EVALUATION OF JOINT INFILTRATION AND DRAINAGE OF RIGID PAVEMENTS

PROBLEM STATEMENT

Rigid pavements traditionally have long service lives. However, water trapped in the soil beneath the pavement can lead to a form of pavement distress commonly referred to as pumping. Pumping can result in the erosion and ejection of soil particles, and ultimately create joint faulting and slab cracking. Minimizing the amount of water retained in the underlying material should assuage the problem of deterioration. Providing an adequate sub-drainage section is considered the most effective long-term method of safeguarding pavements from pumping induced failure.

The FHWA has suggested the following two approaches to drainage for the design of a subbase layer:

(1) The ***steady-state flow*** approach is based on a uniforrn inflow rate (the joint/crack infiltration rate) to indicate the amount of water introduced through the pavement joints. This method requires that the outflow rate equal the inflow rate, a condition that can be generated by the choice of an appropriate subbase layer. Calculations for this method are developed from Darcy's steady state equation,

$$q = kiA$$

where q = flow rate (inflow/outflow)
k = hydraulic gradient
A = cross-sectional area

(2) The ***time-to-drain*** approach assumes water (from a rainfall event) enters the subbase until it is saturated. To prevent the development of excess pore pressures, the subbase must drain the water to a certain saturation level within a relatively short time. This method is more complex than the steady-state infiltration method since it uses non-steady state analysis for a given pavement section to determine a degree of saturation at a particular time. A subbase layer that provides drainage to a particular level in a recommended period of time is the section specified.

The Florida Department of Transportation (FDOT) currently utilizes a joint infiltration rate of 0.7 ft^3/day/ft to determine the subbase thickness based on typical properties of the subbase material.

OBJECTIVES

In this study, the *steady-state flow* and the *time-to-drain* methods were employed to evaluate typical Florida materials. The objectives included:

1. Determining the factors affecting the joint infiltration rate in the *steady-state flow* design approach, including the associated effect that permeability has on the drainage rate of typical Florida soils.
2. Verifying that the 0.7 ft^3/day/ft joint infiltration rate for a subbase layer design is appropriate

for Florida conditions.

3. Analyzing flow patterns beneath rigid pavements as a function of geometry and boundary conditions.
4. Providing recommendations for a more rational design standard.

FINDINGS AND CONCLUSIONS

The Florida subbase materials used in this research are classified as medium to fine sand. Their grain-size distribution curves are approximately the same range but vary in %fines composition. As a subbase material, their hydraulic properties, such as permeability, porosity and water-retention characteristics, are directly related to the %fines content.

The joint infiltration rate indicates the inflow and outflow rates of water through the subbase layer, and is not uniform. It varies in magnitude with the joint type (longitudinal or transverse) and location of the joint with respect to the edge drain within the same line of joint. The suggested uniform value by FHWA is an average value for designing the pavement sub-drainage system including the subbase thickness. A parametric sensitivity study on the joint infiltration rate concluded the following:

1. Joint width has minimal effect.
2. Permeability of subbase ↑, joint infiltration ↑ linearly.
3. Subgrade slope ↑, joint infiltration ↑.
4. Subbase thickness ↑, joint infiltration ↑↑.

The drainability of a pavement system is the measurement of the volume of and rate at which infiltrated water is removed from the subbase after precipitation has ceased. The parametric sensitivity analysis on pavement drainability concluded the following:

1. If %fines in the subbase material ↑, drainability ↓.
2. If subbase thickness ↑, drainability ↑.
3. If subgrade slope ↑, drainability ↑.
4. If drainage length ↑ or the number of traffic lanes ↑, drainability ↓.

Researchers investigated both the *steady-state* and the *time-to-drain* approaches. They found that the joint infiltration value necessary to achieve a well-drained (i.e., effective) section deviates from the 0.7 ft^3/day/ft figure, depending on the methodology used in the steady-state flow calculations. Unlike the *steady-state* flow approach, which is an empirically derived method, the *time-to-drain* technique appears to be a more rational approach that directly indicates the drainage capability of a pavement system.

Analyses based FHWA's recommended *time-to-drain* method revealed that subbases with %fines < 5% can achieve a good drainage quality for a typical two- or four-lane pavement section, and provide a reasonable subbase thickness to reach the desired level of drainage quality. Material with % fines > 5% is unlikely to provide even a "fair" quality of drainage (as defined by the FHWA to achieve an 85% saturation level). Further study of the relationship between pumping and water level in the subbase is needed to determine whether drainage time to a finite phreatic level, rather than to percent saturation, is a better design parameter. The subbase design method based on the time-to-drain provided a more realistic model; however, its drawbacks are the requirement of water-retention properties and a more complicated design process.

The joint infiltration rate can relate to pavement drainability. Pavement with a high joint infiltration rate has better drainability (less drainage time and less retained water). The recommended value of 0.7 ft^3/day/ft was found to be too high or too low, depending on the method applied to calculate the subbase thickness. Using values that are too high will result in an oversized section, and using values that are too low will result in insufficient drainage. The suggested joint infiltration rate for designing a subbase of pavement is not typical for every pavement condition. This value should be predetermined based on the time to drain and the method of design in order to obtain a sufficient and economical section.

BENEFITS

This research provides a much improved understanding of and insight into which which engineering properties affect embankment drainage under rigid pavements in Florida. This knowledge will help FDOT to avoid pavement pumping problems in the future.

This research project was conducted by David Bloomquist, Ph.D, P.E., at the University of Florida. For more information, contact Bruce Dietrich, P.E., at (850) 414-4371, bruce.dietrich@dot.state.fl.us.