ROAD CONSTRUCTION 1

Road drainage system and Structures

Prepared by Eng Edson B. Rogasian

THE IMPORTANCE OF DRAINAGE AND THE CONTROL OF WATER Cont.

- A properly engineered drainage system is the means whereby water is controlled. Falling rain, runoff and rising ground water need to be disposed off as rapidly as possible to protect the road and its environment from damage, and its disposal has important environmental implications.
- Drainage of one sort or another is one of the most important factors controlling road performance and the construction of the drainage system is always a significant proportion of the cost of a road project.
- Drainage therefore needs to be considered during all stages of project development.

THE IMPORTANCE OF DRAINAGE AND THE CONTROL OF WATER

- Water is capable of causing considerable damage to a road.
- It has two principal effects.
  - First its presence weakens most road building materials, especially unbound materials including the subgrade, causing the road to deteriorate quickly.
  - Secondly, flowing water erodes materials and transports them to somewhere where they are not wanted thereby damaging not only their place of origin and their final resting place but also the route taken by the flow of the water.
  - In extreme cases, where water is not adequately controlled, it can cause landslides, wash away whole sections of road, and generally cause immense damage.

DRAINAGE SYSTEM

- Water contributes to the wear and damage of the road.
- The water can be in the form of ground water (inside the earth), surface water (ponds, streams), or rain (which will become surface water when it has reached and collected on the surface).
- Water can damage the road in two ways:
  - ✓ by washing away the soil (erosion or scouring) or
  - ✓ by making the road less strong to traffic (lowering the road bearing capacity).

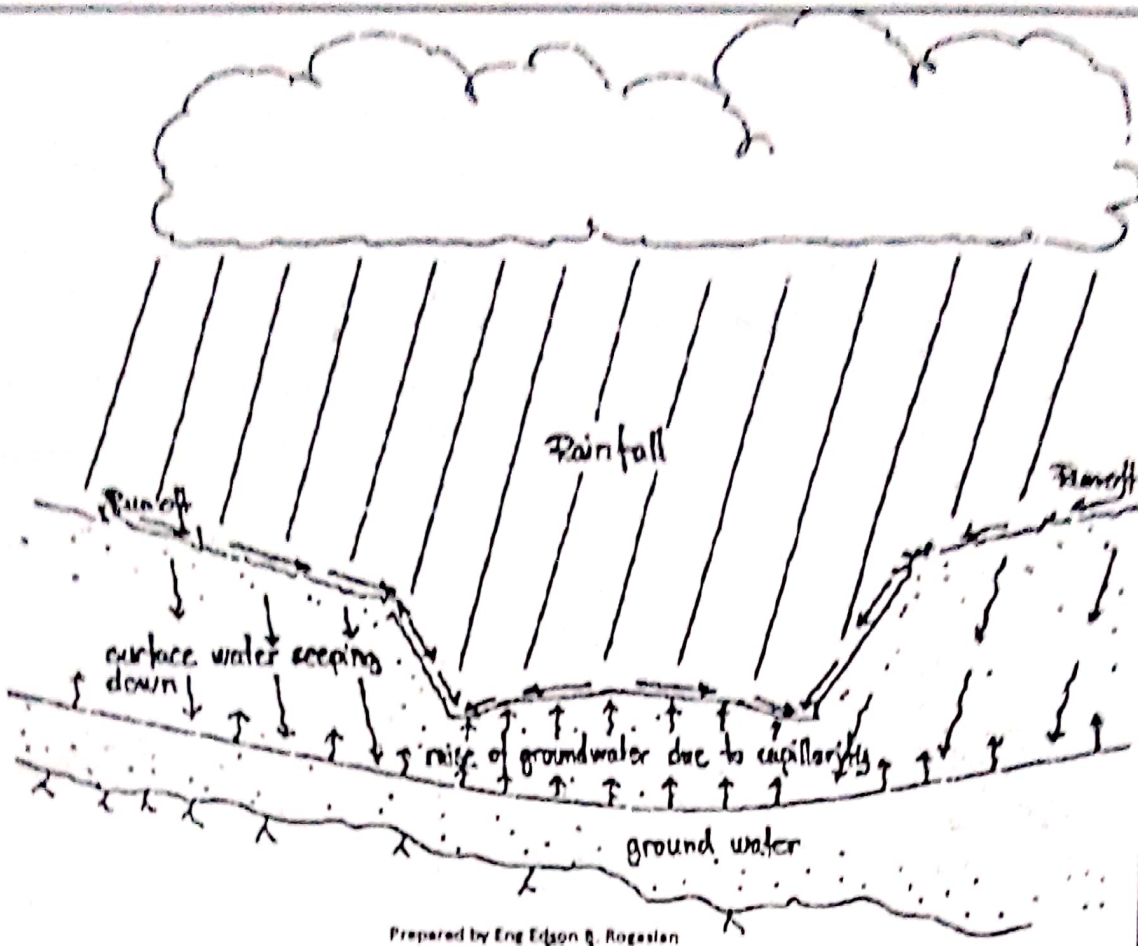

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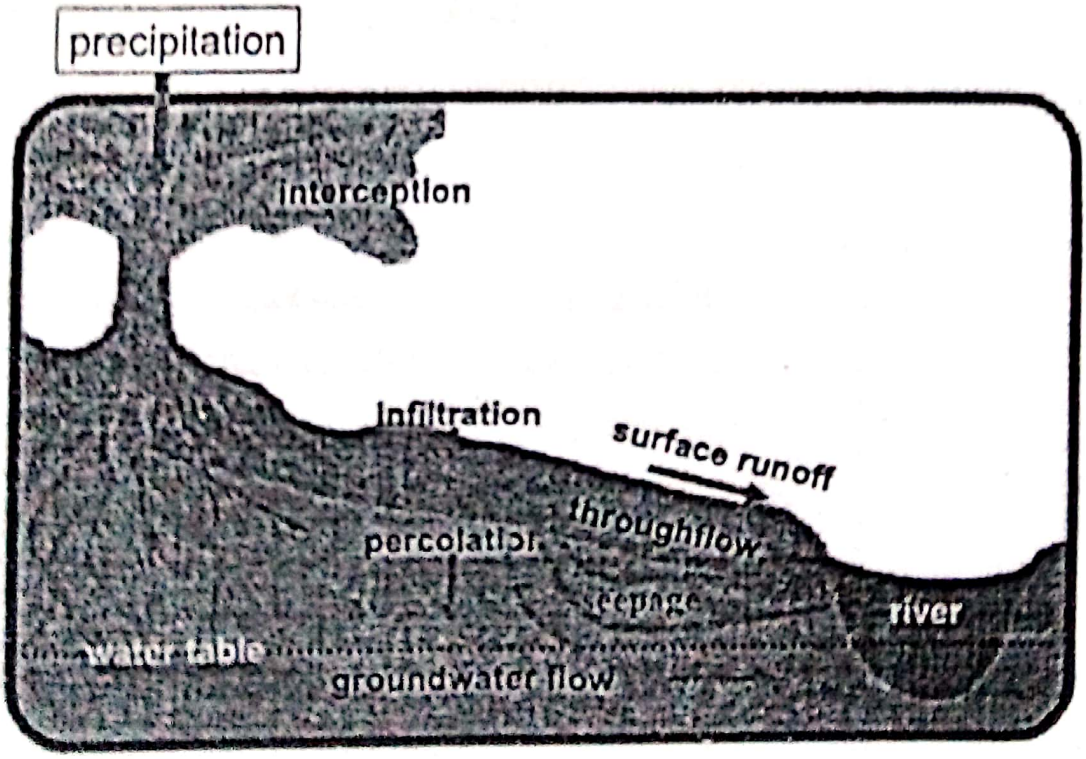
Fig 1



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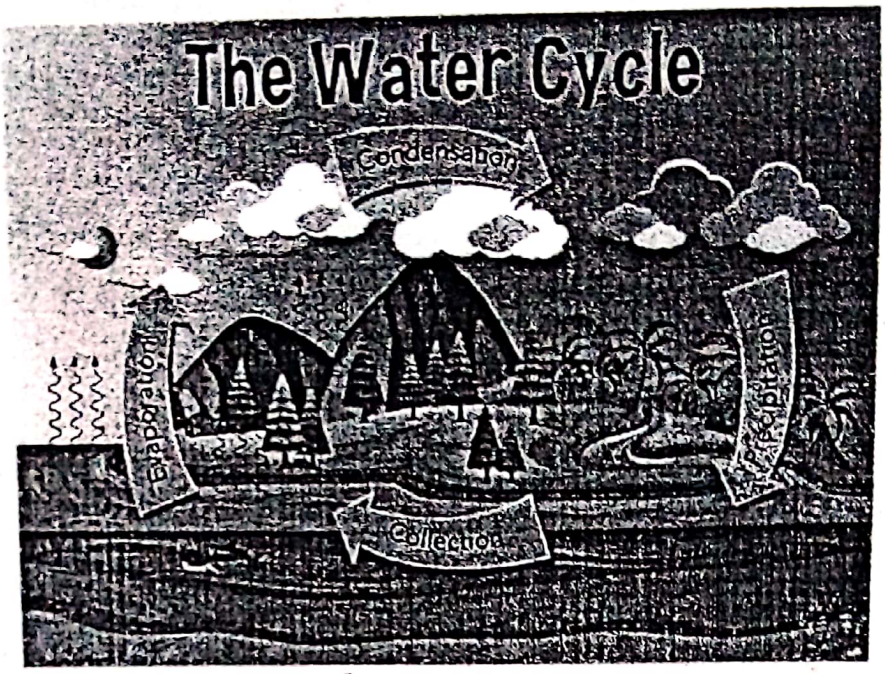
Water Cycle



GOOD DRAINAGE SYSYTEM

- It is therefore very important to have a good drainage system which allows for the water to flow off the road and away from it as quickly as possible. Such a system consists of several components:

✓ **Road surface drainage** which makes the water flow off the road surface;

✓ **side drains, urban drains and mitre drains** which lead the water away;

✓ **catchwater drains** which catch the surface water before it reaches the road;

✓ **scour checks** which prevent erosion in the ditches by slowing down the water;

- ✓ **culverts** which will lead the water in the side drains under the road to the other side;
- ✓ **drift/ford** which substitute culverts in case of shallow water levels and low traffic volume
- ✓ **Water-table drainage** which will lower the level of underground water or prevent capillary rise

All these drains have to work together if the results are to be good and it is the construction supervisor, who have to set out, instruct labourers, control and decide if the drainage system is correct.

DRAINS

Side Drains

- Side drains carry water parallel to the road to a mitre drain, water course or water crossing where it can be disposed off.
- They also help to lower the water table.
- Side drains should be large enough to carry all the carriageway water or the run off.

ROAD SURFACE DRAINAGE (CAMBER)

- The purpose of the road surface drainage is to **prevent water** from eroding the road surface or **penetrating into the road.**
- In order to avoid such damage, it is necessary to lead the water away quickly and this is achieved by shaping the road so that the water will flow freely into the side drains. It is of course important that the surface of the roads is free from holes or ruts in which water could be trapped.

Camber

- The camber is the slope from either side of the centre-line towards the sides. For earth and gravel roads this slope should be 4 per cent to 6 per cent.

Side Drains Cont.

- Increasing the width of side drains allows water to flow more slowly with less risk of erosion. Side drains should not be deep and steep-sided because this can be dangerous to vehicles leaving the carriage way, whether deliberately or accidentally.

Side Drains Cont.

- It may be necessary to reinforce the slopes of the side drain if run-off enters the drain at high speed.
- The inside slope is also prone to erosion by water flowing from the carriageway and should be either protected with vegetation or very well compacted.

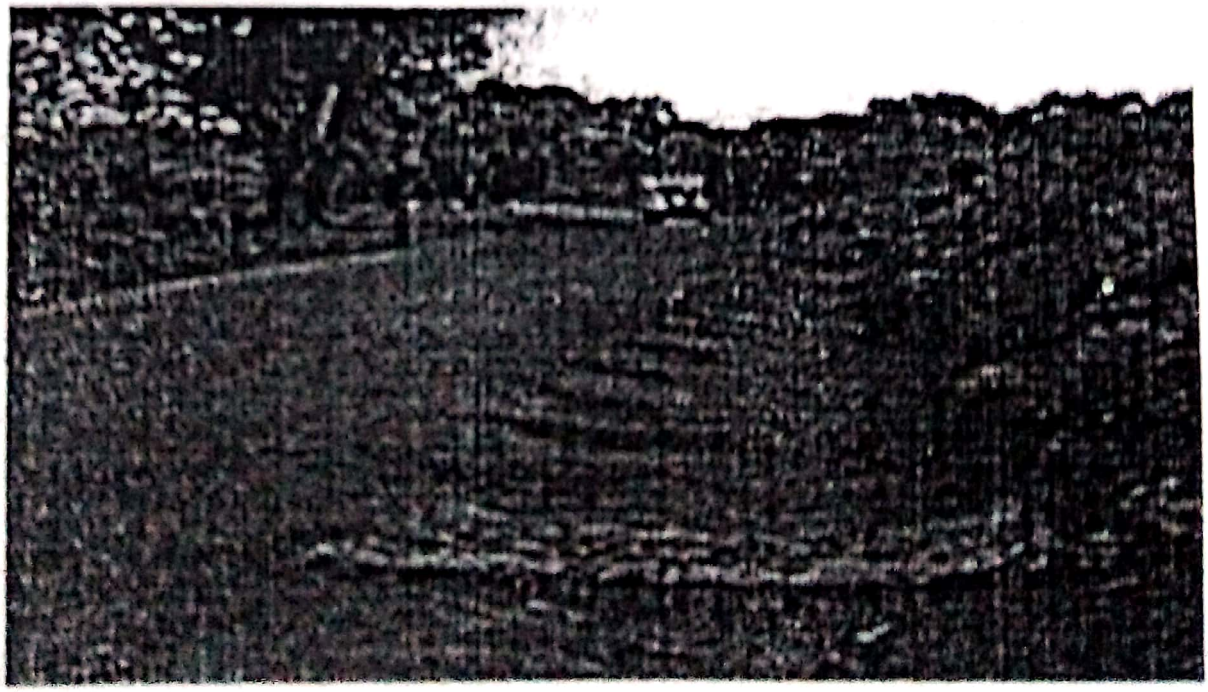
Side Drains Cont.

- Erosion in steep side drains can be reduced by constructing a non- erodible drain lining or by reducing water speeds with masonry, concrete, wood, turf or bamboo scour checks with a well-profiled upper edge and a non-erodible apron.
- The spacing of **scour checks** depends upon the erodibility of the soil, the width of the carriageway, the gradient of the drain and the rainfall intensity, typically ranging from 2 to 50 metres.

Side Drains Cont.

- If practical, side drains should have a minimum longitudinal gradient of 0.5 per cent to ensure that water continues to flow in the desired direction and to prevent sediment from being deposited.
- This can be achieved in flat terrain by excavating side drains of variable depth.

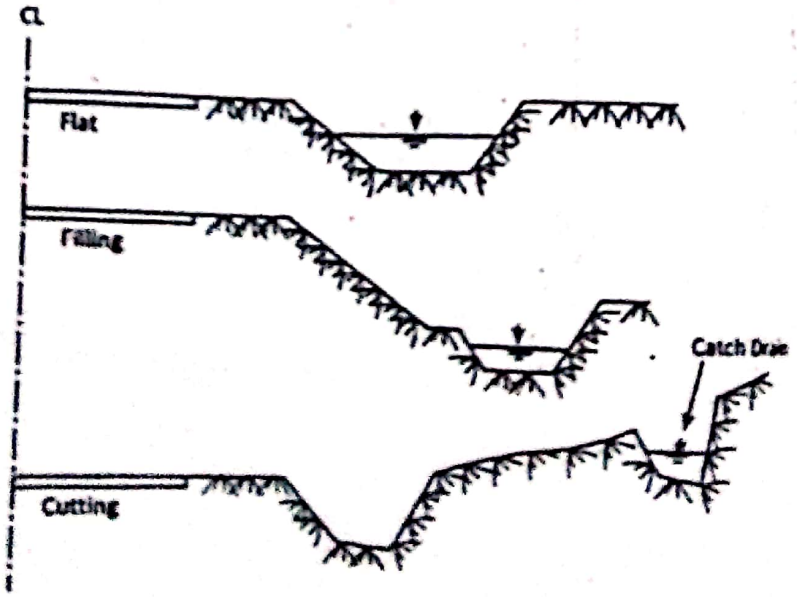
Side Drains Cont.



Side Drains Cont.

- The volume of water in a side drain can normally be reduced by excavating mitre drains, although this is difficult in side-long ground and impossible in a cutting. In such cases the side drains must be large enough for the increased water volume which will accumulate.

Side Drains Cont.



Side Drains Cont.

- Side drains may be 'V' or 'U' shaped. The former can be maintained by a grader; the latter can be maintained by a back hoe or by labour and the flat base is less likely to erode.

Classification of side drains

On the basis of the shape of the drain, it is classified as:

i. Rectangular
ii. Trapezoidal
iii. Triangular
iv. Semi-circular

Classification of side drains

On the basis of the finished surface, it is classified as:

i. Vegetation
ii. Un-lined
iii. Lined

Urban Drains

- Many urban roads have side drains below the carriageway and into which water flows through gully or kerb inlets at the edge of the carriageway or shoulder.
- It is important that there are sufficient inlets to drain the carriageway and prevent water ponding excessively on the carriageway or shoulder.

Factors which facilitate performance of side drain

a) Size of the drain
b) Shape of the drain
c) Slope of the drain
d) Catchment area
e) Presence of miter drain or diverting facility at the required interval
f) Lining consideration

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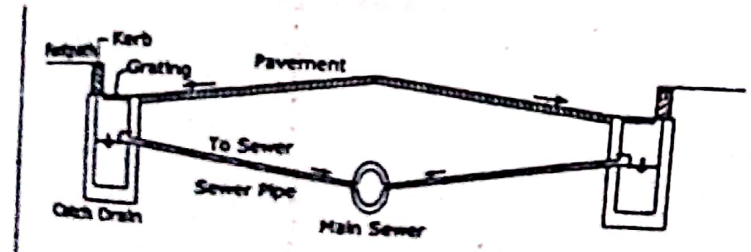
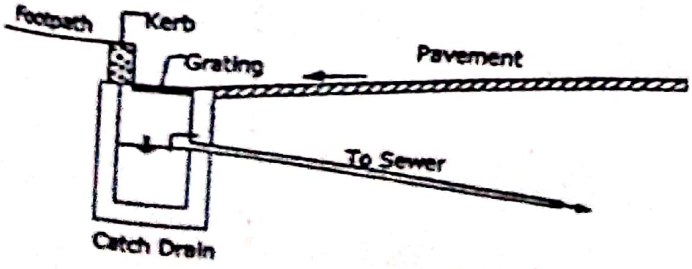
Urban Drains Cont.





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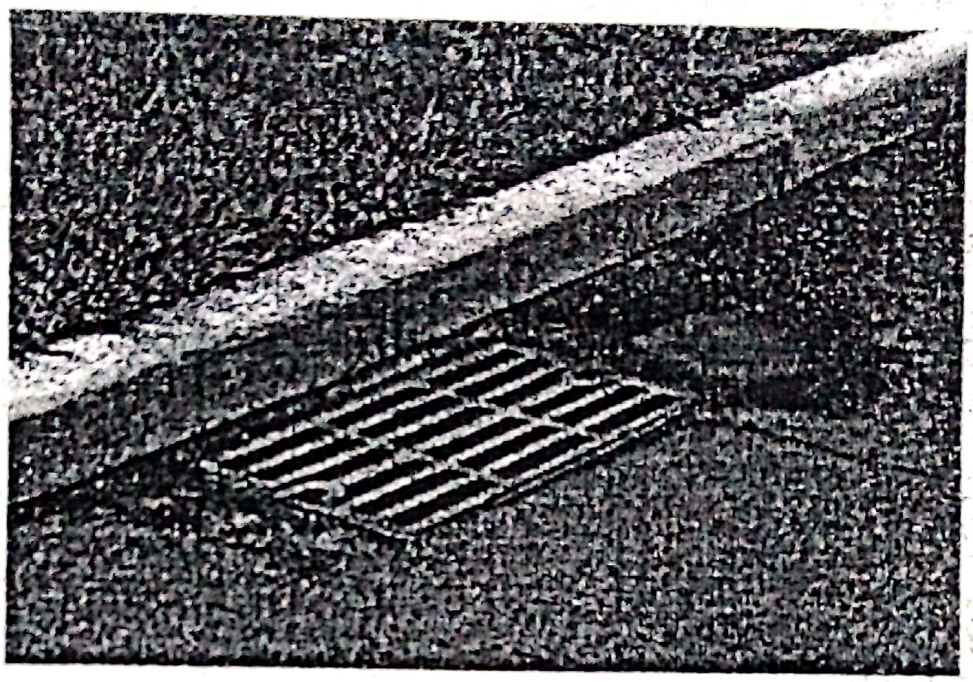

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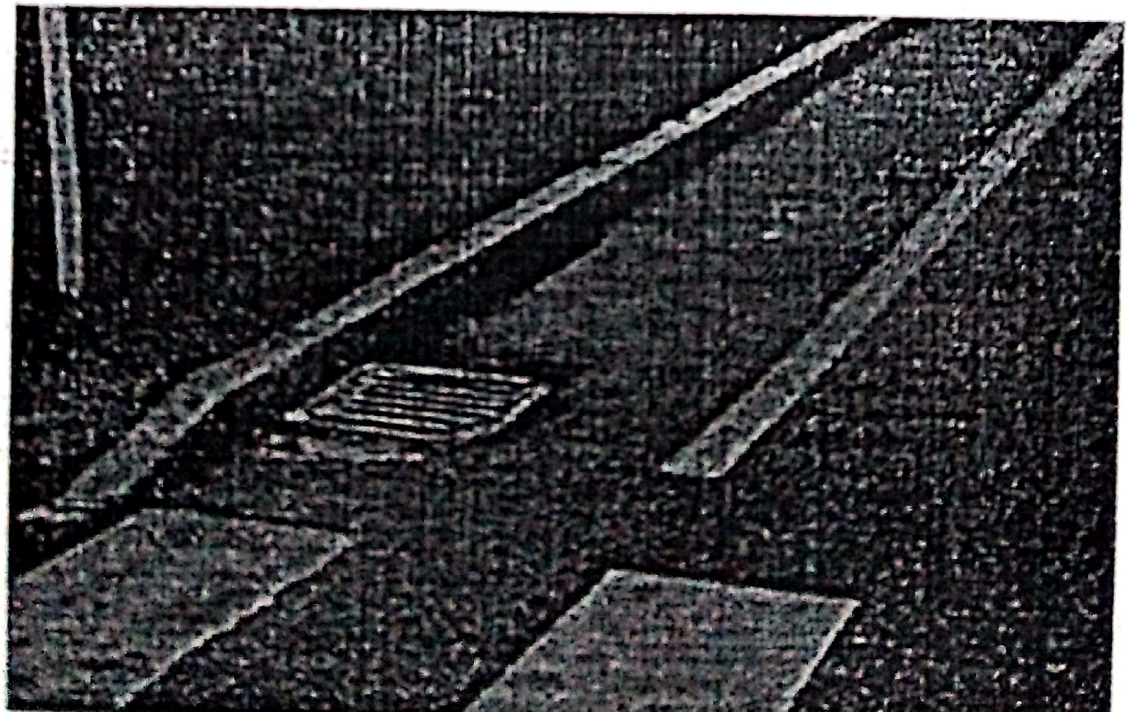

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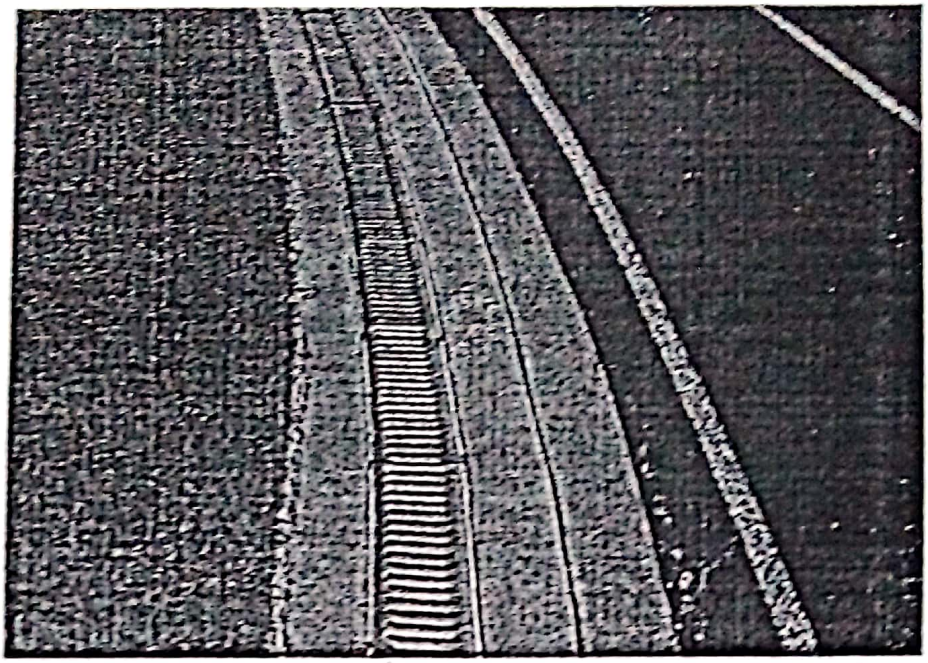


Mitre drains

- Mitre drains carry water from a side drain and dispose of it at a site away from the road where it will not flow back to the road or cause erosion.
- They are used to reduce the volume of water flowing in the side drain. It is often difficult to set out a mitre drain on the uphill side on side-long ground.

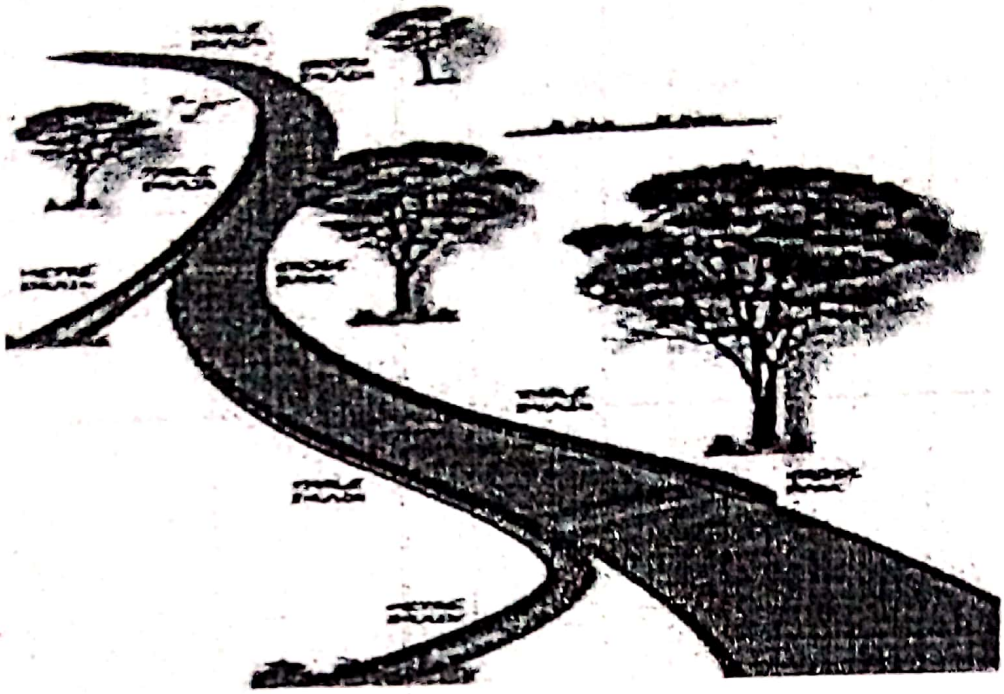
Mitre drains Cont.

- The spacing of mitre drains depends upon the **erodibility of the soil, the width of the carriageway, the gradient of the drain** and **the rainfall intensity,** typically ranging from 5 to 50 metres.

Cut-off drains (interception ditches)

- Interception ditches (or cut-off drains) are excavated approximately parallel to the road and on the uphill side on side-long ground or near the top of cut slopes.
- **Their purpose is to trap run-off flowing over the ground (or in the top portion of the soil) and prevent it from compounding erosion and flow problems.**
- However, if interception ditches are not maintained properly, and this is highly likely since they cannot be seen clearly from the road and access to them may be difficult, they can be a source of serious weakness because they can allow water to permeate the soil at vulnerable places and cause landslides.

Mitre Drains



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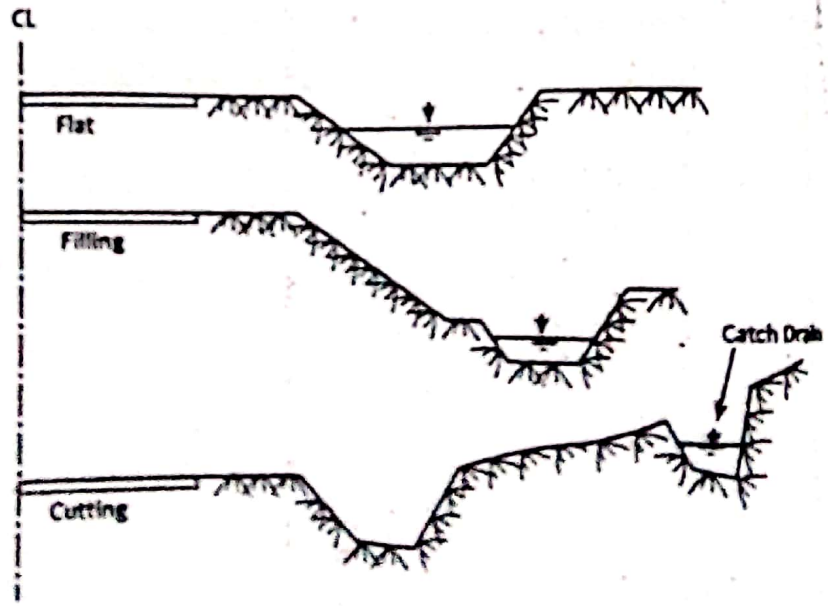
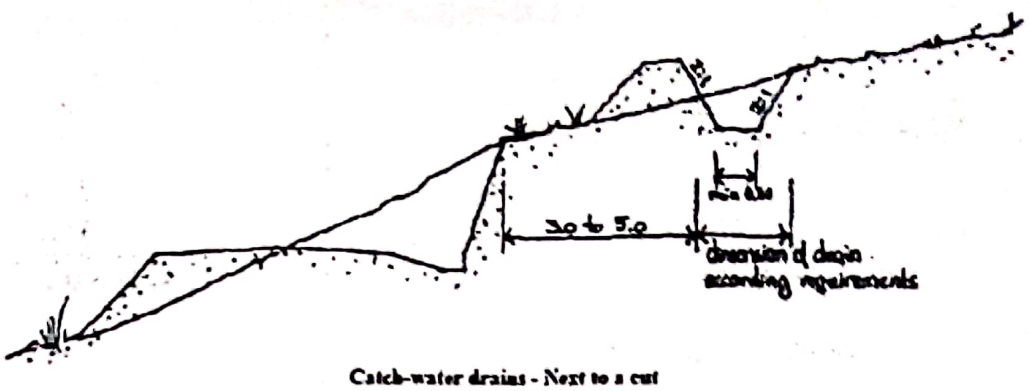
Cut-off drain in a cutting area





Catch-water drains - Next to a cut

Catch-water drains - Next to an embankment

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SEEPAGE FLOW

Flow of water through soils is called Seepage flow

Control of Seepage Flow

- When the general ground and impervious strata below are slopping, seepage flow is likely to exist. If the seepage zone is at depth less than 0.6 to 0.9 meter from the sub grade level, longitudinal pipe drain in trench filled with filler material and clay seal may be constructed to intercept the seepage flow.

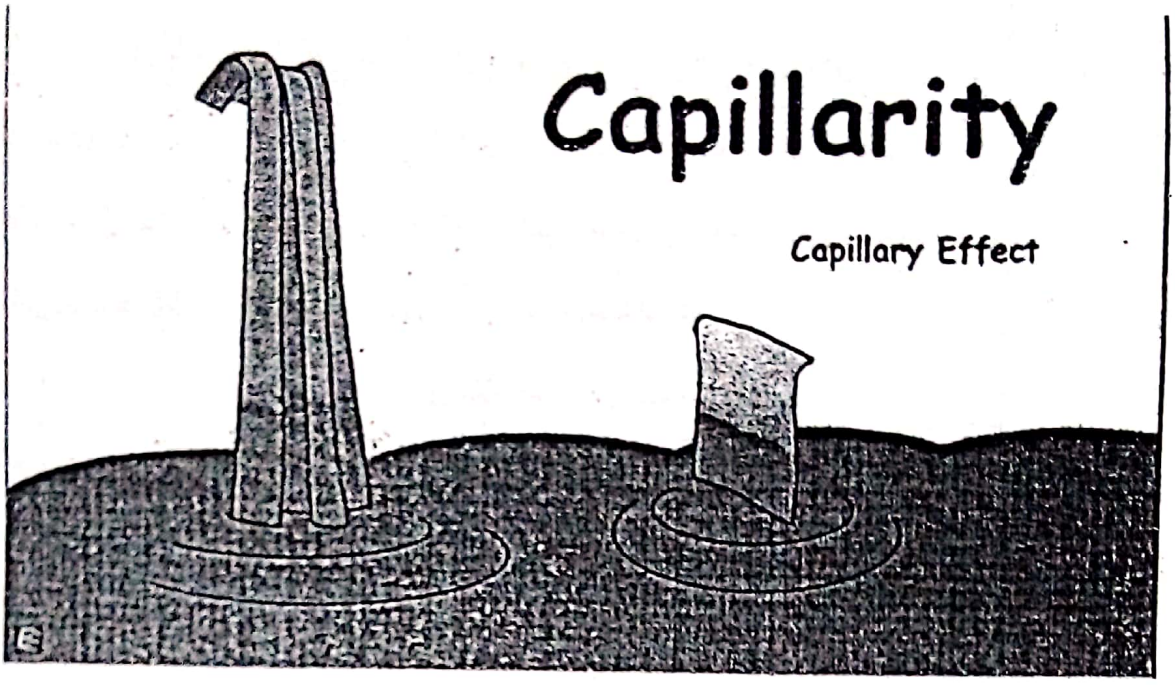
Sub-surface drains

Longitudinal and transverse sub-surface filter drains and pavement drainage blankets (i.e. **a permeable pavement layer designed primarily to allow water to flow freely through it and to stop capillary action)** can be used to reduce the level of the water table in the vicinity of the road. Since these can become blocked and cannot be inspected, it may be more practical to construct an embankment for the road or realign it away from areas of high water table.

Capillary Rise

- **DEFINITION:** A **rise** in a liquid above the level of zero pressure due to a net upward force produced by the attraction of the water molecules to a solid surface, e.g. glass, soil (for those cases where the adhesion of the liquid to the solid is greater than the cohesion of the liquid to itself)

Capillary Rise



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Control of Capillary Rise

a) A layer of granular material of suitable thickness is provided during the construction of embankment, between the sub grade and the highest level of sub surface water table.

b) Another method of providing capillary cut-off is by inserting an impermeable or Bituminous layer in the place of granular blanket.

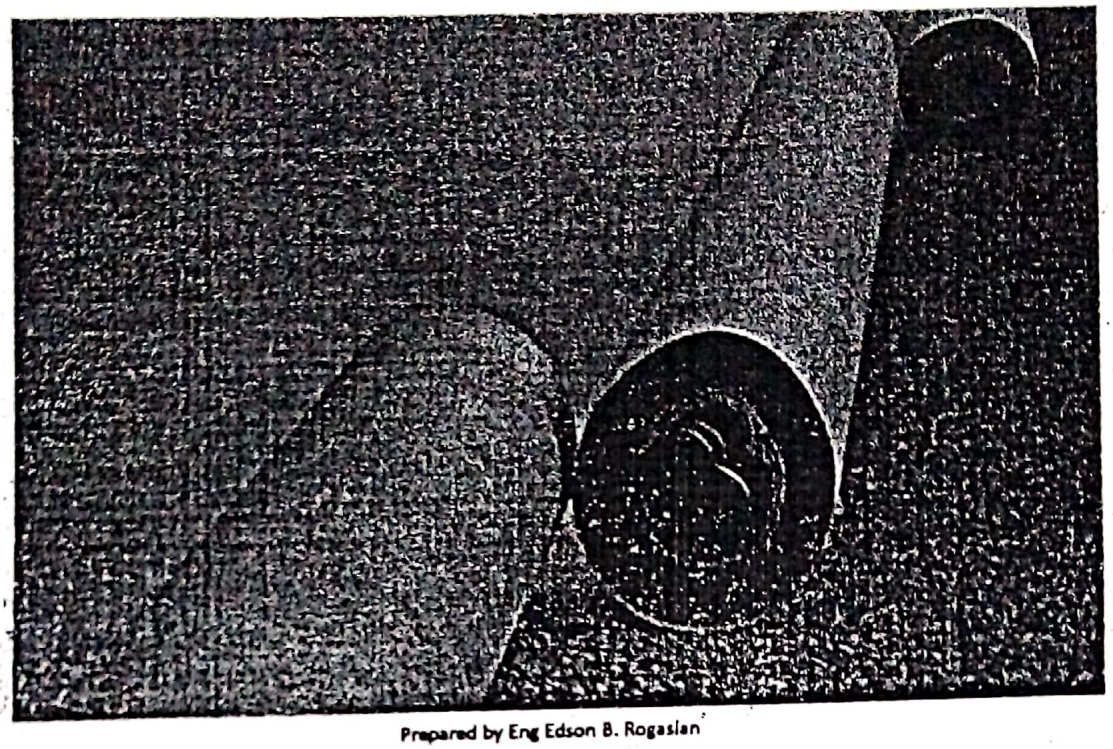
Control of Capillary Rise

If the water reaches the subgrade due to capillary rise is likely to be detrimental, it is possible to solve the problem by arresting the capillary rise instead of lowering the water table. The capillary rise may be checked either by capillary cut-off of any one of the following two types:-

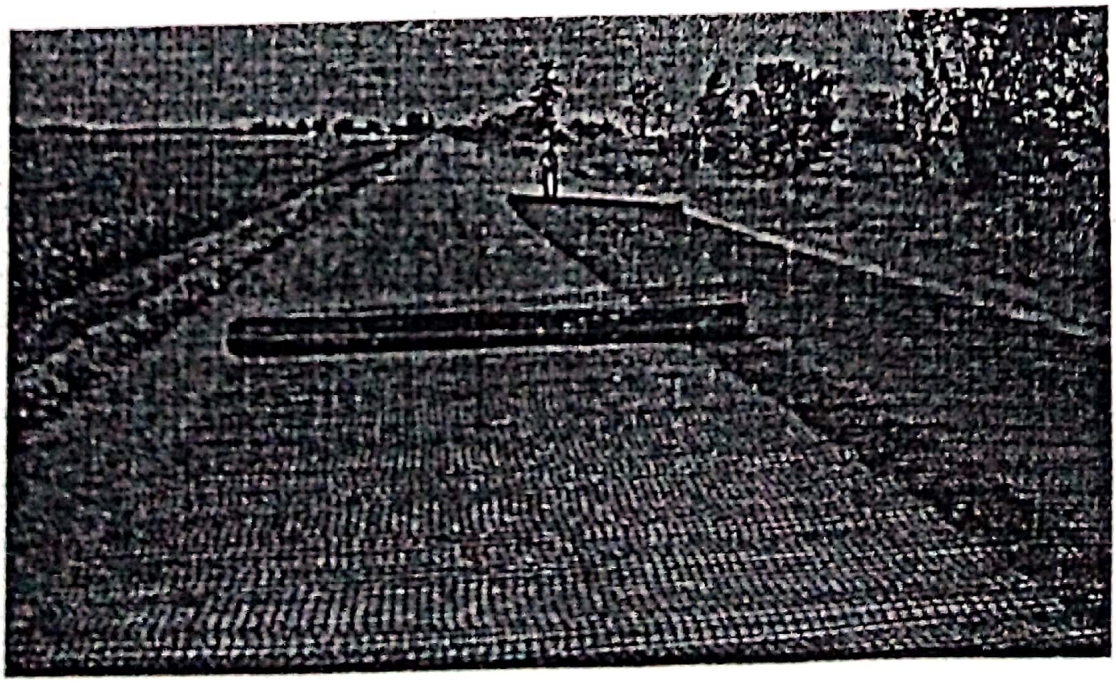
Geotextile separation layer

- In road construction, geotextiles have a very important function – **Separation.**
- ✓ It means geotextile will prevent the two adjacent soils intermixing together.
- ✓ Used between subgrade and stone base in unpaved and paved roads, geotextile separation layer will separate fine subgrade soil from the aggregates of the base course. The separation geotextile fabric preserves the drainage and the strength characteristics of the aggregate material.

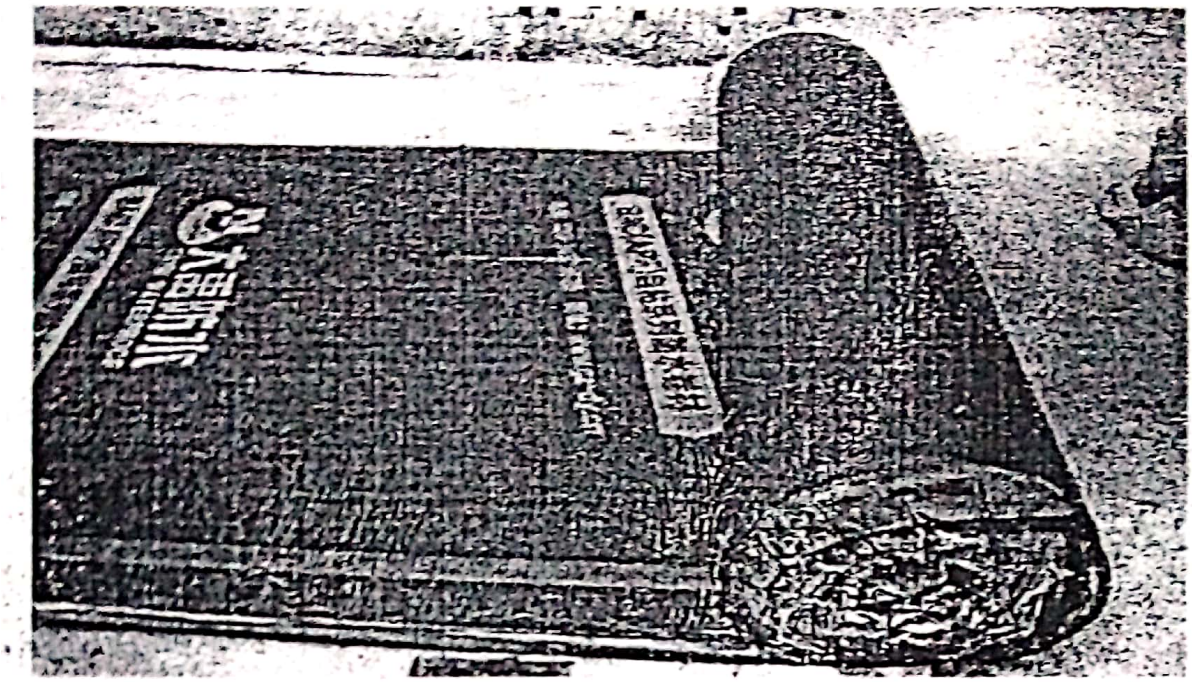
Geotextile separation layer



Geotextile separation layer



Geotextile separation layer



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Geotextile separation layer

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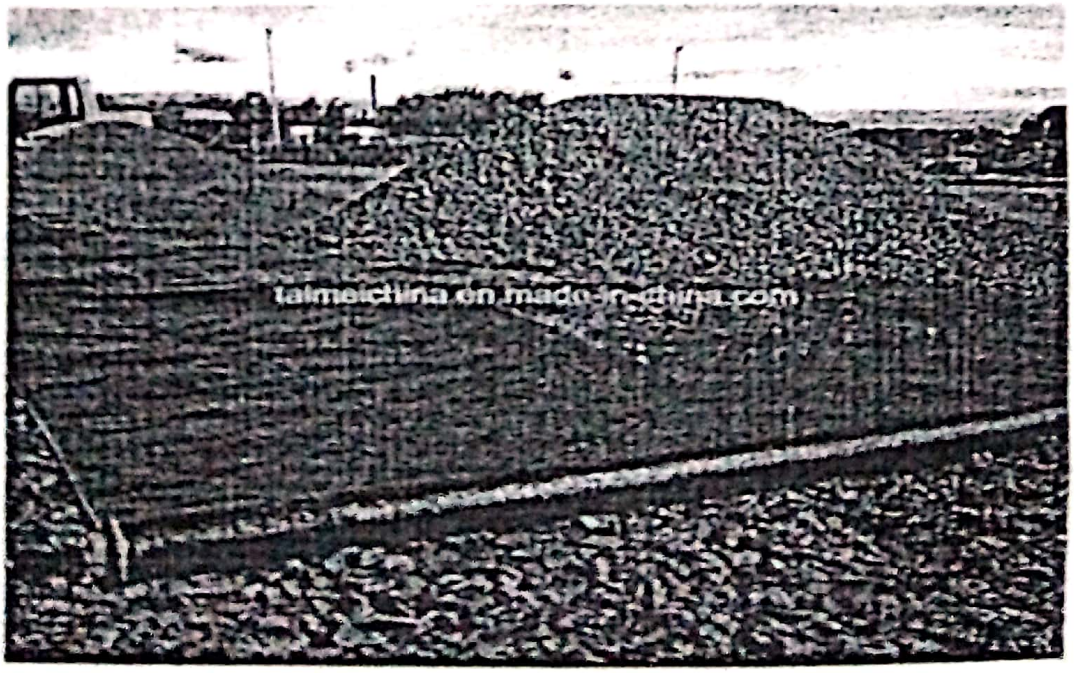
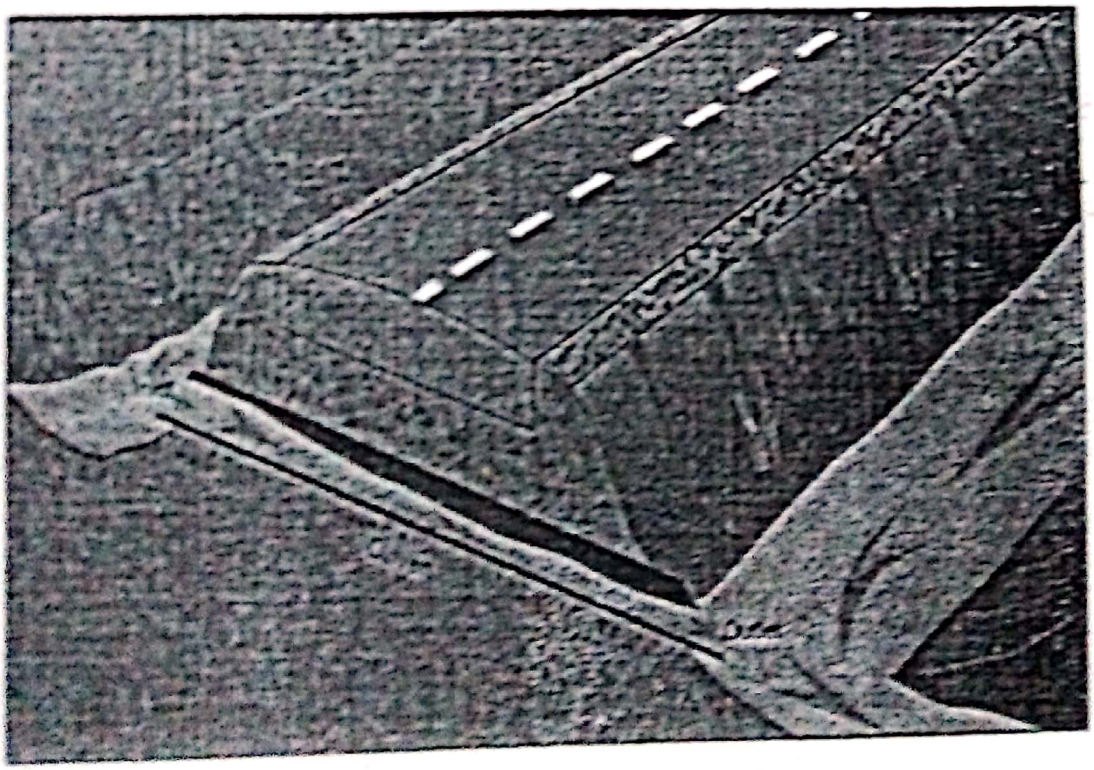


CROSS DRAIN STRUCTURE

- There are three common road cross drainage structures which are;
  - ✓ Culverts
  - ✓ Bridges
  - ✓ Drifts/ford
- Bridge and culverts are almost the same as they both carry water across the road under road structure.



Culverts

- Rural Culverts provide drainage under driveways, roads, slopes, and adjacent areas.
- Their grade and direction should conform as closely as possible to that of the water they are carrying. See figures below

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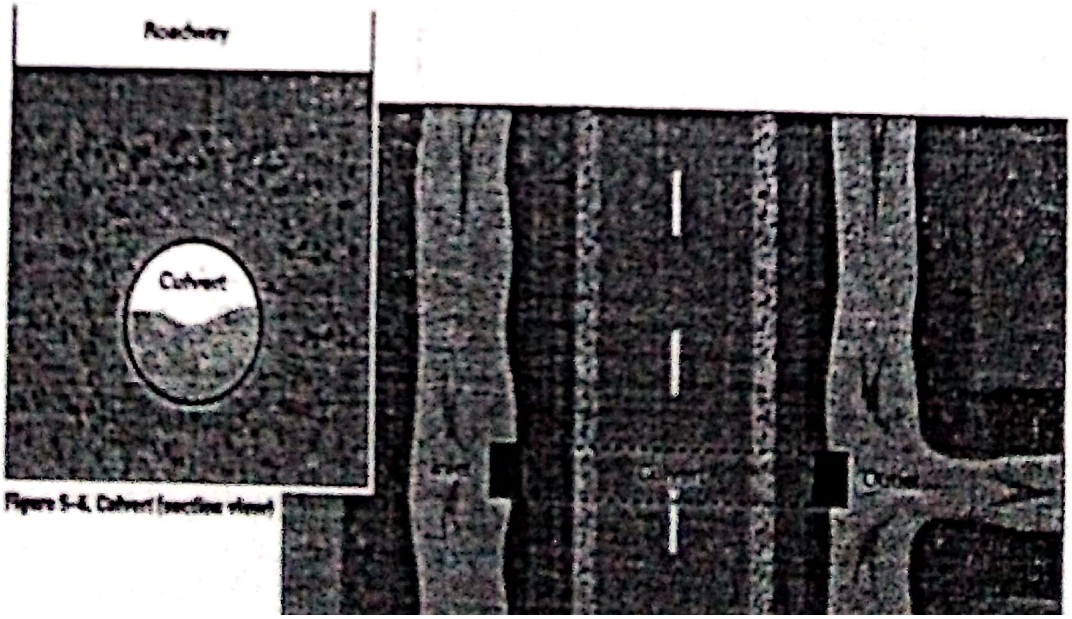


Figure 5-6. Culvert (section view)

- Culverts Pipes / culverts of 600mm in diameter are the recommended minimum size for road crossings, as smaller pipes than this block easily and are more difficult to clean. However, to use 600mm pipes the drains need to be deep, which is not always possible.
- The culverts should have headwalls to provide a visible indication of the edge of the road for vehicles and pedestrians.
- Pipes / culverts however should be avoided wherever possible due to the difficulty in their maintenance.

- Depending on the circumstances, instead of using large diameters which require a high fill over the pipes (overfill), two or more rows of a smaller dimension can be used.
- The spacing between the rows should be at least one diameter of the rings and one row could be placed lower than the others to accommodate small flows without silting.

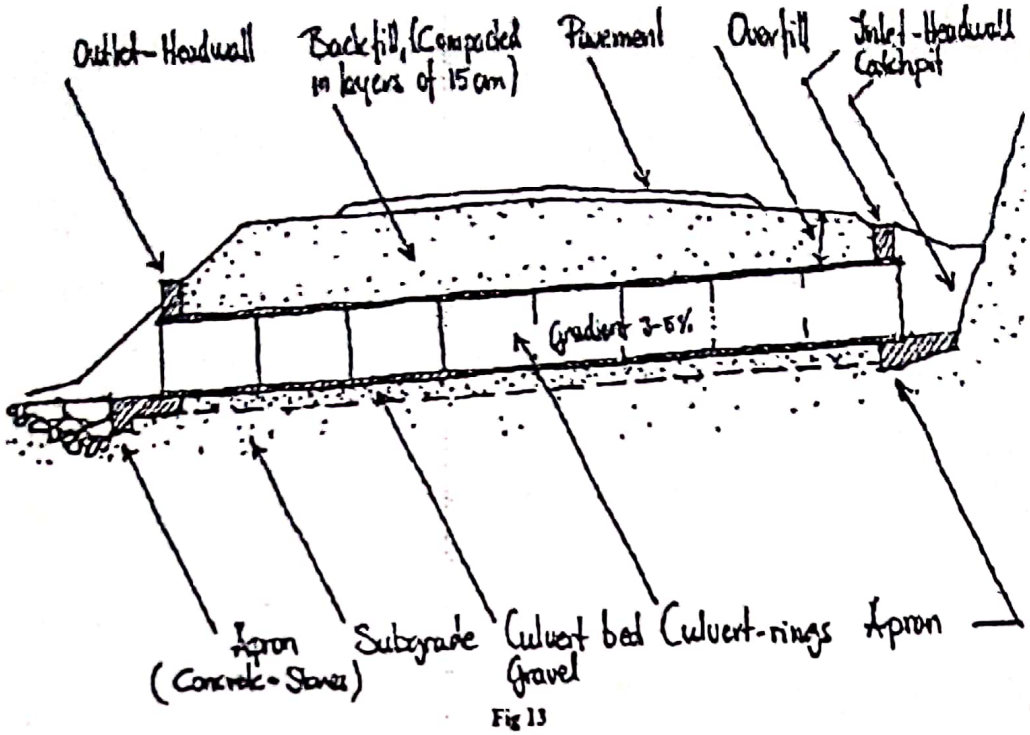


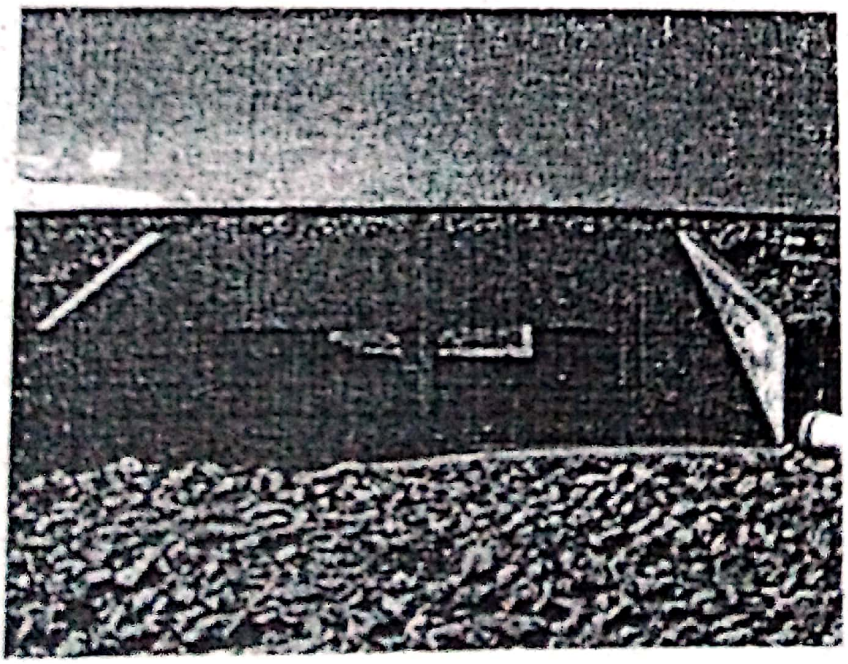
Fig 13

CULVERT BED

- The culvert bed has to be stable and at the correct level. Remove stones which might damage the pipes. If the natural material is not suitable, a bed of gravel should be made.
- The bed should be constructed to the correct gradient .A string, spirit level and folding ruler or measure tape can be used to set out the right gradient.
- The bed can, if the ground is swampy, be made "floating". Such a bed should be of at least two layers (of round timber minimum diameter 7 1/2 cm, each layer across the other). The width of the "floating" bed should be at least one and half times the diameter of the rings. The timber should be covered with a layer of 20 cm gravel.

APRON

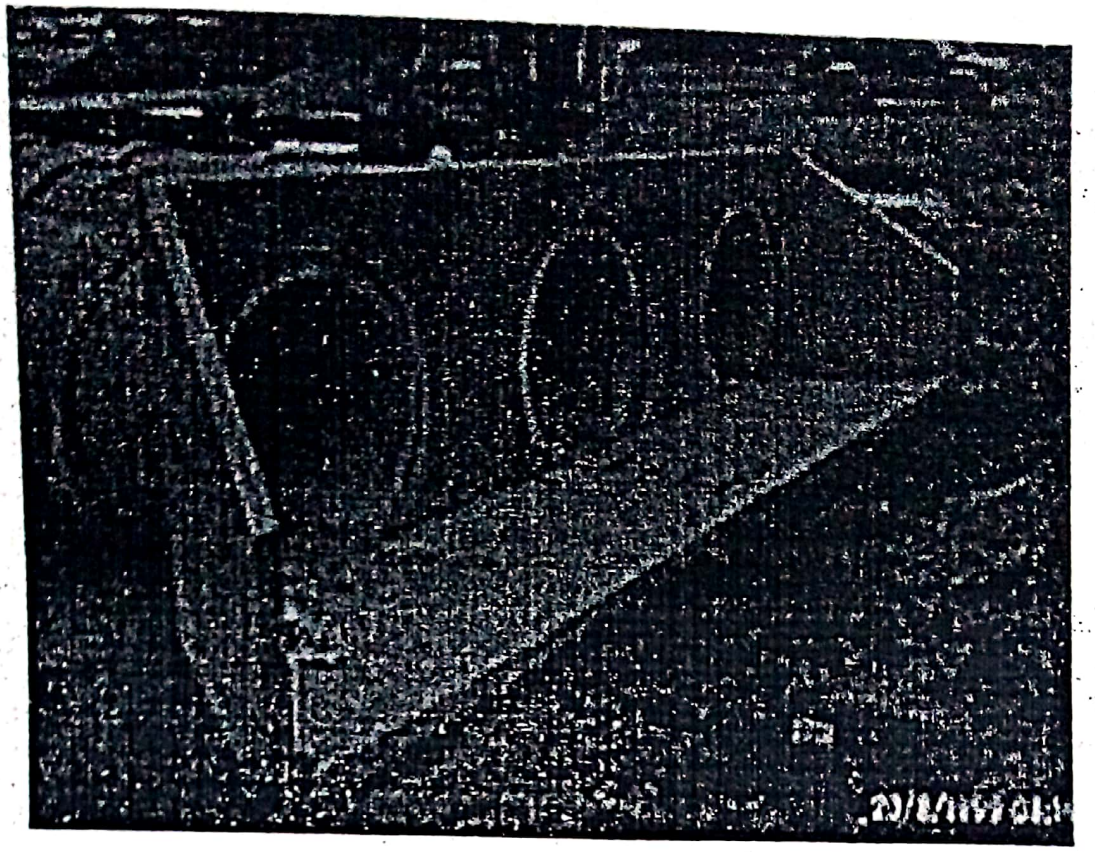
- Aprons should be constructed at the inlets and outlets to protect the culvert bed and the ditch bottom from erosion.
- They can be made of handpicked stones, masonry or concrete. Their length should be at least one and a half times the pipe diameter for inlet and twice the diameter for the outlet.



HEADWALLS

- The purpose of the headwalls is to support the road embankment and protect it from water damage.
- Headwalls or wingwalls also improve the flow of water into and out of conduits, provide anchoring support for the pipe and prevent dislodging under excessive pressures, control erosion and scour resulting from high water velocities and turbulences

- Headwalls should always be built parallel to the centre-line of the road in order to take the pressure from the traffic evenly.
- They can be built in handpicked stones, masonry or concrete. It is not always necessary to make headwalls and instructions to build them should come from the engineer who also would design them and specify materials.



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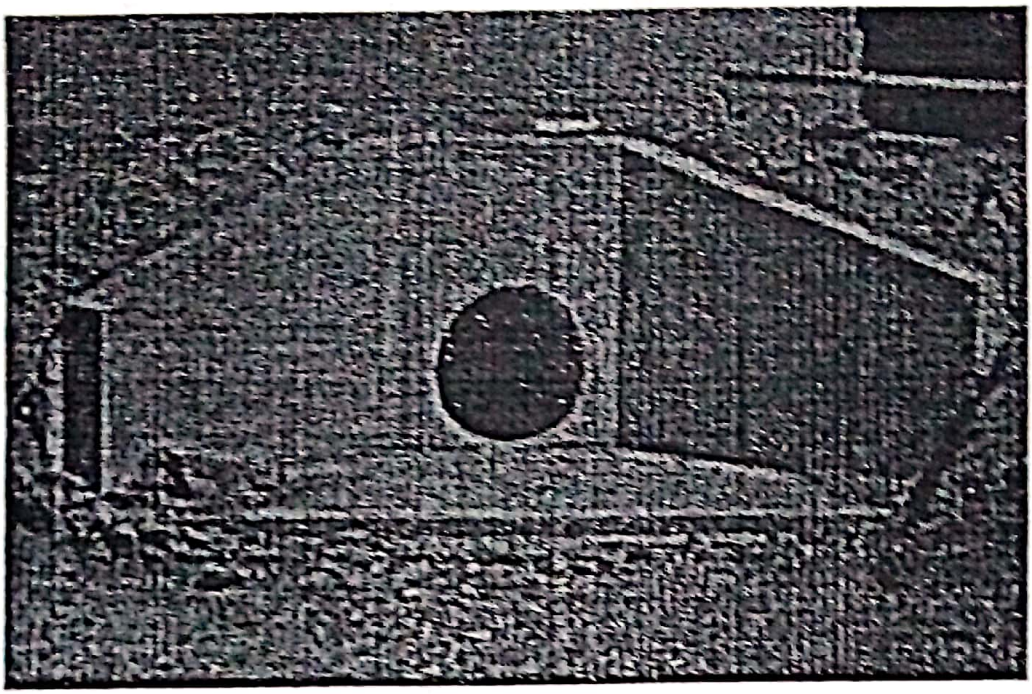
BACKFILL

- The backfill around the pipes has to be well compacted and should be made of gravel, sand or other suitable material (not expanding soils like "black cotton").
- The backfill has to be well compacted., using hand-rammers and watering. The minimum compacted thickness of the layer on top of the pipe, the overfill, should not be less than three-quarters of the diameter of the pipe.

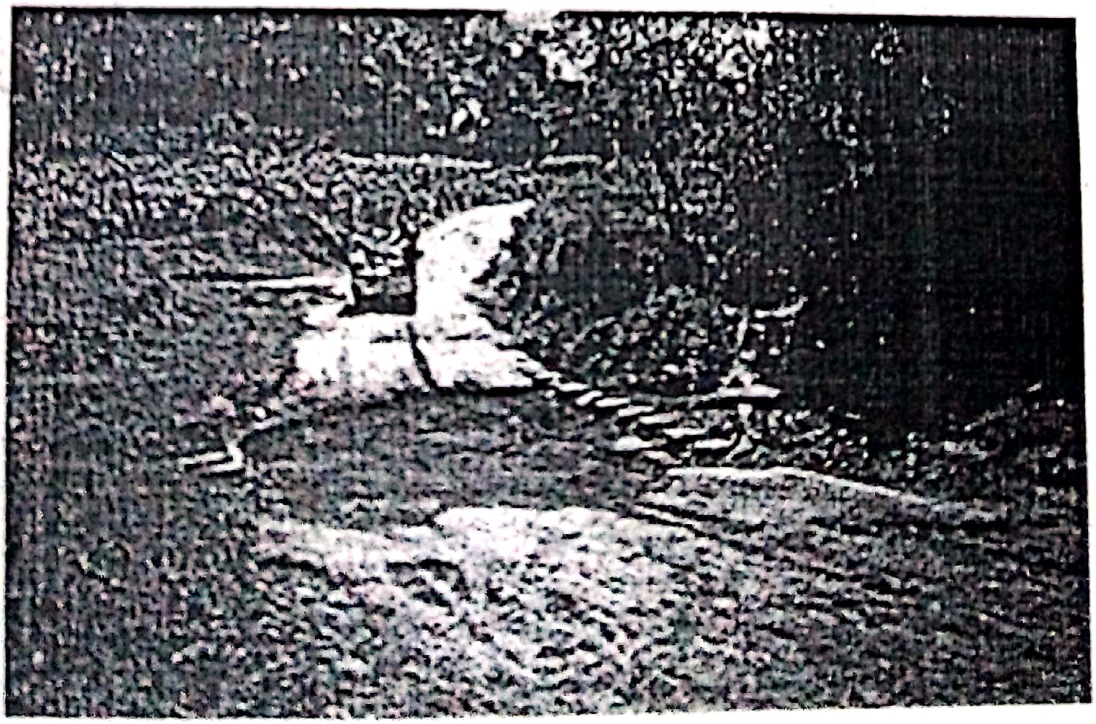


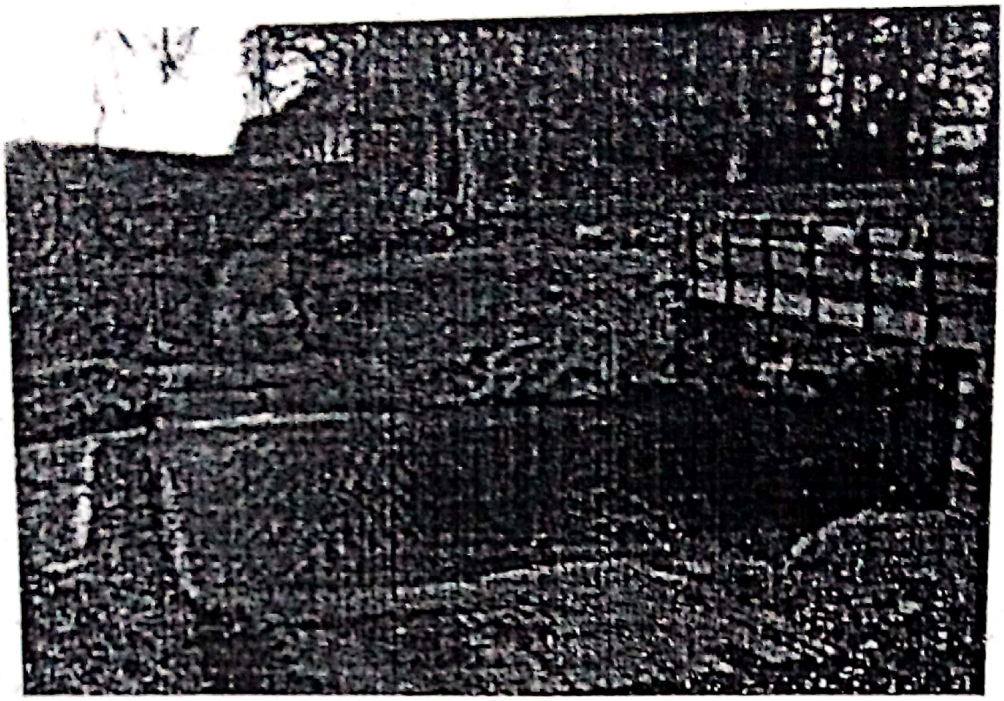
GRADIENTS

- The gradient of a culvert depends on the terrain situation but to prevent silting up and erosion, the gradient should normally be kept within 3 and 5 per cent.
- If the gradient exceeds 5 per cent, erosion at the outlet has to be prevented by an apron of stone or a paved waterway. Where possible the pipe inlet level should be at the same level as the original water course.

DRIFT/FORD

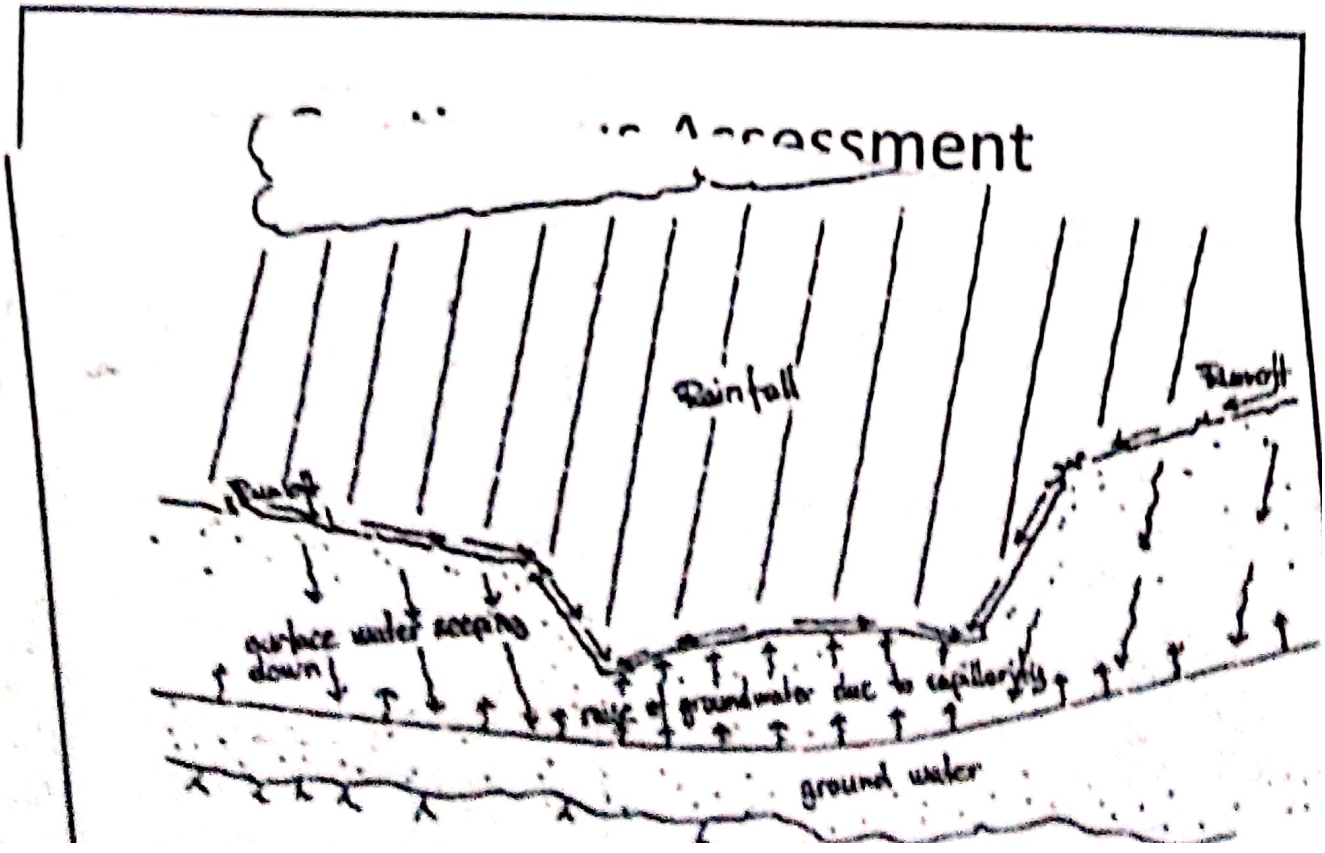
- A ford is a shallow place with good footing where a river or stream may be crossed by wading, or inside a vehicle getting its wheels wet.
- A ford is mostly a natural phenomenon, in contrast to a low water crossing, which is an artificial bridge that allows crossing a river or stream when water is low.
- A ford is a much cheaper form of river crossing than a bridge, but it may become impassable after heavy rain or during flood conditions.
- A ford is therefore normally only suitable for very minor roads (and for paths intended for walkers and horse riders etc.).
- Most modern fords are usually shallow enough to be crossed by cars and other wheeled or tracked vehicles (a process known as "fording").





- At places where the water is shallow enough, but the material on the riverbed will not support heavy vehicles, fords are sometimes improved by large stones, well graded road gravel and small chippings, or can have a surface of concrete with weld mesh or reinforcement bars on top of a stone foundation.
- In case of concrete slab a curb (kerb) is often placed on the downstream side to prevent vehicles slipping off, as growth of algae will often make the slab very slippery.

- The entrance and exit slopes of the road should have a maximum 5% slope to ensure that vehicles can pass over them easily without hitting the underside of the vehicle on the ground.
- Fords may be also equipped with a post indicating the water depth, so that users may know if the water is too deep to attempt to cross. Some have an adjacent footbridge so that pedestrians may cross without getting their feet wet.



- The most important design considerations for a drift/ford are:
  - ✓ There should be a fall across the drift and there should be a clear outlet for the water, so that the water will not stop and pond on the drift.
  - ✓ The base of the drift and the approaches should be firm enough that they will not deform significantly when there are vehicle movements when the ground is wet.