers or semi bottoms (single large trailers). These trailers have chains on the bottom gates that control the amount of aggregate flowing through the gates as the trailer moves forward and dumps. I prefer to have the truck drivers set their chains to spread 100 feet. That setting will cover an area 100 feet long, 10 feet wide and 4 inches deep. This accomplishes two things: It keeps the windrow of aggregate small enough so the trucks can straddle the windrow without getting stuck; and the 4-inch spread is a perfect depth for maximum compaction by the roller.

It's important to have an experienced dump person who can handle the trucks. He'll know as soon as he looks at the windrow being dumped if it's too heavy or too light, and he'll tell the driver to loosen or tighten the chains on his trailers. He can also hand-dump areas he feels need more gravel. There's a small lever at the rear of the gate that's used to hand-dump gravel. It's usually located a little over waist-high above the gate, and has a release button that prevents accidental operation. Press the release button first, or the lever will keep kicking back on you each time you try to open the gate. By hand-operating the gate, the dump person can control the amount the gate opens and dump a small windrow where needed.

The trucks must dump a continuous windrow with no gaps. That makes it much easier for the grader to spread the aggregate. To ensure a continuous windrow, the dump person must have the trucks straddle the end of the previous windrow for about 20 feet before making a new dump. This is because it takes about 15 feet from the time the dump person gives the dump signal until the trailer gate actually opens to begin the dump. The dump signal is the dump person's arm, with hand and index finger extended, being dropped quickly from shoulder height to point straight down at the ground. When using bottom dumps, dump the back trailer first. Once the back trailer has spread 25 feet of aggregate, the signal should be given to dump the front trailer. This will open the front trailer just before the back trailer empties, making a continuous windrow.

It's important that the back trailer on a bottom dump is always emptied first. If the front trailer dumps first, the truck may lose traction and get stuck. Semi bottoms have much better traction because they have a single box and two axles driving. Bottom dumps only have one axle driving. Both semi bottoms and bottom dumps carry between 24 and 25 tons. Semi bottoms are better in areas where there's poor traction, on dirt fills, or for dumping aggregate uphill where you need more traction. Otherwise, I prefer to use bottom dumps with double trailers.

***Figure 19-5*** *Grader uses wing to move rock ahead without losing it out the side*

## *Spreading and Rolling the Aggregate Base*

Let's look at spreading and rolling aggregate base material on a highway job requiring 14 inches of aggregate, spread 60 feet wide for 4,000 feet. You'll need to order a total of 21,000 tons of aggregate. For the first day of work, you'll need 14,000 tons of aggregate, a grader, vibratory roller, water truck, grade setter and dump person. A scraper isn't necessary while placing aggregate. If the water supply isn't close, you may need an additional water truck. Start dumping 5 feet in from the right choker or row of crows feet. That way, if the grader holds his blade up 4 inches and flat blades each 100-foot windrow spread, the aggregate will flow evenly each way, 10 feet across. The grader operator may need to tilt his blade toward the shoulder to be sure aggregate reaches the crows feet there. Should the gravel be running a little shy of 5 feet each way, it's better to have the center a little low — not the edges.

A good grader operator will get an even spread in two passes, leaving the first pass a little high and trimming the second pass close enough to leave to the roller. If you're dumping and spreading on an open shoulder where you need crows feet, attach a wing to the right end of the grader blade to keep the gravel from being lost over the shoulder edge (Figure 19-5). Dumping a load every 100 feet, it will take 40 dumps from one end to the other. When the foreman sees that the dumping is within 800 feet of the end, he'll have the grade setter stop the trucks coming in and begin checking their dump tickets. Usually the tickets are numbered, so when he sees number 40, he'll start truck number 41 dumping back at the beginning again. The dump man, who also checks the dump tickets, will know that ticket 40 is the last load and will head back to the beginning to relieve the grade setter. If the tickets aren't numbered, check the footage. If the last dump is 800 feet from the end, the foreman will know that he needs eight more loads to finish that pass.

Begin the second windrow 5 feet in from the edge of the first aggregate spread. The remaining four windrows should be done the same way, until the first 4-inch lift covers the entire width of the road. Do the second lift in the same manner. By dumping 40 loads on each pass, you might come out one load short or long. Just pick it up on the next pass. If you were short one load on the first pass, send 41 loads the second pass. If that one comes out one load too much, send 39 loads to the third pass.

At the end of the first day you'll have 14,000 tons of well-compacted aggregate on the grade. That leaves 7,000 tons to be ordered for the next day. Day two, the dumping will be a little different because you'll need to get the grade close enough to start fine trim. The aggregate from the first day is a little more than 4 inches low, so you'll dump down both edges before continuing with the middle four dumps. The reason you want to fill the edges first is so the grade setter can start setting the finish rock grade hubs. Remember to leave room on the end for trim material. On a 21,000-ton job, I'd leave the rock quantity shy about 20 loads, or 500 tons. With an 0.08-foot subgrade tolerance, it'll affect the exact tonnage needed. One or two trucks should be used to furnish the grader with a small excess for trim. On the second day, I prefer to dump heavier at the beginning of the job where the trimming will start. That gives the grader operator trim to work with. A paddle-wheel scraper can pick up any excess and move it ahead if needed. Once the rock hubs are all set, the foreman can check them to determine if 20 loads are enough to finish, or more or less aggregate is needed.

Let's look at another approach to same job. In this case the plant could supply the material and trucks to haul all the aggregate in one day. You would order 20,500 tons — 21,000 minus the 500 tons you need for trim excess. The spread and roll would be pretty much the same, except for two differences: I'd use a Cat 815 compactor to do the initial compaction, and I'd dump two rows of aggregate at a time. Begin the first row 5 feet from the right shoulder or edge and the second row 15 feet in from the right edge. The grader will spread the first two windrows. You need two windrows so there's enough width for the 815 to compact well without chewing up the subgrade. The vibratory roller will follow close behind. You need to keep the aggregate very damp all during the dumping and trimming operation.

When you increase the rock tonnage, be sure that you can put enough water on the grade to meet the 95 percent compaction requirement. Up to 24,000 tons of aggregate can be placed in one day with this setup if all the workers are experienced. With that many trucks dumping, it can get out of hand in a hurry if the dump man isn't well qualified, or the water truck sprays too much water, or the operator on the compactor can't doze smoothly. Rolling to get compaction is very seldom a problem with aggregate, if the water truck has kept the aggregate damp. That's because the water and the aggregate trucks also help roll as they drive through — they're like rubber-tired rollers. If the foreman isn't comfortable using an 815 compactor, a second rubber-tired vibratory-drum roller can be used instead. Whatever combination of equipment the foreman decides to use, he must have at least two rollers.

Working a ten-hour shift, the trucks will be arriving less than one minute apart. You'll need construction signs well out ahead of the work area, and a flag man directing traffic at each end for the trucks entering and leaving the job. If the trucks don't have a long merge into the existing traffic as they leave the work site, then traffic must be stopped for them so they can exit without stopping. There must be a continuous flow of trucks moving through, with no stops to enter, dump or leave the job. That's the only way you can haul this much material in one day.

Make sure that the grader has a 20-foot heavy chain or cable to pull out any trucks that might get stuck in the aggregate. With 80 to 100 trucks or more hauling, one stuck truck can disrupt the smooth flow of traffic. A stuck truck must be removed quickly.

## *Trimming*

Once there's enough aggregate hauled in, it's time for trimming. The final grades will be set according to the agency controlling the work. The surveyors will have grade stakes set on the choker with 2- or 3-foot offsets to the edge-of-pavement and the grades needed. With these stakes, the grade setter can set his boot lath. After the aggregate is spread and rolled, he'll shoot the grade he computes for finish aggregate grade and drive a hub to grade. Then the grader will carefully trim over the hubs until he trims to grade. The usual tolerance allowed on aggregate grade is 0.05. Once he's on grade, the grade setter will swede to be sure there are no humps or low areas between the 50-foot stations parallel to the centerline. When the grade setter is sure the grade is correct, the grader can run sonar off that, using slope control to get to centerline grade. The grade setter could also set a string line above the choker hubs to run the sonar on, eliminating the need to set hubs along the edge. He still must run a row of hubs down centerline to be sure the grade the grader is trimming matches at centerline. Or, he could elect to use a string line at centerline so the sonar can be used at centerline as well. Even if GPS is being used, the grade setter would still set his boots at shoulder and centerline so he can check the grade trimmed with sonar or with GPS.

If bank plugs are set, the grade setter can use them to measure down anywhere along the string line to check grade or set a hub. The grade setter should be aware that if he decides to shoot a grade 5 feet out from the bank plug, he must also compute the percentage of rise or fall in those 5 feet. The surveyors compute the grades and slope of the road from bank plug to bank plug, not from edge-of-pavement to edge-of-pavement. If the road was designed with open shoulders (no choker), the surveyors will usually return to drive hubs on each shoulder edge and centerline for grade.

## Placing Aggregate on Subdivision Roads

Let's look at hauling in aggregate to a subdivision road that's graded for a curb machine to pour sidewalk and curb together. The subgrade for sidewalk, curb and street are all compacted, trimmed and finished together. Notice in Figure 19-6 that a notch for curb and subgrade has been cut.

The first thing to do is calculate the aggregate you'll need. You have 2,000 feet of road, curb and walk, 38 feet wide. That's two 12-foot traffic lanes, with a 4-foot sidewalk and 3 feet of curb on each side. The sidewalk requires a 4-inch aggregate base, the curb 6 inches of aggregate, and the street section 8 inches of aggregate. This is a two-part job. The first part will be dumping enough aggregate to trim the sidewalk and curb so it can

***Figure 19-6*** *The sidewalk, curb and street subgrade are finished together*

be poured. The second will be to return and finish trimming the street grade. The first aggregate haul must be enough to cover the sidewalk and curb to the required amount, as well as enough to cover the street grade. You'll leave the street grade low enough to add to when you return to do the final trim.

Using my shortcut method to compute the amount of gravel you need for the sidewalk on both sides of the street, multiply the length (2,000 feet) by the width (two sidewalks equal 8 feet) by the depth (4 inches deep) and divide by 160 to get the number of tons:

2,000 × 8 = 16,000
16,000 × 4 = 64,000
64,000 ÷ 160 = 400 tons

Calculate the curb and street together. The street is 24 feet wide with a 3-foot curb on each side, which gives you a total width of 30 feet. You're going to cover it with 6 inches of aggregate (leaving 2 inches of fill to be added to the street section later). Here's your calculation:

2,000 × 30 = 60,000
60,000 × 6 = 360,000
360,000 ÷ 160 = 2,250 tons

That gives you 400 tons for the walk and 2,250 tons for the street and curb, for a total order of 2,650 tons of aggregate. You'll also need an additional 600 tons of aggregate to be added to the street subgrade after the curb is poured ($2{,}000 \times 24 = 48{,}000 \times 2 = 96{,}000 \div 160 = 600$ tons). Add that to the initial 2,650 tons for a total of 3,250 tons to complete the job. The 2,650 tons of the first phase is a one-day haul using a foreman, grade setter, roller, grader, dump person and water truck. The first windrows of aggregate will be dumped on the walk and curb. Run the wheels on one side of the bottom dump down the center of the walk. By straddling the curb cut in this manner, the windrow will end up right on the cut line and will give the grader operator gravel to fill the walk grade.

It's important to fill the walk grade first so the roller can start compacting. After the sidewalks have been dumped, move in about 5 feet from the edge-of-curb on each side and dump another windrow. If the grader operator feels he needs more aggregate for the walk or curb, he'll have it, and the remainder can go in the street. With the bottom dumps spreading 25 tons every 100 feet, by dumping two loads on each side, you'll be dumping a total of 100 tons every 100 feet. Now dump one load down the centerline to finish covering the roadbed, bringing the total up to 5 loads (or 125 tons) across every 100 feet. Multiply 125 tons by 20 (2,000 feet $\div$ 100 feet = 20) to get 2,500 tons. That leaves you with 150 tons, or 6 loads, to spread in any low areas that you need to cover on your first phase, before you bring in the additional 600 tons to finish street grade after the curb and walks are poured.

## *Trimming Sidewalk and Curb Grade*

If the string line is already set by the curb crew, trimming sidewalk and curb grade is a quick job for a grader equipped with sonar and slope control. The grader will lock the sonar onto the string grade that the curb crew set for the curb machine, and cut the walk grade. If the string line isn't set, it will slow the job down. The grade setter will need to set boot lath and shoot grade at each station for the grader operator. He must also check grade between stations parallel to centerline for any humps in the grade.

Once the walk is trimmed and rolled well, the grader will move out and start the curb grade. Figure 19-7 shows a grader making his first pass to cut a notch to curb grade. He's locked onto the sidewalk grade with his sonar, cutting a 7 percent slope for the curb, after cutting a 2 percent slope for the walk in the opposite direction. The vibratory roller rolls the curb grade, and then the water truck makes a final pass (Figure 19-8).


***Figure 19-7*** *Grader uses sonar to make first curb grade cut*

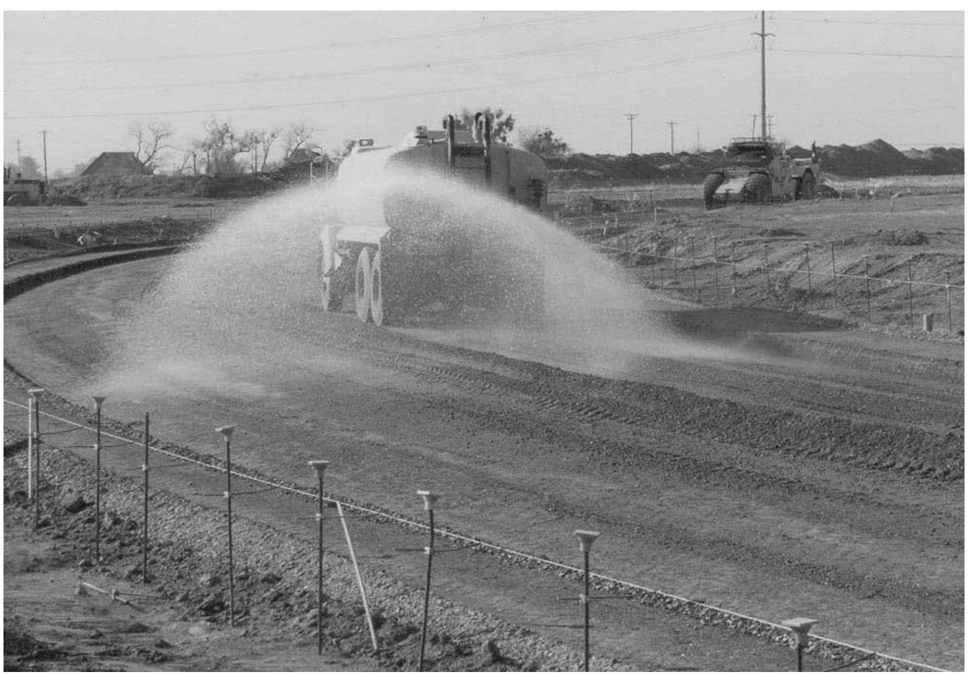

***Figure 19-8*** *Water truck sprays an even spray across aggregate grade*

***Figure 19-9*** *Concrete machine pours on a closely-trimmed aggregate grade*

The walk and curb grade are now ready for compaction tests. The grader will make one more pass to flatten the windrow of aggregate in the street so it can be rolled. If the walk and curb pass the compaction tests, the grading crew will leave and the concrete crew will take over.

One note of caution: Be sure the compaction effort on the sidewalk is finished before cutting the curb notch. Once the curb notch is cut, it's best if the sidewalk isn't rolled again because it will crumble the clean notch edge cut by the grader. The sidewalk should be left 0.05 high and the curb grade right on grade for the concrete machine. This should give the curb machine enough trim to work with. The trim work can all be done with four pieces of equipment: a grader, a scraper, a roller, and a water truck.

## Pouring the Sidewalk and Curb

If the grader uses sonar and the same string line the concrete machine will use, the grade should come out very close, which will make the concrete pour go quickly. Figure 19-9 shows how close the grade along the back edge of the walk can be. Very little trim was needed on this job, making it a fast, good-quality pour. The concrete crew consists of a foreman, two operators and nine or more men following the machine. You need at least

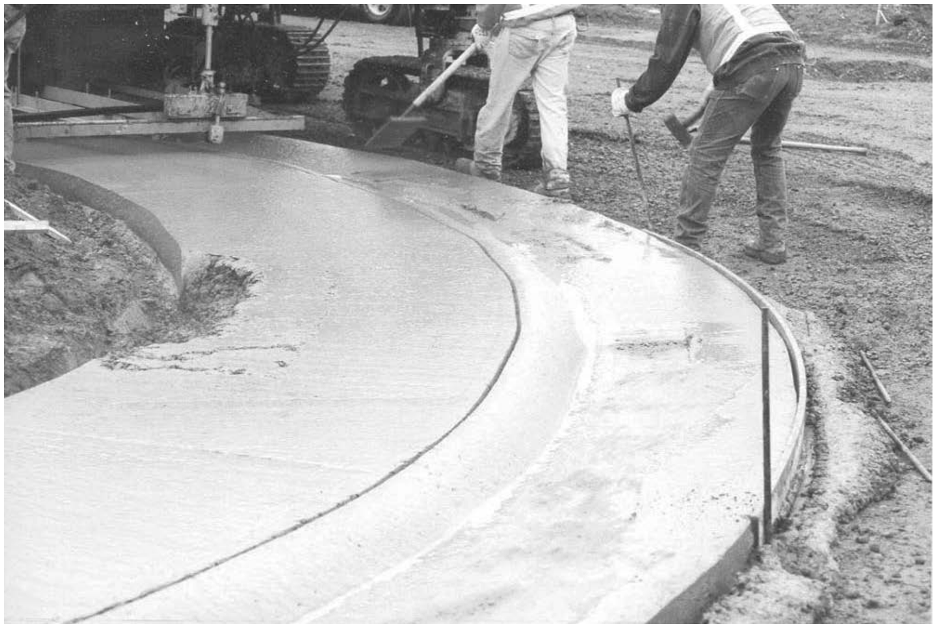

***Figure 19-10*** *Setting radius form*

five men to float finish, score-mark every 10 feet, set expansion joints every 20 feet, mark sewer and water services at the back-of-curb, broom finish, and spray-cure the new concrete. Four of the crew need to go ahead with a bobcat, to shape and tamp the aggregate for pedestrian ramps at the street corners and uncover drop inlet plates. The crew that trims the sidewalk and curb grade doesn't usually spend time doing the ramp grades. The crew of four must fall back, after the concrete machine has made the turn at the corner, to manually shape the concrete for the pedestrian ramp and dig out and set the drop inlet frame and grate, if there is one. That same crew must also quickly set a form to finish the front and back of the turn radius that the machine can't complete. Figure 19-10 shows this being started. The concrete crew will back-drag any spilled concrete so it'll become gravel and won't hinder the grading crew when they return later to finish the street aggregate.

## *Trimming the Road Grade*

Once the concrete has had time to cure, the grading crew can return to finish dumping aggregate and trimming the road grade. The grade was left 2 inches low, so there's about 600 tons of aggregate needed to cover the remaining 2,000-foot length of road. For a trim crew, you'll need a fore-


***Figure 19-11*** *Grader with sonar uses curb for grade*

man, grade setter, water truck, paddle-wheel scraper, grader, vibratory roller, small 2-ton roller and two laborers to dump, sweep curbs and clean edges. On a job this size, you don't want a scraper any larger than a Cat 615.

Start with three bottom dumps hauling aggregate, and after a few hours, if it looks like you don't need that many, you can cut them back to what you do need. Remember, a little room must be left at the end for trim to be spread. About 30 bottom dump loads is all it should take to finish the job. Be sure the grader, roller and water truck start at least one hour before any trucks arrive with the aggregate. That should be enough time to get the water needed back into the base rock and roll it before you add more.

The grader operator can use the sonar off the curb to spread and trim the grade 0.05 high as he moves along (see Figure 19-11). The rollers will roll the grade behind the grader and the water truck will keep the grade damp at all times while it's being trimmed. The grade setter must keep checking grade to be sure the sonar and slope control are dialed in correctly. In Figure 19-12, the grade setter is checking centerline grade by shooting with his eye level back to his swede. He may elect to set some centerline stakes as well. The grade setter needs to paint a line at centerline if no hubs are set. Doing the same job with a grader that has no

***Figure 19-12*** *Grade setter shoots from centerline back to swede at lip-of-curb*

slope control or sonar will create much more work for the grade setter. He'd have to set centerline hubs for trimming every 50 feet, taking his grade from the lip-of-curb and shooting to a swede. With or without sonar, the grade setter must check the lip-of-curb grade closely so it's the correct depth for the asphalt.

After the aggregate has been well-rolled, the grader operator will drop back and start his final trim. A laborer should work with the grader, scraping any loose rock from the curb edge that the grader missed. The grade was 0.05 high, but it's probably now rolled down by half that amount, so there should be very little trim. After he goes about 30 feet, the grader will stop and have the grade setter check the grade to be sure the sonar is still locked in correctly. Figure 19-13 shows the grader making his last pass with two rollers following right behind him, rolling the grade before it has time to dry. The scraper probably has the most tedious grading task — picking up the last trim windrow (Figure 19-14). He must do this without ruining the trimmed grade. When the scraper is finished, the grader will raise his sonar setting 0.02 for the last brush pass, just in case the scraper missed anything. The grade is now ready for paving. If there are existing streets that the new pavement will tie into, make sure that the edges are saw-cut and left for the paving crew to remove at the last moment.

Some agencies may require the rock grade on a highway or subdivision to be oiled. In this case, be sure the aggregate is damp before oiling, or the oil will bead up. When you're working with aggregate, you may have to have a street broom come by several times a day to sweep up rock dust tracked out by the dump trucks. Or, sometimes, a spray from the water truck is all that's needed for clean up.

***Figure 19-13*** *Grader makes fine-trim pass followed by two rollers*


***Figure 19-14*** *Scraper picking up last trim windrow*

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# CHAPTER 19 QUESTIONS

1. **Using the author's quick calculation method, how many tons of aggregate would you order to cover 12,000 square feet with 6 inches of gravel?**

   A) 250 tons
   B) 300 tons
   C) 350 tons
   D) 450 tons

2. **What type of gravel trucks should you use in large parking lots?**

   A) End dumps
   B) End dumps and bottoms
   C) Bottom dumps
   D) Semi bottoms

3. **What happens to gravel if it's overworked?**

   A) It'll become bony
   B) It'll lump together and become unusable
   C) It'll need an extra pass by the water truck
   D) It'll break up and will need to be replaced

4. **How do you keep aggregate fines from separating from the rock?**

   A) Roll it with a vibratory roller
   B) Roll it with a rubber-tired roller
   C) Keep it dry
   D) Keep it very moist

**5. What is the most common tool used for setting hubs in a parking lot?**

A) Swedes
B) Hand level
C) Eye level
D) Laser level

**6. How far out from the edge of asphalt should the grade setter set his crows foot grade stake on an open-shoulder road with a 12-inch aggregate section?**

A) 3 inches
B) 5 inches
C) 6 inches
D) 8 inches

**7. When dumping aggregate with bottom dumps, for the best results, how many feet should the gravel be spread?**

A) 50 feet
B) 75 feet
C) 100 feet
D) 125 feet

**8. How many feet before the spot the gravel is needed must the dump person give a bottom dump the signal to dump?**

A) On the spot
B) 5 feet
C) 10 feet
D) 15 feet

**9. How far in from the choker or open shoulder should the first windrow of aggregate on a highway job be dumped?**

A) 3 feet
B) 5 feet
C) 10 feet
D) 20 feet

**10. What is the usual tolerance allowed on aggregate grade?**

A) 0.05
B) 0.08
C) 0.10
D) 0.15

# LIME-TREATED BASE

20

When the soil is heavy clay or has too much moisture and can't be worked dry, the job specifications may call for lime treatment. Heavy clay may pick up moisture, causing the grade to pump and fail. Moisture resulting from weather conditions may also cause the soil to pump, with the same result. If lime treatment is done correctly, it will set up like concrete. Some agencies will also require lime base to cut the cost of the job if it reduces the amount of aggregate needed.

## Trimming the Subgrade

The need for lime treatment doesn't affect the dirt-moving operation. The difference is in rough trimming the subgrade. When you're going to apply a lime treatment, you first need to grade the subgrade material to the correct level as precisely as possible. That way, large amounts of lime-treated base won't be removed in the finish trimming.

A little more time spent trimming the subgrade before the lime is added will save time on the final trimming. Usually plus or minus 0.08 foot is the tolerance allowed for lime-treated base. It's a good idea to trim the subgrade to at least the same tolerance. Adding the usual 3 to 5 percent lime won't add enough volume to affect the grade level significantly. Also, the shrinkage caused by compacting will usually offset the volume of lime added, unless you're treating over 8 inches of soil. If so, consider undercutting the subgrade 0.05 to 0.08. Remember, before doing any ripping or rototilling, be sure to locate and expose anything in the graded area that could be hit, including manholes, water valves and blow offs.

## Spreading the Lime

When the subgrade has been trimmed, the lime-spreading operation can begin. Use these procedures in stable soil conditions. The first step is to rip up the road surface or parking area to be limed. Then spread the lime at the rate called for in the specifications. Figure 20-1 shows a lime truck spreading lime to be worked into the soil. Lime is usually applied in powder form. In very windy locations, a granular lime can be used that won't blow in the wind, but it requires more mixing. Lime can also be applied in slurry form. As a rule, lime can't be spread or mixed in temperatures under 35 degrees Fahrenheit.

Lime can be mixed into the soil in various ways: mixed off-site and hauled in if you're lime-treating a fill, on-site with a grader, or with a pug mill mixing in the windrows. But the best and fastest way on site is to use a reclaimer, a machine built for this purpose. It's similar to a large rototiller, chewing up the soil as it mixes soil, lime and water together.

Lime-mixing machines usually have a gauge that tells the operator the rate at which water is being added. For most soils, it takes a 15 percent mix of water to start the action of the lime. Nothing is left to chance. The lime machine provides excellent mixing, adding the right amount of water and mixing to the correct depth. During the summer months, I like the water added to be a little on the high side because it helps the lime react better, and with the heat, by the next morning it's perfect to work.

**Figure 20-1** *Lime truck spreading lime*

Figure 20-2 shows a lime-mixing machine making its second pass, 12 inches deep and still adding water to the grade. The hose in front is hooked to a water truck that stays just ahead of the lime machine. Notice the change in color from the first pass (top outside edge) to the second pass (bottom inside edge). The machine in Figure 20-3 is making a third pass, and all the lime streaks are gone. The grade is now mixed and ready for the pad-foot compactor to start rolling. Three passes are usually enough to mix in the lime, depending on soil conditions. The operator watches, and when there are no more white streaks left, the lime is sufficiently mixed. It's important to get the lime mixed evenly — if a pocket of unmixed lime is left, the ground will mushroom up in that area and cause the grade to fail after it's rolled.

## Compacting

A lime base requires 95 percent compaction. Start compaction no more than 24 hours after the final mixing. Begin by checking the specifications. They may require that you roll soil mixed deeper than 6 inches in two

***Figure 20-2*** *Mixing lime on second pass as water is added*


***Figure 20-3*** *Final mixing on third pass — all lime streaks are gone*

lifts. If that's the case, the grader must move the top lift aside so the bottom can be rolled first. Some agencies require a moisture test before compaction begins to ensure enough water was added while mixing. At first, the soil may seem too wet, but lime has a tendency to absorb moisture quickly.

Use a pad-foot or sheepsfoot roller for the initial compaction, followed by a rubber-tired roller. After the mixed soil has been rolled several times and it starts to look firm, with the pads beginning to ride high on the grade, you can begin trimming. A rubber-tired roller usually works well for this process because the material is less likely to stick to the rubber tires. A steel-drum roller might also be allowed. Check your specifications on rolling. Some agencies won't allow you to use smooth-drum vibratory rollers on lime base. It's important to keep the surface damp at all times when working lime base. While the grade is being trimmed, the rubber roller must stay close to the grader so no trimmed material is left loose on the grade to dry.

I think that for good results, trimming should be no more than 12 hours behind the initial compaction. Specifications usually allow seven days to complete mixing, rolling and trimming, but I prefer to finish my lime work in three days. Once it's trimmed and rolled, the grade should be oiled within 24 hours. Oiling the lime base seals in the moisture, keeps the soil from cracking and allows curing to take place. For best results, allow three days for the oil to cure before you let equipment or traffic on the grade. Oil shouldn't be applied in temperatures below 40 degrees Fahrenheit.

Don't oil the base if another layer of lime base is to be placed over the existing layer. In that case, just keep the lower layer damp until the second lift is added. If you're going to place aggregate on the lime base, you may not need to oil it — just water it to keep it damp. Again, check the specifications for your job because they may be different.

## Using Lime to Bridge Unsuitable Soil

Adding lime is an excellent way to stabilize a grade so work may continue. If the road base or parking areas are too soft to work during winter months when the temperature isn't warm enough to dry it out, the developer may elect to lime treat. This is done as extra work.

***Figure 20-4*** *Lime being mixed into very soft subgrade*

For the treatment to be effective, the lime should be mixed 12 inches deep. In Figure 20-4, a lime machine is mixing its first pass 12 inches deep. The subgrade on this job is so soft that no water is being applied for mixing. On the second pass, if the operator sees some dry areas, he'll apply water just to those areas. When lime is used to stabilize the grade this way, the soils engineer will usually let the contractor compact the full 12 inches in one lift. A pad-foot compactor and rubber-tired roller can penetrate the 12-inch layer well enough to compact the bottom 6 inches to the 90 percent required for a fill, and compact the top to 95 percent for the subgrade. This method usually eliminates all the unsuitable soil except for small areas around manholes and water valves where the machine can't mix. Small areas that are still pumping can be underexcavated with a small hoe and filled with aggregate, or remixed.

Once the lime subgrade is trimmed and rolled, it should be covered with aggregate before any rain falls on the grade. However, even if the grade is rained on before aggregate can be placed, it won't ruin the lime grade. It may get sloppy along the edges, but with a few days' break in the weather, a grader can quickly scrape up any sloppy grade, and aggregate can be dumped. You can complete a great deal of high-quality work under adverse conditions. It's just more expensive.

## Using Cement Instead of Lime

Lime treatment doesn't work well in sandy soil. You're better off using cement instead if the soil has a high sand, rather than clay, content. Cement-treated base mixed with aggregate may also be specified. If you're using cement, follow the same procedure as with lime, with two exceptions. First, you don't need as much water. Second, finish the fine trimming and complete the final rolling the same day. Usually, you must complete the final compaction within two hours of the mixing. Cement acts much faster than lime.

Like lime-treated base, cement-treated base must be oiled to avoid cracking. If you're going to add other layers, keep the surface damp by watering to avoid cracking where no oil is used. Concrete-treated soil is seldom used, but in cases where it's required, there will be job specifications outlining the exact procedures to follow. The big drawback to concrete treatment is that concrete dust is highly toxic (more so than lime), and must be very carefully controlled.

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# CHAPTER 20 QUESTIONS

**1. Which type of soil is best suited for lime treatment?**

A) Sandy
B) Rocky
C) Hard pan
D) Clay

**2. To what tolerance should you trim lime-treated subgrade?**

A) 0.08
B) 0.10
C) 0.12
D) 0.15

**3. What percentage of lime is most commonly added to the soil for lime treatment?**

A) 1 to 2 percent
B) 3 to 5 percent
C) 6 to 8 percent
D) 9 to 15 percent

**4. What is the first step in lime treatment?**

A) Pre-rototill the subgrade
B) Spread lime
C) Water subgrade
D) Rip subgrade

**5. Below what temperature should you *not* apply lime treatment?**

A) 29 degrees Fahrenheit
B) 35 degrees Fahrenheit
C) 40 degrees Fahrenheit
D) 45 degrees Fahrenheit

**6. How many passes of the lime machine are usually required for lime subgrade treatment?**

A) Two
B) Three
C) Four
D) Five

**7. For best results, how soon after the initial compaction should you start trimming lime-treated soil?**

A) 6 hours
B) 12 hours
C) 18 hours
D) 24 hours

**8. What type of roller may *not* be allowed for rolling lime base?**

A) Steel drum
B) Sheepsfoot
C) Vibratory
D) Pad foot

**9. With which type of soil would you most likely use cement-treated base?**

A) Sandy soil
B) Hardpan
C) Cobbles
D) Clay soil

**10. How long after the final mixing of cement-treated base should you complete compaction?**

A) After 30 minutes but no more than one hour
B) Within two hours
C) Within four hours
D) Within eight hours

# ASPHALT PAVING

# 21

Removing an old road and replacing it with a new surface on the same alignment presents different problems than a job where you're creating a new road. In this chapter we'll look at the equipment and techniques required for removing old asphalt, then we'll cover repairing and repaving roads with a new asphalt surface.

## Removing Asphalt Pavement

There are several types of equipment that you can use to remove an existing road surface, but by far the most efficient method is to grind it with a profiler grinder.


***Figure 21-1*** *Profiler removes pavement, base and soil to subgrade*

## *Profilers*

Figure 21-1 shows a profiler grinding 3 inches of pavement and 6 inches of aggregate to remove the old road section so it can be matched to the new section being built. The advantage of removing pavement in this way is that the material is cut and loaded, and the grade trimmed — all at the same time. Once the profiler is finished, the subgrade needs a slight cleanup with a grader, then it needs rolling and compacting to 95 percent, and it's ready for new base and asphalt. This method is fast and efficient, and that's very important if the road can only be closed to traffic for a limited time. Another advantage of using a profiler for removing pavement is that, in many cases, the grindings can be reused. The profiler can grind asphalt into small grindings ($2^1/_2$ inches or smaller) suitable for use as subbase material. However, you must have a site nearby to stockpile the grindings so they'll be available when you need them.

If the roadway you're removing is long, the trucks being loaded by the profiler can start dumping on the grade previously trimmed, once the subgrade has been cleaned up, rolled, and compacted. Or, if there's enough width on the road being ground, the trucks can dump the material needed for the subbase on top of the pavement next to the ground section. Then it can be bladed into the ground section as needed, eliminating the need to stockpile the grindings. You can also dump the grindings in the center median of a closed highway and use scrapers to haul them back to the compacted subgrade area to use as subbase. And you can do this without trucks. As the profiler trims, swing the conveyor belt to a 90-degree angle from the machine and allow it to dump the trimmings on the median. Some conveyors are long enough to dump in a median 50 feet away.

I used this method on both lanes of a highway that had 8 inches of aggregate and 3 inches of pavement. It was trimmed in two 9-inch lifts. The new section called for 8 inches of aggregate subbase, 6 inches of aggregate base and 4 inches of asphalt. By cutting two 9-inch lifts, the profiler also trimmed to the new section subgrade. After the subgrade was trimmed, rolled and ready for aggregate subbase, scrapers loaded the grindings from the first lift that the profiler dumped in the median and spread them on the new section as aggregate subbase. The grindings from the second lift, which were contaminated with dirt and aggregate, were hauled to an on-site fill area.

This method of operation can save several thousand dollars because you don't need trucks for hauling grindings away or hauling in aggregate subbase. Scrapers can haul the trimmings much faster than trucks because they can load faster and carry a larger load. You also save the cost of purchasing aggregate subbase. Another cost-saving feature of using profilers is that the pavement doesn't need saw-cutting. The profiler will trim a good straight edge without pulling up chunks of pavement. A final plus is that if traffic must be routed onto the area that was just trimmed with the profiler, it's already smooth and firm. It just needs a little rolling and a shot of water to make it ready to use as a temporary detour for traffic.

Profilers do need a water source. They use water to spray their cutting teeth to keep them cooled. They also need water to keep dust to a minimum. The large profilers have manual control boxes to control grade, steering and moldboard. In Figure 21-2 the grade setter is using the manual control box to control the grade for a short distance to clear some underground obstacles.

Large profilers are capable of taking 12 inches of pavement and aggregate in one pass, but only 1 to $1^1/_2$ inches of concrete in each pass. It's important not to rip the old pavement if you're going to use a profiler or reclaimer.

***Figure 21-2*** *Grade setter manually controls the grade*

## *Reclaimers*

A reclaimer is the same machine that's used for lime-treating base. It works well if the old asphalt is to be ground, recompacted and paved over. A reclaimer should not be used to grind concrete. Reclaimers don't have a conveyor to load trucks, and usually no sonar or slope control equipment. They primarily pulverize the material in place; never picking it up. Reclaimers need a water supply so they can add water to the base as they pulverize. They also use water to spray their teeth and for dust control.

It's important to mark any iron objects, such as manhole covers, cleanouts and water valves, before you do any road grinding. These items will damage a profiler or reclaimer.

## *Hoes and Loaders*

There are other ways to remove pavement that aren't as neat or efficient as profiling. Figure 21-3 shows a hoe removing and loading 4 inches of pavement and 6 inches of base. The remaining subgrade will require major trimming, and the rough edges will need to be saw cut before they're finished. In a small parking lot with several islands, a small hoe is a good choice for removing pavement because of the confined area. A rubber-tired hoe with a 4-in-1 bucket, along with a ten-wheel dump

**Figure 21-3** *Hoe removes and loads pavement and base*

truck for hauling, work well in this case. The hoe can load using either the hoe or the front 4-in-1 bucket.

Another option in a large parking area with few islands is to rip the pavement with a dozer. After ripping, the dozer can push the pave-ment chunks into a pile to be loaded by a hoe or loader. Figure 21-4 shows a Cat 325 hoe using a bucket with a thumb to load the truck. The thumb holds the chunks of asphalt in while the bucket is raised for loading.

When loading chunks of pavement or concrete from a stockpile, I suggest using track loaders because of their extra traction and short turning radius. They can work in a small space close to the truck. Figure 21-5 shows a track loader loading trucks from a mixed pile of rocks and soil. Notice how close to the pile both the truck and loader are. The loader can work in that close because of its short turning radius.

Setting up the correct number of trucks for profilers or loaders is very important. You should drive to the dump site and time how long it takes to make the trip. A profiler or hoe should be able to load a truck in one minute, and a loader in two minutes, but the time in and out of the job site could take five times that long. Be sure to figure that into your haul time as well.


***Figure 21-4*** *Hoe with thumb bucket attachment loading pavement*

***Figure 21-5*** *Track loader is able to work in tight area*

## *Scrapers*

Scrapers can be used very effectively to load asphalt, especially if the asphalt will be used in a fill and be compacted with a heavy-duty compactor like a Cat 825 pad-foot compactor. Though you could also use scrapers to remove asphalt, they're not as efficient as other methods of doing the work. For asphalt removal, the scraper should have at least a 20-yard-capacity bowl. It can be equipped with a paddle wheel, although many foremen, believing that asphalt is hard on a paddle-wheel scraper, will only use open-bowl scrapers. I think that's being overly cautious.

If you're removing asphalt that's 4 inches thick or less and only the asphalt must be removed, I'd use a drop-center cutting edge with teeth. A Cat 623 paddle-wheel scraper with good teeth will pull up the asphalt and stack it neatly in the bowl. Don't rip the pavement when using a paddle wheel. Keep the paddles at a slow speed to prevent damage to the paddles or chain. With a paddle-wheel or push scraper, the operator should set the bowl down so the teeth sit just below the bottom of the asphalt. The remainder of the cutting edge, which is higher than the teeth, will ride just at the top of the asphalt. This way, the asphalt will load easily.

The scraper will cut a strip only as wide as the ripper teeth, approximately 5 feet. It won't cut the full 10 feet of the bowl width. If no other equipment is available, this will get the job done. Make the first pass with the scraper at the edge of the pavement. After the first 5-foot-wide strip of pavement is removed, move over 5 feet and take another 5-foot section, leaving a 5-foot strip in the middle. Cut the middle strip on the third pass.

The reason you need to skip 5 feet each time is to keep the scraper wheels level while making these shallow cuts. If you don't move the scraper over 5 feet after the first pass, the wheel on one side will be the thickness of the pavement lower than the other, causing the low side to undercut.

If the pavement you're removing is 6 inches thick, rip it with a dozer and load it with open-bowl scrapers with a dozer pushing. If the pavement rips into very large chunks, track roll it with the dozer to break the chunks into smaller pieces. This method of ripping and loading is only useful if you can make deep cuts, taking up the base or subgrade as well. If you need to remove 6 inches of pavement without disturbing the base, then your best choice is a profiler.

# Asphalt Paving Equipment

There are various methods of spreading asphalt for paving, ranging from a self-propelled paving machine, a spreader box, a skip loader, a grader, to the most basic — by hand. The self-propelled paving machine is the only one that leaves a surface that meets the most stringent city, county or state job specifications. That's because the asphalt mat leaves the paver screed slightly compacted, and before anyone walks or drives on it, a double steel-drummed roller will compact it further.

A spreader box also leaves a slightly compacted mat behind the screed, but the spreader box isn't self-propelled. The truck dumping the asphalt pulls the spreader box, so if the truck slows down or speeds up, it has an effect on the thickness of the asphalt. The screed man must quickly make adjustments to keep a true grade.

When using a skip loader, a grader, or working by hand, the equipment and men must drive and walk on the soft asphalt, which leaves slight variations in the finished surface. The job will still look good if it's done correctly — it just won't be as perfectly smooth as the surface paved with a self-propelled paving machine. Self-propelled paving machines are the primary paving tool today. They're used on all large jobs where a specification-quality surface is needed.

## *Self-Propelled Paving Machines*

There are two ways for self-propelled paving machines to receive the asphalt. End dump trucks can dump the mix into the paving machine hopper (Figure 21-6), or a pickup machine can scoop up asphalt dumped from bottom dump trucks and deliver it to the paving machine (Figure 21-7). The pickup machine works like a self-loading scraper. It picks up the asphalt from the windrow that was dumped on the ground, and its paddles carry it up and flip it into the hopper at the front of the paving machine.

Figure 21-8 shows a paver moving along at an uninterrupted pace, as a pickup machine paddles the windrow of asphalt into the hopper. The dump man is hand-dumping the asphalt from the truck in front of the paver. This is a very experienced crew. The paver is taking grade from the curb and is running slope control. The foreman and his screed man are checking the asphalt thickness with a stab rod. The sonar has been set so well the raker has nothing to rake. He's pushing up (pinching) the edge to be rolled.

***Figure 21-6*** *End dump truck delivers asphalt to paver*


***Figure 21-7*** *Asphalt dumped from bottom dump is delivered to paver with a pickup machine*

***Figure 21-8*** *Bottom dump delivers asphalt as paver with pickup machine moves along without stopping*

### *Track and Rubber-Tired Pavers*

There are two styles of paving machines: track pavers and rubber-tired pavers. The track paver is excellent for paving on aggregate base, especially if the aggregate is a little loose. A track paver has much better traction than a rubber-tired paver. The tires on the paver can spin occasionally if the base is loose or it's paving uphill, and the paver may actually get stuck in the aggregate. If the aggregate is firm and the paver doesn't get overloaded, a rubber-tired paver will do an excellent job. The rubber-tired paver works well for overlays. It's fast and runs very smoothly on a hard surface.

### *The Hopper and Conveyor Belts*

Let's look at how the paving machine works. The asphalt is loaded into the hopper, either by truck or pickup machine. From the hopper, the asphalt mix is carried to the back of the paver by two metal conveyor belts (Figure 21-9). The conveyors dump it on the ground ahead of the screed. The conveyor gates can be lowered to restrict the amount of asphalt on

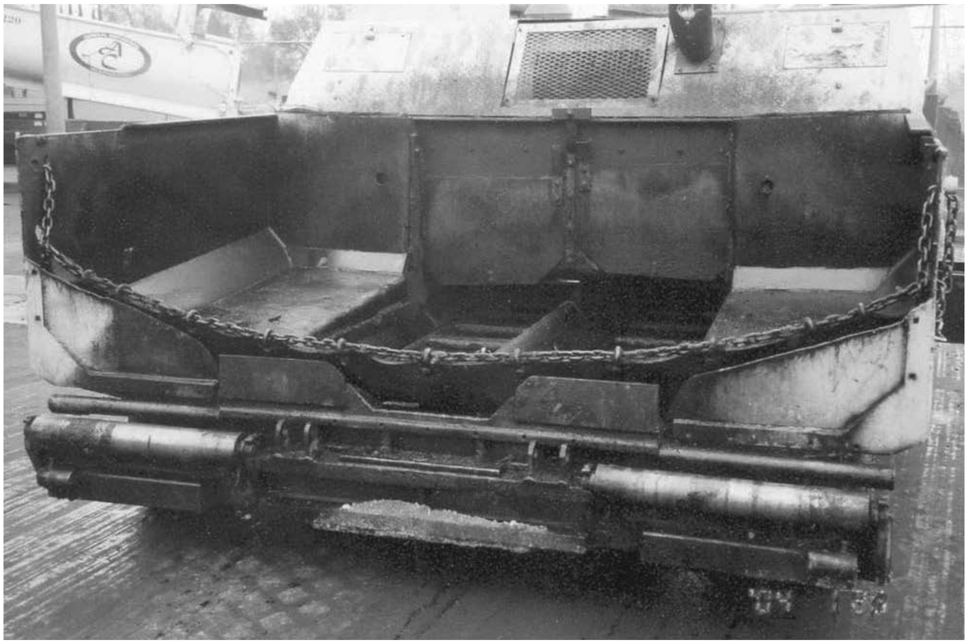

***Figure 21-9*** *Paver hopper*

one side or the other. This works well on a leveling pass, when one side is taking less asphalt. Both conveyors can still run automatically without the operator manually controlling one side. In Figure 21-9, a rubber belt has been added across the front of the hopper, so when the truck dumps, the asphalt won't spill on the ground. The wings on each side of the hopper are in the open position. When the dump truck pulls away, if more asphalt is needed before the next truck backs in, the operator can tilt the wings inward to direct more asphalt onto the conveyer, as shown in Figure 21-10. The rollers on the front of the hopper are positioned against the truck tires as the paver pushes the truck ahead.

### *Screed Augers*

Two screed augers spread the asphalt concrete the entire length of the screed. The screed strikes off the asphalt concrete at the set depth. The asphalt concrete passes under the screed and comes out of the back of the screed smooth and partially-compacted by the vibrating screed. Look back at Figure 21-8. The paver is leaving a smooth, partly-compacted mat behind. Notice the silver tubes at the back of the paver. Those tubes are hydraulically controlled to slide out when needed. This paver can start with a 12-foot-wide mat and extend it out to 20 feet as it paves along.

***Figure 21-10*** *Paving machine hopper with wings raised*

Two sonar sensors, one on each end of the screed, monitor the amount of asphalt that's dumped to the augers from the conveyor. These sensors work independently of each other. If they detect that the augers have enough asphalt on the outer edge, they'll immediately shut the conveyor off until the augers can distribute the accumulated material. The automatic sensors can also be turned off so the mix supplied to the augers can be controlled manually. The operator then controls the conveyor and auger delivery rate.

Once the augers have distributed the asphalt the entire length of the screed, the screed both levels the asphalt at the depth set by the screed man and compacts the mix with a vibrating, tamping motion. The screed man will monitor the sonar to be sure they're supplying the material and grade he's set. The screed on the paving machine can be raised and lowered hydraulically or manually. If the sonar unit is set to adjust, it'll automatically raise or lower the screed as needed. Figure 21-11 shows both sonar units mounted on the paver. The large unit, with the veil wire hanging down, controls the grade on that side. The small unit in the left-hand corner controls the auger on that side. The veil wire on the unit controlling the grade keeps the heat waves coming off the hot asphalt from distorting the reading to the unit.

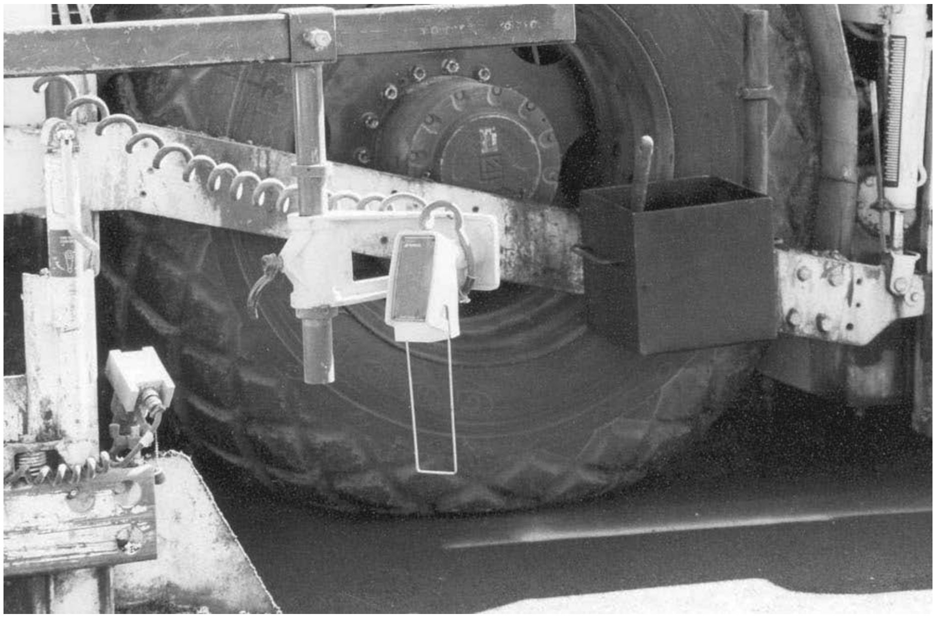

***Figure 21-11*** *Two sonar units on paver control grade and asphalt augered to the outside edge*

### *Expandable Pavers*

There are many models and sizes of paving machines. Some models can lay pavement more than 20 feet wide, as we saw in Figure 21-8. In addition to the hydraulically-operated extension tubes, there are also screed extensions and auger extensions that can be bolted on. Because the screeds hinge in the center, you can also set a crown or a swale in the screed.

When the paver is extended past 18 feet, the asphalt must be augured further to reach the extensions at the outer edge. The operator may need to drop to a lower gear and slow his travel speed if he's paving a deep section. That way, the augers can catch up with the material requirement of the screed. On a 10- or 15-foot paving pass, the augers can usually supply enough material to the outer edges of the screed to permit a higher travel speed, even when placing a thick lift.

The contractor was only able to close the road shown in Figure 21-12 for a short time. He extended the screed to cover 18 feet, crowned at the center, and paved the entire road in one pass. He was able to open the road to traffic by afternoon. Notice that he used a semi-end dump rather than bottom dumps. For paving an area this wide, at $2^1/_2$ inches deep, it

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***Figure 21-12*** *Paver with extended screed can pave entire road in one pass*

would be hard to dump a large-enough windrow to supply the asphalt needed with bottom dumps. Also, there's no room to get around the paver, and bottoms can only back up about 20 feet before they start jackknifing. Your choice of equipment must always match the job conditions, and these are affected by many variables.

## *Using a Pickup Machine*

Using a pickup machine to move asphalt to the hopper substantially increases the hourly tonnage you can handle. The big advantage with a pickup machine is that the paver almost never stops. When using end dump trucks, the paver must stop every time one truck's empty to allow a full truck to back up to the paver and raise its bed for dumping. The disadvantage of pickup machines is that if the weather's too cold, the asphalt dumped on the ground for the pickup may cool before the pickup machine can pick it up. Also, a pickup machine isn't always a good choice if the paver must start new passes frequently. They work best on long, uninterrupted passes.

The paving machine supplies the power that pushes the truck ahead when end dump trucks are used. The paver also propels the pickup machine attached to the front of the paver, though the pickup machine does have its own engine to run the conveyor and hydraulics. You need to adjust the pickup machine periodically so that it scrapes up as much asphalt as possible without cutting into the subgrade.

## Setting String Lines

You need to set a string line on a road job where there are no curbs to follow. You always need a string line set on the shoulder edge, 6 inches out from edge of pavement, where possible. The operator needs to be able to see the line without paving over it. On a wide road it will be necessary to run a string line at centerline as well. The paver uses this for line only, not for grade. Be sure to nail the string down every 30 feet so it won't move.

Usually, you don't need a string line when you're paving a parking lot, because the curbs serve as a reference line. If you're placing extruded curb on the pavement after the parking lot is paved, then the grading crew should use paint or a string to mark the edge-of-pavement line around planters and the lot perimeter. It's a time-consuming job, but they can do it more quickly than the paving crew because they're more familiar with the plans, having just graded the aggregate base.

## Planning the Passes

Let's assume we're paving a roadway that's 64 feet wide — 32 feet each side of the centerline. There's an 8-foot shoulder on each side that has a different percent of slope than the roadway. So, we have 24 feet of road surface and 8 feet of shoulder on each side. Here's the best procedure to pave a road of that width. Set a string for line 6 inches out from the edge-of-shoulder pavement. If the specifications allow it, pave the 8-foot shoulder first. Once the shoulder is paved, the paver should double back to make a 12-foot pass to tie onto the shoulder. This will leave the last 12-foot pass to centerline, where another string line should be placed for line 6 inches out. That will complete one half of the 64-foot road section. Then do the same thing to finish the second half of the road.

If the shoulder grade is the same thickness and percentage of slope as the road section, most agencies will allow you to make two 16-foot passes on each side of the roadway for the 64 feet. Or, with a crown in the screed, you can make a 16-foot pass down the centerline, paving an 8-foot-wide section in each lane. Then, with the crown taken out of the screed, pave two 12-foot passes on each side of the centerline, starting at the shoulder, to finish out the job. That would also yield the 64-foot width. The width you choose to pave with each pass depends on the width the paver can pave most efficiently, the agency requirements, and, if you're working on an existing road, the traffic conditions you have to contend with.

Remember, if the shoulders have a greater slope than the road section, they must be paved separately, and before the last road pass along the shoulder. Some agencies insist that the pavement joints of each pass be at the edge of the lanes where the traffic stripe will be, and not in the travel lane. Read the specifications so you know the requirements you've got to meet. Some pavers are designed to pave the shoulder slope simultaneously with the travel lane, at a different slope percentage. If you're using one of these machines, you may be able to pave each road half with the shoulder in two 16-foot passes. However, some agencies always want the main line paved before the shoulders. Again, check your specs.

If two lifts of asphalt are required, the joints of the two lifts should be staggered. That way, if the top joint should crack with age, the bottom lift will hold the surface intact. There are various widths and starting points you can use. One foreman may use a completely different pattern than the next and they'll both get the same, equally good, result.

## *Warming Up the Equipment*

Some preparation must be done before a paving machine is ready for paving. Allow time for this. Under average weather conditions, the paving screed must be warmed up for 40 to 50 minutes, using an electric screed warmer or fire in the screed tunnel. Any area on the paving machine that comes in contact with asphalt must be sprayed with a light coat of diesel, including the conveyor and the bottom of the screed. This prevents the asphalt from sticking to cold parts. You must also have a water supply on hand to fill the rollers.

If you're using a pickup machine, it should be started, checked for worn or loose parts, and sprayed with diesel. The paving machine is equipped with a pump hose and spray nozzle for spraying diesel anywhere it's needed.

All of the bearings on the pickup machine and the paving machine must be greased and checked for wear. The flight chains that run the conveyor on the paving machine must be checked to be sure they haven't loosened.

## Planning the Dump

Reminder: To estimate the amount of asphalt you'll need, using my quick formula, multiply the square footage to be paved by the depth, in inches, of asphalt to be placed, and divide by 160 to get the number of tons. Remember to order a little under in case the subgrade is slightly off. That way you can adjust the tonnage to correspond to what you need as work proceeds.

If the asphalt delivery trucks are scheduled correctly, and you're using a pickup machine, the paver can pave without stopping. The dump man must make sure that the right amount of mix is dumped ahead of the paving machine. He must know the distance each truckload of asphalt is to be spread. For example, if you're using 25-ton bottom dump trucks, each of the two trailers carry $12^1/_2$ tons of asphalt. Calculate the width and thickness of the asphalt mat being paved to determine how far the 25 tons will go. Let's say our area is 10 feet wide and we're paving 2 inches deep. Use my quick formula in reverse to see how far 25 tons will spread:

25 tons x 160 = 4,000
4,000 ÷ 2 = 2,000 square feet
2,000 ÷ 10 = 200 feet long

We'll estimate that 25 tons of asphalt spread 10 feet wide and 2 inches thick will cover approximately 200 feet. Because of variations in the subgrade, the dump person may have to adjust the spread distance periodically.

### *Checking the Spread*

If you're not familiar with the spread characteristics of bottom dump trucks, here's how to test it. Set the chains on each trailer so the bottom gates will open only 12 inches. Dump the back trailer. Then measure the distance it took to unload. If the distance it took to spread one trailer was more than 100 feet, the asphalt was dumped too light. If the distance was shorter than 100 feet, it was dumped too heavy.

If it was dumped too light, have the truck pull out and come around again. Have the truck straddle the windrow just dumped. Hand dump the front trailer to add more mix into the first 100 feet. Once the 100-foot mark has been reached, start dumping heaver until the front trailer is empty. Reset the chains on both trailers to dump a little heavier when the next load is delivered. Always remember that the complete load must be dumped to cover no more than 200 feet.

If the first trailer dumped too heavy (say it spread only 80 feet), move the truck ahead 20 feet so the second trailer will start dumping at the 100-foot mark. Tighten the chains so the dump will spread lighter on the next load. Keep in mind that it's much easier to dump a little more asphalt later than to get rid of excess asphalt. A dump man with a few years of experience will usually hand dump each trailer on every truckload. He should be able to judge exactly how much is needed without measuring the distance dumped. If the dump man is off in his estimations, the paver will start getting overloaded. The foreman or paver operator will know right away, because the hopper will begin to overfill with asphalt. If this happens, they'll tell the dump person to leave a 30-foot space before the next trailer dump so the extra asphalt will be used up. If the hopper starts to run shy of asphalt, they'll tell the dump person to start the next truck right in front of the pickup machine so it can add enough asphalt to the hopper to bring it up to the level needed. The dump man in Figure 21-13 has done an excellent job controlling the dump. The even, continuous windrow means a good production rate.

When the bottom dump trucks are hand dumped, with the dump man controlling the gates, the front trailer should be dumped first. When the front trailer is empty, the dump man will stand at the spot where the dumping was finished until the back trailer gets to him. Then he'll dump the second trailer. Dumping the front trailer first is only possible on level ground with a good firm base or when dumping downhill. If the grade is loose, or if the truck is dumping on an incline, the truck will lose traction when the front trailer is emptied. If the back trailer is dumped first, the truck has to stop and back up until the front trailer reaches the spot where the back trailer ran out of mix. Remember, whenever possible, you want to dump a continuous windrow of asphalt.

## Placing Asphalt with a Paver

The number of men required to work with the paver will vary from five to eight, including the operator and roller man. More men are needed

**Figure 21-13** *Dump man hand dumps a bottom dump trailer for continuous windrow*

for raking and shoveling if there are cul-de-sacs or tight curves in parking lots to pave. If a pickup machine is used, you need another man to handle the dumping. In many cases, three rollers are needed. This gives you an idea how the crew size can vary, depending on the job type and size. If you're paving where traffic is a problem, you may need two or more flagmen. If a pilot car is needed, you'll need a driver.

## *Watching the Mix*

As paving progresses, the foreman should watch the temperature, texture and oil content of the asphalt closely. If the mix doesn't have enough fine material, it'll look rocky and coarse as it leaves the screed. When the mix is too hot, it'll smoke more than usual and may have a brownish look. A hot mix won't roll well under the first roller and will tend to leave a pebbled surface. When a mix is too cool, it'll be slow sliding into the hopper and may be a little lumpy as it's dumped from the truck.

You can judge the amount of oil in the mix by its shine. A dull surface means it needs more oil and a very shiny look means it has too much oil. Call the asphalt plant if you see a problem with the mix so they can correct it. It's good practice to have an asphalt thermometer on hand to check the asphalt temperature regularly while you're paving.

Asphalt is usually spread at 285 to 350 degrees Fahrenheit. Most job specifications won't allow asphalt to be placed when the air temperature is 40 degrees or below. Open-graded asphalt is spread at a lower temperature, between 200 and 250 degrees. Since it has no fines, open-graded asphalt doesn't retain heat as well and shouldn't be placed when the air temperature drops below 60 degrees. In cold weather or on long hauls, make sure the asphalt is covered with tarps during the trip from the plant to the job.

In very hot weather, if traffic must be diverted over a just-paved mat, the inspector may require that a water truck spray the asphalt to cool it. Traffic can damage a hot mat of asphalt if the cars must stop, start or turn quickly.

### *Sonar and Slope Control*

Most paving is done using sonar for grade control, as well as to control the percentage of slope. These electronic devices help the paving crew turn out precise work at a fast pace. Once the sonar units have been set correctly, they pretty much control the grade, allowing the screed man more time to control the width and line he needs. However, there's a slope level at the rear of the paver if he wants to manually check the percentage setting.

The sonar can be set to take a reading from the subgrade on both sides of the paver. However, if the subgrade was graded poorly, then the pavement will match it. For this reason, some agencies require that a ski several feet long be dragged along over the grade by the paver, giving a reading of the average grade in that distance. If there's a dip in one spot, the ski won't follow it — but the sonar would have. Where there's a curb on one side, you should use the sonar on that side to control grade. Slope control may be turned on to maintain slope and grade to the opposite side. With sonar controlling the grade from the curb side only, there's less chance that it will follow any irregular aggregate subgrade on the opposite side.

When starting a pass with the paving machine, place blocks under the screed on each side so that it's off the ground approximately the thickness of the asphalt to be placed. Notice the 2 x 4 with the lath on it next to the

***Figure 21-14*** *Block of wood holds screed up*

crewman in Figure 21-14. It's used to keep the screed 2 inches up from the base as the paver starts a new pass. This will set the screed so that it won't drop as the paver pulls ahead and the screed leaves the blocks. The screed slides on the wood until it reaches the asphalt.

The first few feet traveled on a new pass may require some quick adjustments, even when using the sonar control sensor. It's good practice to use two men on the screed for a few feet so one is free to make adjustments to the sonar. The screed man should measure the asphalt thickness several times in the first several feet of each new pass, and thereafter as needed. Figure 21-15 shows a typical stab rod used to check the depth or thickness of the asphalt. You can make one like this by simply welding a 2-inch washer to a sleeve. Then set the washer to the desired depth of asphalt. If you stab down

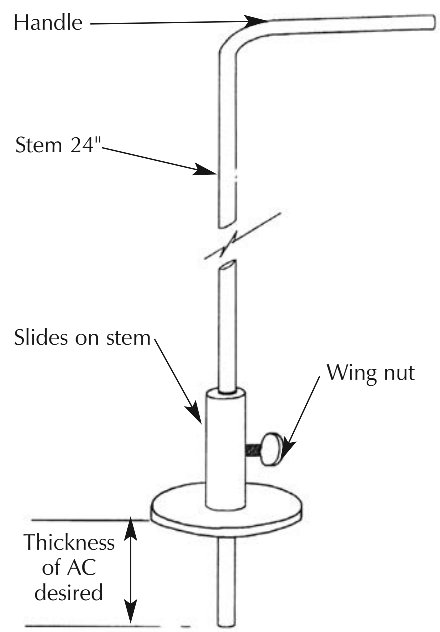


***Figure 21-15*** *Stab rod*

| Asphalt Concrete Screed Setting (Depth) | Asphalt Concrete After Rolling (Depth) |
|---|---|
| $1\frac{3}{16}$" | 1" |
| $1\frac{3}{4}$" | $1\frac{1}{2}$" |
| $2\frac{3}{8}$" | 2" |
| 3" | $2\frac{1}{2}$" |
| $3\frac{5}{8}$" | 3" |
| $4\frac{1}{4}$" | $3\frac{1}{2}$" |
| $4\frac{7}{8}$" | 4" |
| $5\frac{1}{2}$" | $4\frac{1}{2}$" |
| $6\frac{1}{8}$" | 5" |

***Figure 21-16*** *Depth of asphalt needed to achieve finished depth after rolling*

firmly into the asphalt and the washer sinks in $\frac{1}{2}$ inch, the mat is running too deep. If the washer doesn't even touch the mat, then the mat is too thin. You need to make adjustments in either case.

The screed will compress the asphalt somewhat. The asphalt mat will be further compacted by the rollers finishing the surface. You must figure the compaction shrinkage into the depth of the asphalt mat. You don't want the finished asphalt mat to be thinner than called for in the specifications. Figure 21-16 shows the depth of asphalt you need at the screed to achieve the finished depth required after rolling. The numbers will vary slightly with different aggregates, but these are good ballpark figures to start with, until you become familiar with the material used in your area.

## Stopping the Conveyors

The paving machine operator must stop the conveyors when the paver comes to the end of a paving pass. He should be able to judge the material and distance close enough so that the screed will be empty (having passed over all the asphalt that's been dumped) when he's at the end of each pass. It's better to stop the conveyors a little early than to end up with too

***Figure 21-17*** *Hand-grading the end of the pass*

much asphalt on the ground and have to pick it up. More mix can be conveyed to the screed to finish the pass if needed.

Any excess material ahead of the screed at the end of the pass will be left on the ground when the screed is lifted. It must be shoveled back into the machine or spread on the grade. In Figure 21-17 the paving machine operator has cut the asphalt off perfectly. Two crewmen shoveling and one raking finish hand-grading the mat to tie it into the existing pavement. If a pickup machine is used, however, the paver can turn around and paddle up the excess asphalt. In Figure 21-18, the paver has finished the cul-de-sac and the pickup machine is scraping up the remaining asphalt.

### *Paving Grade Changes and Other Irregular Jobs*

Paving highway on and off ramps is difficult because the grade changes rapidly from slope to slope. Usually there'll be a long tapered area to pave and then a narrow shoulder that's at a different slope than the travel lane. This was an even more difficult job before paving machines had sonar and slope control. If a ramp is being paved and the slope starts out at 2 percent then goes to 5 percent and back to 2 percent, the sonar on each side of the screed will follow the subgrade on each side with very few adjustments being needed.

***Figure 21-18*** *Pickup machine scrapes up excess asphalt*

### *Tapers*

When paving tapered areas, it's usually best to stop the full pass just short of where the taper begins, and then pave the taper first. Once the taper is paved, scrape up any excess asphalt slobbered onto the main line grade and continue the main line paving. This will make a smooth transition and both areas can be rolled together while still hot.

If you're using a pickup machine on short radius turns, you can usually paddle enough asphalt from the traffic lane windrow to complete the curve. If you need more mix to finish the radius, paddle a little more asphalt from the traffic lane windrow. Use the same procedure on short tapers. The dump man must be careful with his dumping when there's a taper or radius involved. The normal dump pattern might leave material in the way for pulling a taper or radius. You might need to hold the trucks up until the taper or radius has been paved before you finish the traffic lane windrow. If there are small areas where the paving machine must pick up and reset frequently, don't use a pickup machine. In that instance, end dumps would be the better method.

***Figure 21-19*** *First pass in the cul-de-sac*

### *Cul-de-Sacs*

Paving an average-size cul-de-sac should take three paver passes on each side. The paver can pave a cul-de-sac with a pickup machine attached. The asphalt dumped on the main line is loaded in the hopper until it's full, then the paver backs into the cul-de-sac and paves until the hopper is empty. The paver then returns to the main line windrow for another load. It usually takes three trips on each side. If you can drive out the back end of the cul-de-sac, a windrow can be dumped on each side of the centerline so the hopper can be loaded in the cul-de-sac, saving some time. When using end dumps, the truck can back into the cul-de-sac and dump into the hopper for the second pass.

The paver in Figure 21-19 is making his first pass in the cul-de-sac. Notice that with the extended screed, the paver is able to pave wide as he makes the turn. In Figure 21-20, the paver makes the second pass to centerline to catch the first half of the cul-de-sac. Figure 21-21 shows the paver making the final pass to pave the small pie-shaped section on the corner and finish the first half of the cul-de-sac. To save hand work, a skip loader (Figure 21-22) makes a straight cut in line with the outer curb, picking up the excess asphalt with a 4-in-1 bucket. The paver can now start

***Figure 21-20*** *Making the second pass*

***Figure 21-21*** *The third pass finishes the corner*


***Figure 21-22*** *Skip loader cleans up excess asphalt*

the main line pass. Figure 21-23 shows the paver tying the main line pass to the cul-de-sac mat for the finished product. The raker rakes the surface smooth, and the roller (in the background) will roll it before it cools. It's very important that no gaps, not even as small as 1 inch, remain when paving joints together. Even though raking can make it look fine, after a year or so the pavement will pull apart, leaving a crack for water to enter.

### *Parking Lots*

You can pave around islands in parking lots with a paving machine, although much more hand work is involved. When there are several islands in a small area, you can use a small tractor with a drag box to grade all the corners just ahead of the paving machine. Figure 21-24 shows a skip loader and a four-man crew paving corners ahead of the paver. This frees the paving machine for longer passes and speeds up the operation, since no time is lost trying to maneuver the paver into tight corners.

There are times when a paver must pave areas so short or curved that a truck can't maneuver with the paver. The paver must get a full hopper of asphalt, leave the truck, and lay down the short pass. If more mix is


***Figure 21-23*** *Paver ties main line pass into mat while raker smoothes surface*

***Figure 21-24*** *Skip loader paving corners*

needed, the paver must return to the truck. If there are many of these areas, it may be faster to dump the asphalt on the ground and have a loader carry it to the hopper. This will free the truck to get another load, so fewer trucks are needed.

### Correcting an Overloaded Paver

If you're using a pickup machine and the paving machine becomes overloaded with asphalt because the dump man dumped too heavy, there are two things you can do. If the paving machine operator recognizes the problem soon enough, he can have the screed man raise the screed slightly until the danger of being overloaded has passed. If the grade tolerance is such that the screed can't be raised, the paving machine must be stopped and the extra asphalt removed to some convenient location.

The inspector may allow the paving machine to move ahead and spread a $^1/_2$-inch-thick layer of asphalt in front of the paving operation until the excess has been used. When the dump man gets to the area where the $^1/_2$ inch of mix was spread, he can compensate by dumping less. If there's a taper or shoulder up ahead, it might pay to move ahead and pave that area with the excess, then return to where the paver left off, and continue. On some jobs you might have an area available where excess asphalt can be piled up and then hauled off after the job is complete. However, this is an expensive way to handle the problem and should be avoided if possible.

### Dealing with Paver Breakdowns

Occasionally, a paving machine will have a major breakdown that can't be repaired before the windrow of asphalt has cooled. If no other paving machine is available to take over, use a grader to spread the mix very thin so it can be overlaid when the paving machine is repaired. If the paving machine should break down for two or three hours, the mix remaining in the paver could be cold enough to break a flight chain or cause other damage to the paver when it starts up again. In this case, when the paver is repaired, raise the screed and pull away from the mat of pavement. If a small amount of cold mix is in the hopper, shovel it out. Then spread out the pile of mix left on the ground after raising the screed, either with a shovel or with the screed. This may take more than one attempt. If it has turned to chunks, throw them to the side of the road. If a large amount of mix was in the hopper, it may have stayed warm enough to run through the machine. Try to run the conveyor slowly. If the engine lugs, stop the conveyor. Trying to force mix through the conveyor will usually break a flight chain. On a large paving job, when asphalt is being dumped with bottoms 300 feet ahead of the paver, a second paver and pickup machine should be parked on the job to use for backup.

### *Keeping the Truck Drivers Informed*

It's important to keep the asphalt truck drivers informed of the paving pattern, especially when you're paving several streets. If there are 30 trucks hauling to the paver, it doesn't take many confused truck drivers to obstruct the progress of the paving crew. The truck flow problem is especially complicated with bottom dump trucks because they can't back up very far without jackknifing. Keep your trucks moving in and out of the project by making a map of the paving pattern and ensuring that each driver receives a copy of the map before he leaves the asphalt plant. This will eliminate most of the flow control problems and increase production. Mark the order of the areas to be paved, from first to the fifth, etc. If the foreman wants to deviate from the mapped paving plan, most truckers have CB radios and can pass the change on to the other truckers over their CB. Or, as the truckers are approaching the job, they can talk to truckers on the job and ask where the paver is working. Truckers will usually do this without a map, but the map helps.

## Paving with a Spreader Box

Paving with a spreader box is different from paving with a paving machine in the following ways: The spreader box isn't self-propelled and usually doesn't have a vibrating screed (though some of the newer ones do); it doesn't have a conveyor; and the hopper goes right to the ground and screed. The screed adjustments work essentially the same way, but the spreader box doesn't have an automatic screed control system, and there isn't usually a screed tunnel to be warmed up. As soon as asphalt concrete slides under the screed on the first pass, stop the spreader box for five minutes and let the asphalt heat the screed. Like the paver, the spreader box needs to be oiled. Just use a garden sprayer to spray a little diesel oil on all the areas the asphalt will touch.

The truck that's dumping the mix also pulls the spreader box. The spreader box has arms with rollers that attach to the wheel well of the truck's back wheels. The arms are pulled tight against the wheel wells with a hydraulic jack-type pump. The spreader box rolls on wheels or tracks.

Adjust the chain on the truck's tailgate so it only opens about 15 inches. This will keep the asphalt from dumping too fast. You must also watch the angle of the truck bed closely. It's very easy to overfill a spreader box. Some spreader boxes are pretty elaborate. They have small motors that run the hydraulics for the arms that attach to the truck, and for the screed extensions, screed lifts, screed vibrator and hopper door.

Most truck drivers have a tendency to pull the spreader box too fast. The speed should be kept slow and even. The screed man needs time to react to grade changes and check the thickness of the mat. If he doesn't make screed adjustments when the truck speeds up, the mat will get thinner; if the truck slows down, the mat will get thicker. A steady speed will help to control mat thickness. The raker must also keep up with the spreader box. If he can't, you'll either have to slow the box down or add a second raker. When using a spreader box without a vibrating screed, you should leave the asphalt mat approximately $^{3}/_{16}$ to $^{1}/_{4}$ inch thicker than you would with a paving machine.

When each pass is finished, the box must be lifted by the truck and moved to the point where the next pass begins. To lift the box, hook a chain from the back of the spreader box to the top of the truck's tailgate when the truck bed is raised. When the bed is lowered, it will lift the spreader box off the ground. The arms remain attached to the truck's wheels during lifting and moving. Most spreader boxes have hydraulically-operated gates that close to hold any mix left in the box while it's being moved. When the truck is in position for the next pass, raise the truck bed until the spreader box is on the ground and there's slack in the chain. Unhook the box, open the hopper gate, dump more mix into the spreader box and resume paving.

At the end of each shift, remove all asphalt from the box or paving machine. Spray diesel oil on every surface the asphalt concrete has contacted. Give special attention to moving parts.

## Scheduling Asphalt Trucks

The size of the area being paved and the number of cul-de-sacs, short stub streets, and islands will determine the tonnage that a paving crew can put down in a day. A subdivision with a few cul-de-sacs may use 200 to 350 tons per hour. A parking lot job with several islands to be paved around using end dump trucks might use 100 to 225 tons per hour. If a long section of road is being paved using a pickup machine and bottom dump trucks hauling the asphalt, the tonnage could range from 600 to 1200 tons per hour. Paving 1200 tons an hour is very hard to achieve. In order to do this, you'll need to have bottom dumps hauling the asphalt and have more than one batch plant supplying asphalt. And those plants must be dedicated to just your job, supplying no other customer that day.

Experienced superintendents can usually look at a job and determine the daily tonnage. However, it's not uncommon to have to add more trucks or reduce the delivery rate once the paving has begun. If you're in doubt as to how many tons you need for a shift, seek advice from the estimator or the paving machine operator. Experienced operators usually know how much area they can pave in a day.

The number of trucks needed for a paving spread depends on the distance they must travel from the plant to the project, as well as the amount of asphalt that's needed. You must know the driving time between the plant and the job site before you can schedule the trucks. After estimating the tonnage needed and the travel time from the plant to the job and back again, you should be able to determine the number of trucks you'll need. If the batch plant can only produce 450 tons an hour, that will also affect the daily production and number of trucks you should schedule.

Always use your high estimate when scheduling trucks. Once the paving begins, it's easier to lay off one truck than to add one truck. It's cheaper to have a truck standing by until an adjustment can be made than to keep the paving machine and crew waiting for a truck to arrive.

If the plant supplying the asphalt is a distance from the job, you may have several trucks on the road at all times during the day. Keep this in mind when you're coming to the end of the job or at the end of the shift. If there are 15 trucks hauling asphalt, and you only need 15 more loads, you must let the truck drivers know not to return after they dump. If load numbers are marked on each scale ticket, you can call the plant and tell them to stop loading at a given load number. But be sure to have the plant hold one or two trucks at the plant until you're sure you have enough asphalt returning to the site to complete the job. You don't want to find that you need one more truckload and there's no truck to deliver it.

It's easiest to have the plant control the load cut-off point. But to do this, someone must keep ahead of the situation and notify the plant before the last required load leaves the plant. Some asphalt plants hold prepared mix in a hopper. If this is the case, the plant personnel must know in advance of the shut-off time, tonnage, or final load number so the hopper can be emptied before their shift is over. At the start of the day, check with the plant foreman and ask how much advance notice they need to clear the hopper.

## Rolling the Spread

The weight of the roller you use and number of passes you make on a new asphalt spread determines the quality of the finished surface. The job specifications will usually spell out the type and number of rollers, the order in which they should roll, and the passes required.

When rolling asphalt, always make your first pass on the low side of the asphalt mat. It's best to roll with the bull wheel first and the tiller wheel trailing. (The bull wheel propels the roller and the tiller wheel steers it.) If the area being rolled is level, start rolling on the edge away from the side of the next pass. If the paver will soon make the second pass, don't roll the last foot on the second pass side. It's much easier to pave up to an edge that hasn't been rolled. In warm weather you can wait as much as half an hour before tying into and rolling the edge.

Some asphalt job specifications require that you use three rollers: a 12-ton double-drum vibratory roller, a pneumatic-tired roller, and an 8-ton tandem roller. The initial rolling is done with the double-drum vibrating roller. This is called the breakdown rolling. The vibrating tandem must keep up with the paving machine, never falling far behind. Figure 21-25 shows the raker followed by the breakdown roller, both working right behind the paver. The second rolling, done with the rubber-tired roller (Figure 21-26), should start when the asphalt mat has cooled slightly, but not below 180 degrees. The third or finish roller is the 8-ton tandem (usually not vibrating).

Local requirements and the size of the job can also determine how many rollers you'll need. In some localities the specifications may only require a double-drum vibratory breakdown roller with an 8-ton tandem roller to finish, eliminating the need for the rubber-tired roller.

Many small jobs require only an 8- to 10-ton vibrating roller for breakdown and finishing. In a parking lot with many islands, use a 3- to 5-ton vibratory double-drum roller to smooth out the creases and roll the


***Figure 21-25*** *Raker following paver with the breakdown roller close behind*


*Reprinted courtesy of Caterpillar Inc.*

***Figure 21-26*** *Rubber-tired roller follows the breakdown roller*

***Figure 21-27*** *Plate tamper working on asphalt edge*

corners and noses that are too difficult for the 8-ton roller. Or, in place of the 3- to 5-ton roller, you can use a plate tamper to tamp noses and corners (Figure 21-27). You may need a steel hand tamper on inside corners where none of the equipment can reach. The hand tamper has an 8-inch-square steel plate welded to the end of a steel handle.

On a road job, if open-graded asphalt is being paved, don't use a tandem roller weighing any more than 10 tons. A heavier roller may crush the rock or drive it too deep into the pavement. All asphalt rollers must be equipped with fiber mats and water to keep the drum or tires wet. Moist surfaces don't collect asphalt as easily as dry surfaces. Once the tires on the rubber-tired roller get hot, the asphalt won't stick to them, so water usually isn't needed after the first several passes. It's important on roads, parking lots or patch paving to have a good raker, and for the roller to work closely with him so the raked areas don't cool.

When core samples are required, they're usually drilled within two hours of the last rolling, though the specifications may call for them to be done sooner. Most jobs don't require core samples, just compaction tests.

***Figure 21-28*** *First lift of cold asphalt is oiled before second lift is paved*

## Applying the Tack Coat

Emulsified asphalt (tack coat) must be sprayed on all edges and all cold asphalt surfaces that will be paved over or joined. The only time this tack coat isn't needed is when two hot asphalt joints are being joined together. On an overlay job where a new surface is being put on an existing road, an asphalt tank truck, commonly known as a boot truck, can be used to apply the tack coat (Figure 21-28). If you need to spray joints or curbs, use an oil pot with a hand sprayer to apply the asphalt emulsion. You can also use an oil pot to spray the tack coat on most small overlays requiring 100 gallons or less.

The amount of tack coat you apply is usually determined by the inspector. It can vary from 0.03 to 0.10 of a gallon per square yard of surface. Generally, you'll be required to apply 0.05 of a gallon per square yard. The asphalt emulsion appears brownish when sprayed on the base or curb. No asphalt should be placed over or against it until it's had time to turn black. If the weather is hot, it'll turn black quickly. In cool weather it may take 15 minutes or more.

***Figure 21-29*** *Boot truck spraying oil and laying fabric*

When spraying a tack coat, be careful not to spray it on anything that won't be paved. Use a piece of plywood to collect overspray when spraying against a wall. A rag and diesel fuel will remove asphalt emulsion that was accidentally sprayed on a smooth surface, but sandblasting may be your only option for removing it from a rough surface. If traffic must cross the tack coat, spread a thin layer of sand over the tack coat so it won't get on the cars driving through. You must use dry sand; wet sand won't work at all. If no dry sand is available, you might have the asphalt plant run a load through the dryer for you. The sand can be placed by hand with a shovel or with a sand spreader for large areas. A good crew can place the sand just right so you can pave over it without sweeping it off. The hot asphalt will pull the oil up through the sand to create a good bond.

You may need to place construction fabric before you pave. The fabric keeps cracks on the existing road surface from causing the new surface to crack as well. When placing fabric, you first need to have a boot truck spray a tack coat to hold the fabric down. Figure 21-29 shows a boot truck with a roll of fabric on the back. The truck both sprays asphalt emulsion and lays the fabric as it moves forward. Notice that the truck is equipped

**Figure 21-30** *Fabric ready to be paved over*

with a broom device that smoothes the fabric as it's laid. It's important to have a tractor or truck lay the fabric in this manner so all the wrinkles are eliminated.

Figure 21-30 shows fabric that was placed correctly. There are no wrinkles and the edge is straight. The fabric is laid about 14 inches out from the curb. This is very important. It will ensure that a good bond is made with the old road base when it's sprayed with a tack coat of oil. Overlay the entire surface of the old road with fabric as you proceed with the paving. Make sure no oil seeps through the fabric or it will cause the fabric to stick to the tires of the asphalt trucks. If too much oil is sprayed in one spot and it does seep through, spread some sand or asphalt over that fabric area to keep it from sticking to tires. Oil under fabric is usually sprayed at 0.25 gallons per square yard of surface covered. Fabric edges or ends should be overlapped 2 to 4 inches. Wrinkles must be cut and lapped over, flat. Any excess fabric should be cut off and removed.

## Patch Paving and Trench Paving

An oil pot and small roller are essential for paving small areas, patches, and trenches. It takes an experienced crew to maintain a smooth surface on these jobs. It's especially important to have an experienced raker to feather or taper the edges over existing pavement.

There are three steps to follow in feathering:

1) The existing asphalt must be well-primed with an asphalt emulsion (tack coat).

2) When the asphalt is applied, all larger rocks must be raked out, leaving mainly fine material. When specifications pemit, $^{3}/_{8}$-inch asphalt mix should be used to make the raker's job easier and provide a better-looking surface.

3) The feathered edge must be rolled quickly before it has time to cool. This will leave a smooth edge. The roller should be standing by to roll as soon as the raker finishes.

The raker must work fast to keep the edge from cooling before it can be rolled. He should use a good quality asphalt rake (loot) so he'll get a clean edge. This is about the only time the low side of the mat isn't rolled first. If the cold joint being tied into is on the high side of the mat, run a tandem roller on the cold mat, rolling the cold mat plus approximately 2 feet of the hot mat. Roll as soon after the raker finishes as possible. Once this is done, make the low side pass, working progressively up to the cold edge. As soon as the raker has more edge raked, the roller operator must leave the regular rolling pattern and roll the edge again. Hot mix feathered over cold mix must be rolled very quickly. If it cools, it can never be rolled smooth unless more hot mix is placed over it, and that will create a hump. When making a tie-in or placing patches in cold or damp weather, use a propane burner to warm the existing pavement edge before placing the oil and asphalt.

The asphalt raker should carry a putty knife with him so he can scrape off any asphalt that sticks to his rake. It's important to keep the rake clean, especially when feathering an edge. He should spray diesel oil on the rake frequently. When the asphalt is less than 1 inch thick, it's best to pull out the rocks generated and discard them rather then pushing them out on the mat to be rolled back in.

When asphalt is placed by hand and you need a smooth surface free of indentations, pave the area in two lifts. The size of the roller you use depends on the size of the job. To get a smooth final surface when you need asphalt 3 or 4 inches thick, place the first lift 2 or 3 inches deep and roll it well. Then tack the edges with asphalt emulsion and pave the last 1 or 2 inches. You'll leave a much smoother job if you put down a 1- to 2-inch finish course.

Never use asphalt with larger than $^1/_2$-inch aggregate when patching, paving small areas by hand, or when you need a smooth feathered edge. For skin patches that must be feathered to match existing areas, use $^3/_8$-inch aggregate mix. Always use $^1/_2$-inch asphalt when using a spreader box. In many cases, $^3/_4$-inch asphalt concrete (so called because you use $^3/_4$-inch aggregate) will be specified for a top lift put down by a paving machine on road jobs.

A crew that's doing patch work or small paving jobs that involve a lot of hand spreading and tamping of corners may be as small as four: two shoveling, one raker and a roller operator. They'll need the following tools: a gas-operated plate tamper, hand tamper, garden type spray can, square nose shovels, asphalt rakes, 5-gallon bucket, push broom, picks, rags, oil pot, roller, and diesel for cleaning tools. If the area is very small, you can eliminate the roller and oil pot. You can spread the oil with a 5-gallon bucket and a concrete brush, and use a small gas-operated plate tamper in place of the roller. When placing oil with a bucket and brush, be sure to soak the brush in diesel and let it drain dry for 3 hours before using it to brush on your tack coat. If you use a brush that hasn't been soaked in diesel, the oil will cause the brush to ball up, making the job almost impossible. These tools work well for jobs such as paving around a manhole or over a small ditch line. It's very hard to get a good, smooth and level surface with a plate tamper. A 3- to 5-ton vibrating roller is excellent for small areas when a larger roller isn't specified.

### *Using a Tamper*

If edges along curbs or walls can't be rolled with the roller, they must be tamped with a plate tamper or a hand tamper before they cool. Use a garden spray can of water to moisten the asphalt ahead of the tamper to prevent the asphalt from sticking to the tamper plate. Most plate tampers are equipped with a small tank for diesel or water. The fluid drips onto the plate from a tube along the front, and the vibrating action sprays it onto the asphalt. Although water will keep asphalt from sticking to the plate tamper, you've got to use diesel oil on rakes, shovels, and hand tampers. Keep a bucket or spray can of diesel available at all times when paving, regardless of whether you're paving by hand or machine.

### *Paving Trenches*

For trench paving, two lifts are advised but not essential, unless you're placing more than 3 inches of asphalt. The best procedure when paving a trench with 3 inches of asphalt is to dump enough mix in the trench to fill it close to the top of the existing asphalt on each side. Then tamp it well with a plate tamper or narrow roller if it fits the trench width. When it's rolled, it will be compressed approximately 1 inch below the existing asphalt on each side. Spray the existing edges with an asphalt emulsion and dump in more asphalt. This time rake the edges so that only a small amount of fine material extends past the trench edge, and leave the asphalt $^3/_8$ to $^1/_2$ inch higher than the trench edge. Finally, roll it level with the existing surface. I prefer to keep the new trench pavement $^1/_4$ inch higher than the existing pavement instead of rolling it level. That way, the trench will settle once traffic starts running on it, leaving you a smoother surface over time.

If you're doing a lot of trench paving, you can modify a spreader box and use that to pave the trench. Spot-weld plates in the box to narrow the opening to match the trench width. When you use a spreader box, you need to apply a tack coat to the edges first. If you're placing $2^1/_2$ inches of asphalt or less, pave the trench in one lift, followed by a 5- or 8-ton roller. If the paving will be more than $2^1/_2$ inches thick, two lifts may be required. You'll need a strike-off plate in the spreader box to keep the first lift down 1 inch or more, depending on the asphalt depth. With two lifts, I prefer to not tack-coat the trench edges until the second lift is placed, if the inspector will allow it. If the inspector insists that you need a tack coat for the first lift as well, be careful to only tack the sides, because tack on the top surface of pavement will pick up fines. Then, when the second lift is paved, the cooled fines will cause a slight hump at the edge of the trench line.

## *Finishing Up the Paving Job*

If you're a contractor doing primarily agency work on highways and airport runways, you should have a nuclear test gauge on site while paving. Then, when the required rolling passes are complete, you can take a back-scatter test to find out if you've achieved the required 95 percent compaction. Airport jobs usually require more than 95 percent compaction. If the compaction is less than required, the pavement can be rolled again immediately before it cools down, making rerolling less difficult.

On an existing roadway where traffic will begin running again right after it's paved, place floppy reflectors to delineate the lanes until the lane lines are painted. The reflectors must be placed carefully so they're slightly offset from where the new lines will be painted. You don't want them to interfere with the painting. If double floppies are used at centerline, space them far enough apart so the paint lines will fall between them. If you need stop bars, use reflector tape until the stop bars are painted. You can also use reflector tape for arrows or letters. When it's time to remove the reflector tape, use a burner with a propane tank to heat the tape. It comes up easily when heated.

## Chip Seal

Chip sealing may be used on old road surfaces that still have a good base, but the pavement surface is worn with slight cracks. The oil will seal the cracks and the chips will add more wear to the surface. Before you apply chip seal, the old surface must be washed or broomed, or both, to completely clean the surface of all dirt, loose material and vegetation. When the road surface is clean and dry, and if the atmospheric temperature is above 65 degrees F, a boot truck can spray the surface with asphaltic emulsion. The coverage should usually be from 0.20 to 0.35 gallons per square yard of road surface, and the oil should be between 130 to 180 degrees when it's applied. Once the oil is sprayed on the road surface, immediately spread the chips with a self-propelled chip spreader. The chips are usually spread at the rate of 15 to 30 pounds per square yard. The chip machine pulls the truck in reverse so the chips are down before the truck runs on them.

Roll the chips with two rubber-tired rollers until they're well set. Then broom the chips so there are no loose rock pockets left on the surface. Make another pass with the oil truck to cover the chips, and then place a second spread of chips. Figure 21-31 shows the chip machine placing the second spread of chips, with the oil truck working just ahead. Roll the second spread the same as the first, and sweep all the loose rock off. Be sure to have some sand on site. If there are any spots where the oil comes to the surface because it was applied too heavily, they must be sanded. This will keep the traffic from picking up chips.

There are many jobs where only a single chip seal coat is required. You may need to place building paper at the edges, where the chip seal starts and ends. Whether a single or double chip seal is called for, the contractor must return in no more than four days to sweep up the chips that become dislodged by traffic.

***Figure 21-31*** *Second chip seal is done with oil truck working just ahead of chip machine*

Any time you're paving, oiling or chip sealing, you must check the job specifications for thicknesses, type of asphalt mix, required temperatures, and rolling requirements. They will vary slightly from one agency to the next. Some agencies require the asphalt to match the lip-of-curb; others want the asphalt to be $^1/_4$ inch higher than the curb lip when finished.

Remember, all the requirements mentioned in this chapter will vary from city to city, county to county and state to state. For this reason, you must study the specifications for the job you're working until you're familiar with the controlling agency's requirements, including types of mix required, temperatures, equipment for rolling, minimum or maximum lifts acceptable, and rates of spread for asphalt, oil and chips.

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# CHAPTER 21 QUESTIONS

**1. What is the most efficient way to remove an old road surface?**

A) Rip it with a dozer
B) Grind and load with a profiler
C) Load it with a hoe
D) Grind with a reclaimer

**2. What is the best choice for asphalt removal in a small parking area?**

A) A profiler
B) A reclaimer
C) A track hoe with a bucket thumb
D) A rubber-tired hoe with a 4-in-1 bucket

**3. What's the advantage of using a bottom dump truck with a pickup machine?**

A) The paver doesn't have to stop
B) The paver can start and stop anytime
C) The asphalt has time to cool
D) A smoother grade can be carried

**4. What is the acceptable temperature range for asphalt when paving?**

A) 200 to 250 degrees
B) 285 to 350 degrees
C) 325 to 450 degrees
D) 400 to 525 degrees

**5. Open-graded asphalt shouldn't be placed when the weather drops below what temperature?**

A) 32 degrees
B) 40 degrees
C) 50 degrees
D) 60 degrees

**6. When the paver is using sonar to follow a curb grade, what should control the grade on the other side?**

A) Nothing else is needed
B) Sonar
C) The screed man
D) Slope control

**7. What is the purpose of a stab rod?**

A) To lower the screed
B) To check asphalt temperature
C) To check asphalt thickness
D) To check the asphalt density

**8. When rolling asphalt, where should the first pass be made?**

A) Down the center
B) On the lowest side
C) On the highest side
D) On a diagonal

**9. Unless specifications say otherwise, what size asphalt mix should you use for skin patches that must match existing areas?**

A) $^1/_4$ inch
B) $^3/_8$ inch
C) $^5/_8$ inch
D) $^3/_4$ inch

**10. What is the usual spread rate for chips when chip sealing?**

A) 15 to 30 pounds per square yard
B) 5 pounds per square foot
C) 1 pound per square foot per inch of asphalt depth
D) 10 to 15 pounds per square yard for chips less than $^1/_4$ inch; 15 to 20 for larger chips

# TRENCHING AND PIPE LAYING

# 22

In this chapter we'll look at the essentials of laying pipe, from selecting the correct trenching equipment for each type of job, to placing the pipe and then testing it after it's laid.

## Trenching for Water Pipe

The surveyors must stake the water line and service runs before any trenching can begin. If you're laying pipe in an area that's rough graded, the surveyors should mark the cuts on all their stakes. If you're laying pipe in an area that has been fine graded or in existing pavement, then usually only line is needed. When only line is given for trenching, be sure to check the specifications for the minimum and maximum depths required.


***Figure 22-1*** *Trench dug with trapezoid bucket for safety*

You can use a rubber-tired hoe, a track hoe or a trencher for water pipe, depending on the size of the job and the equipment that's available. Water trenches are generally less than 5 feet deep and don't require shoring. The usual minimum cover you'll need in the street is 36 inches, deeper in unimproved areas. If the ground is unstable, using a track hoe will provide good production and help prevent trench cave-ins. Figure 22-1 shows a $4^1/_2$-foot-deep trench with sloped sides dug by a track hoe with a trapezoid bucket. The bottom 18 inches of the trench were dug vertically with a 2-foot bucket to meet the job specifications for trench width. With quick-release buckets, the hoe can quickly drop the trapezoid bucket and connect to a 2-foot bucket with very little time lost.

A rubber-tired hoe is capable of getting good production at 4-foot depths, especially on small jobs with good soil. You can use a second hoe to help trench the main line, dig service lines, dump bedding material, spread and lay pipe, and backfill. Even though a wheel trencher isn't used as often, it's capable of trenching more footage per day at a 4- or 5-foot depth than a hoe. I prefer a wheel trencher for long trench runs with stable soil. The drawback is that a grader must cut a level pad for the trencher to run on. Otherwise, the trench walls will lean. A hoe with outriggers can level itself; and a track hoe can swing 180 degrees and level the grade behind him for the tracks to run on, if needed.

***Figure 22-2*** *Vermeer trencher with carbide teeth for trenching rock and hardpan*

In deep hardpan or rock, a Vermeer trencher (Figure 22-2) is an excellent choice. The bucket line is built like a dozer track with numerous carbide-tipped teeth. A crumbing shoe wraps around the end to keep the ditch bottom clean of loose material. This is a very efficient machine. With some materials, such as decomposing granite, a Vermeer trencher can produce spoil so fine it can be used for the initial fill over the pipe. It's also excellent for trenching through asphalt.

## Laying Water Pipe

Regardless of what method of trenching you choose, the trench must be undercut for bedding material. Remember that the cuts the surveyor marks on his stake are flow line of pipe — not trench bottom. The grade setter must always add the thickness of the pipe and the bedding material depth to those cuts. You must use a laser or string line for placing the bedding. It must be spread as smooth as possible at the required depth. If the person spreading the bedding doesn't carry a smooth grade, it will make joining the pipe difficult. This is especially true of larger pipe.

***Figure 22-3*** *Water valve is placed on a 12-inch PVC pipe section*

Now that asbestos cement pipe can no longer be used, the pipes most often used for water mains are polyvinyl chloride (PVC), ductile iron or cast iron. These pipes are preferred because they come with bell and spigot joints or slip-on couplings, which make them faster to lay than pipe with welded-steel or mechanical joints. You just need to hollow out a slight indentation where the bell or coupling will sit in the trench. When laying bell and spigot pipe, have your helper spread pipe lubricant in the bell end of the pipe, then guide the pipes together and give a firm push with a steel bar. They should join easily. With pipe larger than 6 inches, lubricate both ends of the pipe. It seems to help them seat together better. Be sure to keep the ends clean or you won't get a good seal and the pipe may leak. It usually takes a three-man crew to lay pipe: the pipe layer, a helper and a worker hooking pipe for the hoist operator.

Larger water pipes require mechanical couplings. The coupling should be bolted on the pipe section before placing the pipe in the trench. You'll need a fourth crewman if there are several fittings and the pipes require cutting. Usually the fitting locations aren't at the ends of the pipe, so pipes must be cut with a cut-off saw. The crew in Figure 22-3 is placing a valve on the end of a cut pipe. After cutting the pipe, the burrs were

***Figure 22-4*** *Materials spaced for easy access to trench*

cleaned off inside, and the outside edge was beveled so the valve would slide on easily. The crew placed the flange and rubber gasket on the pipe before the valve, so they could slide it forward against the valve and bolt it down to make a tight fit. No lubricant was required to slide the valve on because it isn't a tight slip joint. The valve is placed before the pipe is lowered into the trench to alllow the pipe layers the room they need to work.

The water pipe, whether it's PVC or steel, will have a line around the end as a guide to show how far to slide the pipe into the bell or flange. The pipe layer should pay close attention to this mark each time he joins a pipe, and make sure the pipe seats in all the way. If the pipe's been cut and there's no line, the pipe layer should draw a line with a marking pen before joining the pipe together. He must also make sure each pipe is lined up straight before pushing them together so the rubber slip ring isn't dislodged. If the trench has a slight turn in it, the pipe should be turned only after it's seated.

## *Planning the Installation*

For pipe laying to go smoothly, the bedding material, fittings and pipe should be close to where they're needed. Figure 22-4 shows pipe stacked at intervals along the trench, and bedding material stockpiled close at hand.

| Required 5 Gram Calcium Hypochlorite Tablets* | | | | | |
|---|---|---|---|---|---|
| Pipe Diameter (inches) | Length of Pipe Section (feet) | | | | |
| | 13 or less | 18 | 20 | 30 | 40 |
| 4 | 1 | 1 | 1 | 1 | 1 |
| 6 | 1 | 1 | 1 | 2 | 2 |
| 8 | 1 | 2 | 2 | 3 | 4 |
| 10 | 2 | 3 | 3 | 4 | 5 |
| 12 | 3 | 4 | 4 | 6 | 7 |
| 16 | 4 | 6 | 7 | 10 | 13 |
| *Based on 3.25 grams of available chlorine per tablet. Any portion of tablet rounded to next higher number. | | | | | |

***Figure 22-5*** *Use table to estimate chlorine requirements*

There are two hoes working; one trenching, the other placing bedding material. The second hoe will also be used to lay pipe, backfill and compact with a compaction wheel if needed. The pipe was unloaded and spaced perfectly so the loader, using bucket forks, can place it at the trench edge as needed. Notice the plugs in the pipe. You must have a watertight plug in the pipe end when the crews leave each night. The plugs keep small animals, reptiles, insects, blowing debris, rain or mud from getting inside the pipes.

Mechanical fittings aren't required for most small pipe, eliminating the need to bolt the pipes together before they're placed in the trench. Smaller pipe can be loaded on a boom truck and laid directly from the pallets on the truck into the trench, saving a step in the process. This type of planning makes a job very profitable because there's no down time.

You must place calcium hypochlorite tablets in every pipe to kill bacteria when the pipe is filled with water. Apply Permatex No.1 to one side of the tablet and press it to the inside of the pipe. The table in Figure 22-5 provides an estimate of chlorine requirements based on pipe size and footage. Because requirements may vary, be sure to check your specifications. They'll tell you how many chlorine tablets you'll need.

***Figure 22-6*** *Service saddle and valve wrapped and taped and locater wire in place*

## *Water Service Taps*

Where the water services are marked, tightly bolt down a bronze service strap saddle and drill a hole in the PVC pipe. Then screw the corporation stop valve to the service strap threaded opening. Water service lines are usually polyethylene or Type K copper. Check the specifications to determine what type of fitting is required to connect the corporation stop and service line. Not all agencies use the same fittings or pipe threads. Many require you wrap and tape metal fittings with 8-mil polyvinyl. Or, they may require you to wrap all valves and fittings before you pour kickers or backfill.

Most agencies require you to string No.10 gauge insulated wire the entire length of the pipe, up each service line and every valve and hydrant (see Figure 22-6). The wire allows the pipe to be located with a metal detector after the trench has been backfilled. Without it, you wouldn't be able to locate underground plastic pipe. The wire must run on the outside of the valve risers. If the wire is 600 feet or longer between valves, you may be required to have a locater wire box. The locater box is usually a water valve box with a 6-inch diameter riser pipe to the water main. The locater wire is looped through the riser up to the box at the top and back down to continue along the main. Because there's no actual water valve,

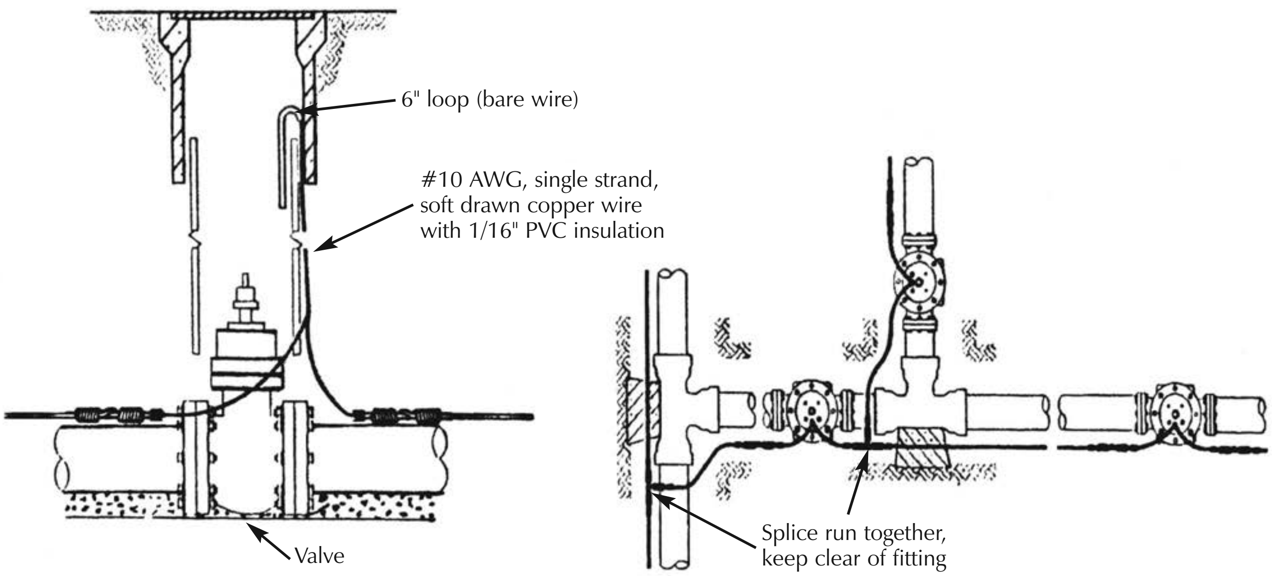



***Figure 22-7*** *Locating wire*

the wire is run inside the riser. There are no standard fittings, boxes or methods among water districts, so check your plans and specifications carefully. The drawings in Figure 22-7 are similar to what you may find on the plans.

## *Backfilling and Testing Water Lines*

Backfilling water, sewer or drain lines is done in the same way. Check your specifications for the type of initial backfill needed, and whether you're required to place blue warning tape 18 inches above the pipe. Warning tape, used in most areas to prevent accidental damage to buried pipe, is color-coded to indicate the type of pipe: blue for water, green for sewer, yellow for gas, red for electrical, and orange for telephone. (Warning tape usually isn't used for storm water pipe.) You can use a hoe with a compaction wheel and a bucket with quick connections to do the backfilling. You may also need a water truck. When the water line and services are backfilled and all the valve risers and blow-offs are up, the line is ready to test.

The new water main and service lines can't be tied into the old until the lines have passed the required water and bacterial tests. The two systems are joined by a 2-inch pipe attached to a blow-off on the existing line and a blow-off on the new line. You must install a check valve so water from the new line can't enter the existing line, as well as a gate valve that allows water flow into the new line.

Before you begin the water test, the line must be filled slowly. Once it's filled, all the high-point valves, blow-offs, water services, hydrants and air-relief valves must be cracked open slightly to bleed the air off. When the air is released and the line is full, shut down the valve feeding the line and allow the line to set for 24 hours before pressure testing. This allows the hypochlorite tablets time to completely dissolve and kill any bacteria in the new pipeline.

For the test you'll need a pump to add pressure and a 55-gallon water drum with an indicator that shows the amount of water used. The pump draws water from the drum and pumps it through a discharge hose attached to a blow-off or hydrant in the system. There should be a valve and a pressure gauge attached to the discharge hose. Close the valve and shut down the pump when the pressure reaches 150 pounds per square inch, or whatever the test requirement is for your project. Refill the water drum.

The 150 pounds of pressure must stand for one hour. Some agencies test by measuring the pressure lost in that time. Most agencies measure the gallons needed to refill the line by measuring the amount of water drawn from the drum when the pump refills the line back to 150 pounds of pressure. The amount of leakage allowed varies from one agency to another; it should be stated in the specifications. Your inspector will have a chart to compute the gallons lost to determine if the line passed or failed the test. If it failed, bleed the air in the line again and retest. It takes very little air remaining in the line to fail a test. Close the valve and fill the water drum so a new measurement can be taken when the water is pumped back in again. If it fails again, start looking for leaks. Check for any damp areas that appear in the trench above the water pipe. If the trench has been completely backfilled, it may take up to three days under pressure before the dampness from the leak is visible. All leaks must be repaired.

Once the line passes the pressure test, it must be flushed well at every high point and every water service. These should still be uncovered, with the water service and locater wire still exposed. Once you're sure all the excess chloride is flushed out of the system, a water sample can be drawn so a lab can perform a bacteriological test. If the test results are good, schedule a shut down of the existing main so you can tie the systems together. Then backfill all the service lines and mark their locations. This part of the job is complete. You'll have to return when the paving is finished to raise the water valve boxes and blow-offs. Be sure to mark all your tieouts on the plans so you can find them easily. The best system to use for tieouts is GPS.

## Trenching for Sewer Pipe

Before you can begin any work, the surveyors must set the hubs and grades to follow. Be sure to let them know which side of the trench you want the stakes set on and how much offset you'll need for your equipment.

Your next order of work is to unload the pipe correctly so it won't have to be moved a second time. Where you unload will depend on whether the pipe will be placed by equipment or by hand. If you use equipment with a swing boom, you have two choices: You can place the pipe close to the edge of the trench, or place it far enough from the trench edge so the equipment can drive between the trench and the pipe. I prefer placing the pipe bundles away from the trench edge. It's safer for the people working in the trench, and it won't be in the way of the equipment supplying bedding material to the crew grading the trench. Generally you'll have a loader (or rubber-tired hoe with a loader bucket) with a fork attachment that can move bundles of pipe quickly, or spread pipe as needed.

If the pipe is being unloaded in strapped bundles, it's important to know how many linear feet of pipe are on each pallet. Space the pallets so you have the right length of pipe between each trench station. Make sure that a pile of bedding gravel and any sewer services needed for that section of sewer line are positioned nearby as well. As mentioned earlier, strategically-placed materials will save you time and money.

Be prepared for the pipe when it arrives. Have an unloading pattern already worked out and make sure you have the correct equipment for the job. You must know the weight of the pipe bundles in order to have the right slings or hooks available to unload the pipe or pallets without damage. Your supplier can furnish you with the weight information, tell you how the pipe is loaded, and suggest the best method for unloading it.

Many pipe suppliers will even supply the slings or hooks needed for unloading. Talk with your supply company before the shipment is sent out. Some suppliers will even do the unloading for you, but you'll still have to direct them to the correct areas.

Trenching is the most difficult part of a sewer job. Today, most sewer trenching is done with hoes. The depth and width of the trench determines what size hoe you need. You should always trench up-grade, from the low end of the trench to the high end, and lay pipe the same way. Before you begin trenching, set up a laser level with the correct slope dialed in. Place it behind the start of the trench, as close to line as possible. (Chapters 3 and 5 explain setting string lines and laser grade.)

Let's look at three different types of job that demonstrate the range of equipment and requirements you'll deal with in sewer trenching operations.

### *Trenching in Stable Ground*

The first sewer job has 5,000 feet of 8-inch sewer to be laid 9 to 5 feet deep (low end to high end). Your first concern is the stability of the ground. Let's assume the ground in this area is firm and will stand without fear of a cave-in. Use a medium-sized track hoe and two rubber-tired backhoes to start. The track hoe will trench the main line while the other two backhoes help to move the shoring (required in all trenches over 5 feet deep), dump bedding material, lay pipe, dig sewer services and cover the pipe with the specified initial backfill. Because conditions are good and you can expect to lay a lot of pipe each day, you may want to add a boom truck and use that to lay pipe while the small hoes are busy with services. As work progresses, you'd bring in a second medium-sized track hoe to start backfilling and compacting with a compaction wheel. You'll probably need a water truck to keep the bedding material wet and to supply water for the backfill and dust control. If you have another job close by, you might be able to divide the water truck between the two jobs to keep the cost down.

### *Trenching in Loose Ground*

Next we have a sewer job with 5,000 feet of 12-inch sewer pipe to be laid 12 to 8 feet deep. The ground for this job is loose gravel that can't be shored safely, so the trench must be sloped, making it 24 to 36 feet wide at the top. The amount of slope required for safety depends on how soft the trench walls are. In the best of conditions, you should never have a slope steeper than $^3/_4$ to 1. Use a large track hoe to trench the main line, with a

***Figure 22-8*** *Grade setter checks ditch grade as hoe slopes loose gravel*

trapezoid bucket for the top 8 to 10 feet and a 2-foot-wide bucket for the bottom 2 feet. The job specifications usually call for the last 2 feet of trench to be vertical and no more than 1 foot wider than the pipe on each side. This keeps the pipe from being damaged by the full bearing weight of the width of the trench. Regardless of the hoe you use, you must have someone with a laser rod checking grade for the hoe operator. In Figure 22-8 the hoe is digging the last 2 feet of trench depth with a 2-foot bucket. You can see the trapezoid bucket on the top bank. The grade checker is checking grade with a laser rod. If you use a laser to check grade, you don't need a string line, but you do need to paint a line along the ground so the hoe operator can keep the trench on line.

Because the trench is so wide, you'll need a medium-sized track hoe, like a Cat 225 or larger, for pipe laying. They have a longer reach than rubber-tired backhoes. Have a loader on the job to supply bedding material to the crew grading the trench. You'll need a third hoe to start trenching the services. Use a medium or large hoe, depending on how long and deep the services are. The second day, start a medium-sized track hoe (a fourth hoe) on backfilling and compacting. The hoe should do the initial backfill with a 4-foot bucket, with the loader supplying backfill material to him if sand or gravel is required. If the loader can reach far enough, he can do the initial backfill instead of the hoe. A loader with bucket forks can move any pipe that needs moving and set manhole material where it will be used. It can also help mix and supply spoil for the hoe backfilling and compacting, if needed. As in the first job, you'll need a water truck. The last 5 feet of trench is wide enough to use a pad-drum vibratory roller and small dozer to help expedite backfilling.


***Figure 22-9*** *Large hoe digs trench and pulls shield behind*

## *Trenching in Hard Ground*

The third job has 5,000 feet of 24-inch sewer pipe to be laid in a 23- to 20-foot-deep trench of cemented cobbles that make trenching difficult. It's unlikely to cave in, but it's possible a rock could become dislodged and fall on the workmen in the trench. For this reason, and also because of the depth, you need to use a shield. Figure 22-9 shows a 24-inch pipe being lowered into a shield while a large hoe trenches and pulls the shield forward. There's another large hoe working ahead of the one in the picture that's trenching 16 feet deep and digging the manholes. As the first hoe digs, the spoil is pushed back into the trench with help from a loader, and the trench is filled back to within 4 feet of the top. This makes it safe for the hoe following to straddle the trench. By trenching in this manner, the second hoe has only 7 feet of undisturbed dirt to excavate. This allows him to trench faster, and lets the pipe layers lay more pipe.

The shield can't move ahead any faster than the hoe can dig. Many areas are now using plastic pipe for sewer lines. The big advantage of plastic pipe is that their long lengths mean fewer pipe to handle. This is especially helpful when you're using a shield. The long sections of PVC allow the shield to be pulled along further each time a pipe is laid.

***Figure 22-10*** *Laser receiver on shield controls grade*

***Figure 22-11*** *Hoe with slotted bucket backfilling trench*

A loader supplies a stockpile of gravel for grading to the hoe that's laying the pipe (barely visible on the right side of the picture in Figure 22-9). When the pipe is laid, the hoe pipe sling is unhooked and a 5-foot grading bucket snapped on to supply gravel for bedding. The hoe dumps gravel on the trench bottom ahead of the shield (once it's dug to grade), and then the shield is ready to be pulled ahead. On the back end of the shield there's a hopper filled with gravel that's also supplied by the hoe. As the shield is pulled ahead, the pipe that was laid in the shield is covered with 12 inches of gravel, completing the initial backfill requirement. Some agencies require you to lay filter fabric and warning tape, either over the initial backfill or closer to the surface. Check your job specifications. You can see a roll of fabric and warning tape at the rear of the hopper. It's fed out the back and onto the initial backfill as the shield moves forward. That way no workers need enter the trench outside the shield.

In Figure 22-10 you can see a laser receiver mounted on the front left corner of the shield, and next to the fence, a laser transmitter that's sending a beam to the receiver. When the gravel is dumped in front of the shield, the hoe operator pulls the shield ahead. He watches the laser receiver and raises or lowers the shield as he pulls, smoothing the gravel to grade. This leaves very little grading for the crew working inside the shield. Dragging a shield through turns may cause it to jam if loose rocks get wedged against the sides. If this should happen, you may need the hoe laying the pipe to help shake or bang the shield free as the other hoe pulls forward. Be sure the crew is out of the shield before this is done.

Following behind the shield is a large hoe with a slotted bucket backfilling the trench (Figure 22-11). The bucket lets dirt and small rocks fall through the slots as the operator shakes it, but holds onto larger rocks so the operator can set them aside. You want to keep large rocks out of the first 3 feet of fill so they won't damage the pipe when the trench is compacted. You can see the hoe's compaction wheel sitting on the bank next to where he's backfilling. A water truck will spray water on the fill as needed to keep it at optimum moisture. It's the contractor's responsibility to meet the trench compaction specifications without damaging the pipe, so you must be very careful during the initial backfill. A damaged pipe will cost you both time and money.

These three jobs should give you a good idea of how the depth and soil conditions of the trench can change the tempo of work and dictate the number and types of equipment needed.

***Figure 22-12*** *Pipe layer and helper laying 6-inch sewer pipe*

## Laying Sewer Pipe

The trench should always be undercut enough to place the required bedding for the pipe. Remember, the cuts the surveyor marks on his stake are flow line of pipe — not trench bottom. The grade setter must always add the thickness of the pipe and the bedding material depth to those cuts. Never lay pipe on base that has any movement, or the weight of the backfill will damage the pipe. If the trench bottom is soft, you may need to undercut it to get a stable base. Bring it to the inspector's attention. Undercutting a soft trench bottom should be paid as extra work.

The grading crew should consist of two people: one grading and the other checking grade and directing the grading material being dumped. If you need faster grading, use a third person to knock down the bedding ahead of the person doing the fine grading. In a vertical trench, you also need a person on top to direct the equipment dumping the bedding or laying pipe. The bedding material should always be compacted with a plate tamper before final trim is done.

Figure 22-12 shows two pipe layers in an open trench laying sewer pipe to grade. Keep in mind while laying pipe, the bell of the pipe is always facing upstream. It's important that the pipe layers scrape some gravel away under the bell so the barrel of the pipe rests on the rock base and not the bell. The pipe is only 6 inches, so the pipe layers can manually shove the pipe together and seat it. Then they'll slide the bell back and forth slightly until the pipe barrel is resting on the bedding material. This isn't possible with large pipe. When laying larger pipe, the pipe layers need a square-nosed shovel and 5-foot steel bar with them to seat the pipe and dig out under the bell. Check each pipe joint with the laser to be sure it's on grade. This is very important, because most agencies will run a camera down the line after it's tested and cleaned, and they'll reject any section of pipe that holds more than $^{1}/_{2}$ inch of water.

Sewer pipe material is clay, PVC or cast iron with couplings or bells. All sewer lines have slip joints, so the bell and spigot ends should both be lubricated with pipe soap so the joints will slide together. Clay pipe also

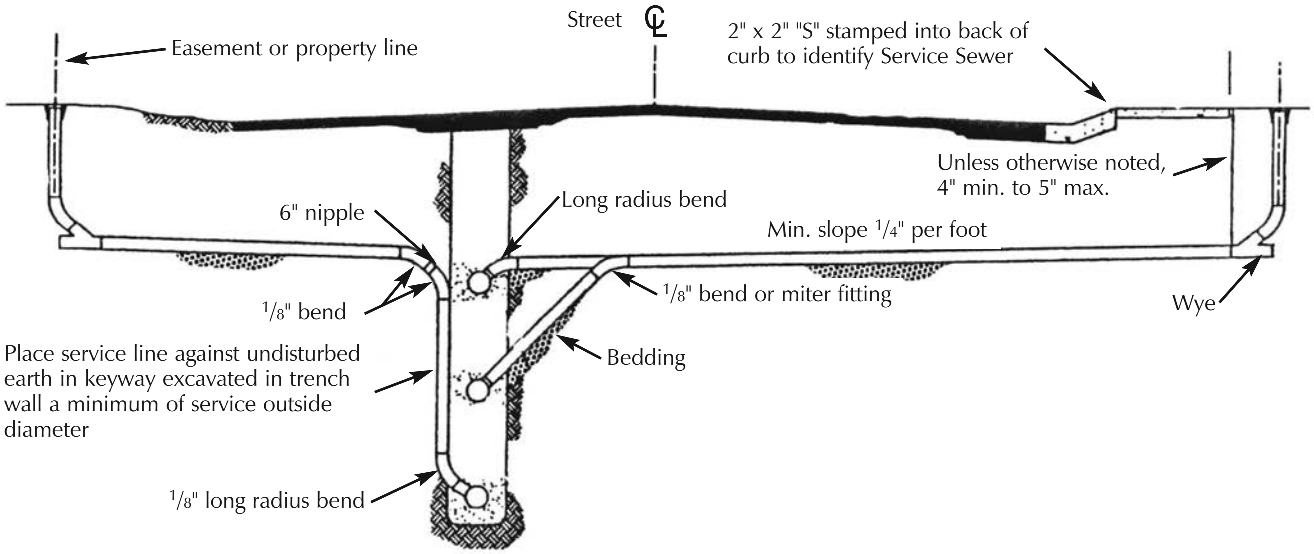



***Figure 22-13*** *Sewer service diagram*

has a rubber ring embedded on both the spigot and bell ends. Some clay sewer pipe may have rubber screw-on couplings — this type doesn't need to be lubricated. If you're laying pipe on a radius, be sure to align the pipe being laid straight with the pipe in the ditch. Push to seat it, and then turn it to match the radius. Never try to seat a pipe on an angle. It's very important to keep the joints clean and not let the pipe end touch the bedding material before it enters the bell or slip coupling. Any sand or gravel that gets between the sealing rings will cause a leak, even if it seats. Don't forget to plug the pipe ends at the end of the day.

Sewer services usually have a fall of 1/4 inch per foot, but may drop off steeply to get to the main. The depth of the main or conflicting utilities will determine the amount of rise when it leaves the main. The pipe layer must know at what angle to lay the service lines as he comes to them. Figure 22-13 shows three service configurations, from shallow to deep. The first service line, top right, has just a slight rise to a cleanout. The other two service lines show much steeper rises from the main. This is the type of diagram you should look for in your job specifications so you'll know what's acceptable for your job. It shows the bends required from the main to get the sewer service up to the depth needed for a 1/4-inch-per-foot rise to the cleanout wye. The note on the left side of the diagram indicates that the service pipe coming up the trench wall should be keyed into the trench wall. The dark areas under the pipe in the diagram show where you need bedding gravel. The hashed lines indicate dirt and the dots indicate gravel. The bedding material required for the service lines is the same as that required for the main sewer line.

### *Backfilling*

The initial backfill should be done immediately after the pipe is laid, with the material and to the depth called for in the job specifications. Be sure the service wyes are marked so you can find them when you're ready to dig the service lines. The specifications may call for a 1-foot sand or aggregate backfill over the pipe before you fill with native material. If no initial backfill is required, be careful that no soil chunks fall on the pipe. A small rock or chunk of hardpan can easily break the bell on a clay pipe. Have the hoe place a layer of dirt gently over the pipe. The specifications may require the initial backfill to be hand tamped or watered heavily for compaction, so check the requirements in your area. If you use $^{3}/_{4}$-inch rock for the initial backfill, no compaction is usually required. A word of caution — all the requirements may not be in the specifications. I've worked with agencies where they did many things as common practice, but their specifications were never updated to show the changes. Be sure to ask plenty of questions at pre-job meetings. Lay out your plans for working the job and get feedback just to be safe.

Backfilling is mainly done with a hoe and wheel, very little jetting is allowed. Hoes and compaction wheels come in all sizes. Your choice will depend on the depth and width of the trench. If a deep trench was sloped, a major portion of the backfill should be done with a dozer and a Cat 815 compactor. The trench must be compacted to 90 percent, so be sure the soil being compacted has enough water added to be close to optimum moisture. Most agencies will only allow loose fill material in 8-inch lifts. I've never had trouble with good moist soil getting to 90 percent using 1-foot lifts, because by the time it's compacted it will be only 8 inches thick. To be safe and to prevent damage to the pipe, I like to start with about 14 inches of cover over the initial backfill and take a little more time with that lift to be sure it's well compacted. I don't recommend using any type of vibratory equipment over the pipe until there's 3 feet of cover over the initial backfill.

As we discussed earlier, some specifications require you to place a warning tape above the pipe. Check the tape depth required for your job. Roll the tape along trench, and then continue backfilling to the top. If the trench is in existing pavement, compact the top 6 inches below street subgrade to 95 percent. You may need a vibrating roller on the top.

Once the sewer line has been compacted, it must be tested. Many agencies also require the sewer be pressure washed and the excess water vacuumed out. A TV camera is then inserted into the line and the line inspected before the job is accepted.

## Pressure Testing Sewer Pipe

There are two ways to test sewer lines for leaks: water tests and air tests. Most specifications require that you test sewer lines after the installation and backfilling are completed. If the house laterals are already connected to the new house service lines, they must be plugged before you begin testing. Usually the only time the house laterals would already be connected is if you're replacing an old sewer line with a new one. Then the house must be hooked up to the new line as it's being laid to continue the service flow.

### *Water Testing*

To conduct a water test for gravity sewer lines, the section being tested must be plugged at each end. Plug the downstream and upstream manholes on the upstream side (see Figure 22-14). You must include the service lines in the test, but plug any other pipe entering the upstream manhole from the sides. It's good practice to tie a wire or short length of rope to each plug and wrap the wire or rope around a board or pin that's much larger than the pipe opening. The board will keep the plug from being pushed down the pipe by the water pressure if it should come loose.

Once both plugs are secure, release water into the upstream manhole until the pipe is full and the water is about 5 feet above the pipe in the manhole barrel. (Check your specifications. Most require a *minimum* height of 5 feet above the pipe.) This supplies enough pressure to the main to conduct the test. Allow four hours for the pipe and manhole to become fully saturated before you begin the actual test. After the four hour period has elapsed, add water to replace the water that was absorbed into the pipe and manhole walls. When the water is again 5 feet above the pipe, you can begin the test. The test usually requires 2 to 4 hours.

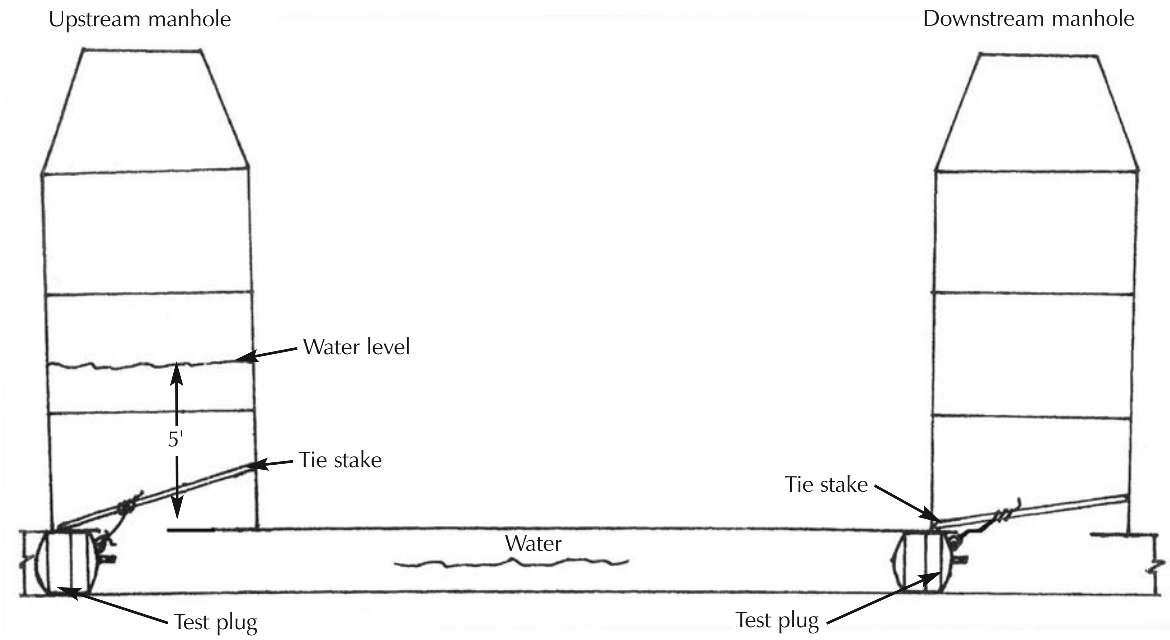



***Figure 22-14*** *Water test for sewer pipe*

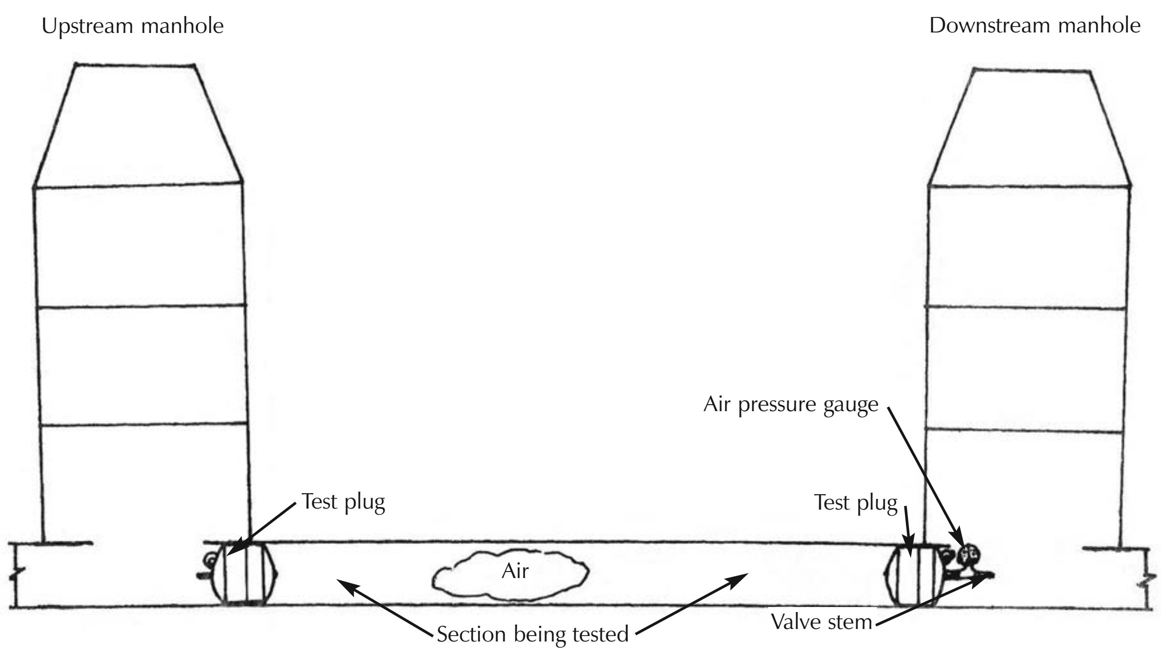



***Figure 22-15*** *Air test for sewer pipe*

The amount of leakage allowed may vary from one job specification to the next, depending on the type of pipe and the agency involved. Different agencies have different requirements. The leakage tolerated is usually 250 to 500 gallons per mile per 24 hours per inch of pipe diameter. The leakage tolerated in a sewer force main is much less, usually around 125 gallons per 24 hours. Don't fill the manhole with more water than required by the specifications. Each extra foot of water increases the pressure in the main substantially. It's to your advantage to test before all the backfill has been completed, especially if the trench is very deep. Build the manholes as soon as possible so you can begin testing.

If a leak develops while testing, keep a good head of water in the manhole until the water seeps to the top of the ground. If you've only placed a small amount of backfill, the seepage will show much sooner and you can pinpoint the leak faster. If the specifications require that you completely backfill and compact the sewer line before testing, you'd be wise to conduct your own test before the backfilling and compacting is complete. It's very hard to find a leak during a water test when a deep trench has been compacted. Remember, if you have a leak, always check the manhole joints for cracks. It may be the manhole or even the plugs that are leaking, not the pipe.

### *Air Testing*

The air test is the fastest, cleanest, and least expensive way to test sewer mains and services. The upstream manhole must be plugged on the downstream side for this test. The downstream manhole is plugged on the upstream side, as in a water test. That way, the air is trapped in the pipe between manholes. One of the two plugs set must have a pressure gauge and a valve stem on the plug pipe, as shown in Figure 22-15. It isn't necessary to tie the plugs to a board in this test. Be sure to clean the pipe well where the plug will seat. Any sand, dirt or gravel will cause air to leak past the plug.

When the plugs are in place, pump air into the line from an air nozzle and compressor. Most agencies require you to pump 3 to 4 pounds of pressure into the main and services. The pipe can lose 1 pound of air, but the length of time allowed for that loss varies with the agency. The amount of time the pressure must hold depends on the size of pipe, the number of service runs, and the length. The agency specifications should have a chart indicating the length, size and time.

The big advantage of air testing is that the test can be done before the manholes are built. If you're laying pipe under adverse conditions and

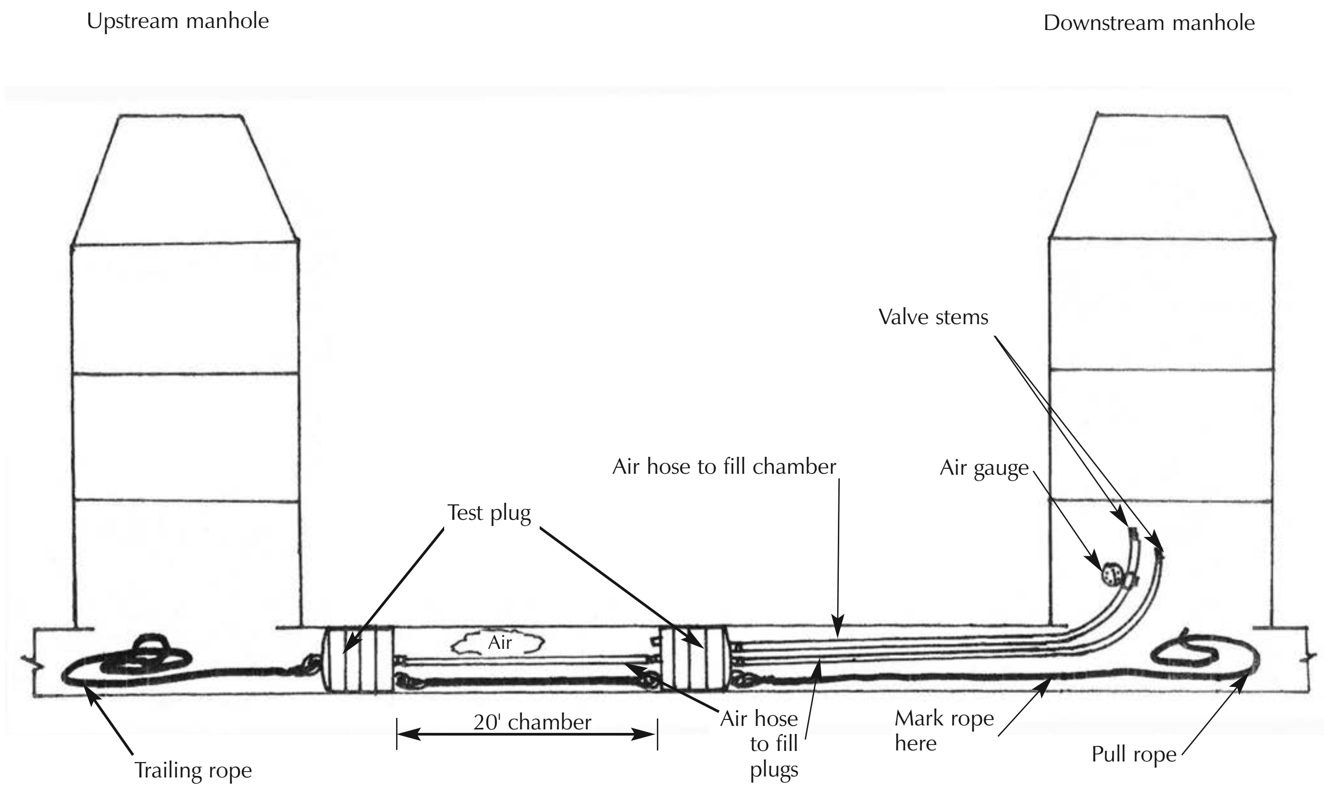



***Figure 22-16*** *Locating leaks*

leaks are a concern, test the pipe regularly during the laying operation. Even if the inspector won't accept the test until all the backfill and compaction is complete, running the test for your own information will save excavating time if there's a leak. If there isn't a leak, you can finish the backfilling. If you discover a leak, before you check the pipe, take a brush and paint soapy water around each test plug to make sure it's not the plug that's leaking. If you rule out the plugs, you must locate the leak in the pipe line before you continue.

Even if the main has been compacted, you can easily locate a leak if you have the correct equipment. To find the leak, begin by removing the two test plugs and replacing them with a special set of test plugs used to pinpoint leaks. These special plugs are inflatable and are connected by an air hose and a rope (Figure 22-16). Measure the distance from manhole to manhole and attach enough air hose and rope so that the test plugs can be pulled through the entire pipe section from the upstream manhole to the downstream manhole. Place the test apparatus in the upstream manhole.

To set up for the test, you need to attach a small cord to the end of the rope that's attached to the plug assembly. Float the cord down through the line or blow it down the line from the upstream manhole to the downstream manhole with a parachute-type device using air from a compressor hose. With the cord, pull the rope and hoses through the line to the downstream manhole. Once you have the ropes and hoses in the downstream manhole, disconnect the cord. Then pull the rope until both plugs on the test apparatus enter the pipe at the upstream manhole. One man must be in each manhole until the plugs and air lines are in place in the main. Once the second plug enters the upstream pipe, you're ready to locate the leak.

Mark the point on the rope when the second plug enters the pipe at the upstream manhole. That's necessary to determine how far the test apparatus has been pulled down line once you locate the leak. The test plugs are usually 20 feet apart, and create a sealed chamber when they're fully inflated. Inflate the plugs with the first air hose. Then pump air through the second air hose to pressurize the pipe chamber between the two plugs. Fill the pipe chamber to the air pressure specified and hold it two minutes. If the pressure remains steady, release the plug pressure. This will also release the pressure in the chamber section. Once the pressure has been released, pull the test plugs downstream 19 feet and repeat the test. Continue this process until you locate the section that won't hold pressure.

When you've isolated the leak within a 20-foot section, you'll need to further pinpoint its location. Do this by retesting. Move the plugs back 3 to 5 feet, and test again. Do this over and over until the test holds, narrowing the leak down to the small 3- to 5- foot section that failed. Measure the amount of rope that's been pulled through the pipe. If 100 feet have been pulled through, measure 100 feet from the downstream manhole toward the upstream manhole and mark the ground at that point. This is the location of the closest plug on the test apparatus, and that puts you in the 3-to 5- foot section of the test chamber where the leak is. Mark that location on the ground. Even though you've located a leak, you don't stop testing. There may be more than one leak. Continue moving the plugs 19 feet each time until you've tested the entire main for leaks.

### *Checking Service Lines for Leaks*

After all the leaks have been pinpointed to within 3 to 5 feet, check the location of the sewer services. If the main shows no leak but a service enters the main at the location where you've isolated a leak, the leak could be in the service line rather than the main line. Expose and check the service line where it connects to the main line and at the property line. These are the most likely spots for leaks. If there's no leak at either end, you've got to check the entire length of the service line. Place test plugs at each end of the main and keep pressure in the line. The line should remain under pressure while you excavate so you can find the leak more easily. When the line is exposed, use a concrete brush and paint the line with soapy water from a 5-gallon bucket to locate the leak. You'll see bubbles coming from the location of the leak.

### *Checking the Main Line for Leaks*

For leaks in the main line, expose the section or sections where you've isolated leaks. Splash the soapy water around the joints and along the pipe to find any small cracks or leaky joints. When water hits escaping air, the soap will bubble up, showing where the leak is. The leak may be caused by a stone or dirt wedged in the rubber fitting between pipes. In that case, air rushing from the fitting may kick up a small cloud of dust, pinpointing the problem area for you. If the leak is caused by foreign matter in a joint, you may be able to clear off enough room to pull the pipe apart, clean it, and buckle it back together. It takes several people to lift enough joints to make this possible. If the pipe is too large to lift, several pieces of equipment and ropes are needed. If the problem is a cracked pipe, buckle a new section of pipe into place. Some agencies will allow a section of pipe to be cut out and a new section to be placed using a rubber caulder coupling to join each cut end.

Using good compacted bedding under the pipe and a good initial backfill over it will help eliminate many leaks. Correcting leaks is expensive. A little care while laying the pipe will reduce the number of leaks and save a lot of time and money.

## Repairing Broken Sewer Pipe

If a pipe or fitting breaks in the middle of a new sewer line, here's how you'd make the repair. Expose and clean the main three joints on each side of the break. Remove all material from the top and sides of the main. Cut out the broken pipe and remove the pieces. For small pipe, you'll need a crew of five in the trench to insert the new section, two on each side and one in the center with the new pipe. Lift the sewer line high enough to buckle the new section of pipe in place. This procedure works with short lengths of small pipe (up to 6 inches) that can be easily lifted by hand.

If the pipe is too large to lift by hand, the procedure is different. Let's assume you're dealing with 18-inch pipe in 6-foot lengths. Use a hoe to trench down as close as possible to the pipe. The trench must be shored or sloped, then hand-shoveled to clean the dirt from the top and sides of the pipe. Remove the broken section. Now the job becomes more difficult because you must use equipment to lift the pipe on each side of the break and buckle in the new section. You'll need seven separate pieces of equipment (hoes and loaders), each with a rope or sling: three on each side to lift the existing pipe and one in the middle holding the new pipe. Fasten the ropes or slings to the pipe on each side. Have the equipment on each side lift the pipe at various heights while the equipment in the middle guides the new pipe section in, aided by two or more pipe layers. Make sure the ends of the existing pipes and both ends of the new pipe you're placing, are clean and well lubricated.

This is very time-consuming and takes experienced workmen. The operators must be careful not to lift any joint too high, or it will come apart. In a deep trench, the equipment operators can't see the bottom of the trench so they must all depend on hand signals, usually from two people on top.

Some agencies will allow you to repair the line by splicing in the new pipe section using mechanical couplings. Be sure to check before proceeding with the repair. If you can use couplings, cut the pipe on each side of the leak with a cut-off saw and remove the bad section. Cut a new section of pipe to replace the old. Because one end of the pipe connection won't have a bell, you need to use a repair coupling to join the two straight ends.

Repairing a leak is always a difficult job. That's a good reason to take care to keep your pipe joints clean and ensure they seat properly when laying pipe.

## Trenching for Drain Pipe

The first item of work, as in any other pipe laying job, is to unload the pipe in the correct location so it doesn't have to be moved later. This is especially important when you're dealing with large concrete drain pipe because of its size and weight. If you need bedding and initial backfill material, be sure to compute the tonnage you need for each pile and how much space to leave between bedding piles. Place the piles close to the trench so the loader or hoe will only need to travel a little way to retrieve the material.

You should have advised the surveyors about how much offset you'll need and the side of the trench where you want the hubs located. Always allow plenty of room in case the trench requires sloping. Set a laser unit behind the trench, as close to on-line as possible, and dial in the correct pipe slope. The grade setter should paint a line on the ground for the hoe operator to follow. If you're using a trencher, you'll also have to set a string line. If no laser is available, you'll need to use a string line for the hoe or trencher for trenching, as well as for grading and laying pipe. Remember, whether you use a laser or string for grade, always trench starting at the lowest end of the line and trench up grade. The grading and pipe laying must be done the same way. And again, be sure the bell or coupling pipe ends always face upgrade.

The right size hoe for trenching a job like this is open for debate. For a trench that's up to 6 feet deep, some contractors prefer smaller rubber-tired backhoes because the rental rate and move-in costs are less than for a larger track hoe. Others feel the larger track hoe has more power and can dig more trench footage, which offsets the extra cost for rental and move-in. My feelings fall somewhere in the middle. If a small contractor has only rubber-tired backhoes and has bid the job that way, then he shouldn't park his equipment to rent track hoes. Rubber-tired hoes are capable of doing a fine job and turning a good profit. On the other hand, if a large contractor has track hoes available, I'd recommend using them. They're faster, and on a large job the cost of move-in will be offset. For deep trenches there's no discussion — you need the larger hoe.

Let's look at how to handle a typical drain job. Drain pipe trenches usually run shallower than sewer pipe. We'll say that the trench on this job runs from 5 to 7 feet deep, so the contractor has decided not to have a shoring crew set shoring. He's selected a track hoe with two buckets to do the trenching. He'll use the trapezoid bucket until the trench is within 2 feet of grade, then change it out for a conventional bucket to complete the final 2 feet to grade. He'll select a bucket size that will provide a width not less than 6 inches or more than 1 foot wider than the pipe on each side. That'll give him the sloped sides that he needs to eliminate shoring and limit the trench bottom to a size that will protect the pipe during compaction. Unless you're working in a confined area, it's much easier to slope the trench than to dig vertical with a hoe and shore it up. We'll cover shoring in detail in the next chapter.

When trenching, be sure to add the thickness of the pipe to the trench depth and also undercut the trench enough to place bedding material. With concrete pipe, which can be up to 6 inches thick, plus the pipe bedding material, this can add another foot to the trench depth. One more reminder — all survey stake grades are to pipe flow line, not bottom of trench. The grade checker should check the trench grade for the hoe operator often. That way, if the hoe gets off grade, he can reach back and correct it easily. A three-man crew works well for spreading bedding material and checking grade after the bedding material is placed. The first man spreads the gravel. The second man directs the loader dumping gravel and uses a laser rod to periodically check rough grade for the spreader. He also checks grade for the third man, who's doing the fine grading.

## *Setting Manholes*

Whether manholes are poured-in-place or precast, the pipe layer needs to plan his layout to correspond to the manhole location. When he gets to the manhole, he needs to cut the bell off the pipe on the upstream end so that it will be flush with the inside of the manhole when the manhole is placed or poured. Using bell and spigot pipe, the spigot end of the upstream pipe must be set 48 inches from the end of the downstream pipe so a 4-foot form can be set between them for the 48-inch manhole. For large pipe using precast rings, there must be less than 48 inches between pipes so the sides of the pipe will be inside the precast ring.

The job we're looking at is using precast manholes, so the pipe laying must stop one joint short of the manhole. When the manhole bottom is set to grade, the pipe layer measures the distance from the downstream end at the inside wall of the manhole casting to the upstream pipe end. He then cuts a pipe to fit, removing the bell at the same time. He lays the cut-off pipe section, with the pipe end extending into the manhole bottom so that it will be flush with the inside wall of the manhole. Once that section of pipe is placed, the precast manhole ring is set by sliding the downstream hole over the end of the pipe. The holes are cast $1^1/_2$ inches larger than the pipe. The gap in the opening will be filled with mortar later. Figure 22-17 shows the manhole ring being set in place. You can see the downstream section of pipe behind the manhole that has already been laid.

## *Laying Drain Pipe*

After the manhole ring is set, the pipe laying continues. The pipe layer slides the upstream pipe into the manhole, then continues laying up the line graded ahead of them. Notice in Figure 22-18 that the pipe is strung out

***Figure 22-17*** *Precast manhole ring being set on precast bottom*

***Figure 22-18*** *Pipe layer laying pipe upstream from manhole*

along the line far enough back from the trench so it's out of the way of the trenching and grading, yet close enough so the hoe can easily reach it. The pipe layer in the photograph has the pipe tipped down so the top edge will catch first as he keeps pushing forward until the upstream end of the pipe just starts to touch the bedding. He'll signal the hoe operator to stop lowering the pipe at that point. Then, while holding the pipe steady with his foot at the bottom of the bell, he'll slide the pipe ends together with his bar.

***Figure 22-19*** *Concrete bell and spigot pipe*

Figure 22-19 shows bell and spigot concrete pipe. Notice the ridge at the end of the spigot pipe and the recessed ridge inside the bell pipe. The rubber rings are placed in the bell ends of the pipes, butted against that ridge. When the bell end is lubricated, the pipes are slid together and the rubber ring creates a watertight seal. As mentioned earlier in the chapter, because the bells on concrete pipes are large, the pipe layer must scrape away some bedding material where the bell will rest. That'll ensure that the barrel of the pipe is firmly supported and resting on the bedding. The barrel won't be properly supported if only the bell is sitting on the bedding.

Again, just as in laying water or sewer pipe, the bells must be clean or they won't join. And even if they do join, they'll leak. When laying pipe on a radius, it's important to hold the pipe together straight before joining. The pipe in Figure 22-20 is laid on a radius. Each pipe bell was held against the right side of the trench until joined, then turned to match the radius. The laser on the left is used for controlling trenching, grading, bedding and pipe laying. When working on a radius, the laser unit must be reset often to keep a good line angle.

***Figure 22-20*** *Pipe laid on radius*

A Ribbed HDPE pipe

B Corrugated metal pipe with couplings and rubber collars

***Figure 22-21*** *Drain pipe*

It takes a well-balanced crew to lay pipe efficiently. The crew in our example consists of 11 people: a foreman, a water truck driver, a hoe operator trenching, a grade checker, two pipe layers, three helpers spreading the gravel in the trench and checking grade, a hoe operator with a wheel for compacting, and a loader operator. When the pipe layers are cutting pipe and setting manholes, the grading crew will stop grading and drop back to place the initial backfill and construction fabric. Everyone understands his job responsibilities, so they work well together.

## *Types of Drain Pipe*

The most common types of pipe used for drain lines are concrete, ribbed high-density polyethylene (HDPE) pipe, corrugated aluminum pipe and corrugated steel pipe. Figure 22-21 shows ribbed HDPE pipe (A) and corrugated metal pipe (B).

Ribbed HDPE pipe has bell and spigot ends. The crew lubricates the rubber ring and joins the ends using pipe soap. Make sure the initial backfill is placed carefully to prevent damage to the pipe. This type of pipe will smash easily.

Join corrugated galvanized steel pipe with couplings that slide over both ends of the pipe and bolt tight at the top. Place a coupling and a rubber sleeve on the upstream end of the pipe (with no bolts in the coupling flanges at this time). Slide the next pipe into the coupling until it butts against the end of the first pipe. Place the bolts into the coupling flanges and tighten them. As the bolts are being tightened, one side of the coupling must slide under the other side to bring the flanges together. Continue tightening the bolts until all of the slack is drawn from the coupling and the bolts become hard to turn. The rubber sleeves will make a more watertight seal. When placing couplings on large ribbed steel pipe, you may need extra long bolts to pull the flanges close enough together to get the standard bolts started. You may also need a helper with a steel bar on each side pushing inward to enable you get the bolts started in the flanges.

The bottom half of each pipe in Figure 22-21 is tarred inside to reduce corrosion. The pipe may have a stripe or mark on one side to indicate the side that must be laid facing up. Be sure to check and see if marks are present when laying pipe. When pipes are tarred, lay the tarred side down.

Contractors seldom use concrete pipe with a flat bell and spigot end that must be mortared together because they're so labor intensive. To place this

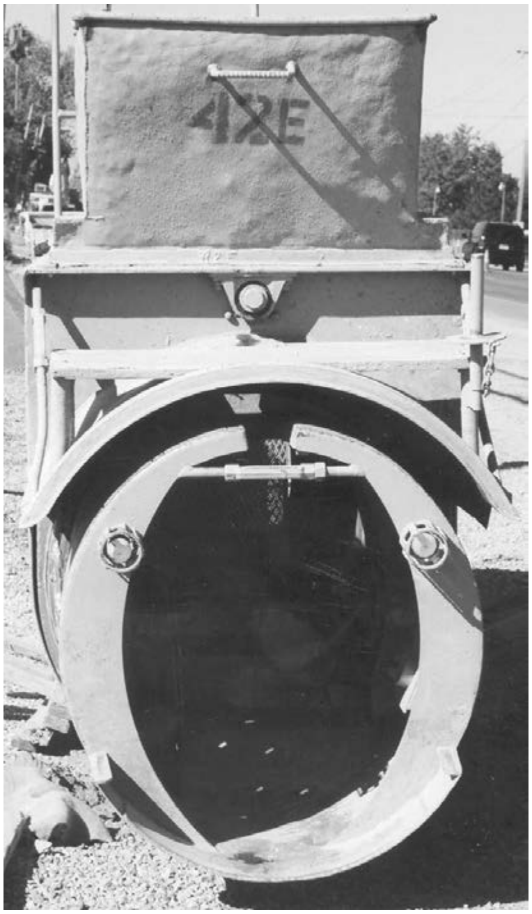



***Figure 22-22*** *No-joint pipe machine*

type of pipe, first clean the bell inside with a brush on a pole. Scrape away a small area of bedding material in front of the bell and place mortar in it. Then place mortar in the bell end half way up each side. Mortar the top half of the spigot end ledge. It's a good idea to add fire clay to the mortar mix so it will adhere to the pipe walls better. Both ends of the pipe must be wet before placing mortar on them. When the pipe is joined together, the pipe layer must reach down the pipe with a pole and brush the joint smooth. Then a mortar band is placed around the pipe, tying into the mortar that was placed on the ground. The person banding must work far enough behind the pipe layer so when the pipe layer joins pipe together, it won't disturb the bands already placed. If the weather is hot, you must place a paper band over the mortar joint or spray the joint with a curing spray. You need a mortar box or concrete mixer to keep a constant flow of mortar going to the pipe layers and the person banding the pipe. If the pipe is larger than 15 inches, use a gas-run mortar mixer to ensure a fast supply of mortar.

### *Cast-in-Place Concrete Pipe*

Drain pipe can also be poured in place. It's called *no-joint drain pipe* or *cast-in-place concrete pipe*. The soil conditions must be good in order to lay this type of pipe because you don't grade the trench or place bedding material. You dig the trench with a hoe that has a bucket the exact size of the outside diameter of the pipe. The hoe bucket has small teeth very close together that must cut extremely close to grade (within a 0.10-foot tolerance), because the grade the hoe digs is the grade the flow line of the pipe will follow. The trench can't be deeper than 5 feet because you can't place shoring.

The concrete is placed using a special machine that pours the concrete pipe as it moves along the trench. Figure 22-22 shows a front view of the

Courtesy of Joe Wilson

***Figure 22-23*** *Metal sheets used for forming are fed to crewman in no-joint machine*

no-joint machine. It has two lights on the front so the person working inside, setting up the braces that hold the forms in place, can see. The forms are steel sheets that are fed through a rubber bladder inside the machine. The first one is fed through before the pour starts. There's a hook on the front of the sheet and a small slot on the back of each sheet for the hook on the next sheet to catch. The first sheet is anchored by the hook to a small cable or chain. As the machine pulls away, the first steel sheet stays in place, and the remaining sheets are pulled down through the bladder as the pour proceeds.

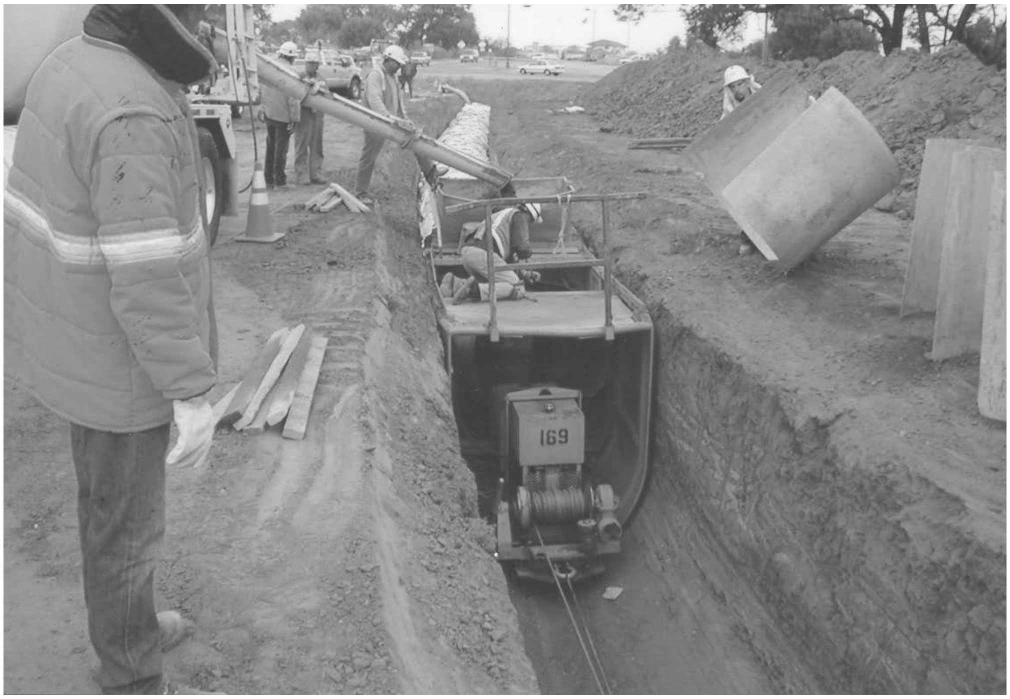
There must be two people working inside the machine — one hooking the steel sheets as they get sucked through the bladder, and the second setting the steel braces. Figure 22-23 shows a crewman on top of the machine getting ready to hand a sheet down to a second crewman, who'll hook it on and feed it into the bladder. The man in the center is holding the concrete chute as it feeds concrete into the hopper. The sheet forms hold the top of the pipe up. In the photograph you can see the metal sheets lined up along the trench waiting to be handed down to the crewman. The crewman sitting in the machine is holding the bottom of

*Courtesy of Joe Wilson*

***Figure 22-24*** *Metal forming sheet is pulled through machine*

*Courtesy of Joe Wilson*

***Figure 22-25*** *Sheet supporting the top half of the pipe is held in place by braces*



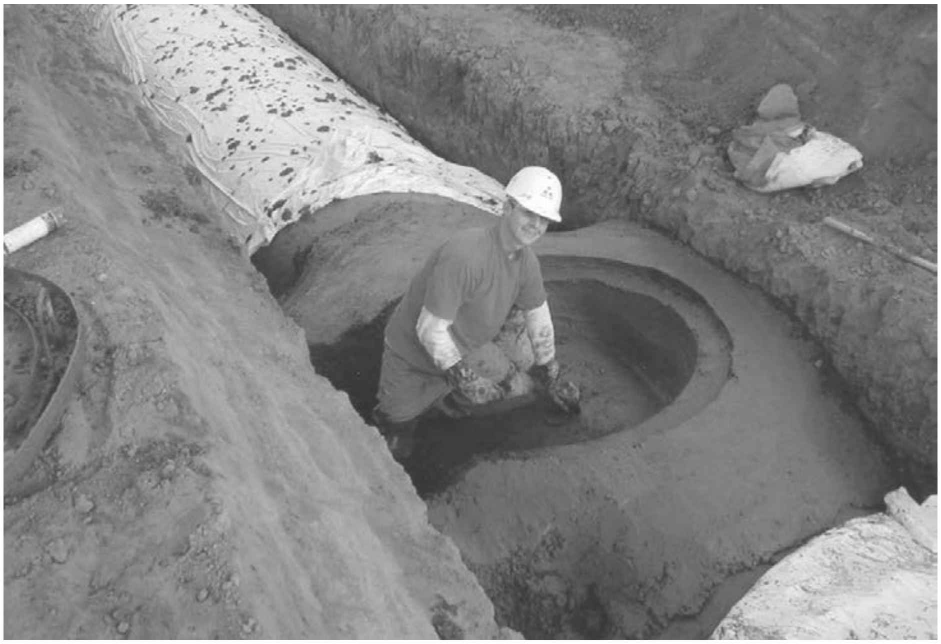
Courtesy of Joe Wilson

***Figure 22-26*** *Concrete machine is pulled by cable*

the sheet down with his feet as it's pulled through (Figure 22-24). Figure 22-25 shows the other inside crewmember, under the hopper of the machine, placing braces to support the metal sheets holding up the top half of the pipe. This is a very hot, sticky job.

The machine is raised up slightly on blocks when the pour is started so the concrete can get under the machine. Concrete from the hopper flows over the top forms and down under the machine, conforming to the trench bottom and sides. Concrete vibrators on the machine help the concrete flow and keep voids from forming. If the walls and bottom of the trench ahead begin to dry out, they must be sprayed to keep them damp. Dry trench walls will draw moisture from the concrete, which will cause cracks in the pipe.

The no-joint machine is pulled along by a cable on a pulley that's anchored down the trench (Figure 22-26). The speed is controlled by a winch mounted on the rear of the concrete machine. If necessary, the man inside feeding the steel sheets can kick the winch out of gear and stop the machine. The downline cable is attached to a hinged cage device that spreads as the cable is pulled, creating an anchor for the pipe machine to pull against.



*Courtesy of Joe Wilson*

***Figure 22-27*** *No-joint pipe manhole*

No-joint pipe is poured *through* the manhole, then the concrete is scraped from the top metal sheet the size of a manhole for the opening. Figure 22-27 shows the shaping for a manhole ring that's almost complete. The concrete has been removed from the top, exposing the metal sheet. (The worker in the photo has his hand and knee resting on the sheet.) The top sides are built up with concrete and shaped, so when the metal sheet inside is pulled, the hole will be opened up and the manhole will be ready for the rings to be set. Inside, the poured bottom and sides are already finished.

After the no-joint pipe is poured, you spray it with a concrete curing compound, or cover it with a polyethylene film (0.0015-thick) so it won't dry too fast and crack. In Figure 22-27 you can see the polyethylene film covering the pipe that's just been poured. When the pour is complete, cover the ends of the pipeline with plywood or plastic material to maintain a humid condition in the pipe for seven days. You'll usually keep the sheets and braces in place for a minimum of six hours before they're pulled. This operation is very labor intensive. All voids must be grouted inside the pipe after the forms are pulled. Generally, no backfill is allowed until the concrete reaches a compressive strength of 2,500 pounds per square inch.

These machines are only used for large pipe because the crewmen must be able to crawl inside to set and remove the bracing and grout voids. It's very specialized work requiring an experienced crew. The foreman must know the correct concrete slump to use, and how many concrete trucks to order to keep the job moving. However, if done correctly, using a concrete machine produces a very good product at a lower cost than precast pipe.

## Efficient Planning Pays Off

An efficient pipe laying operation requires planning and coordination. Have the equipment you need available and calculate the footage you expect to lay each day to determine the number of men you need to shore, grade, lay pipe and set manholes. The grade dug by the hoe must be accurate. Your shoring crew must be able to move quickly enough to stay ahead of the grading operation. You must have enough ladders available for the grading and laying crew to enter and exit the trench. Make sure the men grading have the material they need close at hand. They have to be fast enough to keep ahead of the pipe layers. The pipe should be stacked along the trench correctly so the pipe layers don't have to wait for more pipe. Coordinating all these activities will ensure that you complete your job on budget and in time, which in turn ensures future work.

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# CHAPTER 22 QUESTIONS

**1. When would you use a Vermeer trencher?**

A) For deep trenches
B) For shallow digging
C) For hardpan and rock
D) For very soft soil

**2. How long must the pressure in a water pipe pressure test hold?**

A) One hour
B) Two hours
C) Four hours
D) It depends on the size of the pipe, the number of service runs, and the length.

**3. A trapezoid bucket is used for what type of trenching?**

A) Deep trenching
B) Wide trenching
C) Hard rock trenching
D) Slope trenching

**4. What must be done if the trench bottom is soft?**

A) It must be filled with crushed rock
B) It must be undercut to a stable grade
C) It must be lime treated
D) It must be cement treated

**5. When an agency uses a camera to check sewer pipe flow, what's the maximum amount of ponding they'll accept inside the pipe?**

A) $^1/_4$ inch
B) $^1/_2$ inch
C) 1 inch
D) An amount equal to the amount of fall in the pipe run

**6. How high above the pipe is the water level in the manhole required to be for a sewer pipe water test?**

A) 3 feet
B) 4 feet
C) 5 feet
D) 6 feet

**7. What's the advantage of using air testing over other methods in testing sewer pipe?**

A) The equipment needed is always handy
B) No manholes are needed
C) There's no mess involved to drain it
D) An air leak won't soften the grade

**8. How do you usually repair a broken pipe along a sewer main?**

A) Buckle in a new pipe section
B) Cut the pipe on each side of the break and snap in a double-collar pipe
C) Place a caulder coupling over the break
D) Cover the break with a concrete collar

**9. What's the main advantage of trench sloping?**

A) It's faster to trench
B) It's easier to work with in a confined space
C) No shoring is needed
D) The pipe can be placed closer to the trench

**10. How is cast-in-place trench dug?**

A) Only over-dug 2 inches
B) Extra deep to allow for the equipment
C) Always sloped to allow access for a worker
D) The exact shape and grade of the pipe

# 23

# Trench Shoring, Shields and Sloping

Hydraulic shoring and trench shields are the two most common methods of shoring used by underground contractors. The law mandates that no person can work in a trench that's over 5 feet deep without the protection of an approved shoring method. If the ground is very unstable, even a trench that's less than 5 feet deep should be shored to protect pipe crews from potential cave-ins. The contractor must shore, shield or slope the trench if the crew could be in any danger, regardless of depth.

For a shallow trench in unstable soil, the best method is to slope the trench sides, but no less than a $^{3}/_{4}$:1 slope. This is also the most cost-effective way to treat any trench that's less than 7 feet deep. And it's a good method to use in dealing with a deeper trench if you're working in soil that has loose cobbles that crumble off easily. Pulling a shield in a 14-foot trench with cobbles can be a problem. The cobbles crumbling off on each side can wedge the shield so it won't slide when pulled by the hoe. As long as there's room to pile the excavated dirt, it's faster to slope the trench than to constantly have to free the shield.

***Figure 23-1*** *Sheet shoring set in a 15-foot trench*

# Hydraulic Shoring

Various lengths and widths of hydraulic shoring are available. You can use more than one length of shoring on each point along the trench. For example, if only 6-foot lengths are available and the trench is 12 feet deep, you can use two 6-foot lengths to make a 12-foot-deep shore. That's one of the advantages of hydraulic shoring. The first 6-foot shore is jacked into place at the top of the trench. Then, using a long release tool, the second shore is placed under the first. Setting 6-foot hydraulic shoring is fast because the sections are lighter and easier to handle than 10-foot shores. Also, the bottom shore can be removed first during the backfill, while the top shore remains to keep the top of the trench stable. Remember, the shoring must be placed high enough up from the trench bottom so the pipe crew can work under the bottom cylinder to lay pipe.

Every shoring section has at least two pump cylinders. Longer lengths have more cylinders. If the shoring is longer than 7 feet, you'll need two men to handle the weight. If sheeting is attached to the hydraulic jack, it's best to set it with a hoe because of the weight. Figure 23-1 shows sheet shoring that was set with the hoe as the trench was dug. The pipe crew can now work safely inside the trench.

Even though the shoring uses hydraulic principles, the fluid used in the jacks isn't hydraulic oil. There are several fluids made especially for hydraulic shoring. They're water soluble, much cleaner and less expensive to use than hydraulic oil. Make sure you have several gallons of this fluid on hand because each time you release the pressure to remove the jack, the fluid sprays out. And when you reset the shoring, you need to pump new fluid into the cylinders to replace what was lost.

## *Setting Hydraulic Shoring*

To place hydraulic shoring, begin by setting the folded or collapsed shoring on the ground near the trench (see Figure 23-2). Locate the hydraulic quick coupler at the base of the jack on one of the cylinders.

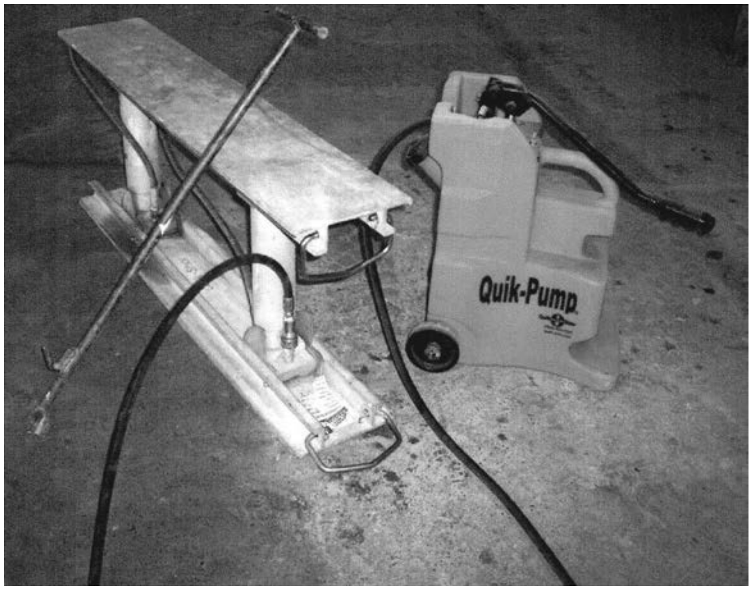



***Figure 23-2*** *Hydraulic jack with pressure tank*

Turn the jack so that the quick coupler is facing upward. Lift the top aluminum plank so the jack extends and the shoring is open or unfolded. Once the shore is open, hook the pump hose to the quick coupler, which is now readily accessible. Notice in Figure 23-2 that a second hose runs from the top jack to the bottom jack so that both cylinders can be activated by the same quick coupler. There are handles on the ends of each side of the jack section.

Open the wing nut valve on the top of the hydraulic pump tank before you connect the quick coupler. After the quick coupler is connected, push down on the top aluminum plank so the hydraulic cylinders compress completely. With the wing valve open, any fluid remaining in the cylinders will flow from the jack cylinders to the tank. Now the hydraulic shoring is ready for placing in the trench.

Both hydraulic arms on the jack are hinged so you can collapse the jack down to about 10 inches wide. Once it's collapsed down, hold onto the handles on each jack plank and slide the jack into the trench. When you've lowered the jack three-quarters of the way into the trench, let go of the handle that will be on the far side, while holding onto the handle on your side of the trench. The jack will spring open. When the top of the jack is at ground level, have your helper pump pressure into the cylinders that hold


***Figure 23-3*** *Pipe crew working in a well-shored trench*

the jack planks apart, extending them across the trench. When the jack is positioned firmly in place, let go of your grip on the jack handle and take hold of the release tool. Once your helper gives you the signal that the pressure has built up enough in the cylinders, pop the quick coupler loose from the jack, and the jack is set.

If the trench is more than 30 inches wide, I'd suggest having two men lower the jack into the trench. The second man can control the jack handle on the far side of the trench using a rebar hook and a short rope. He can keep pressure on the rope so the jack won't spring open too soon. Remember, the wing nut on the hydraulic pump must be open to hook the quick coupler to the jack, and it must be closed to pump pressure into the cylinders. Most tanks have a pressure gauge to indicate when the pressure is high enough to release the coupler. If yours doesn't, pump the handle until it becomes too hard to push. Then you know the jack is set. Figure 23-3 shows the pipe crew lowering a pipe into a well-shored trench. Notice the ladder sticking up out of the trench. It's in the area where the crew below is working, in case they need to make a quick exit from the trench. Should a shored trench ever show signs of becoming unstable or if cracks show up in the wall behind the shoring, get everyone out quickly. Make sure everyone stays out until more shoring is set to stabilize the trench.

When you set hydraulic shoring, try to place the shore planks where the trench wall is straight and smooth. If the trench wall is rough and there's a void behind the jack, pressurizing the jack may bend the aluminum plank. If you can't find a smooth area, place a 2 x 10 wooden plank the length of the shore behind the shore plank to provide extra support and prevent it from bending.

If you're working in gravel or sandy soil, too much hydraulic pressure will cause the trench wall to crumble. In soil like this, pump just enough to provide firm pressure against the wall, but not enough to dig into the wall. You must use sheeting between the shoring planks to prevent the trench walls from crumbling if the ground soil is too loose. Check local and federal safety regulations on trench shoring before you begin shoring. These regulations will spell out very clearly how far apart the shoring can be set, and how thick the sheeting must be at various trench depths. Remember, the contractor and his supervisory personnel can be held criminally liable if a worker is injured in a trench that wasn't shored according to the regulations.

### *Removing Hydraulic Shoring*

To remove hydraulic shoring, stick the release tool through the handle on the quick coupler side of the jack. With the hook facing the center of the trench and the cup at the end of the release tool turned inward, place the cup over the quick coupler. Exert pressure against the quick coupler stem by pushing out (towards the trench center) against the jack handle with the release tool. The fluid will spray out, releasing the pressure in the jack's hydraulic cylinders and allowing the aluminum planks to retract from the trench wall. A helper, with a rope and rebar hooked through the handle of the jack on the opposite side, should also be pulling lightly with you while the pressure is released.

Keep pressure against the quick coupler until there's a good amount of space between the jack and trench wall. Then pull the release tool up with a jerk so the hook catches the handle of the jack. Pull the handle to draw the shoring up and out of the trench. It'll collapse as your helper pulls the handle on the jack plank across the trench toward you as well. If the shoring is long, pull it far enough with the hooks to wedge the shoring at an angle against the opposite side of the trench. Then remove the hooks (both the release tool and the rebar) and pull the shoring the remainder of the way by hand. Be sure you wear gloves and keep your fingers clear of the inside of the shore as it closes. All this is accomplished from outside the trench. No one should ever be in the trench without the shoring — for any reason. On some jobs you may only need one person to remove the shoring. But on others, such as the trench that we discussed above, the hydraulic shoring may be too long and heavy for one person to lift. In that case, be sure you plan to have another helper available. If the trench is extremely wide or deep, you'll need a hook and a short rope to pull the far side handle and collapse the shoring. Or, you may need to lay a plank across the trench to reach the far side handle. If the shoring is too heavy, use a small backhoe to set and remove it.

## Shields

You may work in areas where ground conditions are so bad or the trench so deep that shoring won't hold the trench walls, even when backed with sheeting. If your space is limited and it isn't possible to slope from the trench bottom to the top, you'll need to use a shield. And that will reduce the amount of pipe footage you can lay each day.

There are many types and brands of shields to choose from. Most have adjustable widths. A simple shield could consist of two sheets of steel or lighter metal, separated by welded steel braces. An open area in the center between the braces allows the pipe to be lowered through the shield to the trench bottom. The shield must be pulled along by a hoe as the pipe is laid. Figure 23-4 shows a large shield for a 4-foot wide, 22-foot-deep trench. A shield gives crews protection on both sides, so they can work without fear of cave-ins. Figure 23-5 shows crewmen tamping the aggregate with adequate room to work inside the shield.

### *Manhole Shoring*

It's no more difficult to shore a manhole than a trench. The manhole shield must be free of braces so you can raise or lower materials through it. You can do this by setting a steel tube into the hole. These tubes, or shields, have slots cut into the sides at the bottom to allow them to sit over the pipes. They also have clips at the top so a second shield can be placed on top of the first and hooked into place if the trench is deep. A manhole shield can be round or square depending on the brand. If you're using a trench shield, the manhole shield should be placed right after the

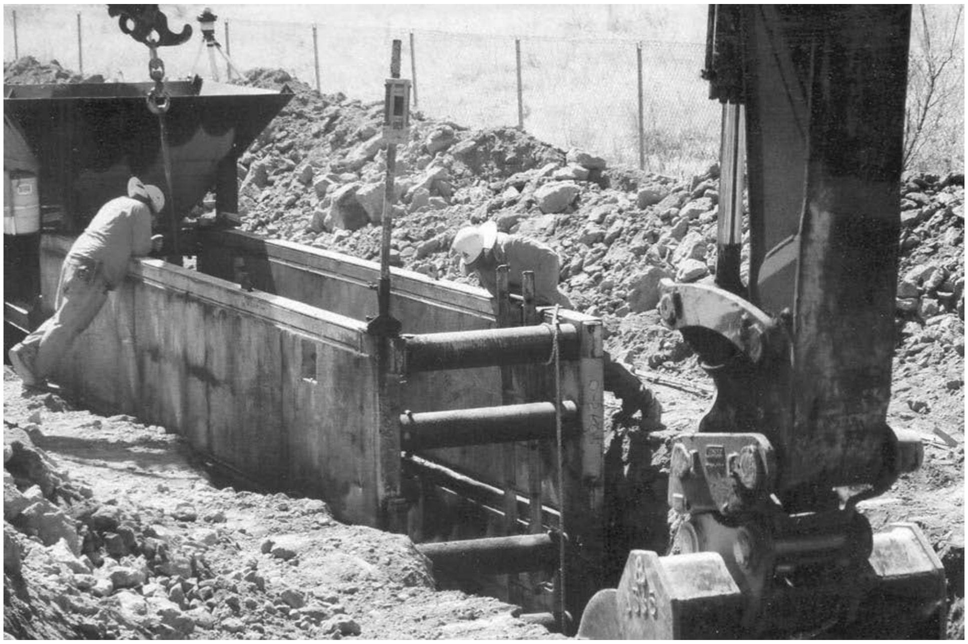


***Figure 23-4*** *Large shield provides protection from cave-ins*

***Figure 23-5*** *Crew working inside a shield*

*Courtesy of Joe Wilson*

***Figure 23-6*** *Setting trench sheets and manhole shield in place*

pipe shield has passed, to prevent damage to the pipe in case of cave-ins. If you're using precast manhole bottoms, place the manhole shield before the bottom is set. Figure 23-6 shows a manhole shield ready to be placed. You can see the slot at the bottom where it fits over the pipe. There are two sections attached to the bottom section to give it the height it needs to sit above ground level. If the trench walls are vertical on each side of the shield, it's good practice to place shores between the shield and the trench walls. This will keep the shield from sliding if a cave-in should occur on one side. Remember — safety always comes first.

# CHAPTER 23 QUESTIONS

**1. At what depth must a vertical trench always be shored?**

A) 4 feet
B) 5 feet
C) 6 feet
D) 7 feet

**2. What's the best method to ensure that a trench 7 feet deep or less is stable?**

A) Use sheet shoring
B) Use a shield
C) Slope the sides
D) Use hydraulic shoring

**3. What's the main problem with using a shield in loose cobble?**

A) It's hard to keep a straight trench
B) It's likely to wedge against the wall
C) It's hard to keep cobbles from entering the shield
D) It's hard to keep a smooth grade

**4. What do you need when setting two 6-foot shores, one under the other?**

A) A long release tool
B) Five people
C) A larger pump
D) A grappling hook

**5. How high above the trench bottom should you place shoring?**

A) High enough for the initial backfill
B) High enough so the pipe won't hit the shoring
C) High enough so the crew can reach the quick coupler
D) High enough so the pipe crew can work under the hydraulic cylinders

**6. When attaching a hydraulic pump hose to the shore, how should you position the quick coupler?**

A) Facing toward the right side
B) Facing toward the left side
C) Facing up
D) Facing down

**7. How can you prevent damage to the shore planks if there's a void in the trench wall?**

A) Place the jack over the void
B) Increase the pressure on the jack to keep it away from the void
C) Place a 2 × 10 wood plank behind the shore
D) Place the planks at an angle to avoid the indentation

**8. When should you use sheeting with the shoring?**

A) When you're working in clay
B) When the ground is damp
C) When the wall crumbles between shores
D) When you're working in hardpan

**9. How is a shield moved along in the trench?**

A) It's pulled by a hoe
B) It's pushed by a dozer
C) It runs on tracks
D) It's set by a crane

**10. What should you do if a manhole shield is set between vertical trench walls?**

A) Slope the trench walls
B) Backfill around it
C) Allow a 2-foot clearance on each side
D) Set shores on each side

# CONSTRUCTING MANHOLES

## 24

In this chapter we'll look at how to build up a concrete manhole form and set rings to bring it level to the required grade. Figure 24-1 shows a poured concrete bottom, precast concrete barrels and dome, and the location of the casting and grade rings. We'll be discussing each of these items in detail.

The three most common manhole sizes that you'll be installing are 48 inches, 60 inches and 72 inches wide, with either a flat or dome top. The 48-inch manhole has a 24-inch opening at the top and usually comes with a flat top or a one-piece precast dome. The 60- and 72-inch manholes have a 36-inch opening and come with a flat top and a one- or two-piece precast dome.

## Manhole Bottoms

Unless you have a sump at the bottom, you need to build manholes that allow for a smooth flow of water. When you use a poured bottom

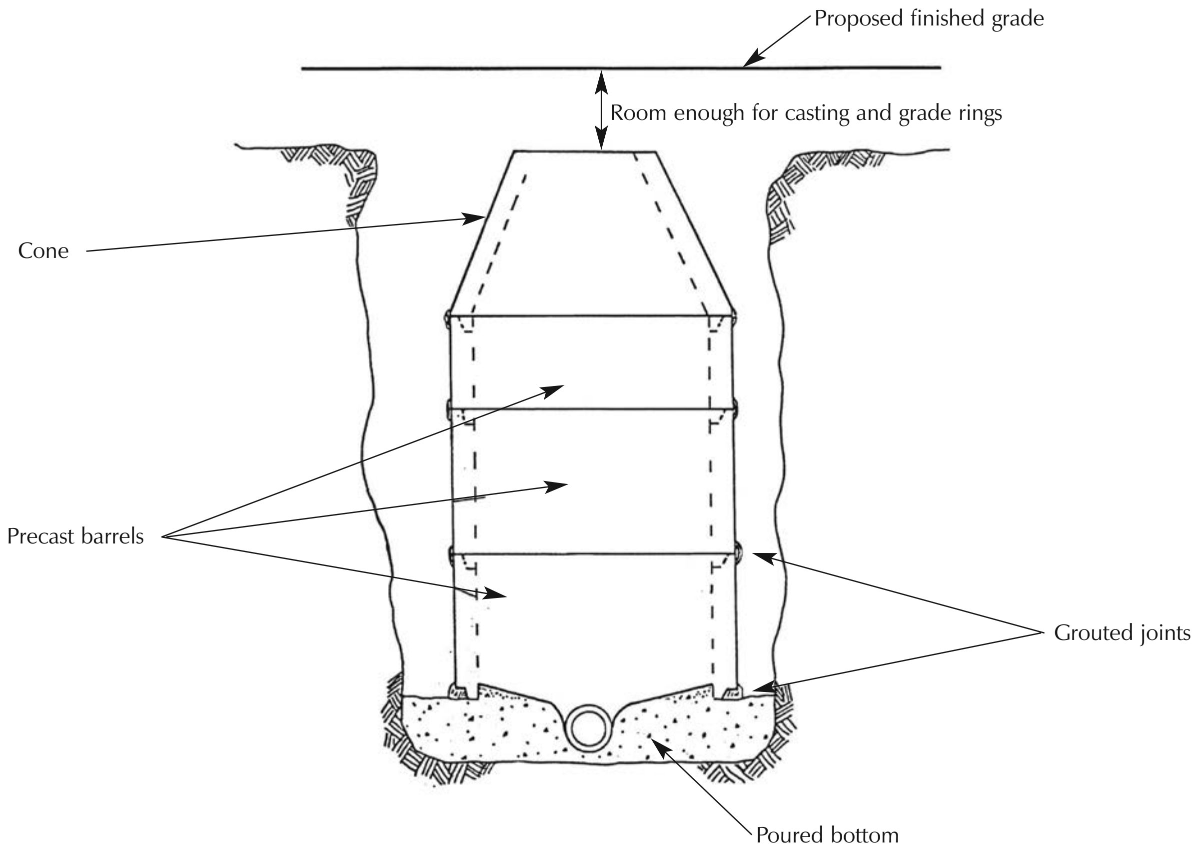



***Figure 24-1*** *Manhole*

rather than a precast bottom for a sewer manhole, you can accomplish this by laying the pipe through the manhole bottom. If the pipe is larger than 14 inches, stop the pipe at the inside of the manhole on each side. If a side lateral enters the manhole, lay it into the manhole to a point where the sweep in the poured bottom starts to enter the main line. If a second lateral enters the manhole from the opposite side, lay it the same way. This will allow a good flow from the side channels into the main. And whether the bottom is poured or precast, it must be level so the manhole won't lean when the barrels are set.

## *Pouring Manhole Bottoms*

You'll need to plug the side lateral pipes with sandbags or something similar to keep the concrete from running into them when you pour the bottom. Be sure that the manhole is excavated far enough under the pipe and that it's the diameter the job specifications require. For pouring and finishing a manhole bottom, you need a hammer, a square-nose shovel with a short handle, rubber gloves, a finisher's or bricklayer's trowel, a bucket of water, and a concrete brush.

When pouring the manhole bottom, be careful not to pour concrete directly on the pipes that extend across or into the manhole. If the manhole is deep, attach a trunk tube to the concrete chute so the concrete won't fall a long distance and hit the pipe. If you're working in cool weather and must set manhole barrels soon after pouring the bottom, use 2 percent calcium chloride in the concrete mix for a quicker set. Take care to keep the pipe from floating as the concrete rises under it. A dry mix, with about a 3-inch slump, will help eliminate this problem. You'll have to tell the concrete plant the mix size, the slump requirement and the percentage of calcium chloride you'll need in the mix when you order the concrete.

Pour the concrete to about 2 inches above the top of the pipe, and then begin to slope and channel out the bottom. After some initial shaping, let the concrete dry until it's firm enough to hold the shape you want. Then do the final shaping and troweling. It's important to shape the concrete floor starting at the spring line of the pipe so the bottom has a full channel width. (Look again at the poured bottom in Figure 24-1.) The channel should always be as wide as, or wider than, the pipe at every point. If you're also channeling in side laterals, be sure to shape a good sweep and make the slope low enough to allow an even flow into the main line. The channels and bottom you build should as much as possible resemble the precast bottom in Figure 24-2.

Don't break out the top of the pipe laid through the manhole until the concrete bottom has hardened for at least 12 hours. If you don't allow the concrete enough curing time before breaking the pipe, the pipe may crack past the manhole bottom into the line. This will cause a leak, and you'll have to replace the pipe. If the sewer is steel or PVC pipe, use a cut-off saw and cut the top of the pipe out.

After you break away the excess pipe, grout the manhole bottom to give it the appearance of being molded, like a precast bottom. Once you've troweled the bottom as smooth as possible, use a fine damp brush to lightly etch the finished surface. A hand-finished bottom won't look quite as smooth as a precast bottom, but you should try to make it as much like that as possible.

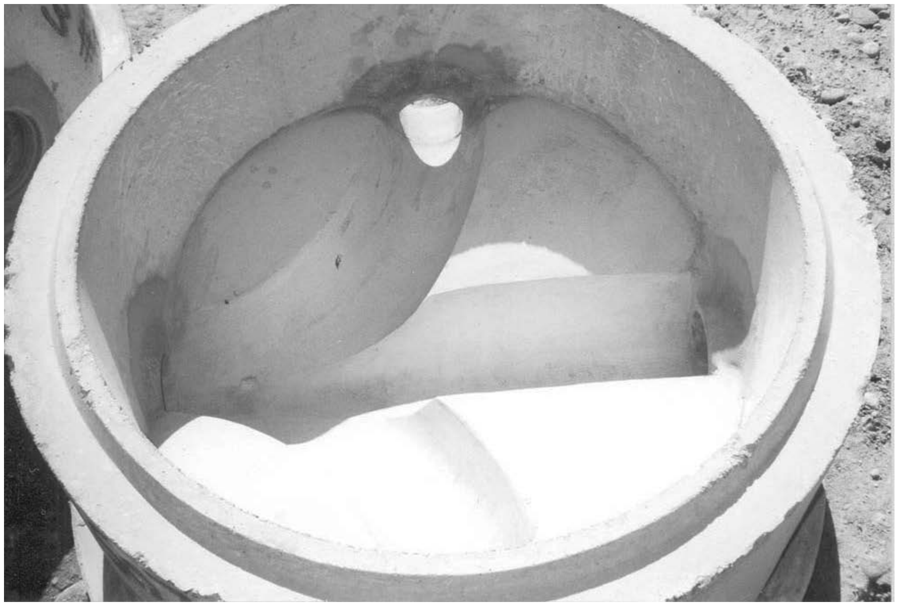


***Figure 24-2*** *Precast sewer manhole bottom with two service lines*

## *Precast Manhole Bottoms*

If precast manhole bottoms are available, you should consider using them. A precast manhole bottom is ideal when time is important because it eliminates the wait of two or more hours between pouring a concrete bottom and setting the barrels.

For bottom grade, calculate the distance from the base of the precast bottom to its flow line. Over-excavate for the manhole bottom. Then, allowing for the thickness of the precast bottom, place at least a 1-foot level layer of $^3/_4$-inch crushed rock in the excavation. Make sure that when the bottom is set, the openings for the pipe in the precast bottom will match the pipe in the trench.

Check the job specifications. Most will require short sections of pipe on each end to connect to a precast manhole, as shown in Figure 24-3. The short pipe section will help prevent damage to the pipe if the manhole should settle. Connect the manhole bottom to the downstream pipe using the 2-foot section of pipe with two male ends, each with a rubber ring. Some specifications may require a mechanical coupling. Lay the upstream pipe into the manhole using the short pipe section. When both the upstream and downstream pipe lines are joined to the manhole, the pipe

***Figure 24-3*** *Use a short pipe section to connect the sewer pipe to a precast manhole bottom*

laying can continue. The manhole bottom is now finished and ready for setting the barrels.

If possible, pressure-test that section of sewer before setting the manhole rings. It'll save you the trouble of climbing in and out of the manhole later. If there's a leak, you can find it before the trench is completely backfilled.

## *Manhole Bottoms with a Sump*

There's usually a sump required when pouring drain manholes. If the agency or specifications require a sump, don't lay the pipe through the manhole. Instead, extend the pipe just far enough into the manhole to reach the inner wall. On a 48-inch manhole, leave a space of 48 inches between the two pipes. Dig the manhole 48 inches wide plus the thickness of the walls and a 4-inch overbuild, and to the depth specified. Be sure not to over-excavate the manhole excessively because it'll waste concrete if you don't use outer wall forms. First pour the bottom. Then insert the inner wall form, setting it on the poured concrete bottom.

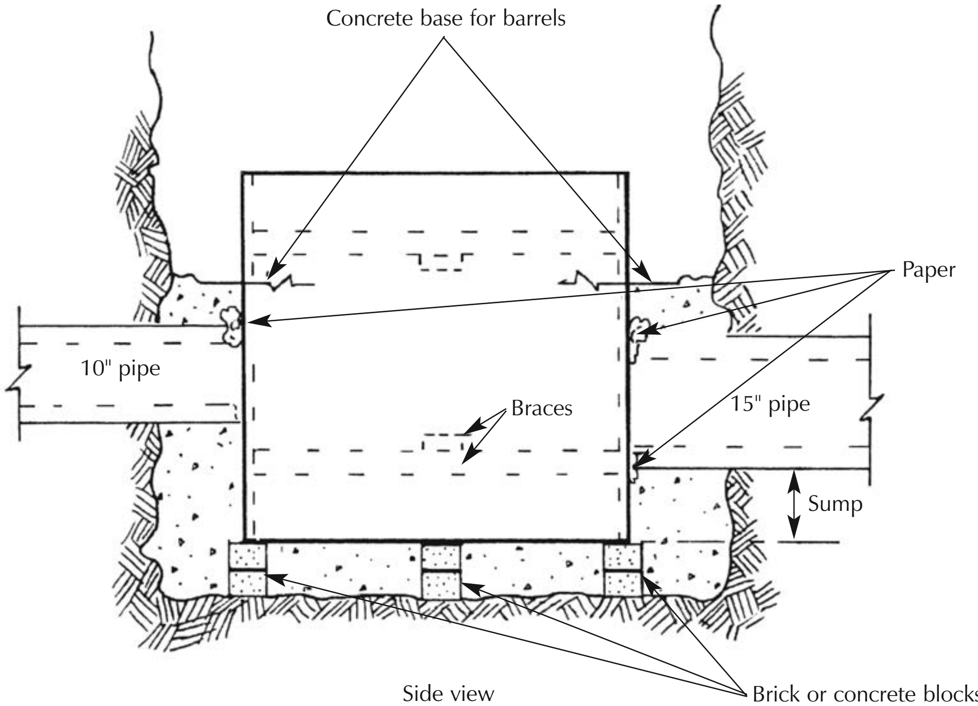



***Figure 24-4*** *Form for a manhole with sump*

As an alternative, you can raise the inner wall forms to the bottom grade, as shown in Figure 24-4, and pour the sides and bottom at the same time. Set the forms on bricks or concrete blocks. Use wood, metal or Sonatube for the inner wall forms. If there's a space between the forms and pipe large enough for the liquid concrete to pass through, use newspaper or paper from concrete sacks to plug the holes. Place braces inside the form to keep it from distorting from the weight of the concrete, as shown in Figure 24-5. You may need sandbags to prevent the concrete from flowing down a trench excavated for a pipe of this size.

Figure 24-4 also shows a sump. A sump collects silt in the line. When a sump is called for, the depth may vary from 6 inches to 2 feet. As a rule, large drain pipe (over 30 inches) don't call for a sump.

If both the bottom and the sides of a manhole are being poured together, pour the sides first. Pour several inches of concrete all the way around the form. Never let the concrete build up unevenly on one side of the form, or the weight of the concrete may cause the form to slide off center. Repeat the circular pouring pattern until the concrete reaches the

*Courtesy of Joe Wilson*

***Figure 24-5*** *Manhole form with braces*

top of the pipe. Always pour to the top of the highest pipe if pipes are entering the manhole at different elevations. Check across in both directions with a level on a straightedge to make sure the poured concrete is level all the way around.

Use a pole to prod and settle the concrete, making sure that all the voids are filled. Tap the inside of the form slightly with a hammer as the concrete is being poured. This helps leave a smoother surface after the forms have been pulled. Unless it's required, I don't like to use a vibrator. If it's overdone, a vibrator will cause the concrete to seep into the pipe at the end spaces.

Once the sides are poured, you can pour the bottom. Be careful to keep the concrete just below the bottom of the form. If the concrete is poured higher than the bottom edge of the form, the form will be very hard to remove when the concrete hardens.

The curing time needed before you can pull the forms depends on the weather and how high the sides are poured. On a warm day, if time is an issue, three hours should be enough curing time. To test the concrete, bang it with the handle of a shovel. If the handle sinks in or dents the

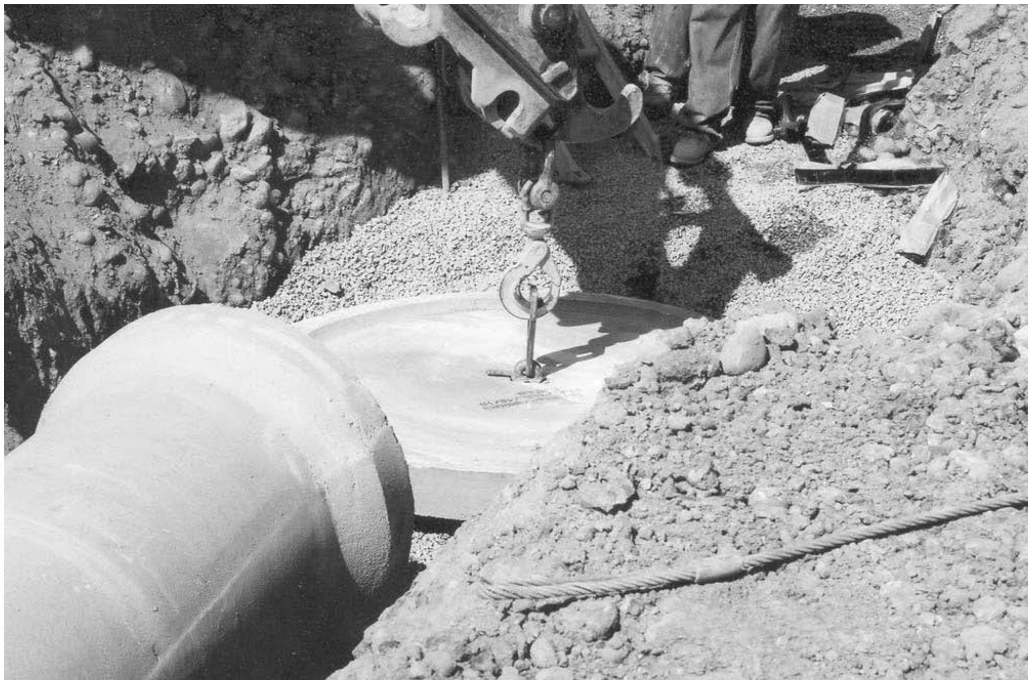


***Figure 24-6*** *Setting the precast drain manhole bottom*

concrete easily, don't pull the forms. If the concrete feels solid, you can remove the forms. Once the forms have been pulled, clean the paper from the ends of the pipe and knock off any rough points of concrete. Grout any voids in the manhole with mortar, then brush the concrete smooth.

## Setting the Barrels

You use the same procedures for setting and testing manholes whether you're working with sewer or drain manholes. Figure 24-6 shows a drain manhole bottom being set on a bed of crushed rock. Once it's in place, you're ready to lower a precut barrel into position. Slide the opening on the barrel over the drain pipe on the downstream side (Figure 24-7), then set it carefully on the precast bottom. When the upstream pipe is laid, all you need to do is place mortar around the pipe to complete the manhole bottom. Notice the pipe holes that are cut into the manhole barrel. No sump is required for this large drain line.

***Figure 24-7*** *Setting the precast barrel section of the drain bottom*

The next step is to set the remaining precast barrels. You need the correct hookup to set the barrels safely. There are pin holes on the sides of the manhole barrels. These holes don't go all the way through the wall, so the pins you use must be large enough not to slip out. Figure 24-8 shows the correct hookup for setting manhole barrels. The chains are long enough so no outward pressure is placed on the pins, and the pins fit snug enough so there's no danger of them slipping out of the holes.

Your job specifications will state the type of joint material that you must use between barrels. It's usually a tar-like material. I use a material called *Ram-Nek*. In Figure 24-9 you can see the *Ram-Nek* placed correctly around the joint of the barrel, with the ends overlapping by 1 inch. When the next barrel is set, the *Ram-Nek* will create a watertight joint.

Setting precast barrels is like stacking blocks. Most are designed with a tongue on one end and a groove on the other. Place the tongue down and the groove up. The barrels come in various lengths. Choose the correct lengths for each manhole so that when the dome is set on the top barrel, it'll be far enough below finished grade to leave room for the casting and possibly a grade ring or two.

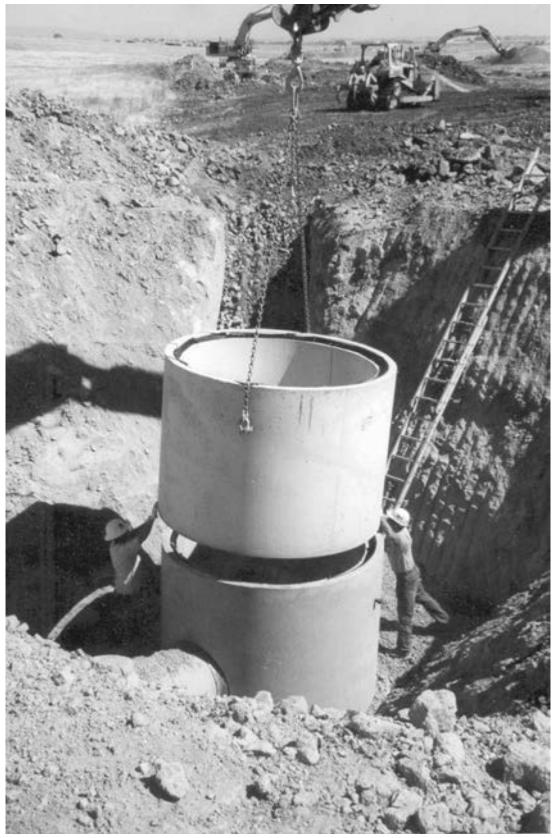


***Figure 24-8*** *Correct chains and pins are needed for setting manhole barrels*

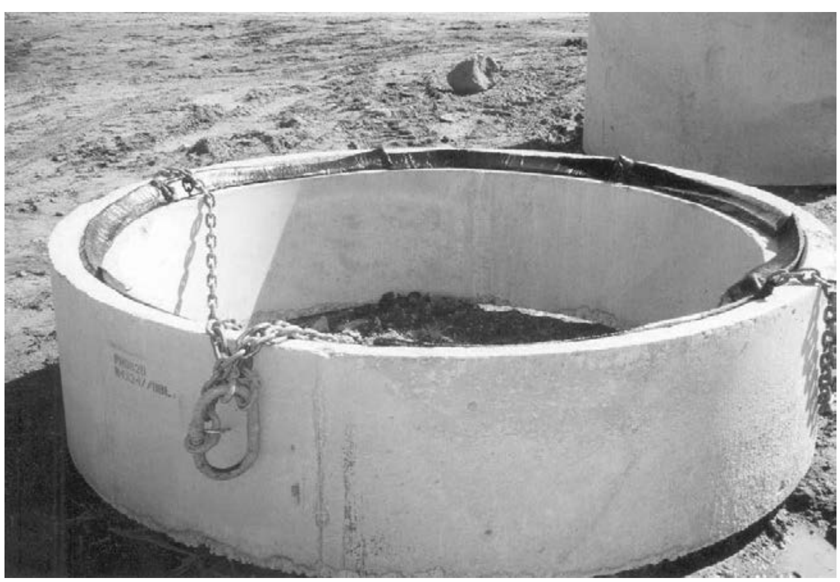


***Figure 24-9*** *Use Ram-Nek for a good seal between barrels*

***Figure 24-10*** *Flat top on a 60-inch manhole*

When the surveyors mark the manhole and pipe flow-line cuts, they should also mark a top-of-manhole grade. If they fail to do so, the plans should give the invert elevation (flow line) of the pipe at the manhole, and also the street or ground elevation. Subtracting the invert elevation from the street elevation will give you the total height of the manhole, from the flow line of the pipe to finished grade at the top. Now subtract the thickness of the cast iron manhole casting that'll be used on top. That's the height you need from flow line to the top of the dome. It's wise to leave the dome 3 to 6 inches lower than needed, and use a 3-inch or 6-inch grade ring if necessary. If you end up with the dome too high, you'll have to pull it off and make a barrel change. You always want to avoid putting yourself in that situation.

You can make minor height adjustments with 3-inch or 6-inch grade rings. Your job specifications will list a maximum number of grade rings that you can use on each manhole. The maximum neck height is usually 18 inches, including the casting. Be sure the barrels are set high enough to keep the number of grade rings within the specifications. Figure 24-10 shows a flat top being set to finish this manhole to grade. Notice the combination of barrels that were used to get the required grade. The person on the ground in front of the manhole is placing joint tape on the barrel seams. If joint tape isn't available, you can use mortar to fill the seams. Mortar is always used on the inside for the seams, and around the inside and outside of pipe joints on drain manholes.

When all the manhole barrels are set and the joints mortared and taped, the finished manhole should be tested. Figure 24-11 shows a vacuum test in progress. There's an outer ring on the vacuum plate that's actually a special bald tire that inflates to 45 pounds of pressure and creates an airtight seal. Once it's inflated, a compressor hose is hooked to


***Figure 24-11*** *Vacuum testing a manhole*

a cylinder device that creates a vacuum in the manhole as the air from the compressor blows through it. To pass the test, the manhole must hold a one-pound vacuum for one minute. Of course, you must plug both ends of the pipe in the manhole before you begin the test so you're not testing the pipe as well. Be sure the test plugs are seated securely so they won't leak.

## Setting the Manhole Casting

The accepted way of placing manholes in new streets is to leave them deep enough so that they can be covered with a temporary steel lid and paved over. After the paving has been completed, the manholes are uncovered and grade rings and castings are set.

When setting the castings, you must be sure that they're level with the pavement. The best way to do this is to use two 8-foot 2 x 4s like the ones shown in Figure 24-12. Drill holes for two L-bolts in each of the 2 x 4s.

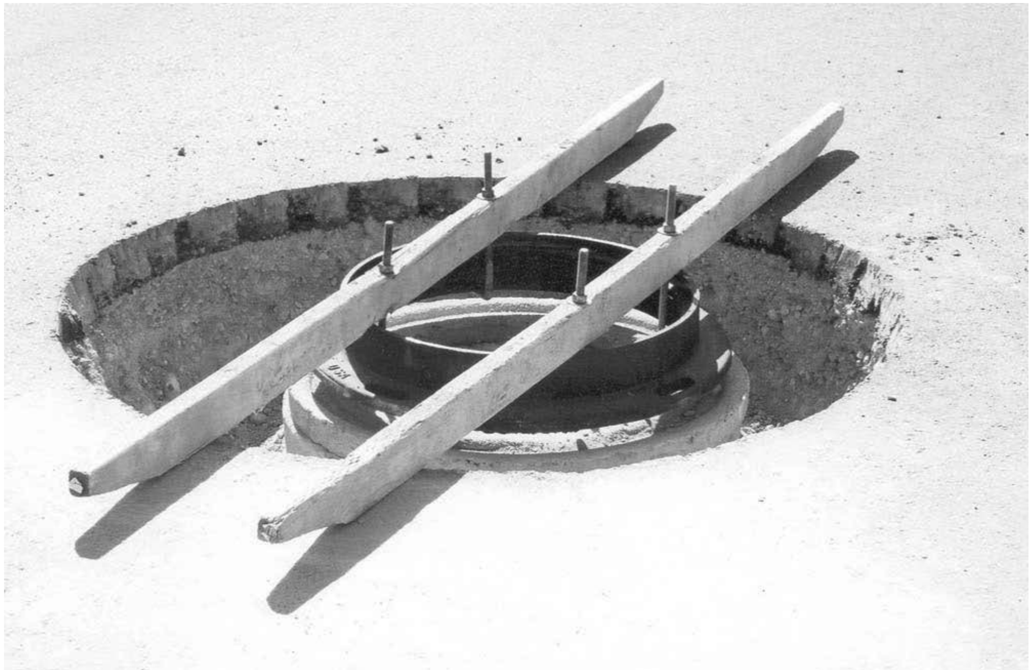


***Figure 24-12*** *Use 2 x 4s to hang casting for pouring concrete*

Put the L-bolts through the 2 x 4s and hook them under the inside bottom of the casting. Place a nut on top of each L-bolt and screw it down until the casting is drawn up to the bottom of the 2 x 4s. Measure the space between the manhole top and the casting. Remove the casting and set the grade rings needed to bring the casting up level with the pavement. Using the 2 x 4s, center the casting over the grade rings. If there's space between the last grade ring and the casting bottom, as shown in Figure 24-12, but not enough for another grade ring, fill the space with concrete. That will save filling the space with mortar later.

Pour concrete into the excavation around the manhole and grade rings to within 2 inches of the casting top, as mentioned above. When the concrete has set for 2 hours, loosen the bolts and the casting is set. The neck of the manhole must be finished inside with mortar, as well as any inside joints that were missed while setting the rings.

If you're working on a traveled street where the raised casting must be poured and paved around, timing is important. Take care when paving around manholes. If you don't make a smooth match to the existing pavement, it'll be obvious to every driver on the roadway. Use a $^{1}/_{2}$- or $^{3}/_{8}$-inch asphalt mix to pave the last 2 inches to match the existing road grade. Be sure to tack coat the bottom and edges before paving. A good four-man crew can finish digging, setting, and paving nine manholes in an eight-hour day. If traffic must use the lane late that afternoon, add 2 percent calcium chloride to the concrete for a quicker set. I prefer to use a six-sack concrete mix rather than the usual five-sack mix in this situation — I think it hardens better.

A word of caution: When setting manholes and handling manhole lids, be sure all crew members keep their fingers clear. And always wear rubber gloves and safety glasses when grouting or working with concrete to avoid concrete poisoning or eye injuries.

When you're using precast manhole bottoms, be sure the supplier has a set of your plans well ahead of time. The supplier will need time to custom-make sewer and drain manholes for your job.

# CHAPTER 24 QUESTIONS

**1. A 48-inch manhole has what size opening?**

A) 24 inches
B) 36 inches
C) 42 inches
D) 48 inches

**2. What's the largest pipe size that should be laid through a manhole?**

A) 10 inches
B) 12 inches
C) 14 inches
D) 16 inches

**3. How far above the pipe should you pour the concrete on a poured sewer manhole bottom?**

A) 1 inch
B) 2 inches
C) 3 inches
D) 5 inches

**4. How long should a poured concrete bottom be allowed to set before the top of the pipe is broken away?**

A) 3 hours
B) 5 hours
C) 9 hours
D) 12 hours

**5. What is the *minimum* amount of gravel that should be placed under a precast manhole bottom?**

A) 6 inches
B) 8 inches
C) 10 inches
D) 1 foot

**6. What's the major difference between sewer and drain manholes?**

A) The sewer manhole is deeper
B) The drain manhole has no side outlets
C) The drain manhole usually has a sump
D) The sewer inlets are always smaller pipe

**7. What material is used in the joints between manhole barrels to get a good seal?**

A) Ram-Nek
B) Cement mortar
C) Epoxy and sand
D) Plastic cement

**8. What's the maximum neck height, including the casting, allowed on a manhole?**

A) 12 inches
B) 18 inches
C) 24 inches
D) 30 inches

**9. Manholes are vacuum-tested to how many pounds?**

A) 1 pound
B) 2 pounds
C) 3 pounds
D) 5 pounds

**10. What's the best percentage of calcium chloride to use for a quick concrete set?**

A) 8 percent
B) 5 percent
C) 2 percent
D) 1 percent

# UNDERDRAINS, CULVERTS AND DOWNDRAINS

25

Most of the work we'll be looking at in this chapter is done on highways and country roads with roadside ditches. Several types of drains are used to keep water from accumulating on or under roadways. We'll be looking at underdrains, culverts and downdrains.

## Underdrains

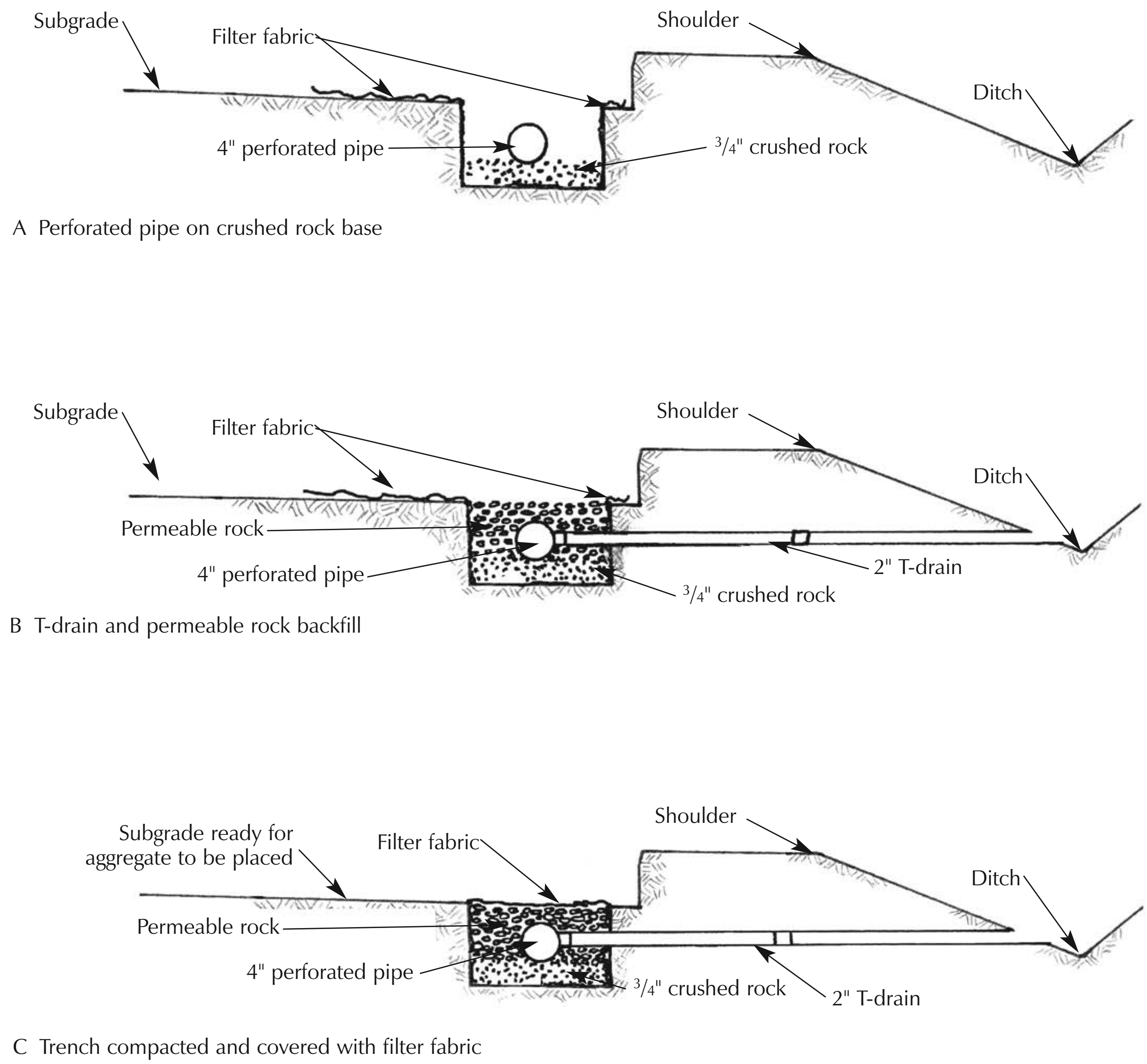
Underdrains are designed to collect and carry off water that accumulates under the road surface. This is done by digging a shallow trench, usually not more than 18 inches deep, along the outside edge of the pavement or shoulder. They're usually on the low side, but they can be placed on either the high or low side of the road, depending on where seepage is expected. Before any underdrain work can be done, the road subgrade needs to be trimmed and rolled, prepared for aggregate, and accepted by the inspector. When the inspection is complete, you can dig the underdrain trench. All the dirt from the trench must be hauled away so the road subgrade isn't disturbed or changed in any way.

Lay construction fabric in the trench. Make sure you have enough fabric to cover back over the top of the trench after you place the material. Fill the trench 4 to 6 inches deep with $^3/_4$-inch crushed rock. Lay a 4-inch perforated pipe (usually PVC) on the crushed rock, with the holes facing down. Fill the remaining 1 foot of the trench with permeable material. The permeable material is usually 1- to $1^1/_2$-inch washed rock with practically no fines at all, so the water can seep freely through the rock. The rock has a coating of cement or asphalt that binds it in place. After the permeable material is in place, tamp it with a plate tamper before you fold the remaining construction fabric over the top.

Every 200 feet or more there should be a 2-inch T-line off the 4-inch underdrain line to carry the water collected under the road to the roadside ditch. See Figure 25-1. The plans should show the station number where each T-drain is to be placed. No grade or line needs to be staked. The line is taken from the road stakes or choker, and grade from the finished subgrade. Lay the T-drains at a slight slope to the ditch. After the underdrain is completed, you can place the aggregate road base. Figure 25-1 shows the steps for installing an underdrain.

# Culverts

A culvert is one good way to control surface water. The engineer may design a culvert with a dirt cap (Figure 25-2) so the road rock and the drain culvert rock don't come together, as they do in an underdrain. If you need a dirt cap, lay the culvert pipe after you complete the rough subgrading of the road, unless the culvert is to be placed under a 20-foot fill. If the culvert will be under a deep fill, be sure to place the culvert before the fill is completed. A good rule of thumb is to trench the drain once the fill is 3 feet above the top of the culvert pipe. This should be enough fill to protect the pipe from equipment running over it after the culvert is laid and the fill continues. Culvert drain pipe isn't perforated. It's designed to carry water from one area to the next. Concrete or




A Perforated pipe on crushed rock base

B T-drain and permeable rock backfill

C Trench compacted and covered with filter fabric

***Figure 25-1*** *Underdrain installation*

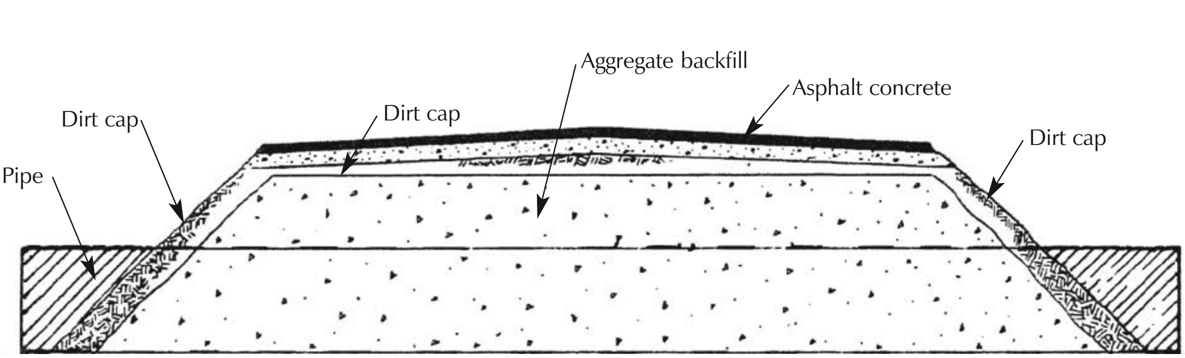



***Figure 25-2*** *Culvert with dirt cap*

corrugated metal drain pipe is usually used for culverts on highway projects. Plastic ribbed culverts are used more on subdivision roads. Lay culvert pipe on a good gravel bedding. There's usually an initial gravel backfill required as well.

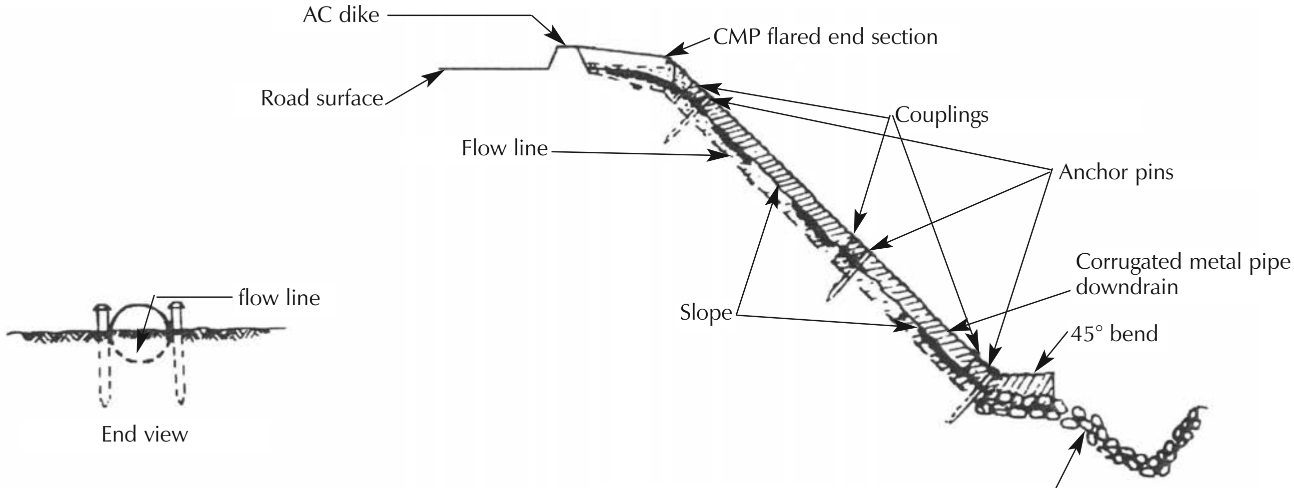
On many jobs the drain lines and culverts are just below subgrade. If so, do the rough grading and the finished subgrade work before laying the drains. If the drains are shallow, haul away the material excavated from the ditch, or use it for road fill. Keep some dirt fill to plug the ends and cap the top of the drain, as shown in Figure 25-2. Some specifications will allow you to lay corrugated metal pipe on the dirt grade. Other specifications may require you to encase a shallow culvert pipe in concrete. Be sure you read the specifications carefully.

## Downdrains

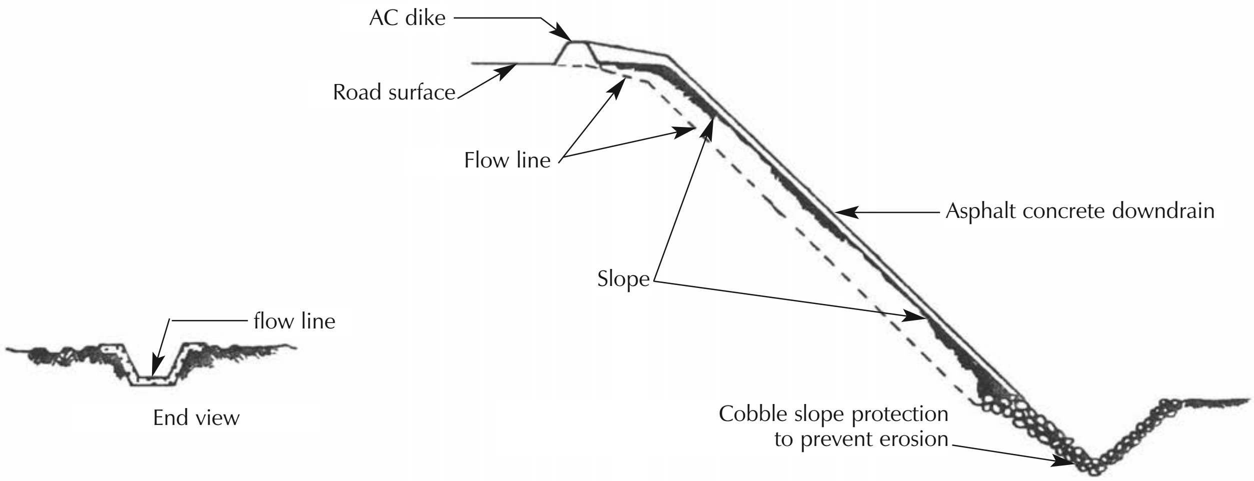
Downdrains are designed to handle water runoff from the road and shoulder surface. The three most common downdrains are corrugated metal pipe, corrugated metal trough and asphalt pavement trough. The main point to remember about placing downdrains is that they can't be placed until the road is paved and the shoulders have been finished or paved. Putting them in earlier will obstruct and slow the road work. If they're metal, they're placed just ahead of the dike work. If they're asphalt, they're placed after.

For a downdrain to be effective, you'll need to put in a dike. The drain is put in first, then the dike. If the downdrain is an asphalt trough, you can put it in during or after the dike operation. If you use metal pipe for the downdrain, anchor it with corrugated metal stakes. Downdrain pipe is laid very shallow — often, the top of the pipe is exposed. If the slope is long, brace the pipe to keep it from sliding. Figure 25-3 shows both (A) a corrugated metal pipe downdrain, and (B) an asphalt trough.

Downdrain outlets for medians are designed to run vertically, deep into the fill slope and out of the bank well below the road surface. In this case, the drain will have to be put in as the fill is built up. Cap the pipe just below the median grade, and uncover and finish it after the median is trimmed. In this case, no trenching is needed. You can extend the drain pipe up, one section at a time, during the fill operation.




A Corrugated metal pipe downdrain




B Asphalt concrete downdrain

***Figure 25-3*** *Downdrain details*

A metal trough downdrain is primarily a surface-type drain. Be sure to anchor the drain to keep it from sliding down the slope when it fills with water. You can install this type of drain just ahead of the dike operation. The job plans will usually have a detail drawing on the type of downdrain required.

# In Summary . . .

We've tried to cover every phase of highway and subdivision road construction, from underground projects to parking lots, without becoming overly technical. The book begins with grade stake and plan reading because we feel it's important for everyone on the job to have a good knowledge of what's being built — and that's really where every job begins. First you need to understand the plans and specifications, and then you can begin the actual work, whether you're setting the grade stakes or reading them as you operate the equipment. You start with the basics and build from there. It's been our goal to help you understand the fundamentals of excavation and grading, as well as how to deal with the complicated challenges that you'll face on the job.

We've also tried to highlight some of the safety concerns that you'll face. We believe that there are two major causes of accidents: inexperienced workers, and workers who've been doing the job for so many years that they've become lax about safety. You can't emphasize safety enough. You're working with very big equipment in what can be very dangerous circumstances. Everyone must be constantly vigilant — for their safety and for the safety of those around them.

A successful operation depends on good people. A project can only be profitable if you have a professional crew working together as a team to maintain the schedule and keep costs in line. That's the only way you'll continue to win contracts for your company. The superintendent, foreman, equipment operators and laborers should all be aware that the only guarantee for continued work is a good job, done at or below cost.

Every company, large or small, must watch their cost per crew. If one crew continues to run over cost on a job, *everyone's* job is at risk. Years ago, I overhead a superintendent tell his foreman, "It doesn't matter how much I like you. If you can't make money for the company, one of us will be fired — and it's not going to be me!" I never forgot that — and I never wanted to be on the receiving end of that lecture! But like it or not, that's the hard reality of the construction business. You won't stay in business long if you can't control your costs. Once you understand that, you've got a good future.

Whether you're just starting out or you've been in it for a long time, construction is an exciting and rewarding career. It's always changing — new techniques, new equipment, new materials and new technology. The innovations created by GPS alone will keep you challenged for years to come! This book contains the knowledge of our combined 75 years in construction. Excavation and grading is our business — and we've done well. We hope you will too. Remember: work smart, work fast and *always* work safe.

# CHAPTER 25 QUESTIONS

**1. Where are underdrains usually placed?**

A) On the low side of the road
B) Down the centerline
C) In the median
D) Under the choker

**2. At what point during the subgrade operation are underdrains placed?**

A) After 4 inches of aggregate have been placed and rolled
B) When the subgrade fill is first made
C) After the subgrade is rough trimmed, but before the fine trimming
D) When the subgrade has been fine trimmed and it's ready for aggregate

**3. Where is the water from the underdrain line carried?**

A) To roadside drop inlets
B) To the median ditch
C) To a roadside ditch
D) To the nearest culvert line

**4. What covers the top of the underdrain pipe?**

A) $^{3}/_{4}$-inch crushed rock
B) Type 1 asphalt
C) $^{3}/_{4}$-inch aggregate base
D) 1- to $1^{1}/_{2}$-inch permeable material

**5. What is an underdrain trench lined with?**

A) Plastic sheeting
B) Construction fabric
C) Sand
D) Chopped straw

**6. When should the culverts be placed if there's a deep fill?**

A) When the fill is finished
B) When the fill is 6 feet deep
C) When the fill is 3 feet above the top of the pipe
D) When the fill reaches subgrade

**7. What part of a culvert usually requires a dirt cap?**

A) Just the downstream end
B) Both the ends and top
C) Only the top
D) Just the upstream end

**8. What type pipe is seldom used as culvert pipe?**

A) Clay
B) Concrete
C) Ribbed plastic
D) Corrugated metal

**9. What type of runoff are downdrains designed to handle?**

A) Runoff from the road and shoulder
B) Runoff from the median
C) Runoff from the fill slope
D) Runoff from the roadside ditch

**10. What can happen if a downdrain isn't properly anchored?**

A) It may not drain
B) It may break apart
C) It may fill up with dirt and debris
D) It may slide down the slope

## Appendix A

# Equipment Operating Tips

We talked with a number of equipment operators to find out what, in their opinions, makes a good operator. Then we asked for tips and suggestions on how to become a *better* operator. Here are their responses.

What makes a good equipment operator?

- Safety is your first and most important responsibility as an operator. Nobody wants you on their job if word is out that on a previous job somebody working with you got hurt.
- Pay close attention to advice from those more experienced than you — there's no substitute for experience.
- Learn from your experiences — don't make the same mistake twice.
- If you're on a piece of equipment and you find yourself in a situation you're not comfortable with, don't keep it to yourself. Get help and/or advice from a more-experienced operator. Trial-and-error is a bad idea when it's applied to heavy equipment.
- Always be extremely cautious when operating equipment on steep terrain.
- Never, at any time, try to operate equipment faster than you are capable of controlling it.

***Figure 1*** *Wheel tilt*

Following are some tips to help you more efficiently, *and safely*, operate the more-common grading equipment. Some are basic operating skills you probably already know, and some are tricks and workarounds that most of us learn over the years. They separate the experienced from the inexperienced operator.

# Motor Graders

## *Wheel tilt*

- When the wheels of the grader are tilted, as shown in Figure 1, the deep lugs on the edge of the tires make better contact with the ground, providing improved traction.
- Tilt the wheels on the grader in the same direction that you're moving the windrow. In a heavy cut, this will help keep the front of the grader from sliding toward the cut side. For example, when moving a heavy windrow from right to left, tilt the wheels to the left.

- In Figure 1, the operator has the blade (mould board) on the left side of the grader off the ground, and is beginning a ditch cut on the right side. He's rotated the blade closer to the front wheel on the right side, so the dirt cut will drift left. The front wheels are tilted to the left to help keep the front from sliding to the right. Note: When the mould board and cutting edge are attached, most operators refer to that as the blade. However, don't let this confuse you. They are two separate parts of the equipment.
- When cutting a slope, start by tilting the wheels of the grader into the slope. If you feel the front sliding up the slope, then tilt the wheels *away from* the slope.
- You can also use the wheel tilt to shift the grader over a couple of inches without steering. By leaning the wheels to the left, it will cause the cutting edge on the left side to move out to the left two or more inches without moving the steering wheel. You must be aware that when you do this, the blade will also cut a little deeper on the left side. If you're operating manually, you must raise the blade slightly on that side to maintain the same grade. This method of steering is used mainly when you're using sonar on a string line. You can steer straight down the line and make slight steering adjustments by tilting the front wheels left or right. The sonar will automatically make the grade adjustments.

### Mould board slide

- A mould board provides better access to tight areas, such as grading a parking lot with existing curbs. Slide the mould board all the way to one side, as shown in Figure 2, to grade inside corners that the grader may have trouble reaching.
- The slide also provides a longer reach when grading slopes. In Figure 3, the mould board is extended to the left to cut a slope. Notice how close the blade is to the rear tire when it's in this position. You must be very careful not to hit the tire.
- For heavy grading work, position the blade in the center of the machine for optimum production.

### Mould board tilt

- As the material being cut with the grader becomes a harder surface, tilt the mould board forward to narrow the contact of the

***Figure 2*** *Mould board extended to one side*


***Figure 3*** *Mould board extended all the way to the left for a slope cut*

***Figure 4*** *Mould board back*

***Figure 5*** *Mould board forward*

cutting edge with the surface. This will allow it to penetrate the surface easier. Even though you can cut the harder surfaces with the blade rolled forward, the depth of your cut will be less because the blade quickly fills with material, causing the cutting edge to lift out of the cut.

- Tilt the mould board to the rear-most vertical position when moving large windrows and bulk material. In this position, the blade will handle more material because the curvature of the mould board will allow more material to roll up and out in the direction that the blade is angled. Figure 4 shows the mould board back. In this position, you can't see the cutting edge of the blade. You must watch the ground behind the blade to see what the cutting edge is doing.

- Use the full forward position of the mould board, as shown in Figure 5, for brushing up finish grade. Since you can easily see the cutting edge when the mould board is forward, you can watch your last few trimming passes carefully.

***Figure 6*** *Circle shift and yoke*

## *Circle*

- The circle allows you to angle the blade so the material you're cutting will roll out the end of the blade in the direction you want. You can see the circle table in Figure 5. The circle can turn 360 degrees, so you must be careful not to turn the mould board into the rear or front tires.

**Circle shift and yoke** — Figure 6 shows a closeup of the circle shift and yoke on the grader. The circle shift is the bottom arm, and the yoke is the arm above with the adjustment holes. The circle shift can be locked in the center position, as it is in the photograph, or in two left or two right positions on the yoke. The farthest right and left shift positions are used primarily for cutting steep slopes (greater than 3:1). For this purpose, the circle is shifted all the way to one side or the other. The mould board can then be swung off to one side of the grader or the other to extend the reach to the slope.

Never try to adjust the pin position while the grader is moving. If you need to change the pin setting, make sure the grader is on fairly level ground and the mould board is on the ground, with no down pressure. You

***Figure 7*** *Articulated grader making a pass on a slope*

can then activate the pin release button, and the pin will withdraw. Use the blade arm levers to slide the circle shift into the position you need. Once the correct adjustment hole is lined up with the pin, activate the pin button, and the pin will slide into place and lock.

The circle shift can be swung to the left and right while locked in the center position of the circle yoke. This allows you to position your windrow of material a little farther out of your rear drive path, so the rear tires aren't running on your windrow as you move forward. However, if you need more extension, you can slide the mould board out about two feet to gain some additional reach without having to adjust the yoke pin.

## *Articulation system*

- The grader is hinged just behind the cab by two large brackets and a pin. There are two hydraulic rams, one on each side, that turn the grader at that point. When the hydraulic ram is fully extended on one side, it substantially offsets the rear of the machine from the front, as shown in Figure 7. The articulated body increases the grader's maneuverability and allows it a sharp turning radius because it provides the grader with a third turning point: The first turning point is the steering wheel, the second is the wheel tilt, and the third is the articulation system. A good operator will take advantage of all three at once, or use each separately, depending on the situation.

- When making a pass on a slope, the articulation system allows you to run the front tires on the slope at or near the hinge point, and the rear tires on the bench at the bottom (see Figure 7). Make each grading pass parallel to the cut slope. When grading large slopes, run the front tires of the grader as near as possible to the last pass finished on each succeeding pass on the slope.

# Dozers

Dozers can come equipped with many types of blades for use in different operations.

## *Dozer grading*

Some D-6 and smaller dozers have angle blades that can windrow material right or left. Larger dozers sometimes have blades that can tilt forward and back, like the one in Figure 8.

- When using an angle dozer blade, small cuts may be more effective than trying to take too much at one time. If you cut too much on each pass, the front of the dozer gets pulled into the cut, and you'll be constantly turning away from the cut to stay straight. You'll end up with a very rough, up and down, cut area. You can eliminate this problem by ripping first. Loosening the cut area will allow you to make larger cuts. A good operator can tell after the first pass if the soil can be cut, or if it needs to be ripped for better production.

- Forward-tilting blades (Figure 8A) allow the cutting edge to cut through harder material. To maximize the blade load capacity, tilt the blade back, as in Figure 8B.


A Blade forward


B Blade back

***Figure 8*** *Dozer with adjustable blade*

- Use extreme caution when working a dozer sideways on a steep slope. A good rule of thumb, for almost all types of materials, is to *never* grade steeper than a 2:1 slope. If you work sideways on a steeper slope and get a rock under the uphill track working in rocky material, you can be upside-down in an instant. If you ever feel the uphill track coming off the ground, set the dozer blade on the ground and turn up slope. This should cause the rear end to slide down slope, stabilizing the dozer.

- A slope board on a dozer is the safest method for grading steep slopes. The dozer can work from a bench, and the slope can be graded with the slope board, eliminating the rollover risk. You can do heavy dozing with the dozer blade to rough the slope in. That relieves the heavy dirt, leaving the fine grade for the slope board.

- The weight of dozers larger than a D-8 makes them useful only for rough passes in removing bulk material from a slope. Big dozers don't work well cutting slopes. They tend to just tear up the slope, doing more damage to the slope grade than good.

### *Dozer pushing*

Leaving extra space can waste time when pushing scrapers. Operators need to develop a consistent routine in the cut so they can keep their machines very close together — without causing a wreck. There are two effective ways to pick up a scraper in the cut.

- The first method is to pick up a scraper at a stop. As the dozer finishes pushing a loaded scraper, the dozer operator will look back to be sure it's clear, and then back up to a stopped scraper waiting to be pushed. When the dozer begins to approach the back of the waiting scraper, he will, while still backing up, turn at a sharp angle to get behind the scraper. When the dozer blade clears the stringer, the operator will immediately change to a forward gear and angle in as he makes contact so that he's in line with the scraper.
- The second method is to pick up a moving scraper. The dozer waits for the scraper to pass him on one side, and then begins to move forward at an angle to close in behind the moving scraper. The scraper operator will slow to a consistent speed that allows the dozer to catch him on the run. This is the most efficient method.

**Push-block blade —** This cushioned dozer blade is designed for pushing operations, such as pushing scrapers. A push-block blade is narrower than the tracks of the dozer, and it doesn't have corner bits that can pop a tire. When pushing scrapers, be sure that contact is made with the stringer on the top quarter of the dozer blade. This type of dozer blade is the safest and most productive blade for pushing applications.

**S.U. blade —** When pushing scrapers with an S.U. (semi-U shaped) dozer blade, make contact with the stringer at the bottom quarter of the dozer blade, just above the cutting edge. You can see, in Figure 9, that this blade is wider than the dozer tracks and has corner bits that can easily pop a rear tire if they should hit the tire sidewall on the scraper. If you're pushing with an S.U. blade, be sure you're in line with the scraper. If pushing around a corner, you'll need to back off and realign with the scraper to continue pushing. This is the only way to prevent tire damage when using such a wide blade. Usually, you would just use this type of blade for pushing when there's also dozing to be done.

## Scrapers

- Be very careful when maneuvering a scraper on sloping ground. If you jackknife the scraper turning up a steep grade, and then


***Figure 9*** *Dozer with S.U. blade pushing scraper*

accelerate, it can easily tip over. Turning downhill in the same manner, and quickly applying the brakes, will drive the nose of the scraper into the ground. In this situation, engaging the accelerator will bring the machine back down on all four tires. The nose of the scraper will usually prevent a forward rollover. When placing fill next to a steep slope, make sure the edge you're driving on is firmly compacted so it won't give way and cause you to roll over.

- On a well-compacted fill slope, you shouldn't get closer than 2 feet to the edge. If you keep up some speed as the material is dumped, it should flow out about 2 feet beyond the scraper bowl. That should bring it close enough to the edge, and the compactor can handle it from there.

## *Self-loading scrapers*

- When cutting with a scraper, the depth is gauged by the slobber bit. Fine grading with a small self-loading scraper takes an experienced operator. The first thing you need to do is find a firm flat surface where you can check the machine. Set the cutting edge on the ground, then lift it just enough to take the pressure off the surface. If the cutting edge touches on one side and is off the ground on the other, call a mechanic to adjust the machine to cut flat. Check the slobber bits. They should match the cutting edge. Also, be sure you have the same amount of air in each tire. That can throw you off level.

- When picking up a windrow, a self-loading scraper tends to load to one side. To avoid undercutting the grade, load with the driver's side on the *down-slope* side. For example, on a street with a centerline crown and a 2 percent cross slope, load with the driver's side *away from* the crown. If a road has significant fall in the direction of travel, for finish grade the scraper loads best going uphill. As the scraper bowl begins to load, the weight of the material on the tires will cause the machine to dig deeper. Raise the scraper bowl a little as it loads to prevent undercutting. When picking up the final windrow of aggregate or dirt, be sure the grade on both sides has been compacted well.

- When excavating dirt with a self-loading paddle-wheel scraper, make a cut just deep enough so you can hear a slight strain on the engine, but not so deep that you cause the tires to spin. A good operator will experiment with what gear is best to load in: He'll start in low, cutting as deep as possible, and time his load. Next pass, he'll load in second gear, cutting as deep as possible, and timing his load again. Once he finds the fastest gear he can use for loading that material, he'll continue to use that gear until the material changes.

- If you're loading with a paddle-wheel scraper that's being pushed with a dozer, be sure to take a very light cut. With a deep cut, the dozer will load the bowl faster than the paddles can handle, jamming the paddles. Should this happen, you must stop, raise the bowl, and reverse the paddles. If this doesn't correct the problem, pull the dump lever to release the pressure.

### Open-bowl scrapers

- When getting a load with an open-bowl scraper pushed with a dozer, let the dozer do the work so the tires on the scraper don't spin. This is extremely important if you're working in rock or any material that can pop a tire. In good dirt, open the apron 12 to 18 inches to allow a good even cut and a quick full load. In oversized material, such as rock, open the apron wide enough to accommodate the largest rock. When the can (bowl) is full, release the cushion hitch and place the apron in float. As you begin to accelerate out of the cut, the can will raise up. The apron will close itself as the can is raised. Take the apron out of float and close it fully. If the apron has a trigger switch control, you can use that instead of placing the apron in float. When you use the trigger switch, as you raise the can, the apron stops closing. So, if you stop raising with the trigger switch engaged, the apron will close. If the apron is fairly wide open, an up-stop, up-stop, up-stop motion with the trigger engaged is the best way to keep the can full as you leave the cut.

- All scrapers dump their loads in a similar manner, regardless of size. Hold the can above the ground at the thickness being placed. If the material is dry and needs moisture for compaction, spread it thin so a compactor can mix it easily. If the material is at optimum moisture, you can place a thicker layer. Your dump speed will be determined by the type of material. If the material is rocky, a first-gear dump may be necessary. With good dirt and a smooth fill, your best choice may be third or fourth gear. With rocky material, the dump and fill is determined by the thickness of the largest rock to be dumped (12 to 18 inches). If the rocks are larger than 18 inches, the fill should be set up so the scrapers dump off the end of the fill. This will allow the larger rocks, that can't pass under the scraper bowl on level ground, to roll out at the end of the fill.

## Hoes

For our purposes here, I'll refer to a backhoe as a hoe on rubber tires, with a digging hoe in the back and a loader bucket in front. And, I'll call a track hoe any hoe on tracks that doesn't have a front loader bucket.

### *Backhoe*

A backhoe is a very versatile piece of equipment, especially on a pipe laying job. You can use it to trench an accurate ditch grade, as well as to lay pipe or supply gravel for grading. If the trench is out of reach of the concrete truck, a backhoe can supply concrete in the bucket for the waterline kickers. You can use the front loader bucket with a fork attachment for unloading pipe and placing it where it's needed. And, if the trench isn't too deep or wide, you can use the hoe to set the manhole rings.

- Travel and work with the front bucket as low as possible, and make sure your travel area is kept as smooth and level as possible. You must always be aware of the terrain you're traveling over. A backhoe whose operator isn't paying attention can become unstable very quickly.

- When using the front bucket for hauling, backfilling or supplying gravel to the trench, you must have the hoe arm in its locked position. Be very careful when hauling gravel to the trench. If the front bucket is eye level or higher, you may want to swing the hoe arm to the uphill side to act as a counterweight.

- When using the hoe end of the backhoe, first center the back of the hoe with the trench you want to dig. Flip the stabilizer pads over to the side you plan to use, and set the outriggers down. Then release the hoe arm. Now check to see if you're centered on the trench line. If not exactly centered, set the hoe bucket on the ground at the center of the trench line. Put the teeth down about 12 feet out and apply down-pressure on the hoe until you feel the outriggers start to rise slightly. Then turn the hoe arm the opposite direction you want the rear end to move. By applying down-pressure and turning the hoe arm, you'll center the hoe exactly where you want it. Level the rear of the hoe by raising or lowering the downriggers. Stabilize the hoe for digging by setting the front loader bucket on the ground, and raising the front wheels slightly off the ground. The hoe is in its most stable position for digging when it's sitting on the front bucket and outriggers, as shown in Figure 10.

- In normal soil conditions, the front bucket should be set on the ground in the level loading position. If the ground is very hard and there will be extreme pull from the digging, curl the front bucket all the way over in the dump position to help keep the backhoe from being pulled backward. To dig, reach back using about three-quarters of the hoe's reach, and pull the bucket forward, with the teeth at about a 45-degree-or-less angle with the surface you're going to dig. Keep this digging pattern until you reach the depth desired. If the bucket loads quickly, don't drag it all the way to the top, but raise it and dump it quickly.


***Figure 10*** *Backhoe stabilized for digging*

Then set the bucket back just short of your beginning point. This will keep a smooth digging slope from the bottom of the trench to the top, and you won't create any ledges to dig through.

- In very hard soil, create a steeper digging angle. The steeper angle keeps the hoe from sliding backwards as you apply maximum hydraulic pressure to dig through the hard soil. Remember to raise the rear and front of the hoe off the ground each time you pull forward for more digging room.

- You can load the bucket quickly by taking a cut just deep enough so the hoe will strain, but not so deep that it'll stop digging. The bucket will slide up the angle you cut. As soon as you see that it's full, simultaneously raise and curl the bucket so you don't drop any loose material. As soon as the bucket clears the trench, swing the digging arm towards the stockpile as you continue raising the arm and bucket to the height you need. Start dumping as soon as the bucket nears the stockpile, and then swing the empty bucket back to the trench while lowering the digging arm. When the bucket reaches the bottom of the trench, you should already have adjusted the bucket to its digging angle, so you can begin the same process again. A good operator is able to complete this pattern without stopping at any point during the digging, swinging or dumping.

- If the soil is muddy and sticks to the bucket, here's how you get it to dump: With the bucket wide open, push-pull, push-pull on the bucket lever. This will shake the bucket and dislodge the mud.

### *Track hoe*

A track hoe, also called an excavator, digs the same way as a backhoe. The main differences are that it operates on tracks, and it's able to swing 360 degrees to dump. A backhoe can only swing 90 degrees in each direction from the trench to dump — for a total of 180 degrees.

- The track hoe has no downriggers, so it must have a level bench to trench on. If the bench isn't level, place fill behind the hoe track and build up the low side to run on. A track hoe can turn its tracks and move forward or backward to get centered with the trench.

- Use a track hoe for very hard or rocky soil, or to dig over 1,000 LF of deep trench. Track hoes have more power and are more stable than backhoes. If you compare a Cat 430 backhoe and a Cat 324 track hoe, the backhoe weighs about 12 tons, and the track hoe is about 25 tons. The backhoe stick dig force is about 10,000 pounds, and the bucket digging force is about 15,000 pounds. The track loader stick dig force is around 30,000 pounds, and bucket digging force is about 35,000 pounds. The track hoe can efficiently trench about 5 to 8 feet deeper than the backhoe. For just trenching, the track hoe has much more power, but isn't as mobile as the backhoe. Either type of hoe can be set up with a laser or GPS system. Caterpillar has a grading system, called Accu Grade, which is a GPS system that works well and is easy to read. The contractor must evaluate his job to determine which type of hoe or hoes match the job requirements. Whichever hoe you use, in order to get vertical trench walls, make sure that it's sitting level before digging begins.

- When operating either type of hoe, you must be sure no one is standing beside or behind the bucket at any time. One touch of the wrong lever can cause the bucket to jump quickly. Also, never let anyone stand next to an excavator that's in operation. The cab and engine compartment will swing out past the tracks when dumping and can knock a person down or trap them between the housing and the tracks. Always make safety your first priority.

## Loaders

- Loaders are a good stable machine when the bucket is close to the ground. The higher the bucket is raised, the greater the risk of tipping due to operator error. When loading trucks, a good level loading area will help minimize your rollover risk and increase your production.

- Most loaders come with a self-leveling bucket. After the material is dumped, pull the bucket lever back to the locking position. Then, when the bucket and cutting edge are parallel (or level) with the ground, the bucket curl will automatically shut off. You can then place the bucket on the ground and it won't dig into the base that the stockpile is resting on. When you drive the bucket into the material to be loaded, as you raise it, curl it back simultaneously so the bucket can fill. The bucket should be full by the time it reaches half way to its maximum height, or eye-level with the operator. You can then back the loader away from the stockpile and turn it toward the truck. As you approach the truck, raise the bucket high enough to dump without hitting the bed of the truck. A good operator will start dumping as the bucket passes over the edge of the truck bed, and continue dumping until the bucket is empty at the center of the truck bed. He'll then pull the bucket lever back all the way to activate the self-leveling bucket mechanism, and begin backing away at the same time — with no motion lost.

- If it takes more than one bucket load to fill a truck bed, dump the first load in the front portion of the bed first, then the second load about center. Always try to load the truck bed heavier in the front than the back, so the truck has a good weight distribution for hauling.

- When laying pipe, to be safe, take the material load or the pipe to the trench with the loader bucket at less than eye-level height. Then, if needed, raise it to dump gravel into the trench. This will keep the load stable as you're moving, reducing the chance of anything falling off onto workers in the trench.

- The self-leveling device works using a magnetic switch on the loader boom that you can see from the cab of the loader. After the bucket self-levels, if you want to dig, you can judge the tilt of the bucket by watching the magnetic switch on the boom as you tilt the edge down. Do the same when placing material. Watch where the magnetic switch is when the bucket is curled back. By remembering the offset distance of the two sides on the switch, you can quickly go back to the same position each time you dig or place material at the same level.

- Never try to dislodge rocks or stumps from a slope if they're above the height of the operator's seat on the loader. When dislodged, they could roll back into the operator's cab and cause you serious injury.

- Some loaders go into neutral when the brake is applied so you can increase the engine rpm and speed hydraulic movement. This feature works well when loading on relatively flat ground. However, when working next to a trench, or dumping material into a trench, it could be dangerous. While the engine is in neutral, you don't have full drive control — and that could cut down on your ability to respond quickly in an emergency. Newer loaders have a switch in the cab that allows the operator to choose whether or not to have the engine automatically shift into neutral. If you've never used a loader with this feature, practice on level ground before you try it on a sloping grade.

## Skip Loaders and Boxes

You can use a skip loader with a drag box for grading subgrade and aggregate, as well as for paving. For small jobs, say 6,000 feet or less, it may be the only piece of grading equipment you need on the job. When working in small spaces, be careful not to damage curbs, forms or buildings. A skip loader is equipped with two types of boxes. The first I call a grading box, and the second one I call a drag box.

### *Grading box*

The grading box has two cutting edges, one on the front that will cut going forward, and one on the rear that will cut in reverse. These cutting

***Figure 11*** *Skip loader with grading box*

edges are only spaced about 6 inches apart. The box also has a ripper-rack bar mounted at the front that can be lowered to rip. You can see the rack above the box in Figure 11.

- Going forward, tilt the front of the box down to cut with the front cutting edge, or tilt the front of the box up to drag the material without cutting. It works the same way in reverse.

- Moving backwards, tilt the box up to cut; and to drag, tilt the front of the box down.

- The tilt lever does not raise the box off the ground. When you need small grade adjustments, use the tilt lever. This will give you more control than raising or lowering the box.

- Don't try to move too much material at one time. This is a common mistake. You'll end up spinning your wheels and leaving humps in the grade.

***Figure 12*** *Skip loader with drag box*

### *Drag box*

A drag box is used for grading (see Figure 12). The drag box is built lower than a grading box because it moves less material. This also makes it easier to see into. The drag box has two drag points: The first works as a strike off, and has a cutting edge; the second, at the rear of the box, is built like a screed. The screed-like end is about 1 foot deep the width of the box, with a flat bottom. At the rear of the flat bottom there's a cutting edge. To cut in reverse, tilt the front of the drag box up, and it will cut. This box is capable of doing an excellent job of paving or trimming aggregate base. Notice, in Figures 11 and 12, that both skip loader operators have their front buckets up so they have better forward vision.

## Compactors and Rollers

A compactor is used to achieve compaction in a fill. The compactor operator will call for water to be added as needed while he's placing and compacting the material.

## *Sheepsfoot compactor*

- The easiest way to keep a smooth fill is to make a clean pass with the compactor's dozer blade. Start by setting the blade on the ground, lift it slightly to take the blade pressure off the ground, and then move forward into the freshly-dumped material. If the blade gets too full, raise it a little to lessen the load. Never let the wheels spin and dig holes in the fill. It's best to carry some material in front of the blade so you can tell where the cutting edge is in relation to the grade. If the material is dry, use the corner of the blade to dig deep under the surface to allow water to penetrate into the fill material. Once the moisture is mixed in, smooth and compact the fill area so scrapers or trucks can easily enter and leave the area to dump.

- When working a compactor in rocky material, you should maintain an 18- to 24-inch drop off at the leading edge of the fill. This will give you an area to place the rock and help you maintain a smooth fill. As you push the dumped material to this leading edge, the rocks and fines come together to fill the voids, minimizing tire exposure to sharp rocks. Pay close attention to the dozer blade when you're working in rock. If it slides over a large rock, don't continue moving forward. You may end up high-centered and possibly do damage to the machine. Back off and assess your best approach, which may be to work around the rock for now and cover it over with the next layer of fill.

- When you're working on a fill next to a steep slope, as the fill is being made, there may be times when the edge needs to be pushed out and firmed up. In this situation, the safest approach may be to work at an angle to the edge. Roll, with one wheel on the soft edge and three wheels on stable ground, until the edge is stabilized. Never work parallel to an edge with two wheels without first ensuring that the edge is stable.

## *Smooth-drum roller*

The fastest and most stable drum roller is the vibratory drum roller, shown in Figure 13. This is by far the best roller to use when trimming subgrade or aggregate base, but it runs much faster than you should roll for good compaction. There should be at least two vibrating speeds for the drum.


***Figure 13*** *Smooth-drum vibratory roller*

- Run the drum on the highest vibrating speed until the grader is on the final trim pass. By this time, the subgrade or aggregate should have been rolled at least six times, so a low vibrating speed on the last pass should firmly set the grade.

- If the subgrade starts sticking to the drum, you must stop and let the subgrade dry out a little before continuing. In some cases, the soil may have too much clay to be rolled with a vibratory roller and you might need a rubber-tired roller, but this is rare.

- Because drum rollers are fast and you run them in reverse so often, be sure the roller has a good backup horn. Never back up without looking first.

- Even though drum rollers are stable, always watch the drum on a slope. If it seems to be getting into a steep area, turn the vibrator off, and back out. Always make your first pass with the drum going forward.

- Be aware of what underground installations you might be rolling over at shallow depths. These compactors are capable of delivering 60,000 pounds of downward force. There have been cases when pipe placed 2 feet below the surface has been damaged during compaction.

### Pneumatic tired rollers

These rollers are used on some asphalt paving jobs. They also work well on lime-treated subgrade and chip seal jobs. Even though they're also good on dirt subgrade, lime grade and aggregate base, they aren't used much for these jobs because vibratory rollers are faster.

- Always watch your speed when using a rubber-tired roller. They can run faster than you *should* run them, if you want to produce a good job.
- For paving, check to be sure the brush pads on each wheel are in good shape and are down on the tires. And, check the water spray to the wheels to be sure it works. Before starting to roll asphalt, have someone spray a light coat of diesel on the tires as you pull ahead slowly. Even though the tires have a working water spray, I find that when the tires are cold, they pick up asphalt if they're not sprayed with diesel. Once the tires get hot, often water is no longer needed because asphalt won't usually stick to hot rubber.
- When rolling asphalt, use a rubber-tired roller between the breakdown roller in front, and the finish steel roller at the rear.
- Be very careful when operating rubber-tired rollers. They're top heavy and will roll over more-easily than most equipment.

### Steel-drum roller

Steel-drum paving rollers, with a smooth-drum front and back, are used primarily for rolling asphalt.

- Always run them with the stationary drum forward and the drum that steers in back, unless you're backing up over a previously-rolled pass.

- Use a 12-ton double-drum vibratory roller as the breakdown roller, the first roller behind the paving machine. Start the first rolling pass at the low side of the asphalt mat and work up. It seems to do a better job if you run the front drum with the vibrator off (static), and the rear drum vibrating at maximum vibes. Reverse the vibrating procedure when going in reverse. If the roller doesn't have an automatic vibratory shut off when stopping, be sure to shut the vibrator off before coming to a stop to reverse directions.

- A 12-ton vibratory roller also works well on aggregate base when the compaction requirement is 100 percent. It should be the last roller, rolling very slowly. When using a paving roller for aggregate, be sure to raise the mats, or remove them.

- Use a double-drum static roller (no vibrator), also called a two-axle tandem roller, as the finish roller for paving. It should weigh no less than 8 tons. This is usually the only type of roller used on open-graded asphalt. However, for open-graded asphalt, you need a 10-ton tandem roller.

- When ending a rolling pass, be sure to turn slightly before stopping. If the roller leaves a ridge, it will be on a slight angle, making it easier to roll out on the next pass.

## Appendix B

# GLOSSARY

***Backhoe:*** Self-powered wheeled excavation equipment that digs by pulling a boom-mounted bucket toward itself. Backhoes also have a front bucket.

***Balancing subgrade:*** Trimming subgrade to the point where there are several areas that are still too high or low, but which, when fine trimmed, will average close to the finished subgrade tolerance required.

***Bank plug:*** A tapered 2 x 4, driven into the ground with the greater portion remaining about 24 inches above the ground level, used to place a string line. Surveyors hammer nails in the bank plugs at a given distance above the road surface so a string line can be stretched between the plugs to measure grade.

***Base:*** A layer of material, of a given type and thickness specified in the plans, placed immediately below the pavement surface.

***Bench mark:*** A point of known elevation from which surveyors establish all their grades.

***Benching:*** Making step-like cuts into a slope. Used for erosion control or to tie a new fill into an existing slope.

***Bitch pot:*** The name used for an emulsion pot containing an asphaltic mix of oil and water used as a tack coat during road surfacing. It's usually trailer-mounted and pulled by a truck. Also called an *oil pot*.

***Blade:*** An earth-moving machine with a central scraper blade used to smooth the ground surface. It has independent hoist control that allows the operator to change the angle of the blade to cast soil in either direction. Also know as a *grader*.

***Blade wing:*** A steel plate attached to the end of a grader blade to keep dirt or aggregate from rolling off the end of the blade.

***Bones:*** Rocks in the aggregate base which have separated from the finer material and come to the surface, giving the surface a "bony" grade.

***Boot:*** A lath set behind the hub by the grade setter when there are obstructions blocking the line of sight to the hub. The grade setter draws a horizontal line on the lath 1 foot or more above the hub and shoots grade from this line.

***Boot truck:*** An oil truck with a spray rack used for spraying various types of asphalt oils.

***Borrow site:*** An area from which earth is taken and hauled to a jobsite that's short of the earth needed to build an embankment.

***Catch basin:*** A drain box, made in various depths and sizes, used for catching water. Water drains into a pit, and from there through a pipe connected to the box. It's generally used as a collection point for a piping system that routes the water to another location.

***Catch point:*** The point where a cut slope or fill slope meets a change in grade.

***Centerline:*** The location given on a stake or drawing that indicates the half-way point between two sides.

***Chip seal:*** A layer of fine crushed rock that's spread over an asphalt oil base and then rolled smooth.

***Choker:*** A road shoulder that's to remain higher than the subgrade level. It also serves to contain base rock to limit waste.

***Clear and grub:*** To remove all vegetation, trees, concrete, or other obstructions inside the limits of the project that will interfere with construction.

***Compactor:*** A machine for compacting soil. It can be pulled or self-powered. The wheels on a self-powered compactor help with compaction. Some compactors are also equipped with a dozer blade.

***Crows foot:*** A lath set by the grade setter with his mark indicating the final grade at any point in the grading operation.

***Crumbing shoe:*** An attachment on a wheel trencher that keeps loose earth at the trench bottom pulled back into the digging bucket.

***Culvert:*** Any structure, other than a bridge, which provides an opening under a roadway for drainage or other purposes.

***Curb shoe:*** A device bolted to the blade of a grader when grading curbs. The bottom of the shoe is designed to match the shape of the curb bottom.

***Detour:*** A temporary route for traffic around a closed section of a road.

***Dike:*** A raised embankment built on the side of a road to control water runoff and erosion.

***Disc:*** One or more rows of plate-shaped steel wheels, about 3/16 inch thick, which can be attached to a dozer to cut into the earth and turn it, mixing the soil.

***Elevation:*** The height above or below sea level.

***Embankment:*** A ridge or mound built up with earth fill.

***Excavator:*** A track-mounted, self-powered digging machine that digs by pulling a boom-mounted bucket toward itself. Also called a *hoe*.

***Feathering:*** Raking new asphalt to create a smooth transition where it joins with the existing asphalt.

***Finished grade:*** A surface that has been cut or built up to the elevation indicated on plans.

***Grade:*** The surface of a road, channel, or natural ground area. In building or construction, it's the surface level required by the plans or specifications at a particular point on the building site.

***Grade break:*** A change in slope from one incline ratio to another.

***Grade lath:*** A lath marked by the surveyor or grade setter that indicates the correct grade for the equipment operators.

***Grade pin:*** Steel rods driven into the ground at each surveyor's hub. A string is stretched between the pins at the grade indicated on the survey stakes, or at a constant distance above the grade.

***Grade rod:*** 1. A measuring rod, marked in feet and decimals of a foot, used by surveyors to determine the vertical change in grade between the transit (through which he views the grade rod) and the point at which the grade rod is located. 2. A measuring rod used in place of a ruler for checking grades.

***Grader:*** An earth-moving machine with a central scraper blade used to smooth the ground surface. It has independent hoist control that allows the operator to change the angle of the blade to cast soil in either direction. Also called a *blade*.

***Guinea:*** A wood survey marker driven to grade. It may be colored with paint or crayon. Used for finishing and fine trimming. Also called a *hub*.

***Guinea hopper:*** A member of the grading crew who works ahead of the grader uncovering hubs and signaling the blade operator to cut or fill as required.

***High centered:*** A condition in which the tracks or wheels of a piece of equipment sink into soft soil, causing its undercarriage to rest on the soil and preventing the equipment from moving.

***Highway:*** A main or direct public road and/or the whole right-of-way or area that's reserved for and secured for use in constructing that roadway and its appurtenances.

***Hinge point:*** The point at which a fill slope stops and the road or shoulder grade begins.

***Hoe:*** A track-mounted, self-powered digging machine that digs by pulling a boom-mounted bucket toward itself. Also called an *excavator*.

***Hub:*** A point-of-origin stake that identifies an elevation on the ground. The top of the hub establishes the point from which all elevations and distances are computed, or the point to which the surface is to be trimmed. Also called a *guinea*.

***Hypochlorite tablet:*** Chlorination and purification tablets placed inside each joint of water pipe to disinfect the water flowing through the system.

***Information stake:*** A wooden marker on which the surveyor indicates in code the grades and distances needed by the excavation crew to complete the excavation of a project.

***Kicker block:*** Cement poured behind each bend or angle of water pipe for support. Also called *thrust blocks*.

***Lane delineator:*** Bright-colored cylinders or cones which are set up in a series on roadways to mark temporary lane changes or indicate traffic detours.

***Lift:*** One layer of material or soil placed upon another.

***Lug down:*** A slowdown in engine speed (RPM) due to an increasing load. Usually occurs when heavy machinery is crossing soft or unstable soil, or is pushing or pulling at the limit of its capability.

***Mat:*** A smooth, flat layer of asphalt as it comes out of a spreader box or paving machine.

***Maximum density and optimum moisture:*** The highest point on the moisture density curve, which is considered ideal for soil compaction.

***Median:*** The center section of a divided highway which separates the lanes for traffic traveling in opposite directions.

***MEE pipe:*** Pipe that has been *milled on each end* and left rough in the center.

***MOA pipe:*** Pipe that has been *milled over all*, from one end to the other. MOA pipe is easier to join if the lengths must be cut to fit.

***Moisture density curve:*** A graph, plotted from tests, used to determine the optimum moisture content needed to achieve the greatest soil compaction for a particular type of soil.

***Natural ground:*** The original ground elevation before any excavation has been done.

***Nuclear test:*** A test that uses gamma radiation and a nuclear density meter to determine soil compaction. A controlled amount of gamma radiation is directed into the compacted soil. The radiation reflected back from the soil particles is measured to indicate the soil density.

***Oil pot:*** A small wheeled tank with a compressor from which road oil can be sprayed using a hose and spray nozzle. The tank is pulled behind a truck. Also called a *bitch pot*.

***Paddle-wheel scraper:*** An excavating machine that uses chain-driven steel paddles to paddle loose dirt from the cutting edge of the scraper bowl into the bowl, until the bowl is full. The floor of the scraper slides back, and the rear of the bowl slides forward, to dump.

***Pavement:*** Usually the uppermost layer of material placed on the traveled roadway or shoulders. This term is used interchangeably with *finished surface*.

***Pneumatic tired roller:*** A roller with several rubber tires, commonly used for compacting trimmed subgrade asphalt or aggregate base.

***Popcorn:*** A name given to open-graded asphaltic concrete, which is aggregate with no fine material. The most common sizes are $^3/_8$ and $^3/_4$ inch. It's used to keep water from sheeting on a surface and to improve traction.

***Processing:*** Any operation or operations, of any nature and extent, required to produce a specified material. Mixing water into soil to achieve a given density is an example of a processing operation.

***Pug mill:*** A rectangular box on wheels with rows of power-driven steel arms that churn a mixture (usually lime) into the dirt as it is pulled along the ground.

***Pumping:*** A rolling motion exhibited by unstable ground when heavy equipment passes over it.

***Quarter crown:*** The area between the centerline and the curb or shoulder running parallel to it.

***Raveling:*** A cumulative process in which the rock separates from the finer material on the road surface because of excess blading, lack of water, or car and truck traffic.

***Reference stake:*** A stake that establishes the point from which measurements and grades are taken.

***Right-of-way line:*** A line staked on each side of the road marking the limit of the construction area and, usually, the beginning of private property.

***Ripper:*** A tooth-shaped attachment added to equipment to aid in digging through hardpan or rocky soil.

***Roadway:*** Any portion of a road designed to carry vehicular traffic, which must be cleared, excavated, filled, based or paved, including all appurtenant structures and other features necessary to the proper drainage and protection of the highway.

***Sand cone test:*** A test for determining the compaction level of soil. The test is performed by digging a round hole with a volume of $^1/_{10}$ of a cubic foot. The dirt extracted from the hole is weighed. Sand from a cylinder of sand with a known weight is poured into the hole until the hole is full. The sand remaining in the cylinder is weighed to determine the amount of sand removed to fill the hole. The volume of the hole is now known. The soil from the hole will then be dried and weighed again to determine how much of its weight is made up by water. Using a second soil sample from the same location, the lab can then plot a moisture density curve to determine the ideal moisture content to attain the desired compaction for that particular type of soil.

***Scraper:*** A digging, hauling, and grading machine having a cutting edge, a carrying bowl, and a movable front and rear wall that operates as a dumping mechanism.

***Sheepsfoot roller:*** A compacting roller, with feet expanded at their outer tips, used for compacting soil.

***Shoulder:*** That portion of the roadway, adjacent to the traveled way, which provides lateral support for the base and surface courses of the roadway and is also able to accommodate stopped vehicles for emergency use. It may be dirt, aggregate or pavement.

***Spoil site:*** An area used to dispose of unsuitable or excess excavation material.

***String line:*** A nylon line, strung tightly between supports, used to indicate both direction and elevation for checking grades or deviations in slopes or rises.

***Structure section:*** Includes all the road material placed from the subgrade level to the finished road surface.

***Subbase:*** A layer of material, of a specified type and thickness, between the subgrade and the base. It's usually a larger aggregate than that used for the base.

***Subgrade:*** That portion of the dirt roadbed on which subbase, base, pavement or a layer of any other material is placed. The uppermost level of material placed in an embankment or left at cuts in the normal grading of a roadbed and which becomes the foundation for aggregate and asphalt pavement.

***Summit:*** The highest point of any area or grade.

***Super:*** A continuous slope in one direction on a road with no crown.

***Surface:*** The uppermost layer of material placed on the traveled way or shoulder of a road. The term is used interchangeably with *pavement*.

***Swale:*** A shallow dip in a surface, such as a parking lot, made to allow for the passage of water.

***Swedes:*** A method of setting grades at a center point by sighting across the tops of three lath. Two lath are placed at a known correct elevation and the third is adjusted until it is at the correct elevation.

***Tangent:*** A straight line that touches a curve at a single point.

***T-bars:*** T-shaped wood frames used in place of steel pins to support a string line over trenches.

***Thrust block:*** Cement poured behind each bend or angle of water pipe for support. Also called *kicker blocks*.

***Tie out:*** The process of determining the location of existing objects (manholes, meter boxes, etc.) during the excavation of a street by identifying or tying their location to fixed objects that will not be affected by the construction, such as existing curbs, power poles, fences, trees or structures. The objects are measured from these fixed points, or their position fixed by GPS, so that they may be uncovered and raised after the paving is completed.

***Toe-of-slope:*** The bottom or base of an incline.

***Track loader:*** A type of earthmoving equipment, with tracks instead of wheels, used to dig undisturbed soil or pick up and move excavated spoil. It has a front bucket with moveable arms.

***Traffic lane:*** A section of road designated for the movement of a single line of vehicles in one direction.

***Traveled way:*** That portion of the roadway designed for the movement of vehicles, exclusive of shoulders.

***Typical drawing:*** A cross section view of a street or highway, often showing only half of the road if both sides are the same. It includes station numbers to indicate the length of the road section shown on the drawing.

***Vertical curve:*** Indicates a curvature in a horizontal line to a higher or lower elevation.

***Vibratory roller:*** Self-powered compacting equipment that mechanically vibrates as it rolls. It may have a smooth or a padded drum.

***Windrow:*** The spill-off from the ends of a dozer or grader blade which forms a ridge of loose material. A windrow may be deliberately placed by bottom dump trucks for spreading by another machine.

***Wing:*** A steel plate attached to the end of a grader blade to keep material from rolling off the end of the blade.

# Appendix C

# ABBREVIATIONS

| | |
|---|---|
| @ | At |
| ***AB*** | Aggregate base |
| ***AC*** | Asphalt concrete |
| ***ACP*** | Asbestos cement pipe |
| ***ARV*** | Air relief valve |
| ***ASB*** | Aggregate subbase |
| ***BC*** | Back-of-curb or begin curve |
| ***BM*** | Bench mark |
| ***BSP*** | Black steel pipe |
| ***BV*** | Butterfly valve |
| ***CB*** | Catch basin |
| ***CF*** | Cubic feet |
| ***C&G*** | Curb and gutter |
| ***CIP*** | Cast iron pipe |
| ***CISP*** | Cast iron soil pipe |
| ℄ | Centerline |
| ***CL*** | Class |
| ***CMP*** | Corrugated metal pipe |
| ***CO*** | Clean out |
| ***CP*** | Concrete pipe |
| ***CTB*** | Cement-treated base |
| ***CU*** | Conduit |
| ***CV*** | Check valve |
| ***CY*** | Cubic yard |
| ***DBL*** | Double |
| ***DI*** | Drop inlet |
| ***DIA*** | Diameter |
| ***DIP*** | Ductile iron pipe |
| ***DR*** | Driveway |
| ***DWG*** | Drawing |
| ***EA*** | Each |
| ***EC*** | End-of-curve |
| ***EG*** | Existing grade |
| ***EL*** | Elevation |
| ***EMB*** | Embankment |
| ***EP*** | Edge-of-pavement |
| ***EXC*** | Excavation |
| ***FC*** | Face-of-curb |
| ***FD*** | Floor drain |
| ***FG*** | Finished grade |
| ***FH*** | Fire hydrant |
| ***FL*** | Flow line |

| | |
|---|---|
| ***FS*** | Finished surface |
| ***GAL*** | Gallon |
| ***GB*** | Grade break |
| ***GD*** | Gutter drain |
| ***GP*** | Grade plain |
| ***GPS*** | Global positioning system |
| ***GSP*** | Galvanized steel pipe |
| ***GV*** | Gate valve |
| ***HP*** | Hinge point |
| ***IC*** | Interconnect |
| ***ID*** | Inside diameter |
| ***INV*** | Invert |
| ***LBS*** | Pounds |
| ***LF*** | Linear or lineal foot |
| ***LP*** | Lip-of-curb |
| ***LS*** | Lump sum |
| ***LT*** | Left |
| ***LTB*** | Lime-treated base |
| ***Max***. | Maximum |
| ***MH*** | Manhole |
| ***Min.*** | Minimum |
| ***OC*** | On center |
| ***OD*** | Outside diameter |
| ***PB*** | Pull box |
| ***PCC*** | Portland cement concrete |
| ***PG*** | Projected grade |
| ***PI*** | Point indicated |
| ***PL*** | Property line |
| ***PMP*** | Perforated metal pipe |
| ***PSI*** | Pounds per square inch |
| ***PVC*** | Polyvinyl chloride plastic pipe |
| ***R=*** | Radius |
| ***RCB*** | Reinforced concrete box |
| ***RCP*** | Reinforced concrete pipe |
| ***RP*** | Reference point |
| ***RS*** | Reference stake |
| ***RT*** | Right |
| ***R/W*** | Right-of-way line |
| ***S=*** | Slope |
| ***SCH*** | Schedule |
| ***SD*** | Storm drain |
| ***SE*** | Slope estimated |
| ***SF*** | Square foot |
| ***SG*** | Subgrade |
| ***SS*** | Slope stake or sewer service |
| ***ST*** | Station |
| ***STD*** | Standard |
| ***SY*** | Square yards |
| ***TB*** | Thrust block |
| ***TBC*** | Top-back-of-curb |
| ***TC*** | Top-of-curb |
| ***TW*** | Tracer wire |
| ***VAR*** | Varies |
| ***VB*** | Valve box |
| ***VC*** | Vertical curve |
| ***VCP*** | Vitrified clay pipe |
| ***WM*** | Wire mesh |
| ***WSP*** | Welded steel pipe |

# Answers to Chapter Questions

Following each answer is the page in the book where the subject of that question is discussed, or where the topic begins. It's sometimes necessary to read through more than one page when the question asks for a *concept*, rather than a specific point.

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## F



## G



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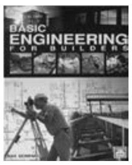
# Practical References for Builders

### National Estimator Cloud

Generate professional construction estimates for all residential and commercial construction from your internet browser. Includes 10 Craftsman construction cost databases, over 40,000 labor and material costs for construction, in an easy-to-use format. Cost estimates are well-organized and thoroughly indexed to speed and simplify writing estimates for nearly any residential or light commercial construction project – new construction, improvement or repair. Convert the bid to an invoice – in either QuickBooks Desktop or QuickBooks Online. Access your estimates from anywhere and on any device with a Web browser. Monthly and one-time billing options available. Visit https://craftsman-book.com/national-estimator-cloud for more details.

### Basic Engineering for Builders




This book is for you if you've ever been stumped by an engineering problem on the job, yet wanted to avoid the expense of hiring a qualified engineer. Here you'll find engineering principles explained in non-technical language and practical methods for applying them on the job. With the help of this book you'll be able to understand engineering functions in the plans and how to meet the requirements, how to get permits issued without the help of an engineer, and anticipate requirements for concrete, steel, wood and masonry. See why you sometimes have to hire an engineer and what you can undertake yourself: surveying, concrete, lumber loads and stresses, steel, masonry, plumbing, and HVAC systems. This book is designed to help you, the builder, save money by understanding engineering principles that you can incorporate into the jobs you bid.
**400 pages, 8½ x 11, $39.50**
***eBook (PDF) also available;* $19.75 at** www.craftsman-book.com

### Concrete Construction


Just when you think you know all there is about concrete, many new innovations create faster, more efficient ways to do the work. This comprehensive concrete manual has both the tried-and-tested methods and materials, and more recent innovations. It covers everything you need to know about concrete, along with Styrofoam forming systems, fiber reinforcing adjuncts, and some architectural innovations, like architectural foam elements, that can help you offer more in the jobs you bid on. Every chapter provides detailed, step-by-step instructions for each task, with hundreds of photographs and drawings that show exactly how the work is done. To keep your jobs organized, there are checklists for each stage of the concrete work, from planning, to finishing and protecting your pours. Whether you're doing residential or commercial work, this manual has the instructions, illustrations, charts, estimating data, rules of thumb and examples every contractor can apply on their concrete jobs.
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An Online Appraisal Estimating Service. Produce credible single-family residence appraisals – in as little as five minutes. A smart resource for appraisers using the cost approach. Reports consider all significant cost variables and both physical and functional depreciation.

Visit www.craftsman-book.com/national-appraisal-estimator-online-software for more information.

### Planning Drain, Waste & Vent Systems

How to design plumbing systems in residential, commercial, and industrial buildings. Covers designing systems that meet code requirements for homes, commercial buildings, private sewage disposal systems, and even mobile home parks. Includes relevant code sections and many illustrations to guide you though what the code requires in designing drainage, waste, and vent systems. **192 pages, 8½ x 11, $39.95**

### BNI Public Works 2024 Costbook

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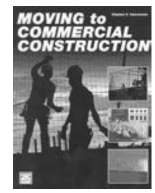
### Moving to Commercial Construction




In commercial work, a single job can keep you and your crews busy for a year or more. The profit percentages are higher, but so is the risk involved. This book takes you step-by-step through the process of setting up a successful commercial business: finding work, estimating and bidding, value engineering, getting through the submittal and shop drawing process, keeping a stable work force, controlling costs, and promoting your business. Explains the design/build and partnering business concepts and their advantage over the competitive bid process. Includes sample letters, contracts, check-lists and forms that you can use in your business, plus a CD-ROM with blank copies in several word-processing formats for both MacTM and PC computers. **256 pages, 8½ x 11, $42.00**
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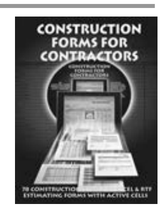


This practical guide contains 78 practical forms, letters and checklists, guaranteed to help you streamline your office, organize your jobsites, gather and organize records and documents, keep a handle on your subs, reduce estimating errors, administer change orders and lien issues, monitor crew productivity, track your equipment use, and more. Includes accounting forms, change order forms, forms for customers, estimating forms, field work forms, HR forms, lien forms, office forms, bids and proposals, subcontracts, and more. All are also on the CD-ROM included, in Excel spreadsheets, as formatted Rich Text that you can fill out on your computer, and as PDFs. **360 pages, 8½ x 11, $48.50**
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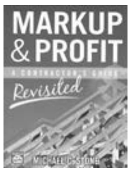


In order to succeed in a construction business, you have to be able to price your jobs to cover all labor, material and overhead expenses, *and* make a decent profit. The problem is knowing what markup to use. You don't want to lose jobs because you charged too much, and you don't want to work for free because you charged too little. If you know how to calculate markup, you can apply it to your job costs to find the right sales price for your work. This book gives you tried and tested formulas, with step-by-step instructions and easy-to-follow examples, so you can easily figure the markup that's right for *your* business. Includes a CD-ROM with forms and checklists for *your* use. **336 pages, 8½ x 11, $59.50**
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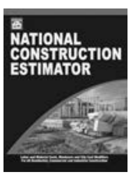


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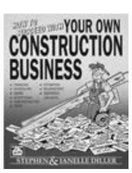


Everything you need to start your own construction business: setting up the paperwork, finding the jobs, advertising, using contracts, dealing with lenders, estimating, scheduling, finding and keeping good employees, keeping the books, and coping with success. If you're considering starting your own construction business, all the knowledge, tips, and blank forms you need are here.
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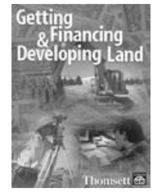


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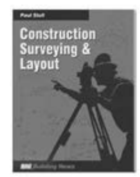


A practical guide to simplified construction surveying. How to divide land, use a transit and tape to find a known point, draw an accurate survey map from your field notes, use topographic surveys, and the right way to level and set grade. You'll learn how to make a survey for any residential or commercial lot, driveway, road, or bridge — including how to figure cuts and fills and calculate excavation quantities. Use this guide to make your own surveys, or just read and verify the accuracy of surveys made by others.
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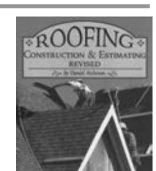


Detailed, step-by-step instructions, with photographs and diagrams, for installing, repairing and estimating nearly every type of roof covering available today for residential and commercial structures: asphalt shingles, roll roofing, wood shingles and shakes, clay tile, slate, metal, built-up, elastomeric, TPO and more. Provides guidance on sheathing, synthetic and felt underlayment, as well as tips and tricks from an experienced pro for dealing with those difficult points on a roof that are prone to leaks, such as valleys and roof penetrations. For each roofing type, instructions are provided for estimating material quantities and labor costs, with formulas, easy-to-follow examples and sample estimates for you to test your skill. Use these methods to create reliable estimates that will help insure a profit on every job you take. **448 pages, 8½ x 11, $62.50**
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