GRANULAR DRAINAGE CONFIGURATION FOR SUB-SURFACE DRAINAGE SYSTEMS FOR HIGHWAYS WITH ELEVATED WATER TABLE

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Abstract:
With relatively close water table, drainage system is one of the main factors that contributes to the long-term serviceability of the highway. Moisture below the pavement will affect the stability of the pavement and degrade the subgrade. Use of gravel and sand with drainage pipes to minimize the water table effect was investigated.

1. INTRODUCTION: Sub surface drainage has a long history where bamboo pipes were used as drain pipes were used some 4000 years ago in China. Pipe drainage started in United Kingdom in 17th century in the form of trenches filled with bushes or stones. The first clay pipes were produced in 1810, followed by concrete pipes a few decades later. A breakthrough in pipe drainage technology occurred in the 1948 when smooth plastic pipes were introduced followed by corrugated polyvinyl chloride (PVC) and polyethylene (PE) pipes in 1959 and 1963 respectively (Schwab and Fouss - 1999). Nowadays, corrugated PE or PVC is the preferred standard. Mechanized installation developed rapidly from 1940 leading to effective machines that could install pipes with perfect control and accuracy. In the meantime, Laser technology has become a standard for mechanized installation. PE pipes of nominal diameter 200 – 300mm are usually used (ASTM F667 - 97)

Drainage is an important aspect for design and construction of pavements. The system should be designed in such a way that it keeps the water level within the permissible highway limits and thereby maintaining the service life of the pavement. Presence of water in subgrade is mainly due to percolation of water through defects in the pavement surface, capillary rise of water or lateral flow of water from adjoining ditches. Removal of this excess water from subgrade is termed as sub-surface drainage. Possibilities of water accumulation into the pavement zone could be by three ways as follows (Robert Charlier (2008), Pierre Hornych (2008) as stated by Moris and Gray (1976))

- Penetration of water from surface defects and shoulders
- Capillary rise of water from the subgrade
- Seepage from the adjacent elevated surrounding soil

Since all the specific locations where water can enter structural sections cannot be predicted in advance, subsurface drainage systems are needed for the full width of pavements that may be subjected to significant numbers of heavy wheel impacts while the sections contain excess water.

2. OBJECTIVE: The objective was to review the subsurface drainage system using gravel and sand with drainage pipes for highways with high water table.

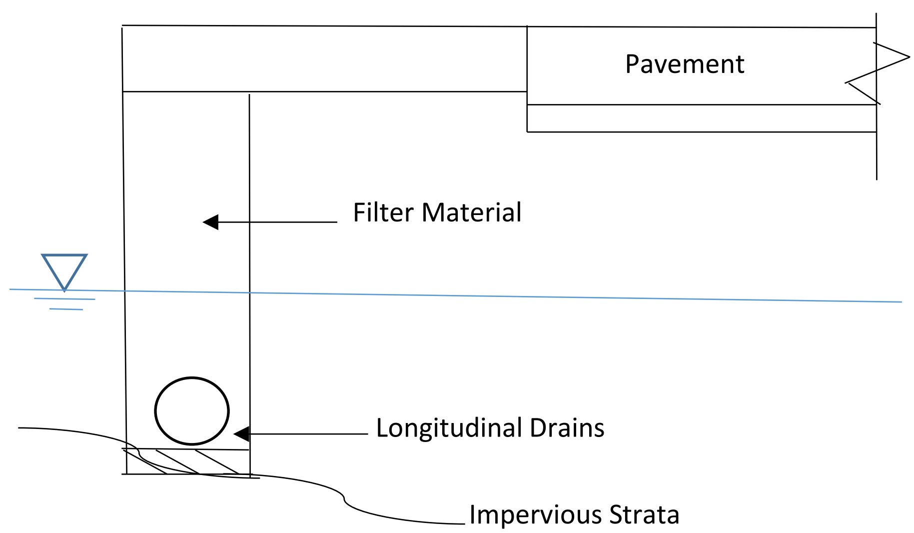
3. LITERATURE REVIEW: Importance of drainage is one of the most important aspects for design of highway due to the following reasons:

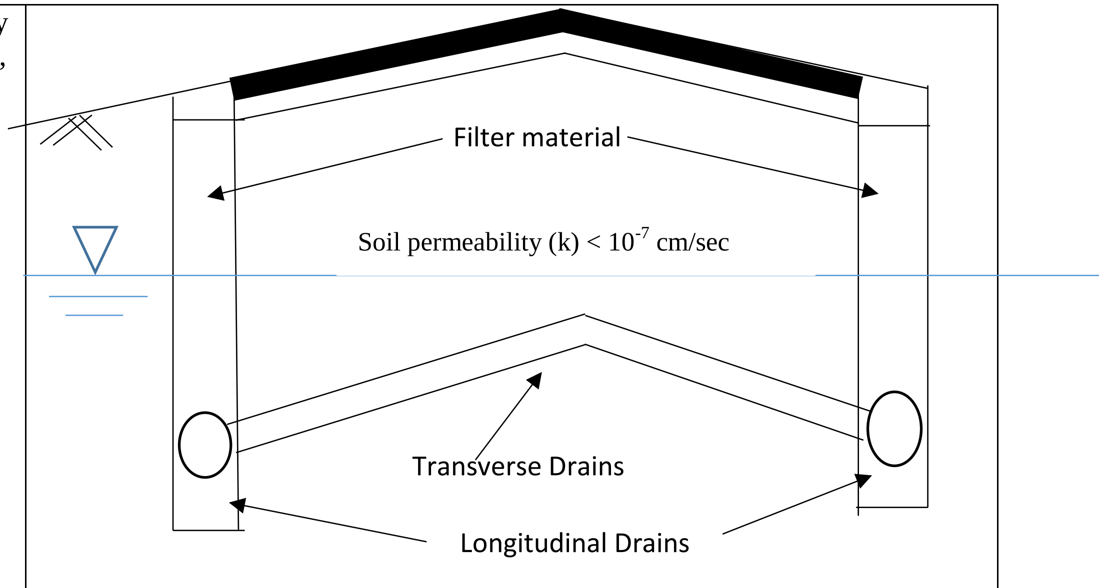
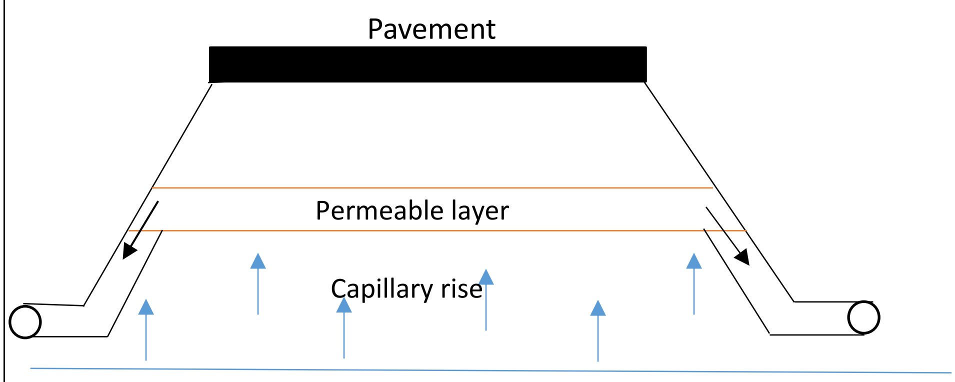
1. Prevent reduction of bearing capacity of pavement: Increased subgrade moisture loosens the intermolecular bond between the soil thereby reducing the bearing capacity of pavement.
2. Decrease volume changes: Volume of subgrade changes due to changes in moisture content especially in clayey soils.

3. Prevent pumping action: Mud pumping occurs due to presence of water in the subgrade soil.
4. To prevent surface defects: Excessive pore water pressure leads to formation of potholes, depressions and uneven pavement surface.

Hence to prevent the above undesirable problems, one (or a combination) of the following methods could be adopted.

TABLE:1. Vertical and Horizontal drainage system

CASE NO.	**IMPORTANT POINTS**	**EXPLANATORY FIGURES**
CASE – 1	If seepage zone is within 1 meter from surface, then intercept the seepage flow by side drains or sub drains under the pavement to release the hydrostatic pressure and thereby lower the water table by installing intercepting drains (See Fig- 1) If impervious strata is deep i.e. 1.3m below the formation, trench could be taken to the impermeable strata.	 Fig – 1 Control of sub-soil flow by intercepting drains

CASE – 2 Control of Water table in permeable soil	In case of relatively less permeable soil, additional transverse drains could be constructed with filter sand. (See Fig- 2)	 Fig – 2 Drainage in low permeable soil with transverse drains
CASE – 3 Control of Capillary rise	Capillary rise could be controlled by providing a layer of granular material between subgrade and highest level of water table (See Fig – 3)	 Fig – 3 Control of capillary rise by permeable layer

Design flow capacity of the pipe: $Q = Q_p \times L_o = (k.\ S_x\ H)\ Lo$ …. (FHWA, 1992)
Q = Pipe flow capacity, (ft3 /day)
Q_p = Design pavement discharge rate (ft3 /day/ft)
L_o = Outlet spacing, (ft)
k = Permeability of granular layer, (ft3 /day)
S_x = Transverse slope, (ft/ft)
H = Thickness of granular layer, (ft)
Also, Manning's equation could be used to determine the capacity of the pipe: (FHWA, 1992)
$Q=AV$ … $\{V = (1.49/n)\ (R^{2/3})\ (S^{1/2})\}$
Q = Pipe flow capacity, (ft^3 /day)
A = Pipe cross-sectional area (ft^2)
n = Manning's roughness coefficient
S = Slope (ft/ft)
R = Hydraulic Radius i.e. (D/4), (inches)

The suggested value (FHWA, 1992) for Manning's coefficient for smooth pipe is 0.012, and for corrugated pipe is 0.024.

Design of permeable Layer:

The separator layer must meet three basic requirements: (a) prevent finer material usually the subgrade soil from migrating up, (b) permeable enough to carry water and (c) strong enough to carry the loads and distribute them to the underlying layers (Ridgeway 1982)

To meet the first requirement; at interface-1 (Fig. 4)
D_{15} (separator layer) $\leq$ 5 D_{85} (subgrade)
D_{50} (separator layer) $\leq$ 25 D_{50} (subgrade)

To meet the second requirement; at interface-2 (Fig. 4)
D_{15} (subbase) $\leq$ 5 D_{85} (separator layer)
D_{50} (subbase) $\leq$ 25 D_{50} (separator layer)
Also, the D_5 size of the filter should be $\geq$ 0.074 μm

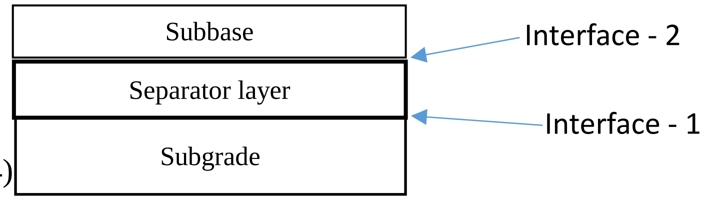


Fig. 4 Permeable Pavement System

To meet the third requirement; strength of the separator layer must be assessed at 100 percent saturation with the effect of cyclic loading being taken into consideration. (Moulton1980)

4. DISCUSSION: Subsurface drainage includes a combination of drainage pipes and filter materials along with permeable layer. Subsurface drainage will help to maintain the bearing capacity of soil and the overlying structure. As subsurface drainage minimizes the quantity of water in the soil, it reduces the possibility of flooding. If drained water is stored in righteous manner, it could be used for other purposes like irrigation. But, as pipes must be dug into the ground; the entire system is expensive to install and maintain. Also, their maintenance becomes inconvenient.

5. CONCLUSION: Based on the study, we can say that subsurface drainage is the process of removing and controlling the excess soil water by keeping the water level within the permissible limits. And this drained water should be disposed of to a safe place.

6. ACKNOWLEDGEMENTS: This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT) and Texas Hurricane Center for Innovative Technology (THC-IT), University of Houston, Houston.

7. REFERENCES:

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