Investigating the Need for Drainage Layers in Flexible Pavements

Masoud Ghavami¹, Maryam S Hosseini¹, Pablo D. Zavattieri², John E. Haddock²
¹PhD student at Purdue University, School of Civil Engineering, West Lafayette, Indiana, USA
²Professor at Purdue University, School of Civil Engineering, West Lafayette, Indiana, USA

INTRODUCTION

- Water can easily find its way into the pavement. Moisture accompanied by traffic loads and freezing temperatures can have detrimental effects on flexible pavement performance.
- A properly designed, constructed, and maintained subsurface drainage system can facilitate the immediate removal of any moisture that may have infiltrated the pavement structure, thereby reducing the potential for pavement distress such as fatigue cracking and rutting.
- Improperly designed or poorly constructed drainage systems, or those not properly maintained, can often trap moisture inside the pavement structure thereby accelerating pavement damage, sometimes even more so than if no drainage system had been constructed.
- The longer moisture remains in the pavement structure, the more likely pavement failure will occur.
- The objective of this research is to evaluate the effectiveness of subsurface drainage for flexible pavements.
- Seepage analysis in the pavement can be useful to evaluate the effectiveness of subsurface drainage.

P AVEMENT DRAINAGE PERFORMANCE AND EFFECTIVENESS

- The effectiveness of a drainage layer is usually evaluated based on the time required for water to drain. The faster a pavement drains, the more effective the drainage layer.
- The FHWA developed the DRAIN (Drainage Requirement in Pavement) software for design and analysis of pavement subsurface drainage. DRAIN analyzes the flow inside the pavement on the basis of the time-to-drain approach by considering the variation of hydraulic conductivity for the drainage layer (base) as well as dimensions of the pavement section.
- The AASHTO 1993 pavement design guide rate the quality of the drainage layer (permeable base) based on the time-to-drain approach (50% drainage), resulting in values from "excellent" to "very poor."

- A typical INDOT asphalt pavement section with incorporated drainage layer is used in the DRIP analysis (Figure 1-3). A pavement section with fixed geometry is modeled and the effects of drainage layer with different material properties investigated.
- The drainage layer is 10 cm thick and 8 m wide (permeable base). The permeable base cross-section is specified as 2 percent. The drainage quality of the different materials was determined using a constant infiltration rate, 0.50 units, and a 1.4-inch per hour rain event. Table 1-1 shows the saturated hydraulic conductivity of different base materials and the results from DRIP based on time-to-drain approach with 50% drainage.

Table 1-1. Results from DRIP

| Base Material | Lab Hydraulic Conductivity (cm/sec) | DRAIN Hydraulic Conductivity (cm/sec) | Quality of drainage layer (based on Table 1-3)
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- Results show excellent qualitative performance (Good, Excellent) of the pavement drainage layer for most base materials, except the dense-graded 25 mm asphalt base. This means they can drain 50 percent of drainable water within a maximum of approximately 6 hours (most do so in less than two hours).

- DRIP considers the pavement fully saturated with the constant hydraulic conductivity for drainable base. This is useful for quickly estimating a pavement section that will always remain below the ground water table (steady state condition), but it should not be used for unsaturated or partially saturated pavement. However, in the case of an unsaturated flow condition, while DRIP will analyze the model, it considers the pavement to be in a saturated flow state. This causes an over estimation of flow quantity because DRIP assumes the same rate of flow for both saturated and unsaturated conditions.

- Studies have indicated that Finite Element Methods (FEM) can be a helpful tool in analyzing seepage analysis of either saturated or unsaturated pavement sections (Ji 2013, Rabab 2007, Hassan 1996). Recent studies recommended unsaturated flow (seepage) principles to be considered in the analysis of pavement subsurface drainage (Rabab 2007). This also requires precise consideration of the boundary conditions and initial conditions as well as material hydraulic properties, including water retention curves and the hydraulic conductivity functions.

- General 2D flow equation: \[ \frac{\partial h}{\partial t} \frac{\partial h}{\partial x} + \frac{\partial h}{\partial y} (k_x h + k_y h) = 0 \]

For the Transient condition: \[ \frac{\partial h}{\partial t} + \nabla \cdot (k \nabla h) = 0 \]

So gives the rate of the change of water stored in the material.

FINITE ELEMENT ANALYSIS

- A 2D finite element model of a pavement cross-section was created in ABAQUS. The main purpose of this study is to investigate the effect of drainage layer on the saturation of the different layers of the pavement, specially subgrade. Two different cases were studied: Case I, the pavement section includes drainage and filter layers; Case II, drainage and filter layers were removed from the model. For the purpose of validation, Case I was created similar to the Hassan et al. model, and finite element results were compared (all the material properties and dimensions were adopted from Hassan et al.). Therefore, this study has two main goals:

  1) Validate the finite element model for the Case I
  2) Compare the two cases

a) Case I, Pavement Layers (Include Drainage Layer):

b) Case II, Pavement Layers (Without Drainage Layer):

REFERENCES

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CONCLUSIONS

- Results from DRIP show excellent qualitative performance (Good, Excellent) of the pavement drainage layer for most of the base materials, except dense-graded asphalt 25 mm base.
- The current model was able to predict the behavior of pavement under rain events.
- The degree of the saturation in the subgrade has a maximum value of 87% when using a drainage layer, while the subgrade is always saturated (100%) for the Case II (no drainage layer). Therefore, presence of a drainage layer in the asphalt pavement section will help reduce the subgrade moisture content.
- The results indicate that the pore pressure at the bottom of the trench for the Case II is smaller than for Case I due to the fact that pavement sections without drainage layers hold more water.

RAINFALL EVENT IN ABAQUS

The same rainfall event was developed for both cases. The degree of saturation for the pavement section at different steps of the rainfall event is shown in the following figures.

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