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Constructing Concrete Pavements with Durable Joints

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"Moving Advancements into Practice"

MAP Brief June 2014

Describing promising technologies that can be used now to enhance concrete paving practices

Constructing Concrete Pavements with Durable Joints

Introduction

Premature deterioration of concrete pavement at joints has been reported in a number of locations in northern states. The pavements affected include state highways, city and county streets, and parking lots.

Not all roadways exhibit joint deterioration; however, the problem is common enough that a focused research effort was implemented to better understand the mechanisms for joint deterioration and to develop guidelines for prevention and repair.

This document describes some of the factors that may be contributing to the occurrence of joint deterioration and provides guidelines on how the risks may be reduced.

Occurrence

Joint deterioration is most commonly observed in city and county streets, both in longitudinal and transverse joints (Figure 1), though local variations are reported.

Figure 1: Typical distress in a city street

The distress is most common in pavements ranging in age from 5 to 15 years old. In some cases, the distress is initially observed as shadowing (Figure 2); later, the joint exhibits significant loss of material.

Joint distress is commonly observed in the form of thin flakes in the paste. A variation in the distress is the observation of cracks that form about an inch from and parallel to the sawn face and are repeated away from the sawn face.

The depth of this distress is about the same as the saw cut (Figure 3). The pieces that come out tend to be sound rather than flakey. In both cases, the exposed face leaves aggregate particles exposed, indicating that the mechanisms are affecting the paste rather than the aggregate.

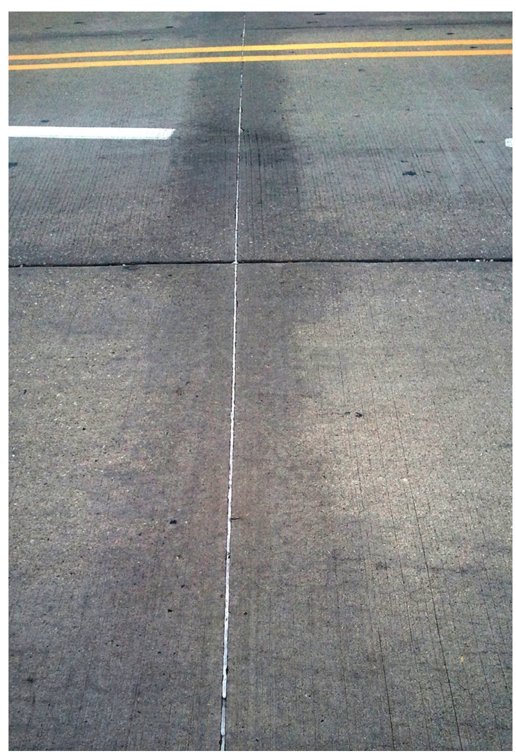

Figure 2: Shadowing

Figure 3: Cracks formed at inch increments from sawn face

Figure 4: A cylinder that had been soaked in MgCl2 solution then exposed to air for 6 months. Note that it still appears wet – demonstrating the effect of MgCl2 in increasing saturation.

Mechanisms

The primary mechanism behind the distress is the freezing and thawing of saturated paste. Water in pores and capillaries in concrete expands when it freezes, leading to internal cracking in the microstructure. Conventionally, this is prevented by entraining small air bubbles in the mixture that provide a place into which the expanding water can move.

The critical parameter is that the bubbles should be close enough together so that their zones of protection overlap. If, however, the air voids have been filled, such that the moisture content of the system is greater than about 85% (Li et al. 2012) then there is insufficient space and damage will still occur. Data by Li et al. indicate that a significant benefit of entrained air is that it delays the saturation of paste immersed in water.

A factor that is likely contributing to the relative novelty of this form of distress is the growing use of de-icing salts, such as magnesium chloride and calcium chloride. Both of these compounds tend to absorb water from the atmosphere and therefore have the effect of preventing surfaces in contact with them from drying out. A joint that has either of these salts inside will therefore exhibit much higher saturation and a higher risk of freeze-thaw damage (Figure 4).

In addition, there may be chemical effects from interactions between the salts and the paste, including formation of expansive calcium oxychloride (Sutter) or Friedel's salt. These reactions are not common but have been observed in the field and will add to the risk of distress.

Another observation is the deposition of ettringite in the air voids, which is a clear indication that the concrete has been exposed to copious amounts of water for an extended period. The effects of the ettringite are debated, but it is likely related to making it easier for water to be absorbed into air voids and thus accelerating the rate of saturation (Stark and Bollman 2000).

Another contributor to increased saturation is failure of the seal, which allows water to collect in the saw cut below the backer rod. This is critical in locations where the base is impermeable or the joint has not cracked out, meaning that the water never leaves the kerf (the narrow cut created by the saw blade).

An additional contributor may be the effects of sawing. It has been noted that a saw that is worn or poorly set up will tend to track in a curve. The effort needed to keep it straight may result in bruising of one face of the saw cut, which will then allow faster access of water into the system. In cases where longitudinal joints are deeper than transverse joints, the water may not have a route to drain, so it will collect and increase saturation.

There is a hypothesis that the interfacial zone around coarse aggregate that is exposed during sawing may also become a conduit for ingress and attack by water and deicing salts, thus leading to the incremental cracking in Figure 2. This is under investigation.

Field investigations have shown that small changes in w/cm, air void system, and/or moisture state (i.e., local drainage) can flip a pavement from survival to failure, thus making it more common to see some sections of roadway in good condition with nearby sections, supposedly similar, that are deteriorating.

Recommendations

In summary, a number of mechanisms appear to contribute to joint distress, with saturated freezing and thawing playing a primary role. The fundamental guidance, then, is to make high quality, impermeable concrete, and to place it in such a way that it is allowed to dry out periodically.

For new concrete pavements in cold regions, it is recommended that the following be specified:

- Maximum w/cm = 0.40 – 0.42
- Minimum air behind the paver = 5%
- Appropriate use of supplementary cementitious materials
- If a sawcut is to be sealed, leave out the backer rod and completely fill the kerf

Other actions that may be considered include the following:

- Apply curing compound to the saw face
- Use penetrating sealants on the saw face to decrease permeability. These may be applied to existing systems where damage is just starting.
- If seals are present, ensure that they are maintained. Fill the saw cut with sealant instead of using a backer rod.
- Make sure the longitudinal joint is well drained.
- Avoid salting new concrete for one season if possible.
- Limit use of CaCl2 and MgCl2 to temperatures below 15°F and, even then, use them sparingly.

Repairs of existing damaged sections depend on the form and extent of damage. The following guidelines are suggested:

- Use partial-depth repairs if the distress is top down and is limited to the concrete above the dowels (Frentress and Harrington 2012). Ensure an intimate bond between the patch material and the existing concrete to prevent water from penetrating the interface.
- Use full-depth repairs if damage is at the bottom of the joint.
- Unbonded overlays may be considered if other constraints allow.

Work is ongoing to develop appropriate ways to assess the effectiveness and quality of penetrating sealants and their effectiveness in slowing distress in existing pavements.

References

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