INDOT Research

# TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

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# *Evaluation of Surface (Top-Down) Longitudinal Wheel Path Cracking*

## Introduction

The objective of the study was to evaluate top-down cracked pavements and assess their structural capacity as well as study in-place materials to propose the best identification of distress type, material selection, and rehabilitation methods to be used in Indiana.

Research involved evaluating three surface cracked pavements during 2002 and 2003. A 500 m section of I-65 North of Lafayette was chosen as the first site (designated as Site 1), an I-65 section in downtown Indianapolis was the second site (Site 2), and US-421 in Madison was the third site (Site 3). Site 1 had 11 year old pavement, Site 2 had 12 year old pavement and Site 3 had 4.5 year old pavement. All these sites exhibited longitudinal wheel path cracking which was later identified as top-down cracking.

The research was carried out by conducting visual surveys, Falling Weight Deflectometer (FWD) testing, and coring the cracked and non cracked pavement areas. Cores were first inspected and then subjected to a full laboratory-testing program to measure rheology and fracture properties of the binders used in the surface mixtures. Then, the measured material properties were utilized in a Layered Elastic analysis program to investigate stresses and strains in the top of the pavement surface.

## Findings

The cores obtained from cracked areas were examined visually and also using x-ray tomography. The visual inspection and x-ray tomography indicated that the cracks were confined in the thin surface mix and did not penetrate deeper into the pavement in any of the sites. This confirms that the observed surface cracking is a top-down cracking.

Based on the visual survey, none of the sites seem to exhibit load-end segregation. However, this finding was not verified by laboratory testing. The systematical pattern in the longitudinal surface cracking in all sites may indicate some longitudinal mix segregation caused by screed extensions in the paver.

The FWD testing indicated that all sites had excellent structural capacity and computed effective structural numbers $SN_{eff}$ were 8.5, 10.2, and 6.1 for Sites 1, 2, and 3, respectively. The thickness of the full depth asphalt pavement was 368 mm, 530 mm and 203 mm for the sites 1, 2, and 3, respectively. Therefore, at least for Sites 1 and 2 the pavement thickness and structural capacity indicate "perpetual" pavement and, therefore, they will not exhibit bottom-up cracking. Site 3 in Madison is also structurally very strong due to the layer of rubblized concrete underneath the asphalt layers. To sum up, it is not expected that bottom-up cracking develops in these pavements.

Binder testing was done only for the binder extracted from the 1.5-2 mm thick surface mix. The original binder grade for Site 3 was PG 70-22 and the other sites had PG 64-22 binder. Based on Dynamic Shear Rheometer (DSR) testing it was estimated that the high temperature performance grade for Site 1 binder was PG 82, for Site 2 PG 76, and for Site 3 PG 82. Thus, Site 1 had aged three PG grades while Site 2 and 3 had aged two PG grades. Therefore, Site 2 binder was aged least and Site 3 binder was aged relatively the most. Compared to binder properties found in the literature, the binder stiffness data does not seem to differ significantly from the “normally” aged binder stiffness values.

The mixture properties were also measured from the thin surface mix layer. The Site 3 had highest air void content average being 10.1%, while Site 1 and 2 had 8.1% and 7.4%, respectively. It can be speculated that the high air void content in Site 3 has accelerated the binder aging compared to the other sites, although it had the highest binder content of 6.3% while Site 1 and 2 had 5.4% and 5.9%, respectively.

All mixtures were fine 9.5 mm surface mixtures and the amount of fines passing 0.075 mm sieve was 2.5 to 2.9% for Sites 1 and 3, while Site 2 had 5.8. The studied mixtures had effective binder volume between 8 to 10%, and voids filled with asphalt ranging from 50 to 55%. Literature suggests that a better mix cracking performance may be obtained by increasing mix density by compaction. In addition, mixtures with more fines may be more crack resistant than mixtures with low amount of fines.

The crack propagation in all sites was confined to the surface layers. Research suggests that when the thickness of the pavement is above 200 mm the top-down cracks are not likely to propagate through the entire pavement layers.

Based on ranking of sites, none of them seem to have properties far better than the others. The binder in Site 2 is softest but does not have good low temperature cracking properties. Site 3 hard binder has aged significantly compared to the other sites. The air void content in the mixes seems to point in the direction that the binder aging is accelerated when the air void content exceeds 7.5%. The higher amount of fines in the mix may prevent binder and mix aging as Site 2 properties suggest.

## Implementation

The implementation of this research can be divided into the short, medium and long term goals. The short and medium term implementation issues are related to the INDOT’s current construction practices and possible changes in them. The medium and long term implementation goals are related to the pavement design issues and therefore to the future research in the local and possibly in the national level (Federal Highway Administration (FHWA) and National Cooperative Research Program (NHCRP)). The short and medium term local implementation issues include:

- Training of contractor and state personnel to enhance construction and QC/QA work (high priority)
- Development of top-down identification, prevention, and rehabilitation guide based on research findings (high priority)
- Modify current construction specifications to reduce segregation (high priority)
- Modify current pavement design practices (low priority)
- Research of tendency of asphalt mix to segregate (low priority)

A short description of items listed above is presented as follows. Training of personnel must be organized in cooperation with INDOT and Asphalt Pavement Association of Indiana. This way the issues hindering good quality can be identified and hopefully remedied. Issues that are needed to be included in the training are mixture compaction, lay down operations, and prevention of segregation.

A guide to identify top-down cracking and select rehabilitation strategy needs to address the following listed items. Not all of these items can be addressed with great detail and this guide must develop over time to incorporate any future research or empirical findings of pavement performance in Indiana.

- Identification of top-down cracking (visual survey and coring)
- Verification of pavement structural capacity using FWD
- Verification of bonding between layers with coring and with possible laboratory test
- Identification of segregation (visual survey, coring and laboratory measurements)
- Material Selection (stiffer or softer binder/mix compared to the replaced material and existing structure)
- Structural issues (surface layer thickness same as before or thicker?)
- Construction practices (the need for tack coat, type of tack coat, type of rollers such as steel wheel or vibratory)

To implement the needs to modify current construction specifications related to the in-situ density and amount of fines in the mixture, a research plan to establish the relationship between mix design and achievable in-situ mixture density must be developed. Some ideas how the research can be conducted are listed below:

- Use Superpave Gyratory Compactor (SGC) to establish a laboratory compaction curve for standard surface and base mixtures in Indiana.

Select the standard mixture such that it represents typical aggregates and binder grade used.

- The compaction curve must be developed for different compaction temperatures by each temperature compacting mixture to the refusal density (zero percent air void content if possible).
- The laboratory gyratory compaction must be correlated to the field compaction by using field test strips. Densification using different roller types must be examined at various temperatures. This will establish equivalency of mix densification between field and laboratory compaction.
- As a part of the mix design process, require SGC compaction test for each designed mix to verify the mix compactability. If possible, use gyratory that can measure shear force during the compaction.
- Measure stiffness of the standard mixtures by SST Shear Frequency Sweep Test and axial dynamic modulus test and Indirect Tensile strength of the standard mixtures and correlate this to the JTRP SPR 2644 study findings.
- Correlate standard mixture material properties to pavement performance
- Modify standard mixtures by changing binder stiffness and/or the amount and type (round or crushed) of fines in the mix.
- To verify boundary conditions (i.e., simulation of real life pavement performance) possible Pur-Wheel tests can be performed.

Pavement structure, i.e., layer thicknesses, number of layers, and type of layers (rigid or flexible) all affect pavement performance, in addition to the type of materials used. Literature suggests that differential stiffness differences affect the stress distribution and thus crack formation in the pavements. In this study two sites had rubblized base underneath the flexible pavement. How this contributes to the top-down cracks was not studied. The combined stress distribution in the pavement structure is affected by the environment and type and magnitude of loading, as we know. What we do not know is what is the worst (or best) possible pavement structure to prevent particular pavement distress and how distresses interact with each other.

To implement changes to the current pavement design practices and verify items related to the structural aspects and construction practices in the developed rehabilitation guide a research plan to study shear stresses and friction between tire and pavement must be developed. Some ideas how the research can be conducted are listed below:

- Construct trial pavement in the INDOT APT pit to study the role of bonding between surface and base layer. The bonding is also related to the friction between the tire and the surface mixture. The high shear stresses that can be developed in the APT by applying high wheel loading without wander provide a means to conducting accelerated pavement surface failure experiments. Testing can be conducted in varying pavement temperatures to separate the cracking and rutting phenomenon. The things related to the bonding of surface layer, the use of tack coat, type of tack coat and compaction are some of the variables.
- In a similar manner, the APT pit can be used to study the role of surface layer thickness for the formation of surface cracks and rutting. Also, the effect of stiff layer (rubberlized concrete) underneath the asphalt layers can be studied.
- This type of research would allow investigation of the issue of using stiff or soft binder in the overlay to replace top-down cracked surface mix (stiffness differentials, layer thickness and rutting versus cracking).

As mentioned above cracks find their way through the least resistance and the coarse portion of segregated mixture typically have high air voids content, low binder content and low amount of fines compared to the job mix formula (Pellinen, 1985). All these properties contribute to the mixture's vulnerability to fracture.

Segregation may be caused by poor mixing or poor lay down of the mix and the degree of segregation is dependent on the mixture's tendency to segregate. The segregation tendency increases when mix has low amount of fines passing 0.075 mm, low binder content, and large aggregate top size (Pellinen, 1985).

The segregation tendency of the mixtures should be considered in the mix design. It would be desirable to develop a quick laboratory method to measure segregation tendency. In the 70's Swedish researchers Hillgren and Sjöblom (1979) developed a method to measure segregation tendency of asphalt mixtures in the field and in the laboratory. Unfortunately testing requires binder extraction and gradation testing of 11 kg of asphalt mix which makes it less practical for frequent use. The method is based on dropping asphalt mix through a funnel and measuring binder content and gradation of fine and coarse portion of segregated mixture.

The segregation caused by paving operations and paver can be prevented to some extent by first understanding when the mix is segregated and then adjusting paver to reduce the segregation. Mixture transfer vehicles have been successful in reducing the load-end segregation but "machine" segregation caused by the paver is still not well understood. Field studies have shown that a thermal camera is an effective way to reveal the segregated spots by measuring temperature differentials in the hot mix asphalt.

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