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Executive Summary Report

Quantification of Cracks in Concrete Bridge Decks in Ohio District 3

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Project Background

Some of the main reasons for the development of cracks in concrete bridge decks include low tensile strength of the concrete, intrinsic volumetric instability, or deleterious chemical reactions. Corrosion of the embedded steel reinforcement can occur in the interior of the concrete when cracks provide a means for ingress of hostile agents into the concrete. The development of cracks in various bridge decks is a severe problem not only in Ohio State, but also in the whole of the United States. It is important to understand the pattern and extent of crack development in bridge decks and quantify crack densities. Such quantification can aid in the identification of the causes, and devising appropriate counter measures to minimize cracking in future bridge constructions. The scope of this project is designed to determine whether structural slabs or stringer supported bridges have a higher tendency to develop cracks. All the bridges surveyed in this study are located in Ohio District 3.

Study Objectives

- The primary objective for this project was to determine if there is a higher propensity for cracking to occur on structural slab bridge decks as compared to stringer supported bridge decks.
- Once it is determined which bridge type has a higher propensity for cracking, a secondary objective was to develop insight that will be helpful in understanding the cracking behavior of structural slab bridge decks and stringer supported bridges decks.
- If it is determined that there is a higher tendency for cracking to occur on structural slab bridge decks, then additional objective was to identify general areas where future research should be considered.

Description of Work

Based on the literature review, the types of cracking are classified as follows:

- Transverse cracking: These are perpendicular to the longitudinal axis of the bridge deck, and they occur at the surface of the bridge deck under which the transverse reinforcement is placed.
- Longitudinal cracking: They are parallel to the longitudinal axis of the bridge deck, and they form above the longitudinal reinforcing steel, on top of the bridge deck.
- Diagonal cracking: They are associated with bridge decks which are skew-shaped.
- Map/pattern cracking: It is very common type of cracking and it is prevalent on all type of bridge decks.

Furthermore, it was found that the primary cause of cracking is due to the low tensile strength of concrete. Other causes include design parameters, material parameters, and construction parameters.

The ODOT has an inventory, which lists the reinforced concrete bridge decks that were constructed in the last ten years. The superstructure types included in this list were: concrete slab, prestressed concrete beam, prestressed concrete box beam, and steel beam bridges. The various categories in the list were structural systems, location, number of spans, deck width, age and type of concrete. In this study, the bridges were classified based on two superstructure categories: structural slab supported bridge decks and stringer supported bridge decks. Structural slab supported bridge decks are supported by the concrete slab itself, whereas, stringer supported bridge decks were bridge decks that are supported by steel beams, prestressed concrete beam, girders, or box beams.

A selection basis was used to pick the typical and representative bridge decks for investigation. The time gap between the construction of the oldest bridge and the most recent bridge was ten years, which lead to the utilization of different types of concrete designs in the construction of the bridges. Thus, it was decided that only the bridges constructed after 2007 be inspected because ODOT has used QC/QA 4500 (Quality Control/Quality Assurance) concrete in the construction of some of these bridges.

The cracks surveys were conducted according to the protocol developed as part of FHWA Pooled Fund TPF–5 (051) “Construction of Crack–Free Concrete Bridge Decks”. This protocol was developed by the University of Kansas in order to implement the most effective techniques for improving bridge deck life through the reduction of cracking. The crack survey protocol calls for researchers to only trace the cracks while bending at the waist. The cracks that can be seen while bending at the waist are assumed to be equal to or larger than 0.007 inches wide. According to ACI Committee reported 224, a minimum crack width of 0.007 inches can cause deterioration related to durability. The entire inspection procedure began with the marking of 5 ft. x 5 ft. grid on the bridge deck. The cracks were then traced by bending at the waist level and were plotted on the scaled drawing of the bridge deck. This plot is called crack profile of the bridge, which was transferred to scaled computer drawing. The cumulative length of all the cracks was calculated using the computer scaled drawing and crack densities were calculated using the following expression:

$$Crack\ density = \frac{Total\ Length\ of\ Cracks}{Area\ of\ Bridge\ Deck}\left[\frac{ft}{ft^2}\right]$$

The crack densities (total cracks) with age of the surveyed bridges are shown in Figure 1. Figure 2 shows the crack densities (shrinkage cracks) with age with values obtained in this study compared with those determined from previous studies.

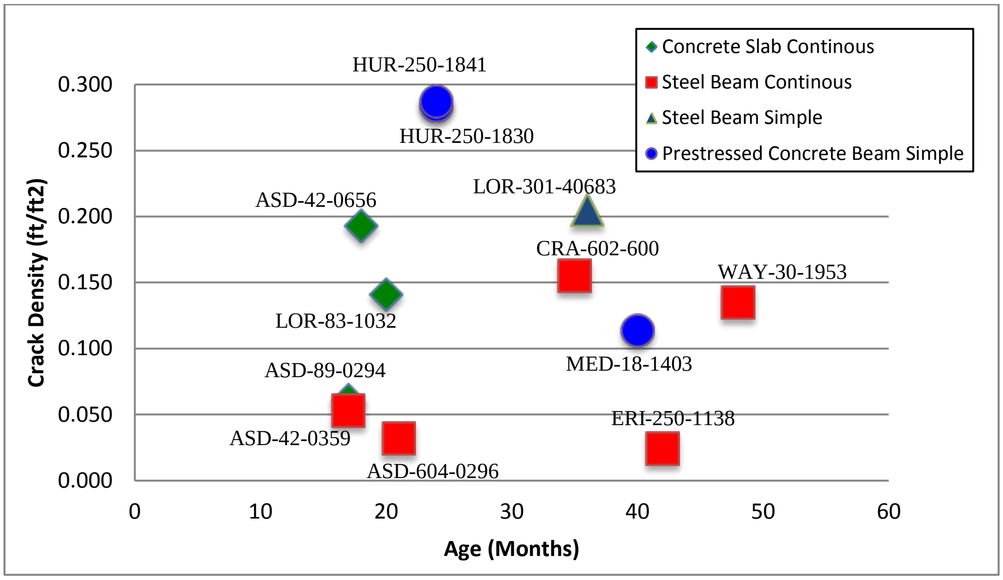

Figure 1 Plot of Total Crack Densities with Age

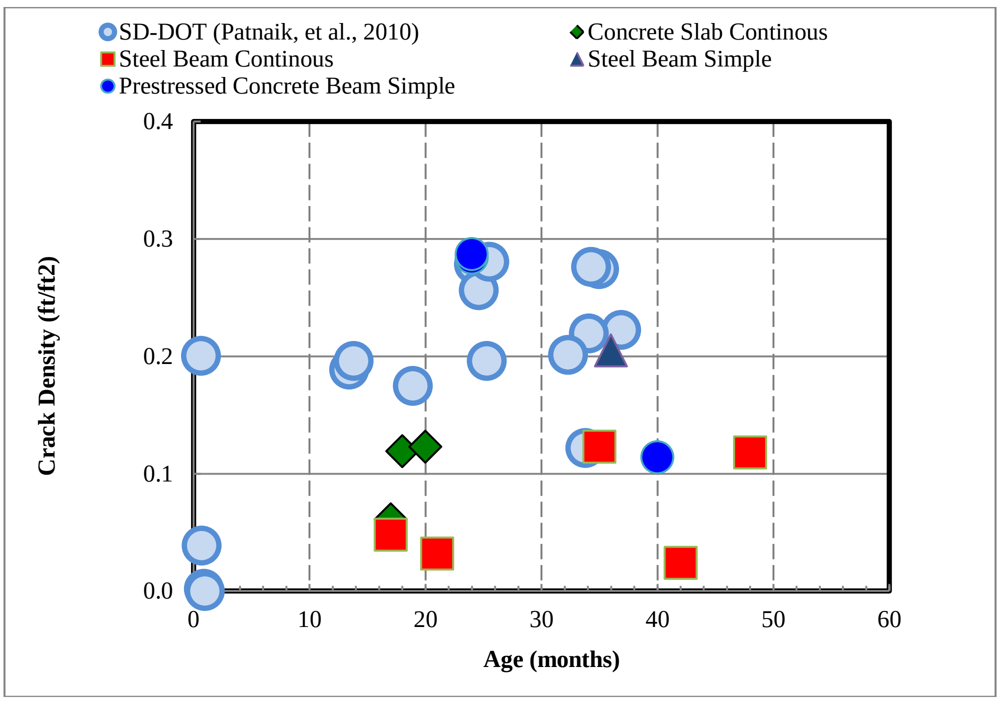

Figure 2 Comparison of Shrinkage Crack Densities with Those from Previous Studies

Research Findings & Conclusions

The following conclusions are drawn after comparing the crack densities for the structural slab bridges with the crack densities for the stringer supported bridges:

(a) Crack densities determined for the twelve bridge decks indicated that structural slab bridge decks have slightly higher shrinkage crack densities compared to the bridge decks constructed with stringer supports. However, the "structural" cracks seem to be wider for structural slabs (greater than 0.007 inch).

(b) There appears to be no direct correlation between the age of the bridge deck and the amount of cracking. However, since the bridges are relatively early-aged, it was not expected that there would be such a correlation.

(c) On bridge ASD-42-0656, which is a continuous slab bridge, there were several large "structural" cracks that were parallel to the intermediate supports. These cracks were very wide and much greater than 0.007 inch giving a reason for concern.

(d) The average shrinkage crack density of bridge decks that are supported on prestressed concrete beams over simple spans was about the same as that of the bridge deck supported on steel beams with simply supported end conditions.

(e) The shrinkage crack densities of the bridges constructed with QC/QA type of concrete were lower than the bridges made with other types of concrete.

Implementation Recommendations

The results from this project demonstrate that shrinkage crack densities of the twelve bridge decks surveyed were considerably lower than the crack densities of similar bridge decks located in other States. Therefore, Ohio bridge decks in general have lower shrinkage crack density than those of other States. Bridge decks made from QC/QA 4500 concrete seem to be performing better than other concretes used in the State. It is recommended that QC/QA 4500 concrete continue to be used to minimize shrinkage cracking.

Continuous structural slab bridges showed cracks much wider than 0.007 inch near the intermediate continuous supports. These cracks were very wide (as much as 0.075 inch at some locations which is more than 10 times the limit recommended in ACI 224 report). The research team classified these cracks at the moment as "non-shrinkage cracks". The frequencies, magnitudes, and widths of these cracks however, were alarming. The possible reasons for the non-shrinkage cracks in structural slab bridges are being thought to be due to one or a combination of the following (1) negative moment due to loading (2) reinforcement details (3) overloading (4) fatigue (5) foundation movements (6) concrete properties (7) construction issues and sequence (8) traffic conditions (9) Other. A thorough investigation of the source, severity and consequences of these "non-shrinkage" cracks in structural slab bridges is needed to develop further insight into the problem of cracking in structural slab bridge decks.