JOINT TRANSPORTATION RESEARCH PROGRAM

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Investigation of Premature Distress Around Joints in PCC Pavements: Parts I & II

Introduction

Some of the concrete pavements constructed within the last 10 to 20 years have shown signs of premature deterioration, especially in the areas adjacent to the longitudinal and transverse joints. This deterioration typically manifested itself as cracking and spalling of concrete, combined with the loss of material in the direct vicinity of the joint. In addition, "bulb-shaped" damage zones were also observed under the sealed parts of the joints.

The objective of this study was to investigate possible causes of this premature deterioration. To reach this objective, the characteristics of the concrete in and near the deteriorated joints were compared and contrasted to the characteristics of the concrete in the non-deteriorated sections of pavement. The study was conducted in two different phases (Phase I and Phase II), and the findings are presented as a two-part report.

During the Phase I of the study, a total of 36 concrete cores were extracted from five different pavements. While Phase I provided important preliminary information as to the potential causes of deterioration, it also demonstrated the need for a more focused approach that would eliminate such variables as the age of the pavement, site-specific subgrade and environmental conditions, materials variability, and quality of construction.

These goals were accomplished in Phase II of the study, which provided the opportunity to directly compare sections that were (1) paved under one construction project by the same contractor, (2) that used similar mix designs and materials, and (3) were most likely exposed to similar environments and deicing practices but showed very different performances. Several pavement sections were in good condition, while one section showed significant deterioration at the longitudinal joints. During Phase II of the study a total of 18 cores were retrieved from five different pavement sections and examined. In addition, where feasible the base material was sampled and the drainage observed at each core hole.

Findings

In general, the cores that came from the mid-span of the slabs included in Phase I of the study had better air void systems than those extracted from locations near the joints. They also had good resistance to freezing and thawing cycles, relatively low

rates of absorption, and were classified as having low or very low resistance in the rapid chloride ion permeability test. The only exception was the core containing slag aggregates.

The cores that came from the undamaged joints showed marginal to substandard air void system parameters, higher rates of absorption than the mid-span cores, variable F-T durability (with most specimens having DF above 60%) and low to moderate resistance in the rapid chloride permeability test. The cores that exhibited higher rates of absorption also exhibited lower durability factors (freeze-thaw test). Moreover, it was noted that cores from undamaged joints contained a considerable quantity of small ($\sim 10 \mu\text{m}$) air voids filled with either ettringite, Friedel's salt, or a combination of both. However, numerous empty air voids were also present in these cores.

The cores that came from the damaged joints mostly exhibited a poor air void system, showed evidence of some of the highest rates of absorption, displayed moderate to high chloride ion penetrability, and achieved relatively low values of the F-T durability factors. Additionally, it was noted that these cores contained numerous microcracks and infilled air voids (both small and large). The secondary (infilling) deposits contained ettringite, Friedel's salt, or a combination of both.

In general, the observed microstructural and chemical changes in Phase I cores were consistent with the appearance of concrete undergoing prolonged saturation (through-solution mechanism for creating deposits in the air voids).

Similar to those observed in Phase I of the study, the concrete samples collected in Phase II also contained a certain amount of infilling of the air void system by secondary deposits. Furthermore, it was observed that the existing air void system in the concrete from panels near the deteriorated longitudinal joint had neither spacing factors nor specific surface values within the range recommended for freeze-thaw durability. Contrary to this, nearly all of the concrete in lanes without damage had an adequate air void system at the time of sampling.

From the observation of the drains performed by the remote camera it was evident that not all of the drains were functioning properly and some were entirely blocked. However, more precise or direct correlations could not be made between the functioning of the drains and observed pavement performance.

Finally, the data collected during this study were limited and thus not sufficient to definitely and unambiguously determine the single cause of joint deterioration. Rather, the results seem to indicate that the observed deterioration is most likely

caused by combination of several variables that may include type of deicers used, type of subgrade, structural design of the pavement, and type of the sealant in the joint.

Implementation

This study provided the Indiana Department of Transportation (INDOT) with first-of-its-kind data regarding the changes in the microstructure of pavement concrete in the vicinity of joints affected by premature deterioration. These data strongly suggest that the high degree of saturation in the vicinity of the sealed joints contributed to their failure by reducing the freeze-thaw resistance of concrete. In addition to saturating the concrete, the constant presence of the high levels of moisture also resulted in significant infilling of the existing air void systems with secondary deposits, thus reducing their effectiveness.

Considering the limited nature of this study, the following implementation actions can be suggested:

1. Necessary steps should be taken to ensure an adequate air void system in the hardened concrete, especially in the vicinity of the joints. The commonly accepted measures of the quality of the air void system needed to ensure of the freeze-thaw resistant concrete include the specific surface area of the air bubbles of at least 600 in.²/in.³ and a spacing factor not greater than 0.008 in. Although having an elevated content of air voids in fresh concrete does not guarantee the quality of the air void system in the hardened concrete, a larger amount of air will generally help. This points to the importance of generating a sufficient quantity of air bubbles in the fresh concrete as some air will be lost due to transport, paving, and consolidation operations. Recent data collected from the SR 26 project in Lafayette, Indiana, indicated that the air content in hardened concrete may be as much as 3% lower than the air content of fresh concrete (measured right after concrete has been discharged from the mixer).
2. Serious consideration should be given to reducing the penetration of water into the concrete at the joints. Water trapped under the sealer will keep the concrete saturated and thus more susceptible to freezing and thawing damage. Furthermore, the degree of saturation will increase in the presence of deicers. Potential solutions may involve applying water repelling penetrating sealers to the surface of the joints, a more rigorous inspection and maintenance program for the sealers in the joints, or use of the unsealed joint in combination with the penetrating sealers.
3. INDOT should consider construction of the test sections to verify some of the solutions proposed in Part II of this report.

It would be useful to establish a data base that can collect information from future paving projects with respect to characteristics of materials used, deicing practices, weather conditions, sealer conditions, and quality of the air void system in the hardened concrete. Having such a database will be very beneficial in addressing future maintenance needs of concrete pavements.

The benefits of this research include:

- Assemblage of detailed field data on the conditions of concrete in the vicinity of the deteriorated joints, which would be useful to INDOT maintenance personnel in the process of selection of rehabilitation and preservation treatments.
- Generation of fundamental information regarding the potential mechanism of deterioration (damage resulting from freezing and thawing of saturated concrete, potentially enhanced by the lack of an adequate air void system, trapping of moisture under the partially damaged seal, and use of deicing chemicals).
- Increased level of awareness among INDOT's engineers and contractors of the factors contributing to observed deterioration, which, if confirmed by additional studies, will lead to changes in specifications with respect to concrete performance requirements and design, construction, and deicing practices.

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