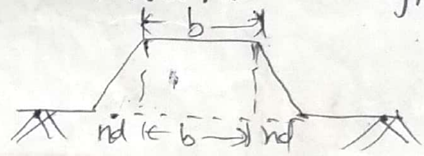
EARTH WORK

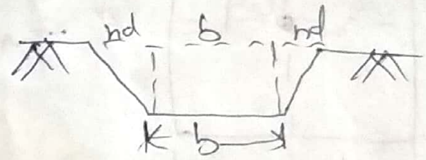
Introduction

All most all the civil engg. projects involves the earth work mostly in construction of roads, railways, tracks, earthen dams, canal bands and will be done by the earth work excavation either in cutting (or) in filling (or) sometimes in both as per existing level of ground to get the desired shape and level.

Embankment :- The quantity of earthwork in filling is known as embankment.



Cutting :- The quantity of earthwork in excavation is known as cutting.



Volume of earthwork :- The volume of earthwork is calculated by multiplying the cross-sectional area and depth is called volume of earthwork. It is denoted by the letter V and its units are in m^3.

Definition of the term 'Lead :-

Lead is the horizontal distance over which the earth is conveyed. It is measured from the centre of the area of excavation / barrow pit to the centre of the spoil bank / bund / heap.

Definition of Lift :-

Lift is the vertical distance over which the earth is conveyed. It is measured from centre of excavation to the centre of spoil bank (or) heap.

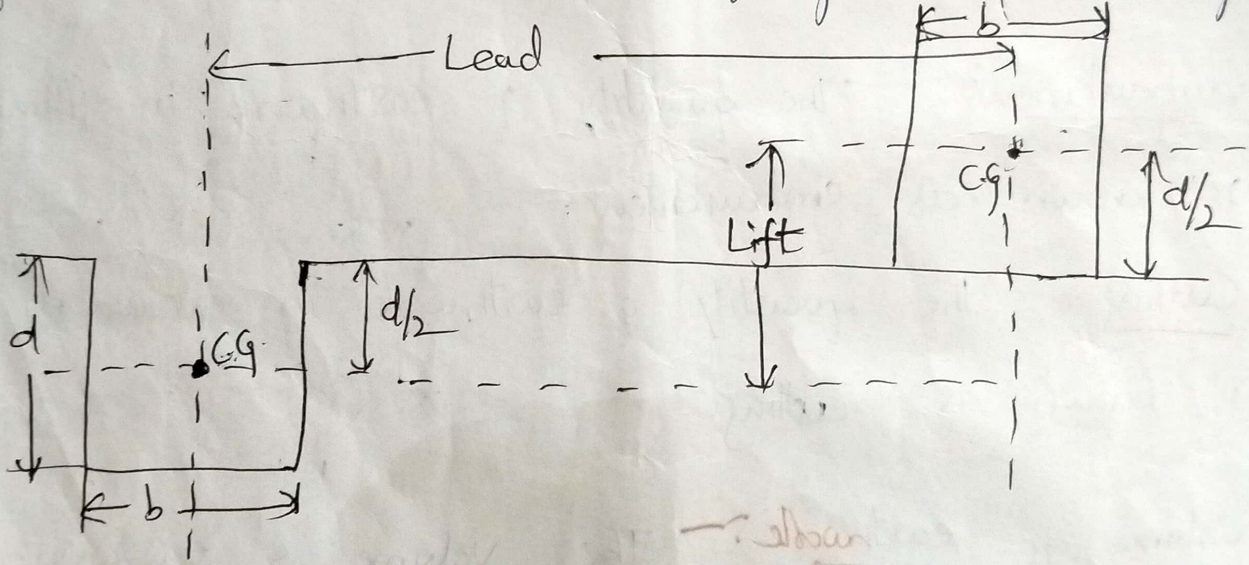


Figure of Lead and Lift.

Standard Values of Lead :-

Initial lead is 10m and for every additional 10m (or) part there of one extra lead is to be paid.

Schedule of rates provides rates for different leads.

Ex:- If the earthwork carried over a distance of 250m three leads are to be given (one initial lead and two additional leads).

Standard values of Lift :-

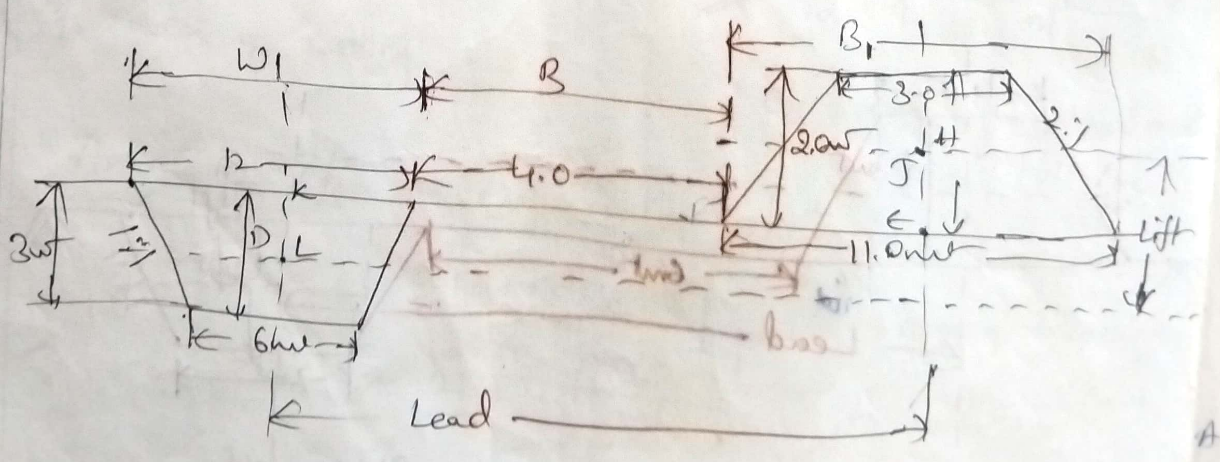
Initial lift is 2m and for additional 1m or part there of one extra lift is to be paid. Schedule of rates provides rates for different lifts.

Ex:- If the earthwork carried to a height of 3.8 m three lifts are to given (one initial lift of 2m and ~~two~~ one additional lifts).

3.8 → 2+1.8

Problems on Lead & lift :-

1) A canal is excavated as shown in fig. Calculate the leads and lifts to be allowed for earthwork excavation.



Sol:- Let 'L' be the centre of the left half of the canal.

Lead = centre excavation to centre deposition

$= LJ.$

$= KF + FG + GL$

$= \frac{W}{2} + B + \frac{B_1}{2}$

$= \frac{12}{2} + 4 + \frac{11}{2}$

$= 6 + 4 + 5.5$

Lead $= 15.5$ mtr

Extra lead $= 15.5 - 10 = 5.50$ (1 extra lead)

Lift $= \frac{D}{2} + \frac{H}{2}$

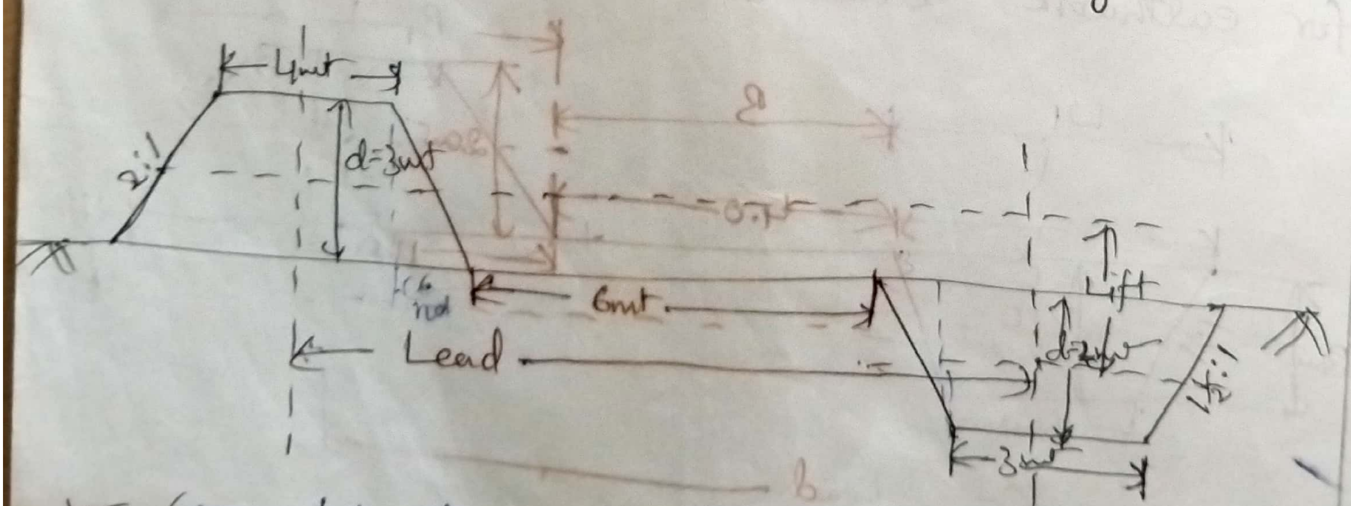
$= \frac{3}{2} + \frac{2}{2}$

$= 1.5 + 1$

$= 2.5$ mtr

Extra lift $= 2.5 - 2 = 0.5$ (1 Extra lift).

2) Find the lead ~~the~~ & lift of the following.



Sol:- Given left side of filling
side slope nd = 2:1
V = depth = 3mtr

Right side
side slopes
nd = 1½:1

$H:V = 2:1$ Depth = 3m

$H:V = 6:3$

V = Depth = 2m

$H:V = 1.5:1$

$H:V = 3:2$

③

$$\text{Lead} = \frac{4}{2} + 6 + 6 + 3 + \frac{3}{2} \quad \text{(or)} \quad \frac{16}{2} + 6 + \frac{9}{2}$$

$$= 2 + 6 + 6 + 3 + 1.5 \qquad 8 + 6 + 4.5$$

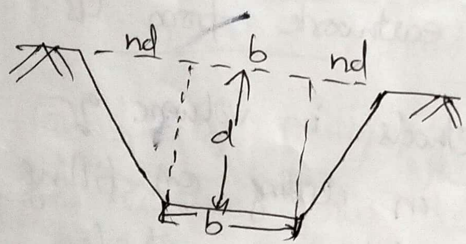
$$= 18.5\,m \qquad 18.5\,m$$

$$\text{Lift} = \frac{3}{2} + \frac{2}{2}$$

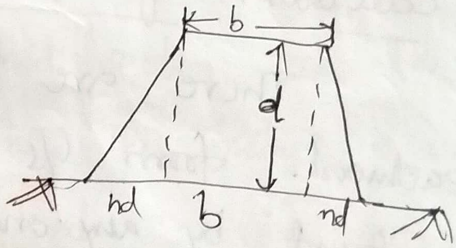
$$= 1.5 + 1$$

$$= 2.5\,m$$

Calculation of areas of earthwork :-



C/s area of cutting



C/s area of embankment (filling)

Area of C/s = Avg width × depth.

$$A = \frac{b + b + nd + nd}{2} \times d$$

Area of trapezium

$$= \frac{1}{2} h(a+b)$$

$$= \frac{2b + 2nd}{2} \times d$$

$$= \frac{\cancel{2}(b+nd)}{\cancel{2}} \times d$$

$$\boxed{A = (b+nd)d}$$

Normally trapezoidal shape is used for calculating earthwork.

Calculation of volumes :- The volume can be calculated by any one of the methods given below :

1. From cross-sections
2. From spot levels.
3. From contours.

Out of three methods, the first two methods are used for calculating the volume of earthwork and third method is used for calculating the capacity of reservoirs.

1) Calculation of volume of earthwork from c/s :-

There are four methods in volume of earthwork from c/s required in cutting or filling is found by any one of the following methods.

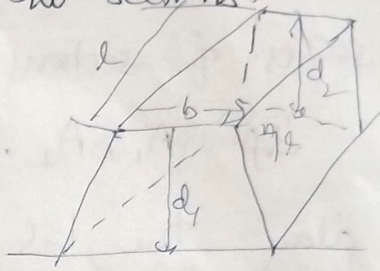
1. Mean sectional area method
2. Mid sectional area "
3. Trapezoidal rule
4. Prismoidal rule.

1. Mean sectional area method :-

In this method average area of the two end sections are considered. This method is most commonly used by the departments calculating the volume of the earthwork. (4)

Volume of earthwork

V = Mean sectional area x distance b/w sections.



$A_1 = (b+nd_1)d_1$

$A_2 = (b+nd_2)d_2$.

Mean sectional area = $\frac{A_1+A_2}{2}$.

Distance b/w two sections = l.

Volume of earthwork V = Mean sectional area x L

$$\boxed{V = A \times L}$$

(2) Mid sectional Area method :-

In this method volume of the earthwork is found by multiplying the mid section area with the distance b/w two sections. This method is used when the ground is fairly level and the sections are taken at closed intervals.

Volume of earthwork = Area at mid section x distance b/w sections.

Area of mid section = $(b+nd_m)d_m$

where depth at mid section $d_m = \frac{d_1+d_2}{2}$

Distance b/w sections = L

Volume = Area of mid section x L

③ **Trapezoidal Rule :-**

This method is the extension of mean sectional area method and is applicable to a series of sections taken at equal intervals.

If $A_1, A_2, A_3 \ldots\ldots A_n$ are the C/s areas along the L.S and L is the equal interval b/w the sections.

Total volume $V = \frac{L}{2}\left[(A_1+A_n) + 2(A_2+A_3+\ldots\ldots A_{n-1})\right]$

(or)

$$V = L\left[\left(\frac{A_1+A_n}{2}\right) + A_2+A_3+\ldots\ldots A_{n-1}\right]$$

4) **Prismoidal rule :-**

It is also known as simpson's rule. This method is used when the shape of the solid b/w two parallel c/s is in the shape of a prismoidal. Volume enclosed b/w the two sections by prismoidal rule is given by

$$V = \frac{L}{6}\left(A_1 + 4A_m + A_n\right)$$

where A_1 = Area of c/s at one end

A_n = Area of c/s at other end

when we are avg depths not avg areas ← A_m = Area of c/s at middle

L = Length b/w the sections.

∴ A_m is the area of c/s at the middle and not the average area.

In case series of section are given. This formula can be extended only when there are odd no. of c/s and the intervals of b/w them are equal.

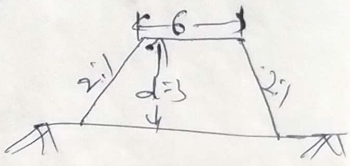
$$V = \frac{L}{3}\left[(\text{First Area} + \text{Last Area}) + 4(\text{sum of even areas}) + 2(\text{sum of odd areas})\right].$$

$$V = \frac{L}{3}\left[(A_1 + A_n) + 4(A_2 + A_4 + \cdots + A_{n-1}) + 2(A_3 + A_5 + \cdots + A_{n-2})\right]$$

Problems on Areas

① Find the area of embankment, if the top width of the road is 6m and the depth is 3m. The side slopes are 2:1

Sol: Given top width of the road



$b = 6m$

Depth $d = 3m$

$n:1 = 2:1$

Area of embankment $= (b+nd)d$, Bottom width of road $= (b+2nd)$

$A = (6+2\times3)3$ $\quad = (6+2\times2\times3)$

$= (6+6)\,3$ $\quad = 18mt$

$= 12\times3$

$A = 36\,m^2$

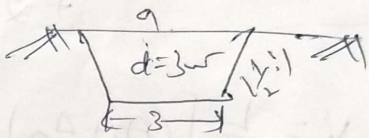
Check:- Area of embankment $= \frac{1}{2}(a+b)$

$= \frac{1}{2}(6+18)3$

$= \frac{1}{2} \times 24 \times 3$

$A = 36\ m^2.$

2) Find the area of cutting if the bottom width of canal is 3m and depth is 3m, side slopes are $1\frac{1}{2}:1$.



Sol:- Given $b = 3m$

depth $d = 3m$

$n:1 = 1\frac{1}{2}:1$

Area of cutting $= (b+nd)d$

$= (3+1.5\times3)3$

$= 7.5 \times 3$

$= 22.5\ m^2$

Top width of cutting $= b+2nd$

$= 3+2\times1.5\times3$

$a = 12m$

Check

Area of cutting $= \frac{1}{2}(a+b)h$

$= \frac{1}{2}(3+12)3$

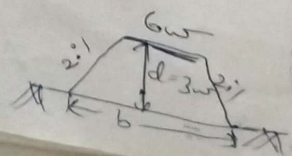
$= \frac{1}{2} \times 15 \times 3$

$A = 22.5\ m^2$

Problems on volume calculations:-

4) Find the volume of earthwork in an embankment of length 1km; top width of a road is 6m and depth is 3m. The side slopes are 2:1

Sol:- Given. Length of embankment = 1km



$d = 3m$

Top width of road $b = 6m$ (6)

$n:1 = 2:1$

Area of embankment

$A = (b+nd)d$

$= (6+2\times3)3$

$= 12\times3$

$A = 36m^2$

volume $V = A\times L$

$= 36\times1000$

$V = 36000 m^3$

*) A canal is proposed to be excavated b/w two points A & B which are 500mt apart. If the bed width is 8mt, side slopes are 2:1 and the depth of cutting is 1.2mt at A and 2mt at B. Calculate the quantity of earthwork by mid sectional area method.

Sol:- Given Length b/w A & B = 500m

Bed width = 8m

Side slopes $n:1 = 2:1$

Depth at A = 1.2m, B = 2m

Mid-sectional Area :-

V = Mid sectional area x Length

$d_m = \frac{d_1+d_2}{2} = \frac{1.2+2}{2} = \frac{3.2}{2} = 1.6mt$

Mid sectional area $A = (b+nd_m)d_m$

$= (8+2\times1.6)1.6$

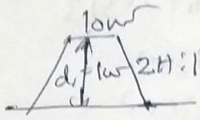
$= 1.2\times1.6$

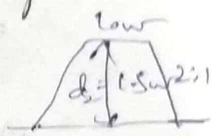
$A = 17.92m^2$

$V = A\times L = 17.92\times500 = 8960\ m^3$

=) 4847.43/-

Calculate the quantity of earthwork for 1 km for a portion of a road in an uniform ground, heights of banks at the two ends being 1 mt & 1.5 mt. The formation width is 10 mt and side slope 2H : 1V. Assume there is no transverse slope:—





Sol: Given length of earthwork

$L = 1\text{km}$

$d_1 = 1\text{m}, d_2 = 1.5\text{m}$

width of road $b = 10\text{m}$

$n:1 = 2:1$

① <u>Mid-sectional Area method</u>:—

$b = 10\text{m}$

Avg. depth $d_m = \frac{1+1.5}{2} = \frac{2.5}{2} = 1.25\text{m}$

Mid-sectional Area $A = (b + nd_m)\, d_m$

$= (10 + 2\times1.25)\,1.25$

$= 12.5 \times 1.25$

$A = 15.625\,\text{m}^2$

$V = A \times L = 15.625 \times 1000 = 15625\,\text{m}^3$

② <u>Mean-sectional Area method</u>:—

A_1 = Area of c/s at one end

$= (b + nd_1)\, d_1$

$= (10 + 2\times1)\,1$

$A_1 = 12\,\text{m}^2$

(7)

A_2 = Area of another end

$= (b + nd_2)d_2$

$= (10 + 2 \times 1.5)1.5$

$A_2 = 19.5 m^2$

Mean Sectional Area

$$A = \frac{A_1 + A_2}{2} = \frac{12 + 19.5}{2} = \frac{31.5}{2} = 15.75 m^2$$

Quantity of earthwork $V = A \times L$

$= 15.75 \times 1000$

$V = 15750 m^3$

(8) Prismoidal Rule :-

$$V = \frac{L}{6}(A_1 + A_2 + 4A_m)$$

$A_1 = 12 m^2$, $A_2 = 19.5 m^2$, $A_m = 15.625 m^2$

$$V = \frac{1000}{6}(12 + 19.5 + 4 \times 15.625)$$

$$= \frac{1000}{6} \times 94$$

$V = 15666.67 m^3$

* Calculate the quantity of earthwork required according to standard prismoidal formula in a road embankment having 10.5m formation width, 2:1 side slopes in a length of 8 chains (30mt). The level difference b/w formation and ground is 0.9m, 0.70m, 1.20m, 3.4m, 2.90, 3.10, 3.40m, 2.6 & 2.4 respectively.

Assume ground is level in transverse direction the centre line.

Soln:- Given $b = 10.5m$

$n:1 = 2:1$

$L = 30m$, $d_1 = 0.9m$, $d_2 = 0.7m$, $d_3 = 1.2$, $d_4 = 3.4$, $d_5 = 2.9$, $d_6 = 3.1$, $d_7 = 3.4$, $d_8 = 2.6$, $d_9 = 2.4m$

$A_1 = (b+nd_1)d_1 = (10.5+2\times0.9)0.9 = 11.07 m^2$

$A_2 = (b+nd_2)d_2 = (10.5+2\times0.7)0.7 = 8.33 m^2$

$A_3 = (b+nd_3)d_3 = (10.5+2\times1.2)1.2 = 15.48 m^2$

$A_4 = (b+nd_4)d_4 = (10.5+2\times3.4)3.4 = 58.82 m^2$

$A_5 = (b+nd_5)d_5 = (10.5+2\times2.9)2.9 = 47.27 m^2$

$A_6 = (b+nd_6)d_6 = (10.5+2\times3.1)3.1 = 51.77 m^2$

$A_7 = (b+nd_7)d_7 = (10.5+2\times3.4)3.4 = 58.82 m^2$

$A_8 = (b+nd_8)d_8 = (10.5+2\times2.6)2.6 = 40.82 m^2$

$A_9 = (b+nd_9)d_9 = (10.5+2\times2.4)2.4 = 36.72 m^2$.

Volume of earthwork by prismoidal rule

$V = \frac{L}{3}\left((A_1+A_9) + 4(A_2+A_4+A_6+A_8) + 2(A_3+A_5+A_7)\right)$

$= \frac{30}{3}\left[(11.07+36.72) + 4(8.33+58.82+51.77+40.82) + 2(15.48+47.27+58.82)\right]$

$= 10\left[(47.79) + 4(159.74) + 2(121.57)\right]$

$V = 9298.9 m^3$

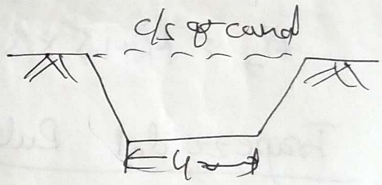
⑧

ground levels along the ridge of proposed canal area as shown in fig. The bed of the canal is 4m wide and sloped at 1 in 100 downwards in Longitudinal direction. The side slopes are $1\frac{1}{2}:1$. R.L of formation level at 0m chainage is 250m.

A	B	C	D	E	F	G
252	252.15	251.7	251.75	251.95	251.85	252
0m	30m	60m	90m	120m	150m	180m

Determine volume of earthwork is cutting by ① Trapezoidal rule ② Prismoidal rule.

Sol: Given $b = 4m$, $n:1 = 1\frac{1}{2}:1$



Formation levels

At 0m chainage $= 250.0m$

30m " $= 250 - \frac{30}{100} \times 1 = 249.70$

60m " $= 250 - \frac{30}{100} \times 2 = 249.40$

90m " $= 250 - \frac{30}{100} \times 3 = 249.10$

120m " $= 250 - \frac{30}{100} \times 4 = 248.80$

150m " $= 250 - \frac{30}{100} \times 5 = 248.50$

180m " $= 250 - \frac{30}{100} \times 6 = 248.20$

Chainage in m	0	30m	60m	90m	120m	150m	180m
RL of GL	252	252.15	251.7	251.75	251.95	251.85	252
RL of Canal bed level	250	249.7	249.4	249.10	249.8	248.5	248.2
Depth of cutting	2.0	2.45	2.3	2.65	3.15	3.35	3.8

$A_1 = (b+nd_0)\,d_0 = (4+1.5\times 2)2 = 14\,m^2$

$A_2 = (4+1.5\times 2.45)2.45 = 18.80\,m^2$

$A_3 = (4+1.5\times 2.3)2.3 = 17.135\,m^2$

$A_4 = (4+1.5\times 2.65)2.65 = 21.13\,m^2$

$A_5 = (4+1.5\times 3.15)3.15 = 27.48\,m^2$

$A_6 = (4+1.5\times 3.35)3.35 = 30.23\,m^2$

$A_7 = (4+1.5\times 3.8)3.8 = 36.86\,m^2$

Trapezoidal Rule :-

$$V = \frac{L}{2}\left[(A_1+A_7)+2(A_2+A_3+A_4+A_5+A_6)\right]$$

$$V = \frac{30}{2}\left[(14+36.86)+2(18.80+17.135+21.13+27.48+30.23)\right]$$

$V = 4206.15\,m^3$

Prismoidal rule :-

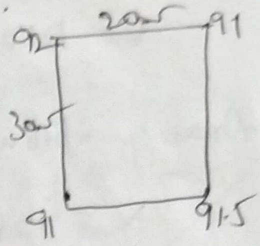
$$V = \frac{L}{3}\left[(A_1+A_7)+4(A_2+A_4+A_6)+2(A_3+A_5)\right]$$

$$= \frac{30}{3}\left[(14+36.86)+4(18.8+21.13+30.23)+2(17.135+27.48)\right]$$

$V = 4207.3\,m^3$

Problems on spot levels

* A plot of 20m × 30m, calculate the quantity of earthwork by using spot levels of as shown in fig. for general levelling of 90m RL.

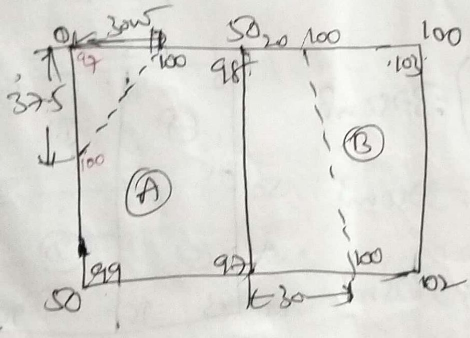


Sol: Area of plot = $20 \times 30 = 600\, m^2$

Volume $V = 600 \left(\dfrac{\overset{92-90}{2} + \overset{91-90}{1} + 1.5 + 1}{4} \right)$

$V = 825 m^3$

* Calculate quantity of earthwork for general levelling 100m RL dressing of two plots as shown in fig and spot levels are given at the corners.



Sol: Plot A

Area of cutting $= \frac{1}{2} \times 30 \times 37.5 = 562.5\, m^2$

$V = 562.5 \left[\dfrac{3+0+0}{3} \right] = 562.5 m^3$

Area of filling $= (50 \times 50) - 562.5 = 1937.5\, m^2$

$$V = 1937.5\left(\frac{0+2+3+1+0}{5}\right) = 2325\,m^3$$

Plot B

$$\text{Area of cutting} = \frac{1}{2}(20+30)\,50 = 1250\,m^2$$

$$V = 1250\left(\frac{0+2+3+0}{4}\right) = 1562.5\,m^3$$

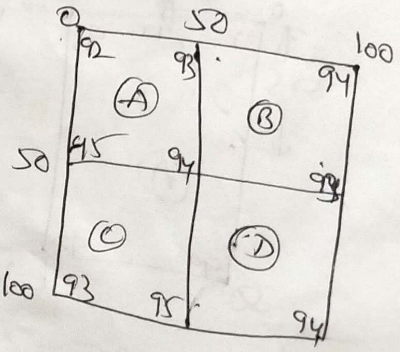
$$\text{Area of filling} = \frac{1}{2}(20+30)\,50 = 1250\,m^2$$

$$V = 1250\left(\frac{0+3+2+0}{4}\right) = 1562.5\,m^3.$$

Total volume of earthwork in cutting $= 562.5 + 1562.5$
$= 2125\,m^3$

Total volume of earthwork in filling $= 2325 + 1562.5$
$= 3887.5\,m^3$

* Calculate the quantity of earthwork in area where general levelling is required upto 92 m RL as shown in fig.



Sol:-
$$V_A = 50\times50\left(\frac{0+3+2+1}{4}\right) = 3750\,m^3$$

$$V_B = 50\times50\left(\frac{1+2+2+1}{4}\right) = 3750\,m^3$$

$$V_C = 50\times50\left(\frac{3+2+1+3}{4}\right) = 5625\,m^3$$

$$V_D = 50\times50\left(\frac{2+1+3+2}{4}\right) = 5000\,m^3$$

Total volume $V = V_A + V_B + V_C + V_D$

$V = 3750 + 3750 + 5625 + 5000$

$V = 18125\,m^3$

...ulate the quantity of earthwork for 200m length for portion of a road in an uniform width ground the heights of banks at the two ends being 1.00m & 1.6m. The formation width is 10m & side slopes 2:1 (H:V) (10)

Sol:

Given $L = 200\,m$

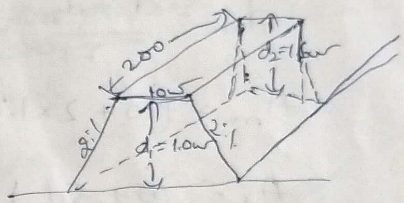
$d_1 = 1.00\,m$

$d_2 = 1.6\,m$

$b = 10\,m$

$s:1 = 2:1\ (H:V)$

①



① Mid sectional area method

$$V = A \times L$$

mean depth

$$d_m = \frac{d_1 + d_2}{2} = \frac{1 + 1.6}{2} = \frac{2.6}{2} = 1.3\,m$$

$$A = (b + s d_m) d_m = (10 + 2 \times 1.3)1.3 = 16.38\,m^2$$

$$V = 16.38 \times 200$$

$$\boxed{V = 3276\,m^3}$$

② Mean Sectional area method

$$V = A_m \times L$$

Mean Area

$$A_m = \frac{A_1 + A_2}{2}$$

where

$$A_1 = (b + s d_1) d_1 = (10 + 2 \times 1)1 = 12\,m^2$$

$$A_2 = (b + s d_2) d_2 = (10 + 2 \times 1.6)1.6 = \cancel{16.38}\ 21.12\,m^2$$

$$A_m = \frac{12 + \cancel{16.38}\ 21.12}{2} = 1\cancel{4.19}\ 6.56\,m^2$$

$$V = \cancel{14.19}\ 16.56 \times 200$$

$$\boxed{V = 3312\,m^3}$$

Prismoidal formula

$$V = \frac{L}{6}\left[A_1 + 4A_m + A_2\right]$$

$$A_m = (b + Sd_m)d_m$$

$$d_m = \frac{d_1 + d_2}{2} = \frac{1 + 1.6}{2} = \frac{2.6}{2} = 1.3\,m$$

$$A_m = (10 + 2\times1.3)1.3 = 16.38\,m^2$$

$$A_1 = (b + Sd_1)d_1 = (10 + 2\times1)1 = 12\,m^2$$

$$A_2 = (b + Sd_2)d_2 = (10 + 2\times1.6)1.6 = 21.12\,m^2$$

$$V = \frac{200}{6}\left[12 + 4\times16.38 + 21.12\right]$$

$$V = \frac{200}{6}\times98.64$$

$$\boxed{V = 3288\,m^3}$$

2) Reduced Level (R.L) of ground along the centre line of a proposed road from a chainage 10 to chainage 20 are given below. The formation level at the 10th chainage is 107 and the road is in downward gradient of 1 in 150 upto the chainage 14 and then the gradient ~~chainages~~ changes to 1 in 100 downward. Formation width of road is 10m and side slopes of banking are 2:1 (H:V). Length of the chain is 30 m.

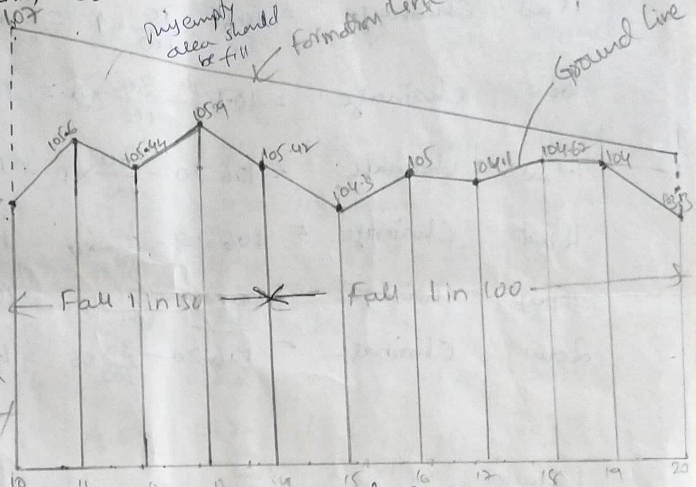
(2)

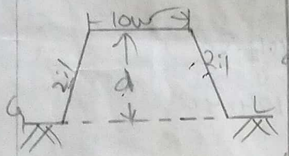
...aw Longitudinal section of the road and a typical ...oss-section and prepare an estimate of earthwork at the rate of Rs. 275.00 % / cum. (14) (3)

Chainage	10	11	12	13	14	15	16	17	18	19	20
R.L of ground	105.00	105.60	105.44	105.90	105.42	104.30	105.00	104.10	104.62	104.00	103.3
Gradient	← Down gradient 1 in 150 →					← Down gradient 1 in 100 →					

every 150 m = 1 m (150)

R.L of formation at 10 m Chainage is 107.00.





C/s of Embankment (filling)

Datum Line 100

Longitudinal Section.

Depth of cutting											
D/Ht of Banking (filling)	2.00	1.2	1.16	0.5	0.78	1.60	0.60	1.20	0.38	0.70	1.10
R.L of Formation	107.00	106.80	106.60	106.40	106.20	105.90	105.60	105.30	105.00	104.7	104.40
R.L of Ground	105.00	105.60	105.44	105.90	105.42	104.30	105.00	104.10	104.62	104.00	103.30
Distance in m	300	330	360	390	420	450	480	510	540	570	600
Chainage	10	11	12	13	14	15	16	17	18	19	20

Calculation of Formation levels

(4)

10 m chainage $= 107.00$ m

11 m chainage $= 107 - \frac{30}{150} \times 1 = 106.80$ m

12 m chainage $= 107 - \frac{30}{150} \times 2 = 106.60$ m

13 m chainage $= 107 - \frac{30}{150} \times 3 = 106.40$ m

14 m chainage $= 107 - \frac{30}{150} \times 4 = 106.20$ m

15 m chainage $= 10\cancel{7}6.20 - \frac{30}{100} \times 1 = 105.90$

16 m chainage $= 10\cancel{7}6.20 - \frac{30}{100} \times 2 = 105.60$

17 m chainage $= 106.20 - \frac{30}{100} \times 3 = 105.30$

18 m chainage $= 106.20 - \frac{30}{100} \times 4 = 105.00$

19 m chainage $= 106.20 - \frac{30}{100} \times 5 = 104.70$

20 m chainage $= 106.20 - \frac{30}{100} \times 6 = 104.40$.

1 chain length is 30 m

Here 10 chain length $= 30 \times 10 = 300$ m.

Similarly 11 chain length $= 30 \times 11 = 330$ m

H	V
150	1
30	X

If you travel distance of 150m for you will go 1m vertically upwards

So one chainage is 30 m

$= \frac{30}{150} \times 1$

Calculation of Quantities of Earthwork (12) (3)

B = 10 m, S = 2 by Mid sectional

Stations (or) Chainages (m)	Distance Length m	Height / Depth G.L − F.L m	Mean Height (or) depth $d_m = \frac{d_1+d_2}{2}$	Central Area Bd m^2	Side area Sd^2 m^2	Total Sectional area $Bd_m + Sd_m^2$	Length in b/w stations m	Quantity $(Bd+Sd^2)L$ Banking (filling) m^3	Quantity $(Bd+Sd^2)L$ Cutting m^3
10	300	2.00	—	—	—	—	—	—	—
			$2+1.2 = \frac{3.2}{2}$	10×1.6	$2\times1.6^2 = 5.12$	$10\times1.6+2\times1.6^2$			
11	330	1.20	1.6	16	5.12	21.12	30	633.60	
			$\frac{1.2+1.16}{2} = \frac{2.36}{2}$						
12	360	1.16	1.18	11.8	2.78	14.58	30	437.40	
13	390	0.50	0.83	8.3	1.38	9.68	30	290.40	
14	420	0.78	0.64	6.4	0.82	7.22	30	216.60	
15	450	1.60	1.19	11.9	2.83	14.73	30	441.9	
16	480	0.60	1.1	11.00	2.42	13.42	30	402.6	
17	510	1.20	0.9	9.00	1.62	10.62	30	318.6	
18	540	0.38	0.79	7.9	1.25	9.15	30	274.5	
19	570	0.70	0.54	5.4	0.58	5.98	30	179.4	
20	600	1.10	0.9	9.0	1.62	10.62	30	318.6	

Total = 3513.6 m^3

$A = (b+nd)d$
$= (bd + nd^2)$

$Q = A \times L$

Abstract of Estimate

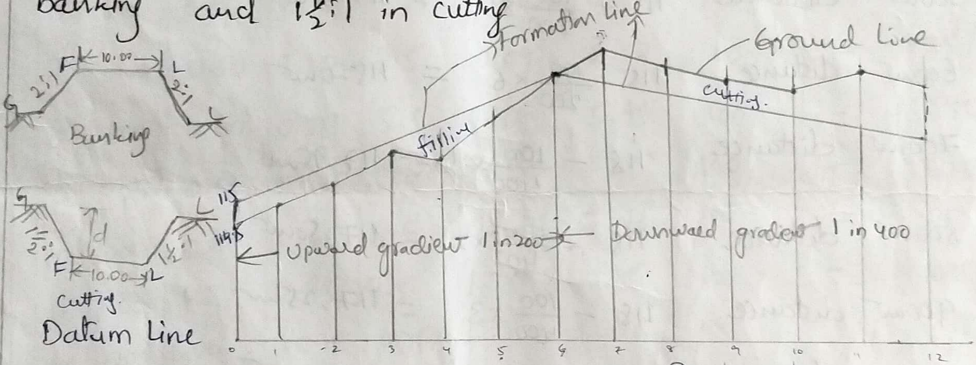
Item No	Particulars of items	Quantity	Unit	Rate	Per	Amount
1.	Earthwork in banking	3513.6	Cum	275.00 $\frac{275}{100} = 2.75 \times 3513.6$	%cum	9662.4

...pare a ~~detailed~~ abstract estimate for earthwork for a portion of a road from the following data :-

(15) (4)

Distance in mt	0	100	200	300	400	500	600	700	800	900	1000	1100	1200
R.L of Ground	114.50	114.75	115.25	115.20	116.10	116.85	118.00	118.25	118.10	117.8	117.75	117.9	117.5
R.L of formation	115	← Upward gradient 1 in 200					→	← Downward gradient 1 in 400 →					

Formation width of a road is 10mt; side slope 2:1 in banking and $1\frac{1}{2}:1$ in cutting



Depth of cutting							0.00	0.50	0.60	0.55	0.75	1.15	1.00
Height of bank	0.5	0.75	0.75	1.30	0.9	0.65	0.00						
RL of Formation	115.00	115.50	116.00	116.50	117.00	117.50	118.00	117.75	117.50	117.25	117.00	116.75	116.50
RL of Ground	114.50	114.75	115.25	115.20	116.10	116.85	118.00	118.25	118.10	117.80	117.75	117.8	117.50
Distance in mt	0	100	200	300	400	500	600	700	800	900	1000	1100	1200

Calculation of R.L of formation

0 mt distance chainage	R.L of formation is 115.00 mt
100 mt distance	$115 + \frac{100}{200} \times 1 = 115.5$ mt
200 mt distance	$115 + \frac{100}{200} \times 2 = 116.0$ mt
300 mt distance	$115 + \frac{100}{200} \times 3 = 116.50$ mt
400 mt distance	$115 + \frac{100}{200} \times 4 = 117.00$ mt
500 mt distance	$115 + \frac{100}{200} \times 5 = 117.50$ mt
600 mt distance	$115 + \frac{100}{200} \times 6 = 118.0$ mt
700 mt distance	$118 - \frac{100}{400} \times 1 = 117.75$ mt
800 mt distance	$118 - \frac{100}{400} \times 2 = 117.50$ mt
900 mt distance	$118 - \frac{100}{400} \times 3 = 117.25$ mt
1000 mt distance	$118 - \frac{100}{400} \times 4 = 117.00$ mt
1100 mt distance	$118 - \frac{100}{400} \times 5 = 116.75$ mt
1200 mt distance	$118 - \frac{100}{400} \times 6 = 116.50$ mt

Calculation of Quantities

$B = 10\,m$, $S = 2$ for banking, $S = 1\frac{1}{2}$ for cutting

Station	Distance m	Height or Depth diff. of GL & FL	Mean height (or) depth d m	Central area Bd m^2	Area of Sides Sd^2 m^2	Total Sect. area $Bd+Sd^2$ m^2	Distance in b/w stations L m	Quantity $(Bd+Sd^2)\times L$ Banking m^3	Quantity $(Bd+Sd^2)\times L$ Cutting m^3
0	0	0.50	—	—	—	—	—	—	—
1	100	0.75	0.625	6.25	0.78	7.03	100	703	—
2	200	0.75	0.75	7.5	1.13	8.63	100	863	—
3.	300	1.30	1.025	10.25	2.10	12.35	100	1235	—
4.	400	0.90	1.10	11.0	2.42	13.42	100	1342	—
5.	500	0.65	0.775	7.75	1.20	8.95	100	895	—
6.	600	0.00	0.325	3.25	0.21	3.46	100	346	—
7.	700	0.50	0.250	2.5	0.09	2.59	100	—	259
8.	800	0.60	0.55	5.5	0.45	5.95	100	—	595
9.	900	0.55	0.575	5.75	0.50	6.25	100	—	625
10.	1000	0.75	0.65	6.5	0.63	7.13	100	—	713
11.	1100	1.15	0.95	9.5	1.35	10.85	100	—	1085
12	1200	1.00	1.075	10.75	1.73	12.48	100	—	1248
							Total	5384 m^3	4525 m^3

Abstract Estimate

S.No.	Particulars of items	Quantity	Unit	Rate	Per	Cost
1.	Earthwork in banking	5384	$1m^3$	275.00	% cum	14806.00
2.	Earthwork in cutting	4525	$1m^3$	350.00	% cum	15837.5
						30643.5

Therefore

Estimate the cost of earthwork for a portion of a road for 400 mt length from the following data :- (10) (8)

Formation width of the road is 10 mt; side slopes are 2:1 in banking and $1\frac{1}{2}:1$ in cutting.

Station	Distance (mt)	R.L of Ground	R.L of Formation
25	1000		52.00
26	1040	51.00	
27	1080	50.90	
28	1120	50.50	
29	1160	50.80	
30	1200	50.60	Downward gradient of 1 in 200
31	1240	50.70	that means (for every 200 mt 1 mt is downward)
32	1280	51.20	
33	1320	51.40	
34	1360	51.30	
35	1400	51.00	
		50.60	

Longitudinal section of the road and type C/s are as given in fig. The rate of banking is Rs. 275.00 % cum and for cutting is Rs. 350.00 % cum.

Calculation of formation levels :-

(or) $\frac{40}{200} \Rightarrow 0.2$ mt
For every RL of formation deduct 0.2 mt

1000 mt distance = $52 - \frac{40}{200}$.

1040 mt " $= 52 - \frac{40}{200} \times 1 \Rightarrow 51.8$

1080 mt " $= 52 - \frac{40}{200} \times 2 = 51.6$

1120 mt " $= 52 - \frac{40}{200} \times 3 = 51.4$

1160 mt " $= 52 - \frac{40}{200} \times 4 = 51.2$

1200 mt " $= 52 - \frac{40}{200} \times 5 = 51.00$

1240 mt " $= 52 - \frac{40}{200} \times 6 = 50.80$

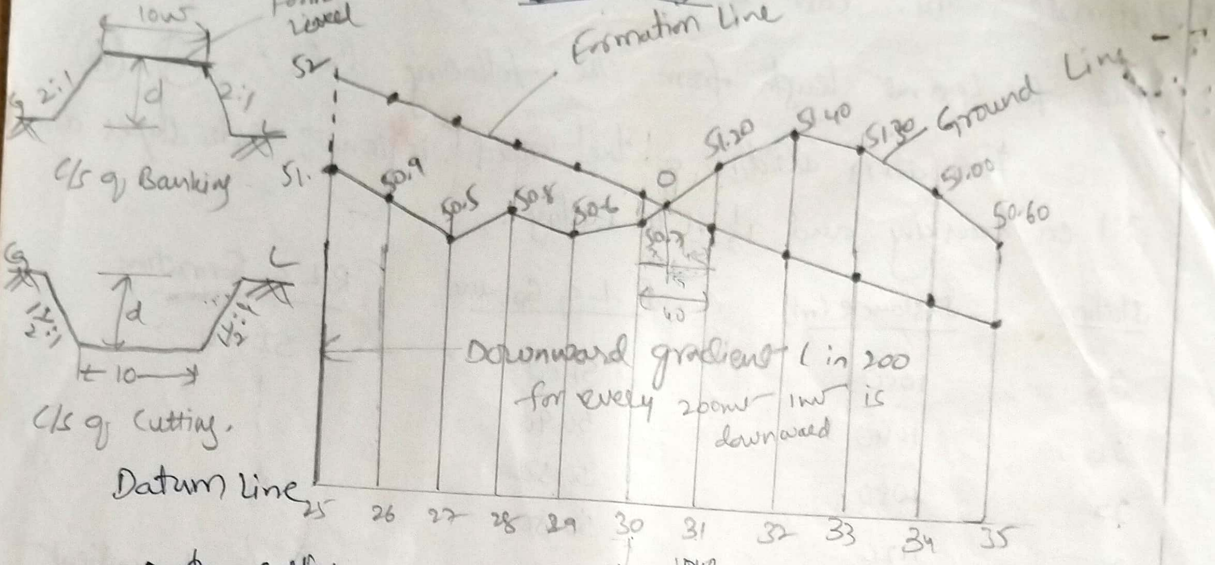
1280 mt " $= 52 - \frac{40}{200} \times 7 = 50.60$

1320 mt distance $= 52 - \frac{40}{200} \times 8$
$= 50.40$

1360 mt distance $= 52 - \frac{40}{200} \times 9$
$= 50.20$

1400 mt " $= 52 - \frac{40}{200} \times 10$
$= 50.00$ mt

L -- Section



Depth of Cutting							0.40	0.80	0.90	0.80	0.60
Height of bank	1.00	0.9	1.10	0.60	0.60	0.30					
R.L. of Formation	52.00	51.80	51.60	51.40	51.20	51.00	50.80	50.60	50.40	50.20	50.00
R.L of Ground	51.00	50.90	50.50	50.80	50.60	50.70	51.20	51.40	51.30	51.00	50.60
Distance in m	1000	1040	1080	1120	1160	1200	1240	1280	1320	1360	1400
Stations	25	26	27	28	29	30	31	32	33	34	35

The road passes from banking to cutting in b/w stations 30 (1200m) and 31 (1240m). The distance where it passes through zero. i.e G.L, may be determined as follows:—

The two triangles on either side of zero point are symmetrical

$$\frac{x}{0.3} = \frac{40-x}{0.4}$$

$$0.4x = 0.3(40-x)$$

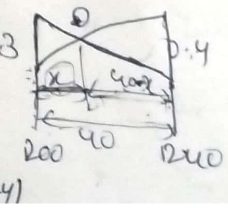
$$0.4x = 12 - 0.3x$$

$$0.4x + 0.3x = 12$$

$$0.7x = 12$$

$$x = \frac{12}{0.7}$$

$x = \underline{17}.14 \Rightarrow 17m$ (say)



0.3 & 0.4m are depths d m

Therefore length of banking portion is 17m; and length of cutting portion is 40 − 17 = 23m.

(16)

Calculation of Quantities

B = 10m, S = 2 for Banking, S = 1½ for cutting

Station	Distance in m	Height/Depth Diff. of GL & FL	Mean depth 'd' m	Central Area Bd	Area of Sides Sd^2	Total sect. area $Bd+Sd^2$	Distance in b/w Stations 'L'	Quantity $(Bd+Sd^2)L$ Banking filling m^3	cutting m^3
25	1000	1.00	–	–	–				
26	1040	0.90	0.95	9.5	1.81	11.31	40	452.40	
27	1080	1.10	1.00	10.00	2.0	12.00	40	480.00	
28	1120	0.60	0.85	8.5	1.45	9.95	40	398.0	
29	1160	0.60	0.60	6.0	0.72	6.72	40	268.0	
30	1200	0.30	0.45	4.5	0.41	4.91	40	196.40	
Passes 1217 from Banking to cutting		0.00	$\frac{0.3+0}{2}$ 0.15	1.5	0.05	1.55	17	26.35	
31	1240	0.40	0.20	2.0	0.06	2.06	23		47.38
32	1280	0.80	0.60	6.0	0.54	6.54	40		261.60
33	1320	0.90	0.85	8.5	1.08	9.58	40		383.20
34	1360	0.80	0.85	8.5	1.08	9.58	40		383.20
35	1400	0.60	0.70	7.0	0.74	7.74	40		309.60
						Total =		1821.95 m^3	1384.98 m^3

S.NO	Description of item	Quantity	Rate	Per	Amount
1.	Earthwork in banking	1821.95	275.00%	cum	$\frac{275}{100} \times 1821.95$ = 5010.3625/–
2.	Earthwork in cutting	1384.98	350.00%	cum	$\frac{350}{100} \times 1384.98$ => 4847.43/–

The area of Side Sloping Surface:-

(17)

The area of sides which may require turfing (or) pitching, may be found by multiplying the mean sloping breadth by the length.

$$\text{The mean sloping breadth} = \sqrt{(sd)^2 + d^2}$$
$$= \sqrt{d^2(s^2+1)}$$
$$= \sqrt{d^2}\,\sqrt{(s^2+1)}$$
$$= d\sqrt{(s^2+1)}$$

where 'd' stands for mean depth.

Area of both side slopes $= 2L \times d\sqrt{s^2+1}$

This also may be calculated in a tabular form -

Stations (or) Chainage	Depth (or) Height	Mean depth (or) Height	Breadth of Side slopes $d\sqrt{s^2+1}$ sloping breadth	Length b/w stations 'L'	Total Area of both side slopes $2Ld\sqrt{s^2+1}$

① Calculate the area of the side slopes of portion of a bank for a length of 200m the heights of banks at the two ends being 2.5m & 3.5m and the ratio of the slope 2:1

a) If the side slopes are to be provided with 150mm thick stone pitching, calculate the cost of pitching at the rate of Rs. 150/- per cum.

Sol:- Given $L = 200m$

$d_1 = 2.50m, \ d_2 = 3.50m.$

$S = 2, \ t = 15cm = 0.15m$

(i) Mean height $d = \frac{d_1 + d_2}{2} = \frac{2.5 + 3.5}{2} \Rightarrow 3.0m.$

Sloping breadth at mid-section $= d\sqrt{S^2+1}$

$= 3.0\sqrt{2^2+1}$

$= 3\sqrt{5}$

$= 6.71m.$

Area of the two sides slopes $= 2Ld\sqrt{S^2+1}$

$= 2 \times 200 \times 6.71$

$\Rightarrow 2684 \ m^2.$

ii) Quantity of pitching = Area X Thickness

$= 2684 \times 0.15$

$= 402.6 \ m^3.$

Cost of stone pitching = Quantity X Rate

$= 402.6 \times 150$

$= 60,390/-$

2) Workout the area of the side slopes of a road embankment 12m wide. The side slopes are 2.5:1. The height of Embankment at one end is 1.35m and at another end is 2.4m. The length of embankment is 216m.

Sol:- Mean depth $d = \frac{1.35 + 2.4}{2} = 1.875m$

Sloping breadth $= d\sqrt{S^2+1}$

$= 1.875\sqrt{2.5^2+1}$

$= 5.049m$

Area of side slopes $= 2L \times d$ M.S.B

$= 2 \times 216 \times 5.049$

$= 2181.168 \ m^2$

Reinforcement UNIT-III Bar Bending and Bar Requirement Schedules

Introduction:- In olden days availability and usage of steel as reinforcement is less. After introduction of steel ~~ste~~ size of the members are reduced, self wt. is reduced tremendously, strength, durability and life of the structure is increased. Almost all engineering structures RCC is used sparingly. Estimation of steel is to be included as a separate item in abstract estimate. Bar bending schedules are very much useful in bending of bars for the required size & shape.

Methods of Estimate of steel:-

1) Estimation of steel from structural drawings.
2) Estimation of steel on the percentage basis of concrete.

1) Estimation of steel from structural drawings:-

The quantity of steel is calculated from the detailed structural drawings by preparing bar bending schedule. The quantity of steel usually measured in wt units. wt. in kgs. No deductions for steel in CC is being made because of small volume occupied by steel in R.CC structures.

1) Length of the bar includes cranks, bends, hooks etc.
2) The wt. of the bar per metre per length multiplied by the length of the bar gives its weight.
3) Density of steel is taken as 7850 kg/m^3 to obtain the weight of the bar.
4) Bar bending schedule is prepared showing shapes & lengths of the bars.

Units weights of Commonly used steel bars.

6mm dia — 0.22 kg/m
8mm dia — 0.39 kg/m
10 mm dia — 0.62 kg/m
12 mm dia — 0.89 kg/m
16 mm dia — 1.58 kg/m
20 mm dia — 2.49 kg/m
25 mm dia — 3.85 kg/m

2) Estimation of steel on the percentage basis of Concrete

This method is used ~~which~~ when the detailed drawings are not available. The percentage of steel depends upon span, type of design, load etc. The approximate percentage of steel used in R.C.C for different elements are given below.

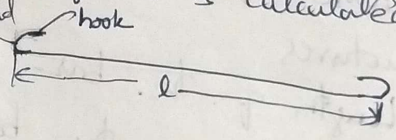
Beams 1 — 2%, columns — 1 to 4%, slabs & lintels — 0.7 to 1%, foundations, raft footings — 0.5 to 0.8%

Shapes of steel bars used in beams & length calculation:—

1) Main straight bars at bottom:— It consists of straight length 'l' and 2 end hooks are provided with a length of 9d on either side. where 'd' is the dia of bar straight length 'l' is calculated by

l = Length of beam + 2 × Bearing − 2 × E.C bend

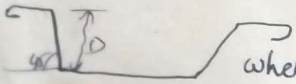
L = Total Length of bar



$L = l + 2 \times 9d$ ..

$\boxed{L = l + 18d}$ (9d for each hook)

2) Main Bent up bars Generally alternate bars provided as main RF length will be bent up at both ends. Bent up bar length is calculated by adding straight length 'l' & additional length due to bent up at both ends plus length of hooks on either side.



Hypotenusal allowance $= \frac{D}{\sin 45°} = 0.414D \Rightarrow 0.42D$

$\frac{D}{\sin 45} - D = D\left[\frac{1}{0.707} - 1\right] = D[1.42 - 1] = 0.414D = 0.42D$

where D is vertical distance b/w the centre of upper & lower arms of bent up bar.

where D = Total depth of beam − Top clear cover − bottom clear cover − Dia. of bent up bar ②

Total length of cranked bar at both ends

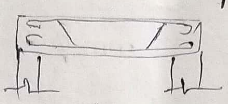
(L) = straight length of bar (l) ~~− 2 × end cover~~ + 2 × Hook allowance + 2 × Bent up allowance

$$\boxed{L = l \cancel{- 2\times E.C} + 2\times 9d + 2\times 0.42D}$$

↑ one

$1 \times 0.42D$

where l = ~~length~~ clear span + 2 × Bearing − 2 × E.C.



3) Anchor Bars (or) ~~Hanger bars~~ :- Anchor bars are provided at top but similar to that of straight bars are provided at bottom as main RF.

Total length of bar (L) = straight length of bar (l) + 2 × 9d.

where l = clear span of beam + 2 × Bearings − 2 × E.C.

$$\therefore L = l + 2\times 9d$$

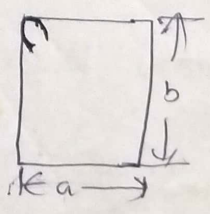
$$\therefore \boxed{L = l + 18d}$$

4) Stirrups :- Generally stirrups are provided two legged at equal intervals.

Total length $L = 2(a+b) + 2\times 12d$.

a = Length − 2 × covers

b = Breadth − 2 × covers.



1) Calculate the quantities of steel of R.C.C Simply supported beam of clear span 3.6m. The walls supporting the beam are 230 mm with full bearing on both sides. Size of the beam is 230 mm x 300mm. Concrete cover at ends of bars and sides 40 mm and that of top & bottom is 30 mm each. The RF details of the beam are given below. Prepare bar bending schedule.

1) Main straight bars at bottom = 12 mm ϕ – 2 nos.

2) Main bent up bars – 12 mm ϕ – 2 nos.

3) Top ancher bars – 12 mm ϕ – 2 nos

4) Stirrups are 6mm dia at both 1mt long and including bearing on either side at 150mm c/c and middle 1.6m length at 210 mm c/c.

Given wt. of bars :- 12 mm ϕ – 0.89 kg/m

6 mm ϕ – 0.22 kg/m.

Sol:- Given Clear span of beam = 3.6m

wall thick – 230 mm.

Size of beam = 230 mm x 300mm.

Side covers = 40mm

Top & bottom covers = 30mm.

1) Main straight bars at bottom :-

Total length of bar (L) = straight length of bar (l) + 2 x H A

where straight length (l) = clear span of beam + 2 x Bearing – 2 x Side cover

$l = 3.6 + 2 \times 0.23 - 2 \times 0.04m$

$l = 3.98 m$

③

Total length (L) = $l + 2 \times 9d$

$= 3.98 + 2 \times 9 \times 0.012$

$L = 4.196\,m$

2) Main bent up bars — 12 mm ϕ, 2 nos.

Total length of bar (L) = straight length of bar (l) + 2 × H.A + 2 × B.A

$L = l + 2 \times 9d + 2 \times 0.42D.$

where $l = 3.98\,m$

where D = Total depth of beam − T.C.C − B.C.C − dia. of bent up bar

$D \Rightarrow 300 - 30 - 30 - 12$

$D \Rightarrow 228\,mm$

$D = 0.228\,m.$

$L = 3.98 + 2 \times 9 \times 0.012 + 2 \times 0.42 \times 0.228$

$L \Rightarrow 4.387\,m$

3) Anchor bars at top — 12 mm ϕ, 2 nos.

Total length of bar = Length of straight bar + 2 × HA

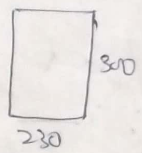
$L = l + 2 \times 9d.$

$L = 3.98 + 2 \times 9 \times 0.012$

$L = 4.196\,m.$

4) Stirrups length

Stirrups length = $2[a+b] + 2 \times 12d.$



where a = ~~Length~~ Width − S^de cover

b = ~~Breadth~~ Depth − T & B covers

$a = 230 - 40 \times 2$

$= 150\,mm$

$b = 300 - 2 \times 30 \Rightarrow 240\,mm.$

$L = 2[150+240] + 2\times12\times6$

$= 780 + 144$

$L \Rightarrow 924 mm$

$L = 0.924 m$

No. of stirrups :-

6 mm ϕ bars for stirrups at 150mm c/c

Total length on each end $= 1 + 0.23 \Rightarrow 1.23 m$.

No. of stirrups at one end $= \frac{1.23}{0.15} \Rightarrow 9.2 \Rightarrow 10$ nos.

For both ends $= 2\times10$

$= 20$ nos.

Total length in middle $= 1.6 m$ at 210mm c/c.

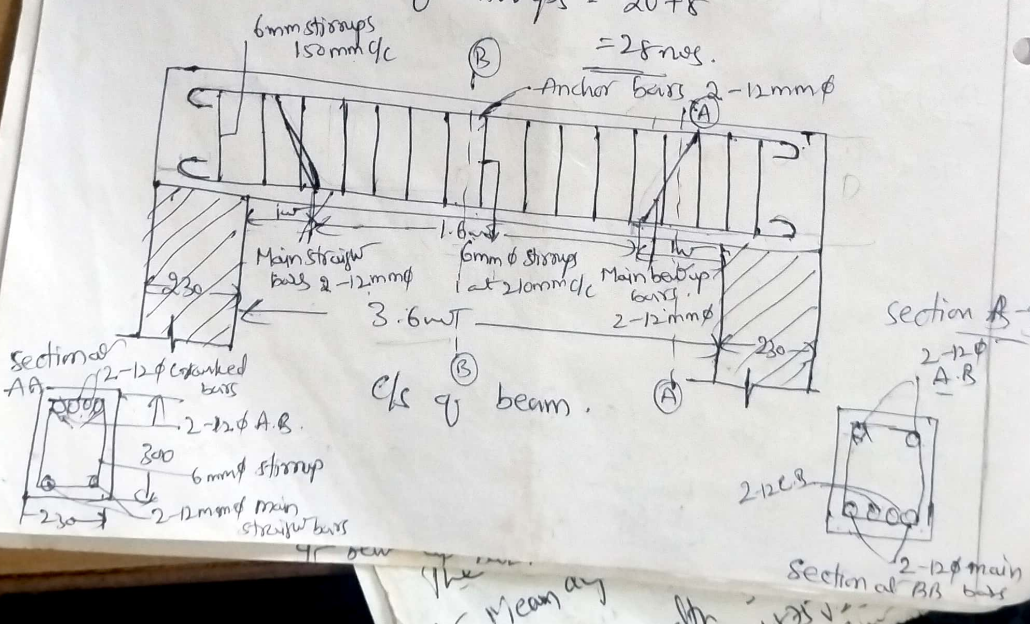
No. of stirrups $= \frac{1.6}{0.21} \Rightarrow$

$\Rightarrow 7.61$

$= 8$ nos.

Total no. of stirrups $= 20 + 8$

$= 28$ nos.



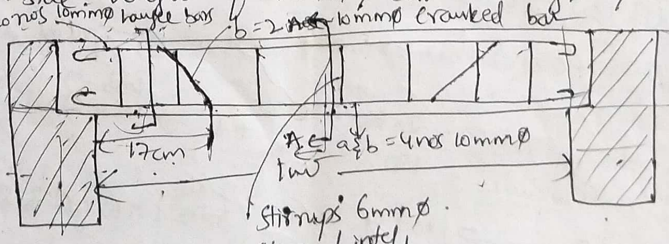
Bar Bending Schedule :-

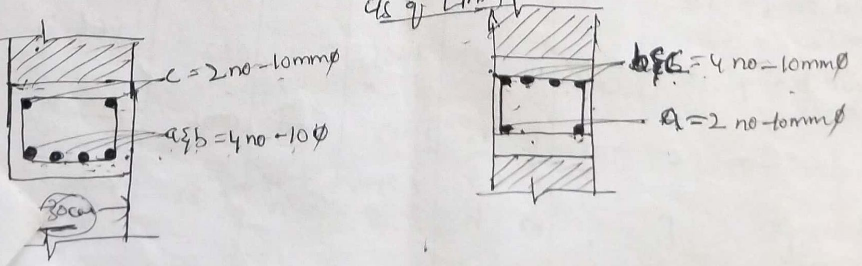
(4)

S.No	Description of bar	Shape of bar	Dia	Nos	Length	Total Length	weight per m	Total weight in kgs (TL × w = T.W)
1.	Main straight bars		12mm	2	4.196	8.392	0.89 kg/m	7.468 kgs.
2.	Main bent up bars		12mm	2	4.387	8.774	0.89 kg/m	7.808 kgs
3)	Anchor bars		12mm	2	4.196	8.392	0.89 kg/m	7.468 kgs
4.	Stirrups		6mm	28	0.924	25.872	0.22 kg/m	5.691 kg.
						Total wt	=	28.435 kgs

Problem on R.C.C Lintel.

2) Prepare a schedule of bars for the R.C.C lintel shown in figure below, assuming bearing of the lintel to be 15cm on walls at each side. weight of 10mm ø bar = 0.62 kg/m & 6mm ø bar = 0.22 kg/m.





Sol:- 1) Main bars — 4 no- 10mm ϕ.

a) Total length of bar (L) = length of straight bar (l) + 2 × H.A

$l = 1 + 2 \times 0.15 - 2 \times 0.025 ~~+ 2x~~ \Rightarrow 1.25m$

$L = 1.25 + 2 \times 9 \times 0.01$

$L \Rightarrow 1.43m$

2) Main bent up bars :— (2 no - 10mm ϕ)

Total length of bar (L) = length of straight bar (l) + 2×H.A + 2×0.42D

$D = 0.15 - 0.025 - 0.025 - 0.01 \Rightarrow 0.09m$

$L = 1.25 + 2 \times 9 \times 0.01 + 2 \times 0.42 \times 0.09$

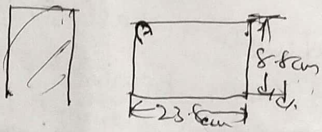
$L = 1.5056m$

3) Anchor bars :—

Similar to main bars at bottom

$L = 1.43m$.

4) Stirrups :— 6 mm ϕ.



$L = 2(a+b) + 2 \times 12d$

$= 2(0.236 + 0.088) + 2 \times 12 \times 0.006$

$L \Rightarrow 0.796$ ~~2.092m~~

Assuming spacing as 150mm c/c

No. of stirrups $= \frac{1000 + 2 \times 150 - 2 \times 25}{150} + 1 \Rightarrow 9.33 \Rightarrow 10$ nos, ~~10.4~~ $\Rightarrow$ ~~10 nos~~.

Bar Bending Schedule :—

1) Main straight bars		10	2	1.43	2.86 ~~5.72~~	0.62 kg/m	1.773 ~~3.546~~ kg.
2) Main bent up bars		10	2	1.505	3.01	0.62	1.866 kg.
3) Anchor bars		10	2	1.43	2.86 ~~5.72~~	0.62	1.773 ~~3.54~~ kg
4) Stirrups		6	10	0.796 ~~2.092~~	7.96 ~~20.92~~	0.22	~~4.602~~ kg. 1.75 kg.

Prepare bar bending schedule of S.S. R.C.C. lintels from the following specifications: Size of the lintel 230mm wide and 200mm depth. Main bars in the tension zone are of Fe 415 grade, 3 bars of 12mm ∅, of which one is cranked through 45° at 180 mm from either end. (5)

1) 2 nos. anchor bars of 10mm ∅ at top.
2) Two legged stirrups of 6mm ∅ @ 150mm c/c
3) Clear span of the lintel is 1200mm; bearing on either side is 200mm. Assume alround cover as 25mm.

Sol:- Given size of the lintel = 230mm x 200mm.

Main bars — 2 nos — 12mm∅.

Main bent up bars — 1 nos — 12mm∅

Anchor bars — 2 nos — 10mm∅

2 legged stirrups — 6 mm∅ @ 150mm c/c

C.S of lintel = 1200mm.

wall thickness = 200mm

Alround cover is 25mm.

1) Main Bars

Total length of bar (L) = straight length (l)

where l = C.S of lintel + 2×B − 2× covers

$\Rightarrow 1200 + 2\times200 - 2\times25$

$l \Rightarrow 1550$ mm

$l = 1.55$ m

$\therefore L = 1.55$ m

2) Main Bent up bars

Total length of bar (L) = straight length + 2×0.42 D.

where D = Depth of lintel − T.C.C − B.C.C − Bent up dia. ∅

$D = 200 - 25 - 25 - 12 \Rightarrow 138$ mm $\Rightarrow 0.138$ m

$\therefore L = 1.55 + 2 \times 0.42 \times 0.138$

$L \Rightarrow 1.665\,m$

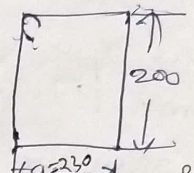
3) Anchor bars

Total length of bar (L) = straight length (l).

where $l = 1200 + 2\times200 - 2\times25 \Rightarrow 1550\,mm \Rightarrow 1.55\,m$

4) Stirrups length :-

Stirrups length $= 2(a+b) + 2\times12\times d$



where $a = 230 - 25 - 25 \Rightarrow 180\,mm$

$b = 200 - 25 - 25 \Rightarrow 150\,mm$.

$L = 2(180+150) + 2\times12\times6$

$L \Rightarrow 804\,mm$

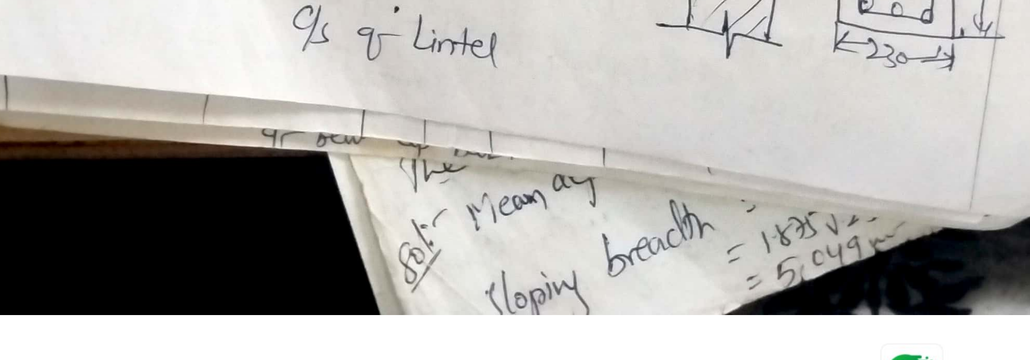
$L = 0.804\,m$

No. of stirrups = $\frac{1200 + 2\times200 - 2\times25}{150} + 1$ (Bearing)

$\Rightarrow 11.33$

$\Rightarrow 11$ nos

S.No	Description of bar	Shape of bar	Dia	No.	Length	Total length	weight	Total wt in kgs. =T.L×W.
1.	Main straight bars		12mm	2	1.55	3.10	0.89	2.759
2.	Main Bent up bars		12mm	1	1.665	1.665	0.89	1.481
3.	Anchor Bars		10 mm	2	1.55	3.10	0.62	1.922
4.	Stirrups		6mm	11	0.804	8.844	0.22 kg/m	1.945
								8.107 kg



C/s of Lintel

R.C.C (1:2:4) rectangular beam 20cm wide x 30cm deep x 3.0mt overall length is reinforced with tor steel bars 3 no.s 16mm ø (1.58 kg/mt) two outer bars straight & L-hooked at ends and the inner bar bent up at 45° at appropriate places with L-hooked at ends. At top, two outer hanger bars are 10mm ø (0.62 kg/mt) straight and L-hooked at ends. Stirrups are 6mm ø mild steel bar (0.22 kg/mt) and spaced at 20 cm centers. All concrete cover = 2.5cm. Prepare bar bending schedule and draw sketches showing arrangements of RF for the beam. and show appropriate method of entering the measurements in the columns of Measurement Book (MB) and prepare a bill of quantities for four such beams. (6)

Sol: Given Rectangular beam 20 cm x 30cm.

Overall length = 3mt including wall thick

Main straight bars = 2 nos – 16mm ø with L-hooked at ends.

Main bent up bar = 1 no.s – 16mm ø with " "

Anchor bars = 2 nos – 10 mm ø " " "

Stirrups = 6 mm ø @ 200 mm c/c.

All concrete cover = 2.5 cm.

1) Main straight bars

Total length of bar (L) = straight length (l) + 2 × H.A (2×6d) for L-hooked F.

where $l = 3.0 - 2 \times 0.025 \Rightarrow 2.95\,mt$

$L = 2.95 + 2 \times 6 \times 0.016 \Rightarrow 3.142\,mt.$

2) Main bent up bars

Total length of bar (L) = $l + 2 \times 6d + 2 \times 0.42D$.

$D = 300 - 25 - 25 - 16 \Rightarrow 234\,mm \Rightarrow 0.234\,mt$

$L = 2.95 + 2 \times 6 \times 0.016 + 2 \times 0.42 \times 0.234$

$L \Rightarrow 3.338\,mt$

3) Anchor Bars :-

Total length of bar (L) ⇒ straight length + 2×6d

2H.A

$l = 3 - 2 \times 0.025$

$l = 2.95\,m$

$L = 2.95 + 2 \times 6 \times 0.01 \Rightarrow 3.07\,m$

4) Stirrups :-

Stirrups length $L = 2(a+b) + 2 \times 12 \times d$

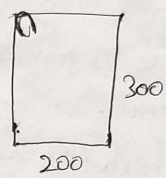
$a = 200 - 2 \times 25 \Rightarrow 150\,mm$

$b = 300 - 2 \times 25 \Rightarrow 250\,mm$

$L = 2(150 + 250) + 2 \times 12 \times 6$

$L = 944\,mm$

$L = 0.944\,m$

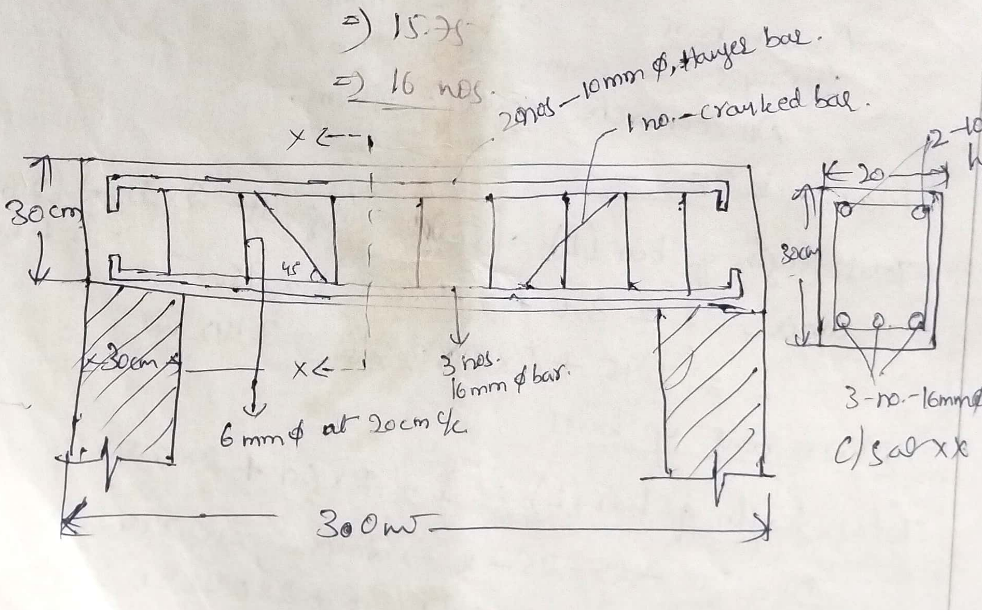


No. of stirrups $= \dfrac{\text{Overall length} - 2 \times \text{covers}}{\text{spacing}} + 1$

$= \dfrac{3 - 2 \times 0.025}{0.2} + 1$

$\Rightarrow 15.75$

$\Rightarrow 16$ nos.



S.No	Description	Shape of bar	No.	Length	Total length = No × L	wt in kg/m	Total wt. (or) Quantity = T.L×W.
1	Main straight bars (16mm ϕ) (Tor steel)		2 for 4 beams = 8	3.142	25.136	1.58 kg/m	39.71 kg.
2)	Main bent up bar (16mm ϕ)		1×4 (beams) = 4	3.338	13.352	1.58	21.09 kg.
3)	Hanger bars		2×4 = 8	3.07	24.56	0.62	15.22 kg.
							76.02 kg.
4)	Stirrups (mild steel) 6mm ϕ	30, 20	16×4 = 64	0.944	60.416	0.22	13.29 kg.

(7)

Measurement Book :-

S.NO	Description of item	No. of ~~bars~~ beams	Length	Breadth	Depth	Quantity.
1.	C.C. R.C.C work (1:2:4)	4	3	0.2	0.3	~~3×0.2×0.3~~ = 0.72 m^3.

Quantity of Bill for Four Beams

1) Torr steel — 76.02 kg.
2) Mild steel — 13.29 kg.
3) C.Concrete — 0.72 m^3.

Problem on Column :-

5) Determine The quantity of concrete and that of steel in R.C.C Square column. Details in fig. Size of base 0.9×0.9×0.2m.

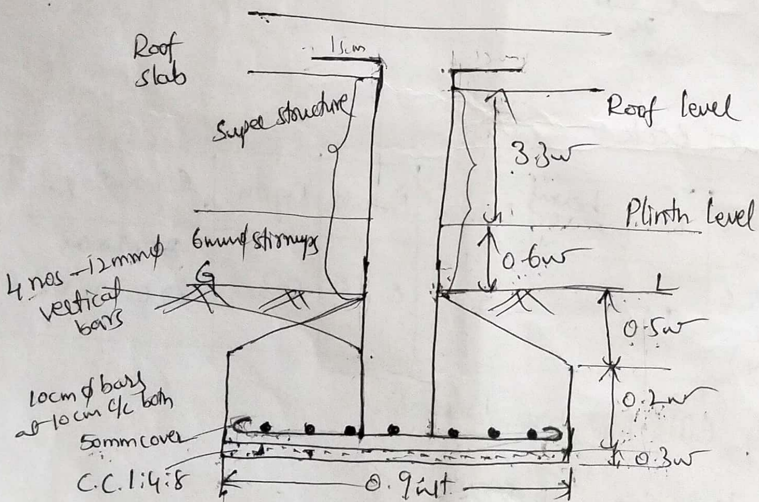
Details of RF :- a) 10 mm ϕ bars at 10 cms c/c in base portion

b) 12 mm ϕ Vertical bars 4 nos. one number at each corner with sufficient holding the base RF

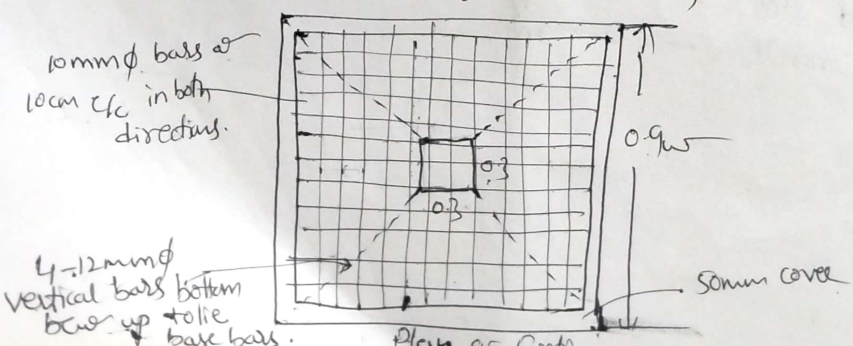
c) 6mm ϕ stirrups at 15cm c/c.

Note:- 1) Height of column from plinth level to bottom of roof slab is 3.3m. Depth of foundations 1.0m below GL. Basement height is 0.6m.

2) Extend vertical rod of column 15cm length above bottom roof level for binding into roof slab.



C/s of column footing

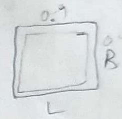


Plan of Footing

Calculation of length of bars :-

(8)

In base of column :- 10mm ϕ bars at 10 cm c/c in both direction.



$$\text{Length} = \text{Length/width of footing} - 2 \times \text{covers}\ (50) + 2 \times H.A.$$

$$= 0.90 - 2 \times 0.05 + 2 \times 9 \times 0.01$$

$$L \Rightarrow 0.98\,m$$

$$\text{No. of bars} = \frac{\text{width of footing} - 2 \times \text{cover}}{\text{spacing}} + 1$$

$$= \frac{0.9 - 2 \times 0.05}{0.1\ (10cm)} + 1$$

$$\Rightarrow 9 \text{ nos.}$$

For both directions, no. of bars required $\Rightarrow 2 \times 9 = 18$ bars. for mat

2) **Vertical main bars :-** No. of bars = 4 nos.

Length of each bar = Bent to join base (AB) + (ht. of base − covers) (BC) + trapezoidal portion height + Basement height + Superstructure height (CD) + Length extend into roof (DE).

$\therefore$ Length of bar = AB + BC + CD + DE

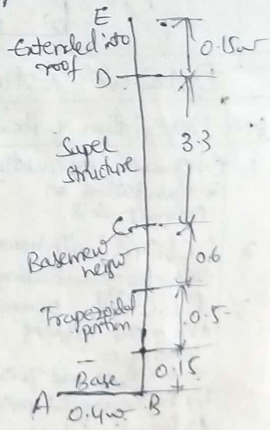
AB = Bent up bar to adjoin the base RF

AB = 40d (but not less than 400mm)

= 40 x 10

= 400mm

AB = 0.4 m



BC = (200 − 50) + 500 + 600 $\Rightarrow$ 1250mm $\Rightarrow$ 1.25m

CD = 3.3m, DE = 0.15m

Length of each bar = 0.4 + 1.25 + 3.3 + 0.15 $\Rightarrow$ 5.1m

3) Horizontal stirrups – 6mm ϕ.

Length of stirrups $= 4(\underset{\text{colum size}}{0.3} - 2\times\underset{\text{(cover)}}{0.05}) + 2\times12\times0.006$

$\Rightarrow 0.944$ m.

No. of stirrups $= \frac{0.15+0.5+0.6+3.3}{0.15} + 1$

$\Rightarrow 31.33$.

$\Rightarrow 31$ nos.

Bar bending schedule

S.NO	Description of bar	Shape of bar	Dia	No.	Length in	Total length	weight in kg/m	Total weight in kg
1.	Main rods base slab mat portion		10 mm	18	0.98	17.64	0.62 kg/m	10.936 kg.
2.	Vertical main bars		12 mm	4	5.10	20.4	0.89 kg/m	18.156 kg
3)	Horizontal stirrups		6mm	31	0.944	29.264	0.22 kg/m	6.438 kg.
								35.53 kg.

Detailed Estimate of Square column.

A = footing size, a = column size

S.NO	Description of item	Nos	Length	Breadth	Depth.	Quantity
1.	Earthwork excavation in foundations in ordinary soils	1	0.9	0.9	1.0	0.81
2.	C.C (1:4:8) with 40mm HBG for foundation	1	0.9	0.9	0.3	0.243
3.	R.C.C (1:2:4) with 20mm HBG metal including centering etc.					
	a) For Base mat portion	1	0.9	0.9	0.2	0.162
	b) For Trapezoidal portion	1	$\frac{h}{3}[A^2+a^2+\sqrt{A^2a^2}]$ $\frac{0.5}{3}[0.9^2+0.3^2+\sqrt{0.9^2\times0.3^2}]$			0.225
	c) For column basement & super structure 0.6+3.3 = 3.9	1	0.3	0.3	3.9 (0.6+3.3)	0.351
						1.791 m^3
4.	Cost of steel & fabrication		Quantity as per bending schedule			35.53 kg

Trapezoidal $\left(\frac{A^2+a^2}{2}\right)\times h$

$\left(\frac{0.9^2+0.3^2}{2}\right)\times0.5$

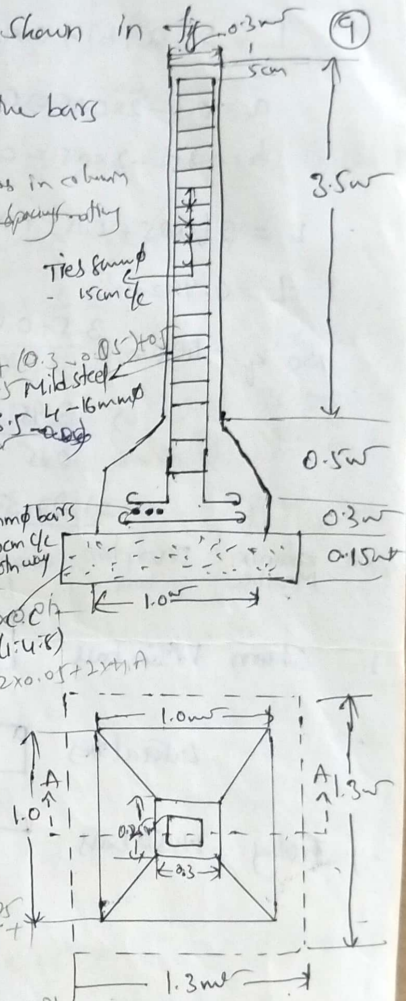
Prepare bar bending schedule with abstract sheet of R.C.C column with footing as shown in fig (9)

Assume cover as 5cm all over the bars

Bars in column = 4 – 16mm ϕ

Bars in footing = 12 mmϕ @ 10cm ~~c/c both ways~~

Lateral ties 8mm ϕ @ 15 cm c/c



Length of column => 4 – 16 mm ϕ

Length of column = 40d + (0.3 – 0.05) + 0.5 + 3.5

Actual length = 40d + (0.3 – 0.05) + 0.5 + ~~(3.5)~~ 3.5

40d + (0.3 – 0.05 + 0.5 + 3.5) = 4.89m

=> 40×0.016 + 0.25 + 0.5 + 3.5

L => 4.89 m

~~Base of column footing~~

Base of column footing :-

L = 1 – 2×c + 2×h
= 1 – 2×0.05 + 2×9×0.012
L = 1.116 m
(1:4:8)
1 – 2×0.05 + 2×1.A

Length = 1.0 – 2×cover + 2 hooks

= 1.0 – 2×0.05 + 2×9×0.012

L => 1.116 m

1 – 2×0.05

No. of bars = $\frac{1.0 - 2\times0.05}{\text{Spacing}} + 1$

$\frac{1 - 2\times0.05}{0.1} + 1$

= 10

= $\frac{1.0 - 0.01}{0.1} + 1$

2×10 = 20 bars

=> $\frac{0.9}{0.1} + 1$

= 10 nos.

For both directions = 2×10 => 20 bars.

Lateral ties :- 8mm ϕ @ 15cm spacing

$L = 2(a+b) + 2\times12\times d$

$a = 0.3 - 2\times0.05 \Rightarrow 0.25$

$b = 0.25 - 2\times0.05 = 0.15$

$L = 2(0.25 + 0.15) + 2\times12\times0.008$

$L = 0.992m$

$L = 2(a+b) + 2\times12d$

$a = 0.3 - 2\times0.05 =$

$b = 0.25 - 2\times0.05$

$= \frac{3.5+0.5-0.05}{0.15} + 1$

No. of ties $= \frac{3.5+0.5-\cancel{2\times}0.05}{0.15} + 1$

$\Rightarrow \frac{3.95}{0.15} + 1$

$\Rightarrow 27.33$ no.

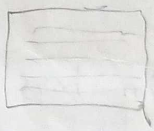
S.NO	~~Column~~ Member	Description of bar	Shape of bar	NO	Dia	Length	Total length	wt. in kgs	Total wt
1.	Column	V.Main bars	L	4	16mm	4.89	19.56	1.58	30.90kg.
		Lateral ties	□	27	8mm	0.992	26.784	0.39	10.445kg.
2)	Footing	HYSD bars	⟷	20	12mm	1.116	22.32	0.89	19.86kg.

Simply Supported Slab (one-way slab)

When $\frac{l}{b}$ ratio ie. long span to short span ratio is more than 2 the type of slab is called one-way slab. Otherwise $\frac{l}{b}$ ratio is less than (or) equal to 2 is called as two-way slab. Generally S.S. slab is supported on all four sides. Main steel is provided in shorter span direction with the designed spacing and alternatively bent up. Distribution steel is provided in the longer direction. All the bars are provided with end hook for M.S bars and Fe 415 HYSD bars - No end hooks are provided.

$\frac{L}{b} > 2$ - one way

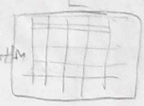
$\frac{L}{b} < 2$ Two way slab



Types of Bars

1) Usally bottom & top cover provided are 15mm end cover will be 25mm.

$L = C.S.S + 2 \times$ Support width $- 2 \times E + 2 \times H.A$

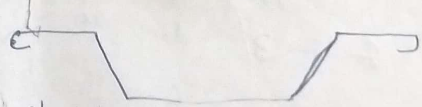


i) Straight Main Bars :-

Length of bar = (Clear S. span + 2 × Support width) − 2 × end cover of S.S + 2 × H.A

Total no. of bars = $\dfrac{\text{C. Long span} + 2 \times \text{end bearing} - 2 \times \text{E.C}}{2 \times \text{Spacing of bars}} + 1$

2) Bent up Main Bars



Total length = Length of straight bar (L) + 2.H.A + 2×B.A

where l = Clear short span + 2 × end Bearing − 2 × end co.
+ 2 × 9d + 2 × 0.42 D.

where D = Depth of slab − 2 × C.C − ~~2 × E.C~~ Dia. of bar.

$$\text{Total no. of bars} = \frac{C.L.S + 2 \times EB - 2 \times EC}{2 \times \text{Spacing}} + 1$$

3) Distribution Bars at the bottom :−

Total length = Clear L.S + 2 × B − 2 × E.C + 2 × 9d

$$\text{No. of bars} = \frac{C.L.S + 2 \times B - 2 \times E.C}{\text{Spacing}} + 1$$

4) Distribution bars at top (Anchor Bars) :− These are provided at top bent up practice of main steel. Usually 3 nos. in short span over distribution bars are provided.

Length = Length of D.B

Nos = 3 + 3 = 6.

Bar Bending schedule for next page problem

Main steel bottom		12	28	3.13	87.64	0.89/m	80.00 kg
Main bent up bar		12	27	3.18	85.86	0.89/m	76.42 kg
D.S (bottom)		6	20	6.52	130.4	0.22/m	28.69 kg
D.S (at top)		6	6	6.52	39.12	0.22/m	8.61
							193.72 kg

4. | Cost of steel & fabrication | Quantity as per drawing

Working out the quantities of steel and prepare bar bending schedule of steel for R.C.C one way slab S.S over walls. Shorter span = 2.5m, larger span = 6m, bearing of slab = 230 mm into the walls. Thickness of slab = 100mm. Take end cover = 25mm, bottom & top cover is 15mm. Main steel 12mm bars alternatively bent up at 120mm c/c. D. steel is 6mm dia and 160mm c/c at bottom and 3 nos at top ends of bent up main bars are bent at a distance of $\frac{l}{7}$ from face of wall. (11)

Sol:- Given S.S = 2.5m, L.S = 6m, Bearing of wall = 230mm

Thickness of slab = 100 mm, end cover = 25mm, T & B cover = 15 mm

Main steel = 12 mm ϕ, at 120 mm c/c

Dis. steel = 6 mm ϕ at 160 mm c/c

$\frac{l}{b} > 2$ (one-way slab)

$\Rightarrow \frac{6}{2.5} > 2$

$2.4 > 2$ (one-way slab)

1) Length of Main straight bar:-

Total length (L) = straight length(l) + 2·HA.

$l = C.S.S + 2\times B - 2\times E.C.$

$= 2500 + 2\times 230 - 2\times 25$

$l = 2910mm$

$L = 2910 + 2\times 9\times 12 \Rightarrow 3126mm = 3.126m$

No. of main bars $= \frac{C.L.S + 2\times B - 2\times E.C}{2\times \text{spacing}} + 1$

$\Rightarrow \frac{6000 + 2\times 230 - 2\times 25}{2\times 120} + 1$

$\Rightarrow 27.7$

$\Rightarrow$ 28 nos.

2) <u>Length of bent up bars</u>

$L = l + 2\times 9d + 2\times 0.42D$

D = Depth of slab − 2× covers − Dia. of bent up

$= 100 - 2\times 15 - 12 \Rightarrow 58mm$

$L = 2910 + 2\times 9\times 12 + 2\times 0.42\times 58$

$\Rightarrow 3174.72mm$

$L = 3.17mt$

No. of bars $= \dfrac{6000 + 2\times 230 - 2\times 25}{2\times 120} + 1$

$= 27.7$

$= 28$ nos.

3) <u>Distribution Bars at bottom</u>

Total length $(L) = 6000 + 2\times 230 - 2\times 25 + 2\times 9\times 6$

$\Rightarrow 6518mm$

$\Rightarrow 6.52mt$.

No. of bars $= \dfrac{2500 + 2\times 230 - 2\times 25}{160} + 1$

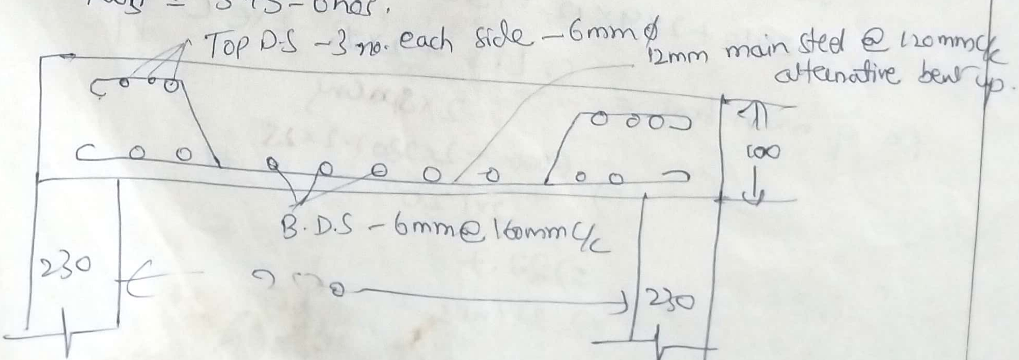
$\Rightarrow 19.18$

$\Rightarrow 19$ nos.

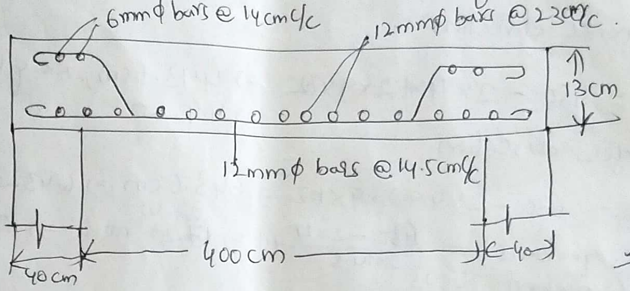
4) <u>Top Distribution Bars</u>

$L = 6.52mt$

Nos $= 3 + 3 = 6$ nos.



The section along the shorter span of room of size 4×5.5m (internal dimensions) is shown in the fig. The (12) thickness of slab is 13 cm. Thickness of wall is 40 cm.



Two-way slab

$\frac{l}{b} < 2$

$\frac{5.5}{4} < 2$

$1.375 < 2$

∴ It is Two-way slab.

Fig. Showing section of Room slab along shorter span.

Prepare bar bending schedule of the R.C.C slab. Assume any dimensions not given in the fig.

Sol:- Given. Internal dimension of room = 4×5.5m

Thickness of slab t_s = 13cm

Thickness of wall, t_w = 40cm.

(∵ In two-way slab Main steel & D.S are provided in both longer & shorter span)

An end cover of 4cm is adopted, top & bottom covers of 1.2cm of bars is equal to 1.2cm width of slab = 400 + 2×40 = 480cm.

Calculation of length of Bars :-

1) Length of main bar in shorter direction = Width of slab − 2×E.C + 2×H.A.

2) Length of main bars in Longer direction = Length of slab − 2×E.C + 2×H.A

3) Length of Distribution bar in shorter direction = Width of slab − 2×E.C + 2×H.A

4) Length of D.S in longer direction = Length of slab − 2×E.C + 2×H.A

5) Length of cranked bars in S.D = (Width of slab − 2×E.C + 2×H.A + 2×0.42D.

6) Length of cranked bars in L.D = Length of slab − 2×E.C + 2×H.A + 2×0.42D

∴ Length of slab = 550 + 2×40 ⇒ 630 cm

1) Main bars of 12mm ϕ.

In shorter direction -

$L = 480 - 2\times4 + 2\times9\times1.2 \Rightarrow 493.6\text{cm} \Rightarrow 4.93\text{m}$, No. of bars = $\frac{480-2\times4}{2\times14.5} + 1 \Rightarrow 17.27 \Rightarrow 17$ nos

In longer direction

$L = 630 - 2\times4 + 2\times9\times1.2 \Rightarrow 643.6\text{ cm} \Rightarrow 6.43\text{m}$

No. of bars = $\frac{630-2\times4}{2\times14.5} + 1 \Rightarrow \cancel{17.27}\ 22.45$ nos. ⇒ 22 nos.

2) Main cranked bars

In shorter direction.

$L = 480 - 2\times4 + 2\times9\times1.2 + 2\times0.42D$

where $D = 13 - 2\times\underbrace{2}_{E.C} + \underbrace{1.2}_{\text{Dia. of bar}} \Rightarrow 9.4\text{cm}$

$= 480 - 2\times4 + 2\times9\times1.2 + 2\times0.42\times9.4$

$\Rightarrow 501.496\text{ cm} \Rightarrow 5.01\text{m}$

No. of bars = $\frac{480-2\times4}{2\times14.5} + 1 \Rightarrow 17$ nos.

In Longer span.

$L = 630 - 2\times4 + 2\times9\times1.2 + 2\times0.42\times9.4$

$L \Rightarrow 651.496\text{ cm} \Rightarrow 6.51\text{m}$

No. of bars = 22 no $\left(\frac{630-2\times4}{2\times14.5} + 1\right)$

3) Distribution Bars - 6mm ϕ.

In shorter direction:- $L = 480 - 2\times4 + 2\times9\times0.6 \Rightarrow 482.8\text{cm} \Rightarrow 4.82\text{m}$

No. of bars = $\frac{480-2\times4}{2\times14} + 1 \Rightarrow 16.85 \Rightarrow 17$ nos.

In Longer direction:- $L = 630 - 2\times4 + 2\times9\times0.6 \Rightarrow 632.8\text{cm} \Rightarrow 6.32\text{m}$

No. of bars = $\frac{630-2\times4}{2\times14} + 1 \Rightarrow 22.$

13

S.NO.	Description of bar	Shape of bar	Dia	NO	L	Total Length	Weight in kg/m	Total wt in kgs.
1)	Shorter span of main bar		12mm	17	4.93	83.81	0.89 kg/m	74.59
2)	Longer span of M. bar		12mm	22	6.43	141.46	0.89 kg/m	125.89
3)	Shorter span of Cranked bar		12mm	17	5.01	85.17	0.89	75.80
4)	Longer span of Cranked bar		12mm	22	6.51	143.22	0.89	127.46
5)	Shorter span of D. bars		6mm	17	4.82	81.94	0.22	18.02
6.	Longer span of D-bars		6mm	22	6.32	139.04	0.22	30.588
						Total wt.	=	452.348 kg

at the

Soln:

23/3/21

2P

4, 6, 11, 14, 16, 18, 21, 22, 24, 29, 33, 37, 38, 39

J.S.B

9