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A case study of evaluating joint performance in relation with subsurface permeability in cold weather region

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ABSTRACT

Water that stays in a pavement system increases the risk of distress due to mechanisms such as freezing and thawing and erosion. This can be avoided by providing permeable subsurface layers to drain excess water from the pavement system. A borehole permeameter developed at Iowa State University was used in this research to measure the permeability of subsurface layers of an existing pavement with a view to investigating causes of joint distress. This research aims to increase understanding of the relationship between concrete pavement performance and the permeability of subsurface layers. Field borehole permeameter test results on a city street indicate that low permeable subsurface layer may contribute to joint deterioration under freezing condition. Laboratory falling head permeability tests on a similar base material under a frozen condition show that permeability of the samples decreases as moisture content increases, and freezing of the moist base material significantly reduces permeability.

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1. Introduction

Water that stays in a pavement system increases the risk of distress due to mechanisms such as freezing and thawing and erosion. This can be avoided by providing permeable subsurface layers to drain excess water from the pavement system. A low permeable base may contribute to pavement deterioration by keeping water in the base of pavement (Stutzman, 1999).

Surface water flows into base layers both from ground sources and through joints and cracks in pavements. A well-drained base layer is helpful in keeping water out of the pavement systems and hence avoiding water related problems in concrete pavements, such as pumping/erosion, faulting, corner cracking, and durability cracking (Rodden, 2010). Water is used to measure the permeability of pavement layers when they are not subjected to freezing conditions. The permeability of drainable subsurface layers typically ranges from 0.0529 cm/s to 0.1058 cm/s (150 ft./day to 300 ft./day) (Rodden, 2010). The Federal Highway Administration (1992) *Pavement Design Guide* recommends that 50% of the drainable water should drain in 1 h for the highest class of roads with the greatest amount of traffic, in 2 h for most roadways.

Because of difficulties with accessing subsurface layers in the field, traditional approaches for measuring in-situ permeability of base layers are either by sampling field material for laboratory permeability tests or by empirical correlations with density and particle size distribution (Richardson, 1997). However, these approaches may exhibit significant errors either from sample disturbance or from invalid assumed boundary conditions.

Further complicating understanding of cold weather distress is that freezing of moist base materials significantly reduces the permeability of subsurface layers (Granger et al., 1984; Kane, 1980). This is due to soil pores being blocked by ice growth (Seyfried and Murdock, 1997). The freezing and thawing cause a reduction in void ratio and an increase in permeability in soils (Chamberlain and Gow, 1979), because of thawing of the ice lens in soil built voids. Freezing of soil made the soil became a complex system, which includes four phases, i.e., soil skeleton, ice, unfrozen water and air (Lai et al., 2014a,b). All these parameters influence the permeability of frozen soils.

The challenge is to directly measure the permeability of subsurface layers under freezing conditions. In the past, air has been used as the test medium to assess the permeability of frozen soil (Bloomsberg and Wang, 1969; Saxton et al., 1993). To address this need, White et al. (2007) developed an Air Permeameter Test (APT) device that effectively measures the permeability of pavement base foundation materials in the field. However, the APT could not be placed below pavement to measure the permeability of subsurface layers in an existing pavement. A borehole permeameter, developed by a research group from Iowa State University, can be inserted in a core hole drilled through a pavement to assess permeability of the base system in place.

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Fig. 1. Borehole permeameter.

This study presents findings obtained with the new borehole permeameter that uses water to measure the permeability of subsurface layers below pavements. The borehole permeameter is a portable device that can be directly placed in a 15.2 cm (6 in.) core hole. The device comprises a standpipe with three sections, a top pipe with a 3.6 cm (1.4 in.) interior diameter; a middle pipe with a 33.0 cm (13.0 in.) interior diameter; and a bottom pipe with a 12.7 cm (5.0 in.) interior diameter (Fig. 1). A rubber annular gasket attached to the bottom section is inflated after seating to seal the space between the device and the pavement at the bottom of the hole. Wedges are used to stabilize the device during testing.

2. Site description and method

2.1. Site description

Field tests were conducted in a city street (South Loop Drive) in Ames, Iowa. The street is a two lane street serving office buildings, and it is approximately 0.8 km (½ mile) long. The street was reportedly paved using concrete in 1997 in one day using a full width slipform paver running from southwest to northeast.

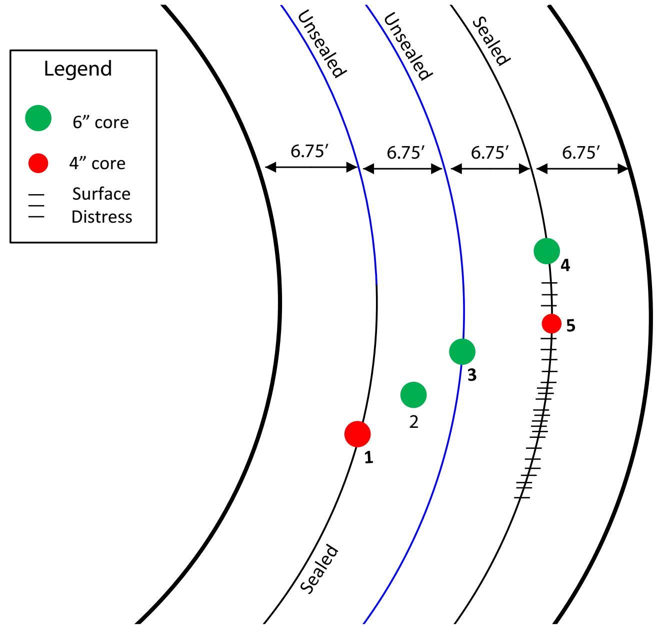

Fig. 3. Plan view of coring and distressed locations on South Loop Drive (not to scale) (West on the left).

A typical cross section of the street is shown in Fig. 2, and the foundation includes a 15.2 cm (6.0 in.) special backfill base layer on top of a 15.2 cm (6.0 in.) special compacted subgrade. The street is 8.2 m (27.0 ft.) wide with a 17.8 cm (7.0 in.) thick portland cement concrete riding surface. A 2% slope exists on both directions of the street, and a 10.2 cm (4.0 in.) perforated subdrain was installed on the West side of the street only. This means that water in the drainable layer on the right East side is trapped in the layer. There is a storm sewer on the East side of the street.

The longitudinal joints were originally unsealed but maintenance crews later installed a hot-seal material in some of the joints. It was noted that premature deterioration of the joints was occurring at some joints and an investigation was initiated in 2010 (Taylor et al., 2012).

The extent of the distress was mapped, along with details of where joints had been sealed (Fig. 3). Five cores were extracted from the pavement over a period of two years. Core 1 from a sound joint and Core 4 from a distressed joint were sent for petrographic examination. Table 1 summarizes the condition of core samples and their locations. Fig. 4 illustrates a distressed joint while Fig. 5 is Core 4 obtained from that joint. The core exhibits bottom up distress which is an indication that saturation of the concrete was from a source of water at the bottom of the slab.

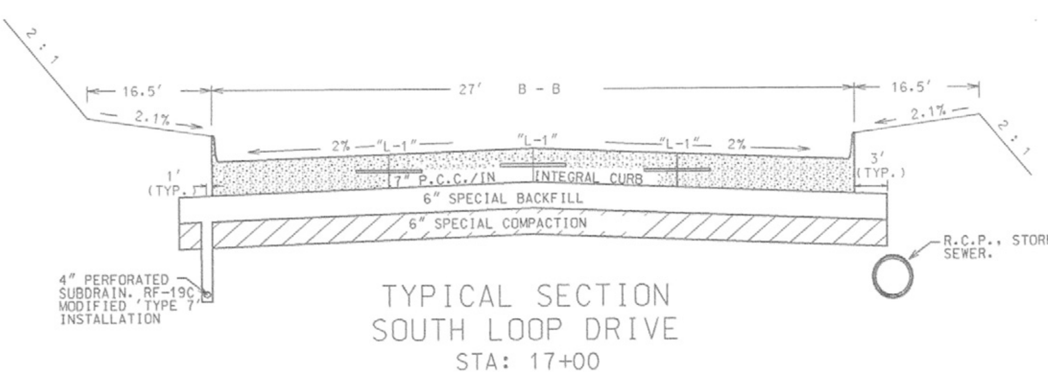

Fig. 2. Typical cross section of South Loop Drive (West on the left).