Highway Drainage : Chapter-6

Def:
Highway drainage is the process of removing & controlling excess surface & sub-surface soil water within the right of way.

→ The instalation of suitable surface & sub surface drainage system is an essential of highway design & construction.

Importance of Highway Drainage

An increase of moisture content causes decrease in strength or stability of a soil mass, the variation in soil strength with moisture content also depends on the soil type & the mode of stress application.
Highway drainage is important because of the following reasons.

→ Excess moisture in soil subgrade causes considerable lowering of its stability. The pavement is likely to fail due to subgrade failure.

→ Increase in moisture cause reduction in strength of many pavement materials like stabilized soil & water bound macadam.

→ One of the most important causes of pavement failure by the formation of waves & coagulations in flexible pavement is due to poor drainage.

-> Sustained contact of water with bituminous pavements causes failures due to stripping of bitumen from aggregates like becoming & deatchment of some of the bituminous pavement layers & formation of pot holes.

-> The preime causes of failures of rigid pavements by mud pumping is due to the prensence of water in fine subgrade soil.

-> Excess of water on shoulders & pavements edge causes considerable damage.

-> Excess moisture causes increases in weight & thus increases in stress & simultaneous reduction in strength of the soil mass.

-> In places where freezing tempretures are predent in water, the prense of the water in the sub-grade & a continous supply of water can cause considerable damage to the pavement due to frost activities.

Requirement of Highway Drainge System

-> The surface water from the carriageway & shoulder should efficiently be drained off without allowing to procolate to subgrade.

-> The surface water from the adjoining land should be prevented from entering the roadway.

-> The side drain should have sufficient capacity & longitudinal slope to carry away all the surface water collected.

-> Flow of surface water across the roads & shoulders along slopes act cause formation of cross ruts or erosion.

-> Seepage & other sources of under ground water should be drained off by the sub-surface drainge system.

-> In water logged areas special precautions should be taken, if detrimental salts are present or if flooding is likely to occour.

Surface Drainage

The surface water is to be collected & the disposed off. The water is first collected in longitudinal drains, generally in side drains & then the water is disposed off at the nearest stream, valley or water course.

-> Cross drainge structures like culverts & small bridges may be necessary for the disposal of surface from the road side drains.

Collection of Surface Water

The water from the pavement surface is removed by providing the camber or cross slope to the pavement.

The rate of this cross slope is decided based on type of pavement surface & amount rainfall.

Hydraulic Design

once the design rainoff 'Q' is determined, the next step is the hydraulic design of drains. The side drains & partially filled culverts are designed based on the principle of flow through open channels.

if 'Q' is the - Quantity surface water m^3/sec.

V - allowable velocity of flow m/sec.

'A' - Area of the cross section m^2

Found the relation.

$$Q = AV$$

The velocity of conlined channel must be high enough to prevent sidting & it should not be too high as to cause erosion.

The allowable velocity of flow depends on the soil type : for sand & silt is 0.3 & 0.5 m/s

By adjusting the value of slope S, It is possible to limit the velocity of flow. V within permissible Limit. Assuming uniform & steady flow through channel of uniform cross section & slope.

Manning's formula is used for determining the velocity of flow or the longitudinal slope which is given by

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

V = Avg. velocity, m/s

n = manning's roughness co-efficient

R = Hydraulic radius in m

S = longitudinal slope of channel.

the value of n = 0.02, whereas for earth with heavy vegetation or grass the value of n = 0.05 to 0.1. In lined channels, the roughness co-efficient depends on the type of lining.

The slope S of the longitudinal drain of a known or an assumed cross section & depth of flow, may be determined using Manning's Formula for the design values of velocity of flow V, roughness co-efficient n & hydraulic radious R.

Data for Drainage Design.

-> Total road of length & width of land from where water is expected to flow on the stretch on the side drain.

-> Run off co-efficients of different types of surface in the drainage area & their respective areas (such as paved area, road shoulder etc)

-> Distance from farthest point in the drainage are to the inlet of the side drain along the steepest gradient & the average value of slope.

-> Type of soil of the soil drain. Roughness co-efficient allowable velocity of flow in the drain.

-> Rain fall data including avrage intensity & frequency of recurrence of flood

Design step

-> The frequency of return period such as 10 yrs, 25 yrs etc. is decided based on finaces available & desired margin of safety, for the design of the drainage system.

-> The value of co-efficient of run-off C_1, C_2, C_3 etc. From drainage areas A_1, A_2, A_3 etc. are found and the weighted value of C is computed.

- Inlet time T_1 for the flow of storm water from the farthest point in the drainage area to the drain inlet along the steepest path of flow is estimated from the distance, slope of the ground & type of the cover.

- Time of flow along the longitudinal drain T_2 is determined for the estimated length of longitudinal drain L up to the nearest cross drainage or a water course, & for the allowable velocity of flow v in the drain i.e. $T_2 = L/v$

- The total time T for inlet flow & flow along the drain is taken as the time of concentration or the design value of rain fall duration $T = T_1 + T_2$.

- From the rain fall intensity-duration-frequency curves the rain fall intensity i is found in cm/sec. Corresponding to duration T & frequency of return period.

- The total area of drainage A_d is found in unit of $1000 m^2$.

- The run-off quantity Q is computed $= C i A_d$

- The cross sectional area of flow in the drain is calculated for a convienient bottom width & side slope of the drain. The actual depth of the open channel drain may be increased slightly to given a free board. The hydraulic mean radius of flow R is determined.

- The required longitudinal slope S of the drain is calculated by Manning's formula adopting suitable value of roughness co-efficient (n).

Sub-Surface Drainage

- Removal or Diversion of excess soil-water from sub-grade is termed as sub-surface drainage.
- The change in moisture of sub-grade are caused by the following
  - Fluctuations in Ground Water Table
  - Seepage Flow
  - Percolation Of Rain Water
  - Movement of Capillary Water
- In sub-surface drainage it is practiced to keep the variation of moisture in sub-grade to a minimum.

Lowering of Water Table

- In order to that the sub-grade and pavement are not subjected to excessive moisture the water table should kept at least 1.0 to 1.2 m below the sub-grade.
- In places where water table is high to take the road formation on embankment of height not less than 1.0-1.2m is the best approach.
- But When the formation level is at or below the general ground level it is necessary to lower the water table.

How to do Sub-Surface Drainage?

Lowering of Water Table

Controlling Seepage Flow

Controlling Capillary Water

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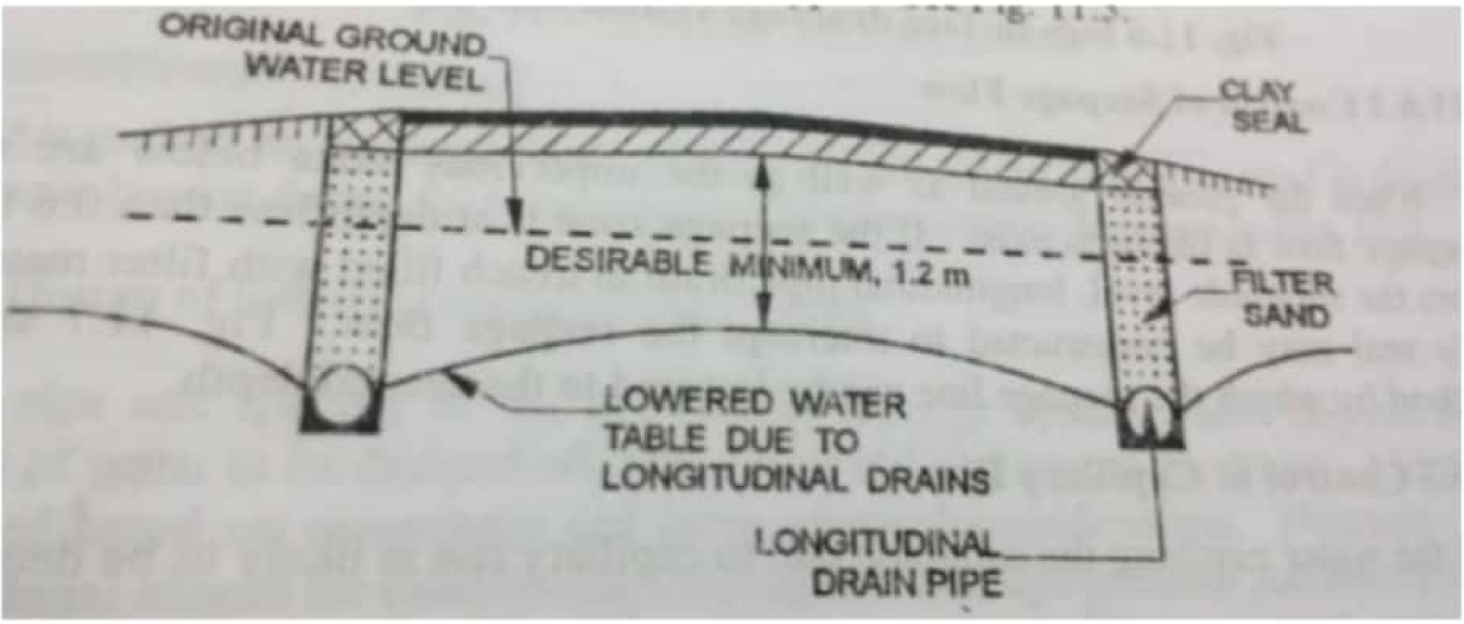
Lowering of high water table in permeable soils



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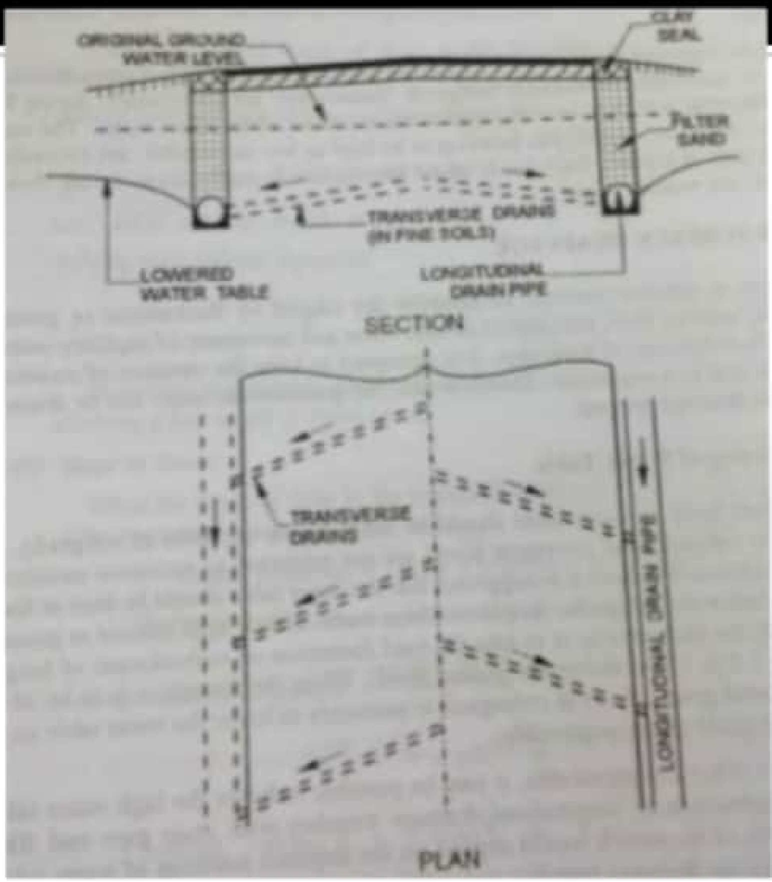
(b) If the soil is relatively less permeable, the lowering of ground WT may not be adequate. Hence in addition to the longitudinal drains traverse drains have to be installed at suitable intervals in effectively drain off the water.



Control of Seepage Flow

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

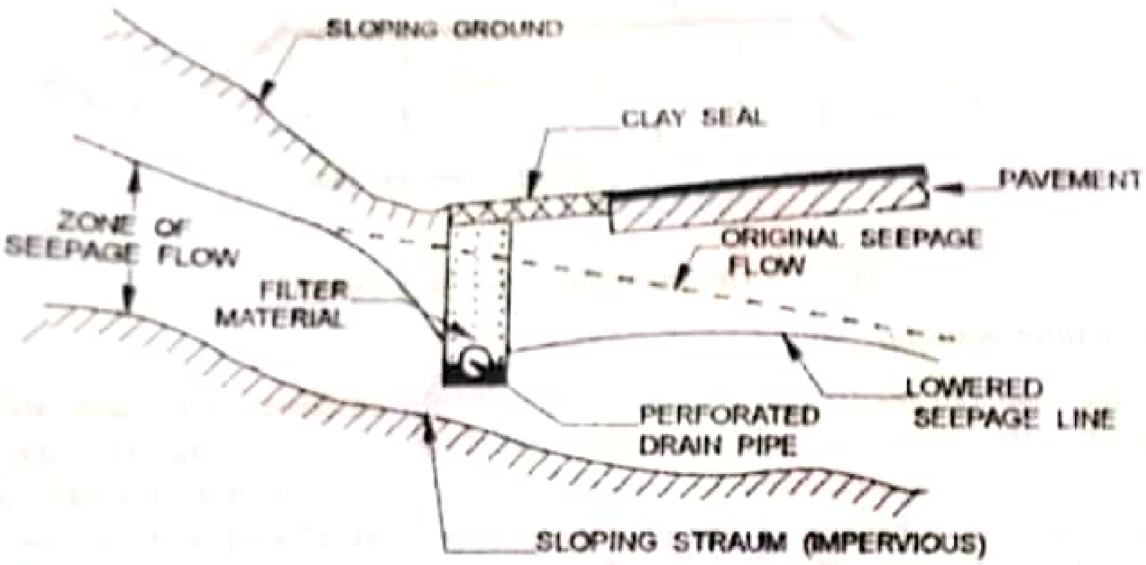


Fig. 11.7 Control of seepage flow

Control of Capillary Rise

- If the water reaching the sub-grade due to capillary rise is likely to be detrimental, it is possible to solve the problem by arresting the capillary rise.
- It can be done by following methods:
  (a) A layer of granular materials of suitable thickness is provided during the construction of embankment, between the sub-grade and the highest level of sub surface water table.
  (b) Alternate method is providing the capillary cut off is by inserting an impermeable or a bituminous layer in place of granular blanket.

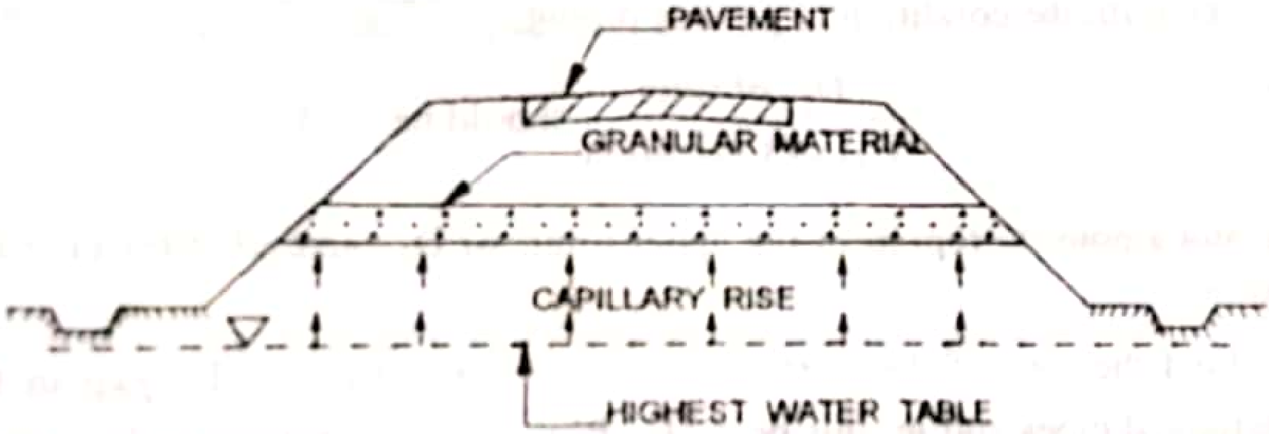


Fig. 11.8 Granular capillary cut-off

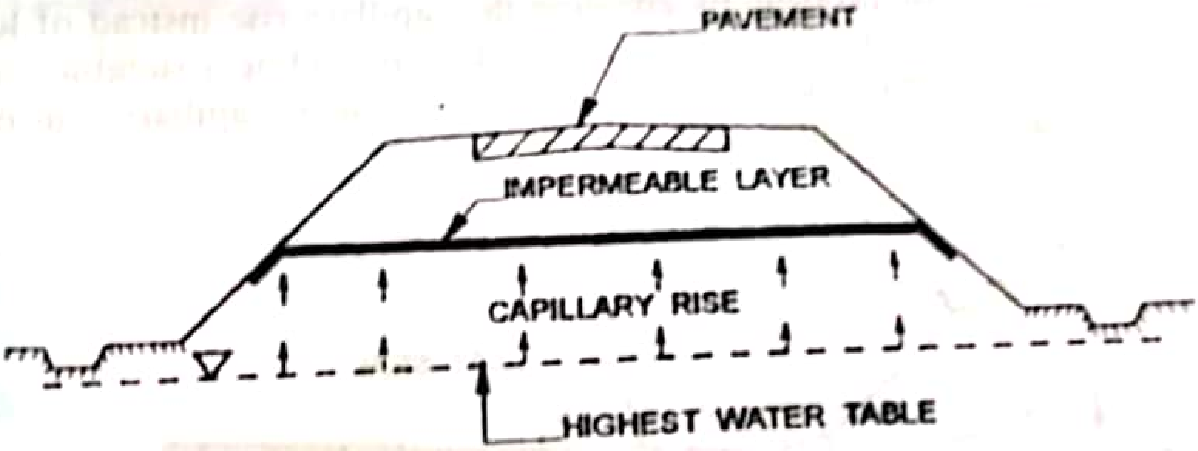


Fig. 11.9 Impermeable capillary cut-off

Design Of Subsurface Drainage System

- The size and spacing of the sub-surface drainage system depend on the quantity of water to be drained off, the type of soil and type of drain.
- The filter material used in sub-surface drains should be designed to have sufficient permeability offering negligible resistance to the flow.
- And also resist the flow of the fine foundation soil resulting in soil piping.

<u>The Steps are as follows:</u>

- Draw grain size distribution curve on log scale %passing vs. particles size for the foundation soil.
- Find the value of D_{15} size of foundation soil.

**Note D_{15}- particle size such that 15%of soil is finer than this size*

- The size of filter material should be 5 times more than the size of foundation soil
  - D_{15} of filter/D_{15} of foundation > 5
- To fulfill the condition to prevent piping.
  - D_{15} of filter/D_{85} of foundation < 5
- Hence plot a point represent the upper limit of D_{15} size of filter given by $5D_{85}$ of foundation.
- Find the size of the perforation in the drain pipe or the gap in the open jointed pipes and let this be = Dp
- Plot a point representing D_{85} size of filter given by the size 2Dp.
- The Shaded area thus obtained represents the region within which the grain size distribution curve of satisfactory filter material should lie.

References

→ Book "S.K Khana & Justo".

→ http://www.engineeringnotes.com.

ASSIGNMENT QUESTIONS

Q.1. Discuss the importance of highway drainage.

Q.2. What are the requirements of a good highway drainage system.

Q.3. Specify the design approach for surface drainage system of a highway.

Q.4. The maximum quantity of water to be discharged by the two side drains on a highway section is 1.4 m^3/sec. Design the side drains for the following conditions silty loam, maximum velocity of flow = 0.8 m/s
Roughness co-efficient = 0.03

Q.5. Write an explantory note on cross drainage & drainages structures.