# FRACTURE-PLANE DETERIORATION OF CONCRETE BRIDGE DECKS
Bridge S05 of 63022, Wixom Road over I 96

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ABSTRACT: Fracture plane deterioration is defined and cited as the most critical type of deterioration of concrete bridge decks. Observations of this phenomenon are reported for two I 96 structures. Missouri specifications for avoidance of this type of deterioration are described, with comments on their applicability to Michigan construction practice.

KEY WORDS: bridge decks, deteriorated concrete, plane failure, fracture, spalling.

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This report summarizes an investigation of deck deterioration on the Wixom Road structure over I 96 in Oakland County, as requested by S. M. Cardone on April 14, 1966. The deck was inspected on April 14 and again on April 21, and was under repair during this period. This four-span, four-lane structure had been constructed in 1958.

The deck deterioration was of two types: 1) isolated spalls or potholes, surrounded or adjoined by hollow areas as determined by sounding with a hammer, and 2) larger spalled areas characterized by undulating fracture surfaces, varying in depth from the top of the upper reinforcement layer to within 1/2 to 1/4 in. below the concrete surface. Previous repairs of these zones with bituminous patches indicated that they ranged in size from 1 to 5 sq ft.

The spalled areas were randomly located throughout the deck surface with the most extensive deterioration of this type in the southbound passing lane of the north end span, the northbound passing lane of the span over eastbound I 96, and the northbound passing lane of the span over westbound I 96. A few repaired spalls or potholes were noted in the other spans, and there was one heavily scaled area in the northbound traffic lane of the span over westbound I 96.

The entire concrete deck of the southbound passing lane in the north end span had been removed and replaced, and an area approximately 19 by 11 ft had been removed down to the upper layer of slab reinforcement in the northbound passing lane of the span over eastbound I 96. A typical isolated spall with adjoining hollow area outlined on the deck surface, as found on this latter span, is shown in Figure 1. On the same span, an undulating fracture (Fig. 2) was noted on a cut section perpendicular to the deck's transverse steel. Examination of the steel reinforcement here showed extensive, intermittent corrosion throughout the entire exposed area (Fig. 3). In some spots, these bars were deeply corroded, with the attack confined primarily to the upper halves of the transverse bars. The longitudinal bars upon which the transverse bars were placed showed practically no corrosive attack. The depth of concrete cover over the transverse bars in this area varied from 1 to 1-1/4 in.

To obtain additional information on the deck spalling phenomenon, a small hollow area was located in which there was no readily visible surface deterioration of any kind. The hollow area was roughly circular and about 12 in. in diameter at the deck surface. By careful use of a small chipping hammer, the loose concrete layer was removed in one piece. The fracture surface extended downward from the periphery of the hollow surface area to the top of the transverse bar. The rupture line passed through the paste and no aggregate was fractured. The resulting length of exposed transverse steel bar was 2 in. The concrete layer removed was sound. Further removal of concrete from around the bar revealed that the bar was corroded for a length of 7 in., with a rust penetration of about 1/8 in. on the 2-in. portion of the bar originally exposed. The average depth of cover over this bar was 1-1/2 in.

The type of deck deterioration exhibited here has been termed "fracture plane" deterioration and is a relatively common phenomenon on bridge decks throughout Michigan and other States. (See, for example, "A Study of Deterioration in Concrete Bridge Decks," Missouri State Highway Department, October 1965). Photographs of this same type of fracture-plane deterioration depicting the spalled area and the undulating fracture surface are shown in Figure 4, as taken on Bridge S02 of 63022, I 96 over New Hudson Road. This type of defect is characterized by a separation or fracture of a layer of concrete undulating from within 1/4 in. of the surface at points between transverse bars, down to the level of the transverse steel at points in line with the bars. When the fracture line extends to the surface, potholes result and ultimately breakup and removal of this surface layer occurs over large areas of the deck. The isolated pothole is also characterized by a larger hollow area, surrounding or adjoining the surface fracture outline.

The cause of fracture-plane deterioration is believed to be as follows: first, the top mat or layer of slab reinforcement offers a barrier to the subsidence of aggregate above the level of the steel and to the natural bleeding of the excess water in the paste as it is displaced toward the surface. Second, early drying out of the top surface results in the formation of a semi-hardened layer which further resists the flow of water to the surface. This gives rise to the formation of a weakened, high-water-content zone which undulates between the transverse bars, as previously described. The restraint to shrinkage of the deck concrete by the stringer and shear developer system causes transverse cracking, normally confined to the upper 2 to 3 in. of the slab. Since the transverse steel bars afford a stress concentration line in the concrete matrix, the formation of transverse cracks usually follows the transverse bars. Fast early drying of the upper concrete surface also produces random or pattern cracks, which again are normally confined to the upper 2-in. layer of the slab. Over a period of time, the entrance of water and deicing chemicals into these cracks and subsequent freezing cycles produce expansive forces. In addition, the corrosion of the steel also causes expansive forces and progressive enlargement of the existing water channels, eventually resulting in a fracture which tends to follow the weakened undulating zone previously described. When the fracture line intersects the surface, continued aggravation by surface traffic loads results in the displacement of the surface area and the formation of a pothole or spall. Further progression of this process eventually leads to large areas of surface fracture of the concrete and disintegration of the reinforcement. This is the most critical type of bridge deck deterioration, since in addition to poor appearance and the riding hazard, it impairs the structural integrity of the bridge slab.

Two approaches, to be used separately or in combination, have been offered in an attempt to prevent fracture-plane deterioration. The first involves procedures during initial construction of the bridge slab to minimize factors relating to the phenomenon, and the second, simply to attempt to provide a waterproof seal over the finished concrete deck. The Missouri State Highway Department, for example, has set up specifications limiting concrete slump to 4 in., requiring all intersections of transverse and longitudinal steel to be tied, providing a minimum concrete cover of 2 in. over the bars, and emphasizing an early start of wet curing and timing the finishing operation so that the concrete is subjected to compaction at intervals throughout the bleeding or subsidence period. A waterproof deck treatment as recommended by Orrin Riley of Howard, Needles, Tammen and Bergendoff, has been tried with promising results and economic advantages. Mr. Riley proposes a coal tar, flexible sand-epoxy resin, waterproof coating covered by a 1-1/2-in. wearing surface composed of a neoprene-asbestos asphalt overlay. (See "The Development of a Bridge Protective System" by Orrin Riley, HRB Committee M-10, Maintenance of Structures).

Fracture-plane deterioration of bridge decks is a serious and complex problem, dependent upon a number of mechanical and environmental factors. Increasing the depth of concrete cover to 2 in. and adopting the associated construction techniques specified by Missouri would certainly decrease the probability of occurrence of this type of deterioration. It is doubtful, however, whether this would entirely eliminate the problem. Use of a waterproof epoxy coating, protected in turn by an asbestos-neoprene asphalt wearing surface, as suggested by Mr. Riley, sounds promising, and if proved successful should provide an economically sound and technically feasible solution to the problem.

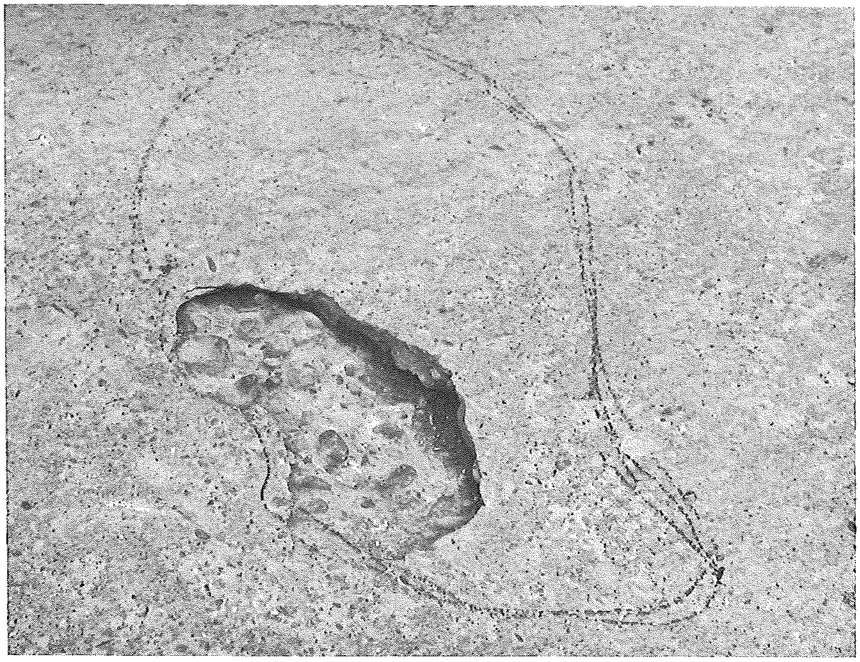

Figure 1. Typical pothole with limits of hollow area outlined in black.

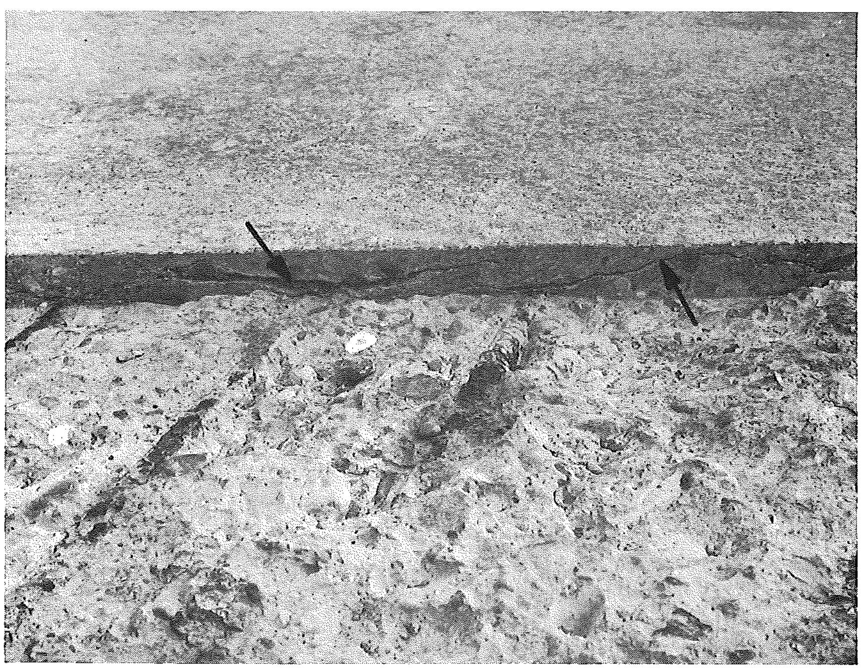

Figure 2. Sawed face of repair area perpendicular to transverse deck steel, with arrows indicating undulating fracture surface.

Figure 3. General condition (top) and close-up view of corroded transverse reinforcing bars in 19- by 11-ft area where deteriorated concrete was removed at surface of northbound passing lane.

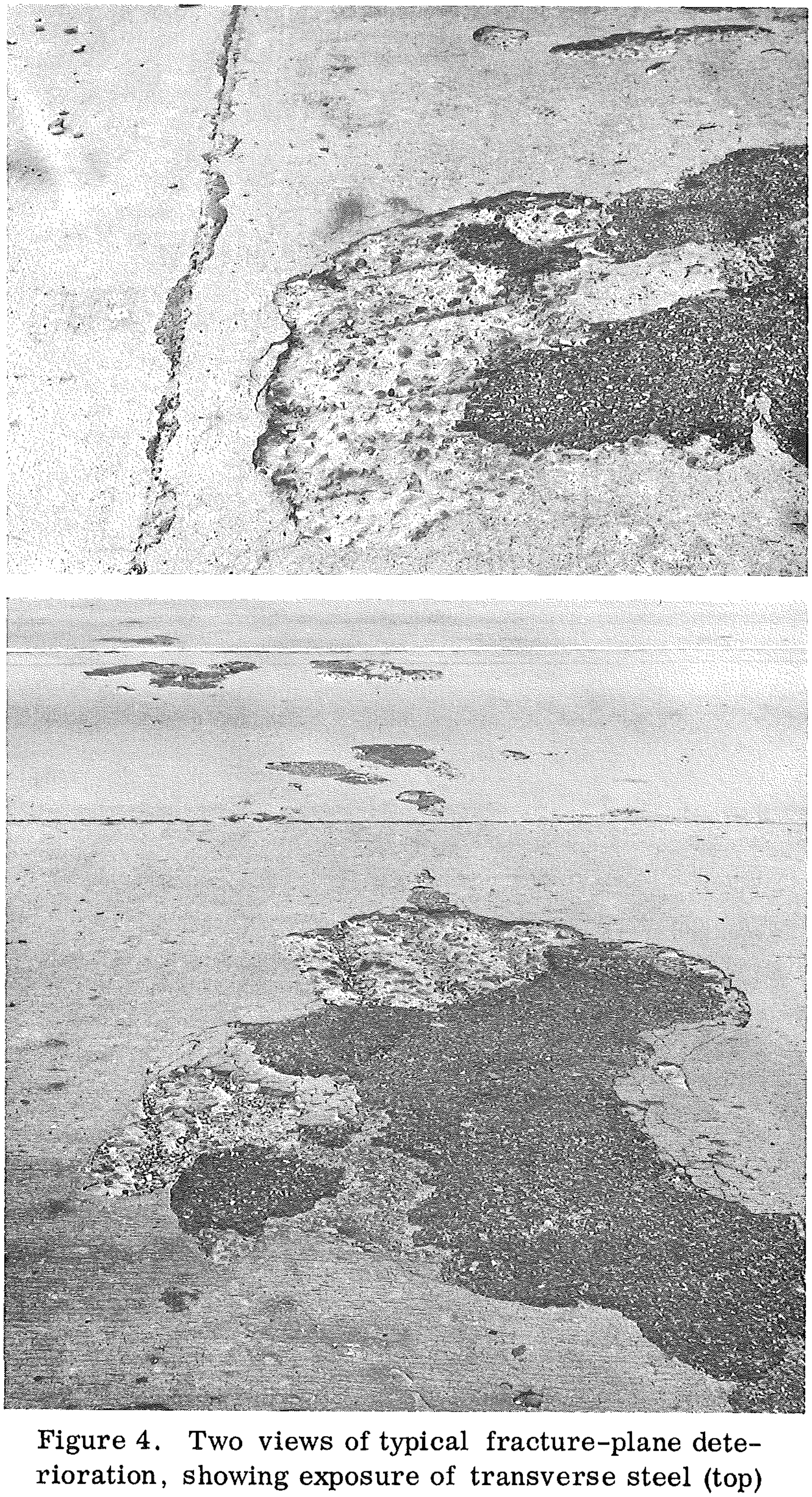

Figure 4. Two views of typical fracture-plane deterioration, showing exposure of transverse steel (top) and undulating fracture surface (bottom), as encountered on Bridge S02 of 63022 (I 96 over New Hudson Road).