

FAILURES OF CONTINUOUSLY REINFORCED PAVEMENT
I 96, Portland Road to M 66

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FAILURES OF CONTINUOUSLY REINFORCED PAVEMENT I 96, Portland Road to M 66

This report analyzes the causes of five failures in the continuously reinforced rigid experimental pavement on I 96 between Portland Road and M 66, as determined from observations prior to and during repair. Failure conditions at these five locations are shown in Figs. 1 and 2.

Three of the five failures occurred in the welded wire mesh sections at Stations 1071+40 and 1045+70 on the westbound roadway and Station 875+90 on the eastbound roadway. The failure at Station 1071+90 was first recommended for repair in October 1960, while those at Stations 1045+70 and 875+90 were recommended for repair in January 1962.

The remaining two failures occurred in the area of the morning pour adjacent to construction joints at Stations 1017+03 and 1044+66 in the bar mat sections on the eastbound roadway. These two areas were recommended for repair in April 1960.

Welded Wire Mesh Failures

The three failures in the welded wire mesh reinforcement sections occurred at laps in the reinforcement and represent either or both of the two types of failure shown in Fig. 3.

Type 1 Failure is characterized by a vertical crack extending from the slab surface to the depth of the reinforcing steel; then by a horizontal crack or separation of the concrete between the steel mats to the end of the lower mat, where a vertical crack extends to the bottom of the slab. Because of an insufficient lap--the first crosswire in the upper mat being placed ahead of the last crosswire of the lower mat so that the longitudinal wires are not properly anchored--the bond resistance of the plain wire is broken and movement is possible as shown in Fig. 3. Poor consolidation of the two concrete layers, as was observed in the areas where this type of failure existed, facilitates the formation of the horizontal crack at the steel level.

Type 2 Failure is distinguished by a vertical crack extending the full depth of the slab through a section at the end of the reinforcing mat. The weld at the crosswire connection in the lap fails as well as the bond to the



Sta 1071+90, westbound roadway
(photo: October 1960)



Sta 1045+75, westbound roadway
(photo: January 1962)



Sta 875+90, eastbound roadway
(photo: April 1962)

Figure 1. Three failures in wire mesh reinforced pavement
(constructed September-October 1958).



Sta 1044+66, eastbound roadway (photo: April 1960)



Sta 1017+03, eastbound roadway (photo: April 1960)

Figure 2. Two failures in bar mat reinforced pavement
(constructed September-October 1958).

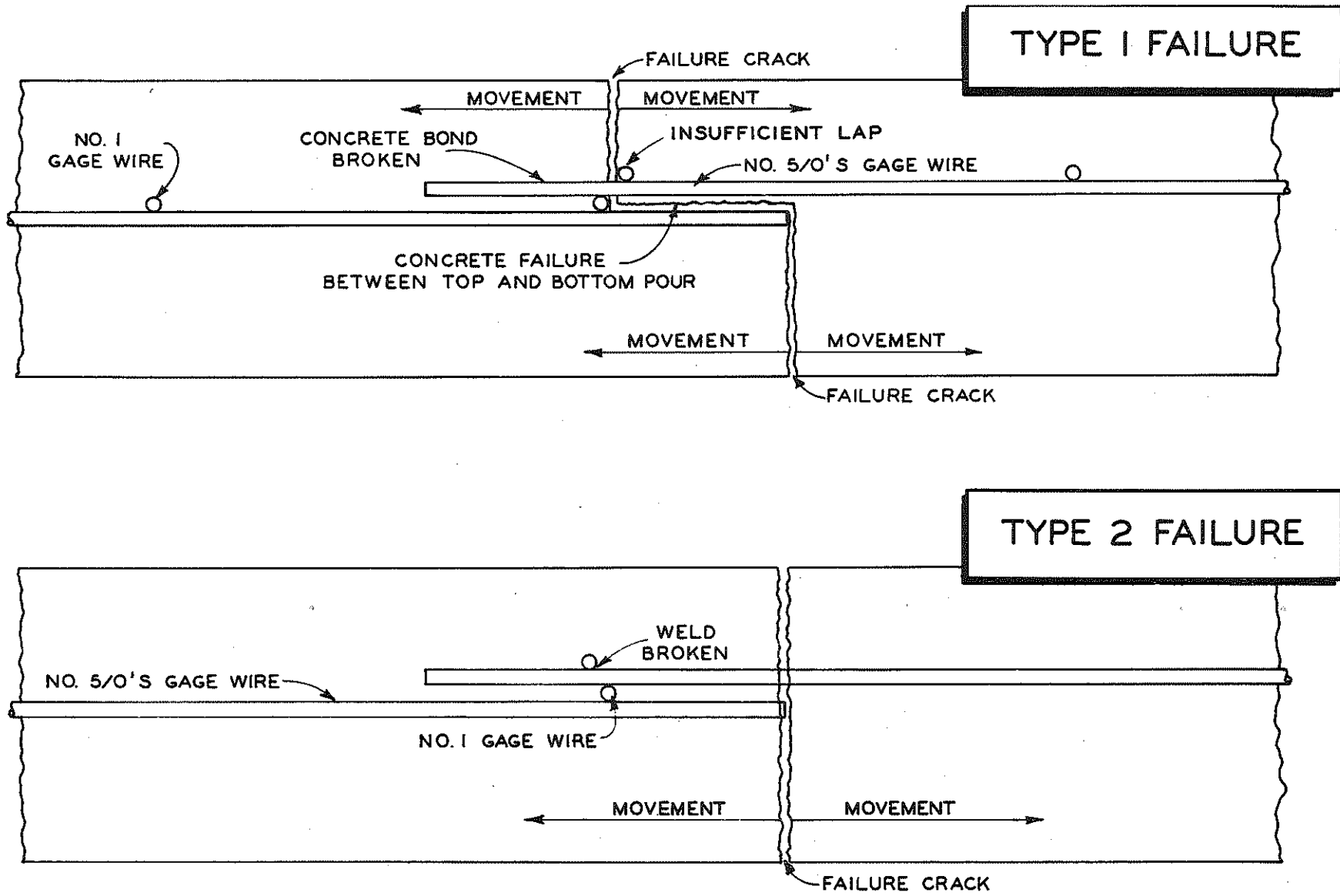


Figure 3. Two types of failure in wire mesh reinforced pavement.

longitudinal steel extending through the vertical failure crack. The slab is then free to move as shown in Fig. 3. Cores taken in the slab at sections through the failed crosswire connection indicate that the presence of moisture causes rusting of the reinforcement steel in the weld area, which undoubtedly increases the possibility of weld failure. Poor consolidation between the two concrete layers in the lap area apparently allows moisture to progress along this plane as water seeps down through the vertical crack. Although the exact nature of the initial cause of the weld failure is not known, it is believed that improper welding or rusting of welds causes some of the crosswire connections to fail before the maximum forces induced by shrinkage and temperature are developed. As a result, the stress normally taken by the failed welds is transferred to the remaining crosswire connections, causing them to be overstressed and a progressive failure to occur across the slab.

The three failures in wire mesh reinforced pavement were analyzed as follows:

Sta. 1071+90, Westbound Roadway. The failure crack originated at the outer edge of the traffic lane, where the reinforcement steel was found to be in two different horizontal planes for a distance of 2 ft from the edge. In addition, the lap was found to be insufficient across the full width of the roadway. Fig. 4A shows the condition of the lap at the time of repair. The steel depth across the roadway in the failure area varied from 2-1/2 to 3-1/2 in. and the slab thickness from 7-3/4 to 8-1/4 in. A core taken through the failure crack at approximately the center of the traffic lane (Fig. 4B) indicates a Type 2 failure. The core shown in Fig. 4C, taken through a section at the crosswire location, was broken to verify that the weld had failed. A Type 1 failure was found to have occurred in the inner 3-1/2 ft of the traffic lane, as illustrated by the core in Fig. 4D. Since the traffic lane failed first, the increased stress induced in the steel in the passing lane, coupled with the rusting of the steel at the failure crack, caused this reinforcing steel to fracture. A core (Fig. 4E) taken in the center of the passing lane through the crack verified that the steel was badly rusted or broken. In addition, as the opening of failure crack increased the broken steel became visible through the crack.

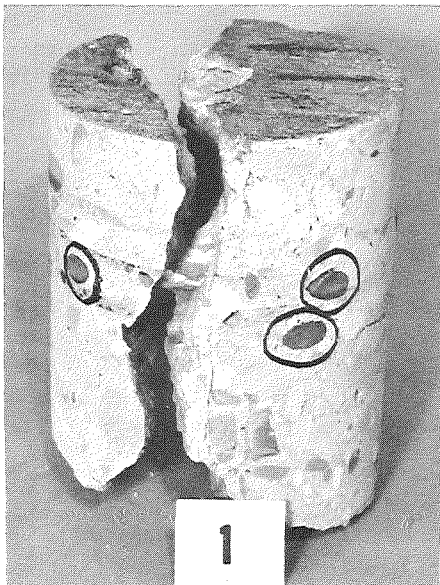
Sta. 1045+70, Westbound Roadway. The failure at this location was confined to the traffic lane only. Cores taken through the failure crack indicated a Type 2 failure similar to that observed at Sta. 1071+90, except the vertical failure crack occurred at the end of the top mat and the weld connection in the bottom mat had failed. The top reinforcing mat remained well bonded to the concrete while the lower mat was not. It was also noted



A. Insufficiently lapped wire mesh in the passing lane.



D. Core through traffic lane failure crack, indicating a Type 1 failure.



B. Core through traffic lane failure crack, indicating a Type 2 failure.



C. Core through section at crosswire in traffic lane, broken at steel level to show failure of crosswire weld.

Figure 4.
Repair excavation
and cores
from Sta 1071+90,
westbound roadway.



E. Core through passing lane failure crack, broken to show fracture of longitudinal steel.

that the longitudinal wires of the lower reinforcing mat were shiny, indicating sliding. Fig. 5A is a core taken through the failure crack in the center of the lane and Fig. 5B shows a core that has been broken to show the weld failure. Fig. 5B also indicates poor consolidation of the concrete in the lap area; thus water entering through the vertical crack would have easy access to the weld and would increase the possibility of weld failure by rusting of the steel. The steel depth across the lane varied from 2 to 3 in. and the slab thickness varied from 7-3/4 to 8-1/4 in. The lap in the reinforcement was sufficient the full width of the lane.

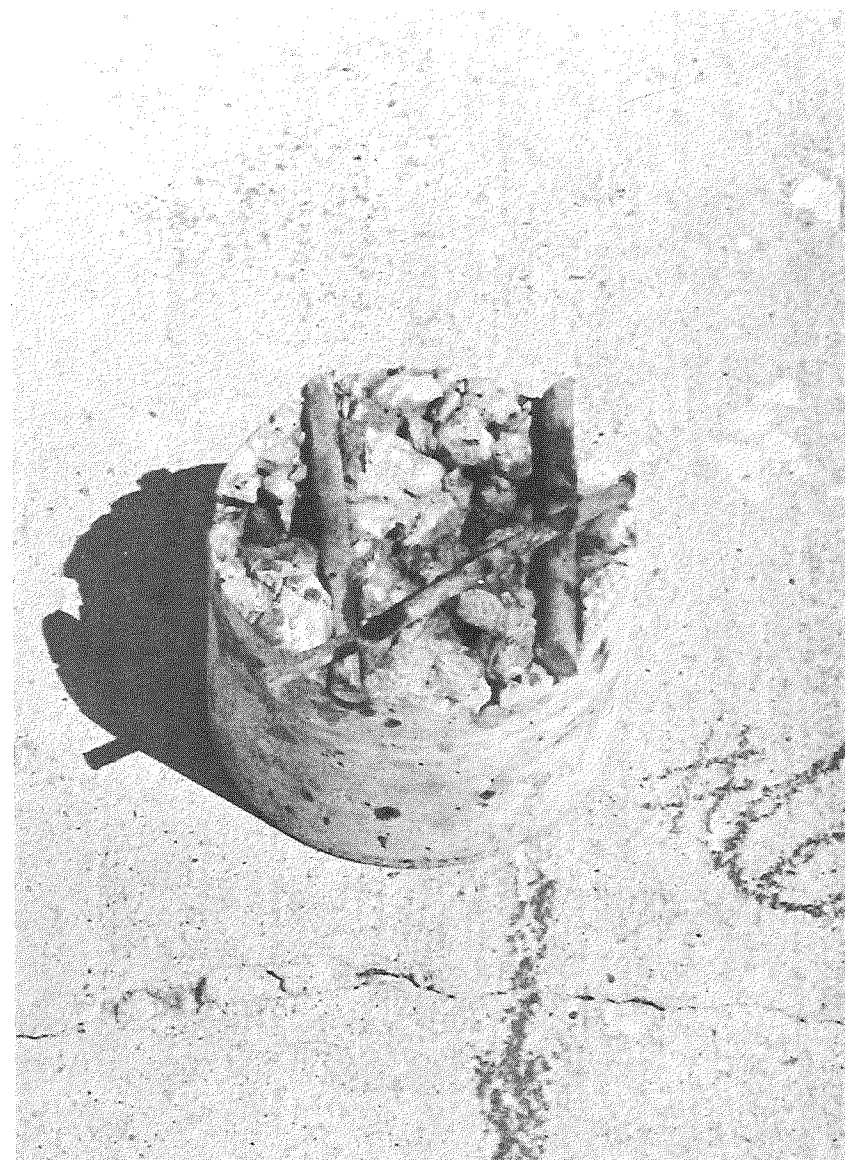
Sta. 875+90, Eastbound Roadway. A Type 1 failure was observed to have occurred in the traffic lane, where the failure crack originated. An insufficient lap of the reinforcement in this lane probably aggravated the formation of a failure crack at this location. Fig. 6A shows a core taken through the failure crack 3 ft from the outside edge of the traffic lane. Although the core broke horizontally during removal it can be seen that the bottom of the core is not cracked vertically and the lower steel reinforcement is still bonded to the concrete, whereas the bond in the top part of the core has failed. The core in Fig. 6B, taken at a section through the point of ending of the lap, shows the horizontal failure crack extending to the center of the core, and also the vertical crack that completes a failure of this type. Again, as observed at Sta. 1071+90 on the westbound roadway, the passing lane apparently failed due to excessive stress and rusting of the reinforcing steel. Fig. 6C shows the condition of reinforcement in the passing lane adjacent to the traffic lane edge. At the time of repair it was observed that seven longitudinal wires had failed completely, 14 were near the point of failure and the remaining 25 toward the inside shoulder were rusted to a lesser extent. The steel depth below slab surface was measured to vary from 3 to 4 in. in the area of failure, and slab thickness varied from 8 to 8-1/4 in.

Bar Mat Failure

Observations during repair of the two failed areas and information obtained from test cores revealed that the failures were caused by poor consolidation of concrete in the area and a discontinuity in the steel reinforcement as a result of the reinforcement being placed in different horizontal planes at the lap following the construction joint. Typical cores taken from these two areas showing poor consolidation and placement of steel are shown in Figs. 7A and 7B. A view of the depressed condition of the reinforcement through the construction joint at Station 1017+03 is shown in Fig. 7C. Compression tests of cores taken from these areas

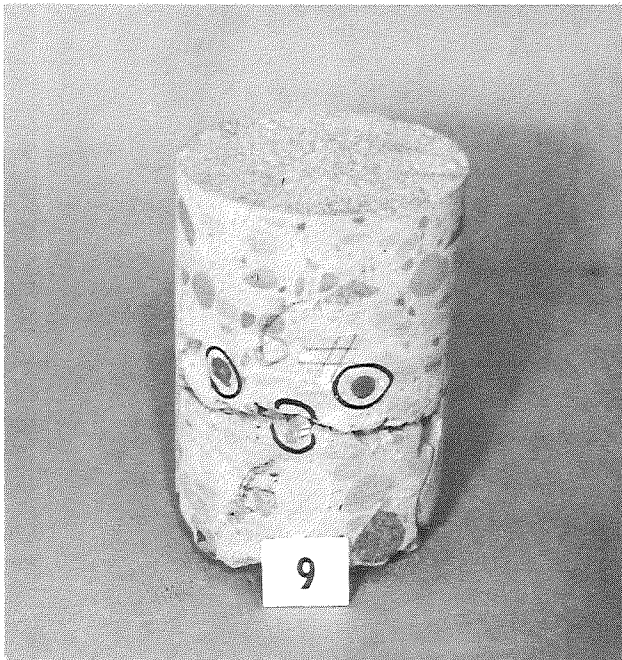
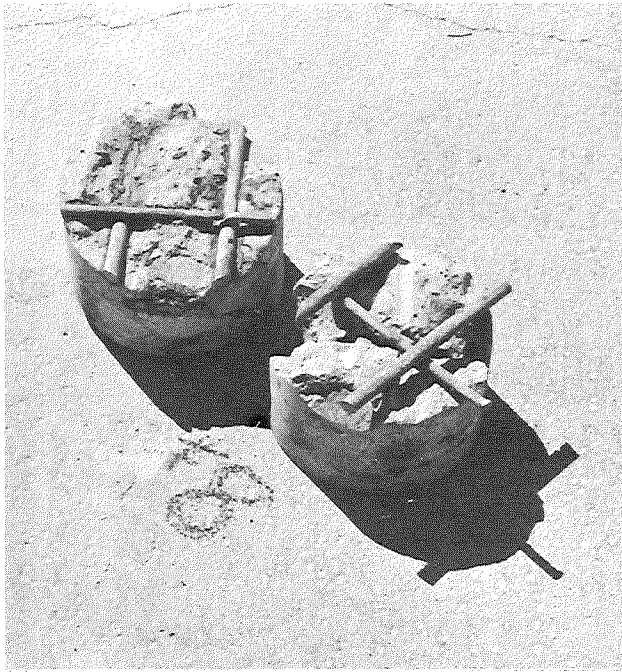


A. Core at failure crack, indicating a Type 2 failure.



B. Core through section at crosswire, broken at steel level to show failure of crosswire weld.

Figure 5. Two cores from the traffic lane at Sta 1045+90, westbound roadway.

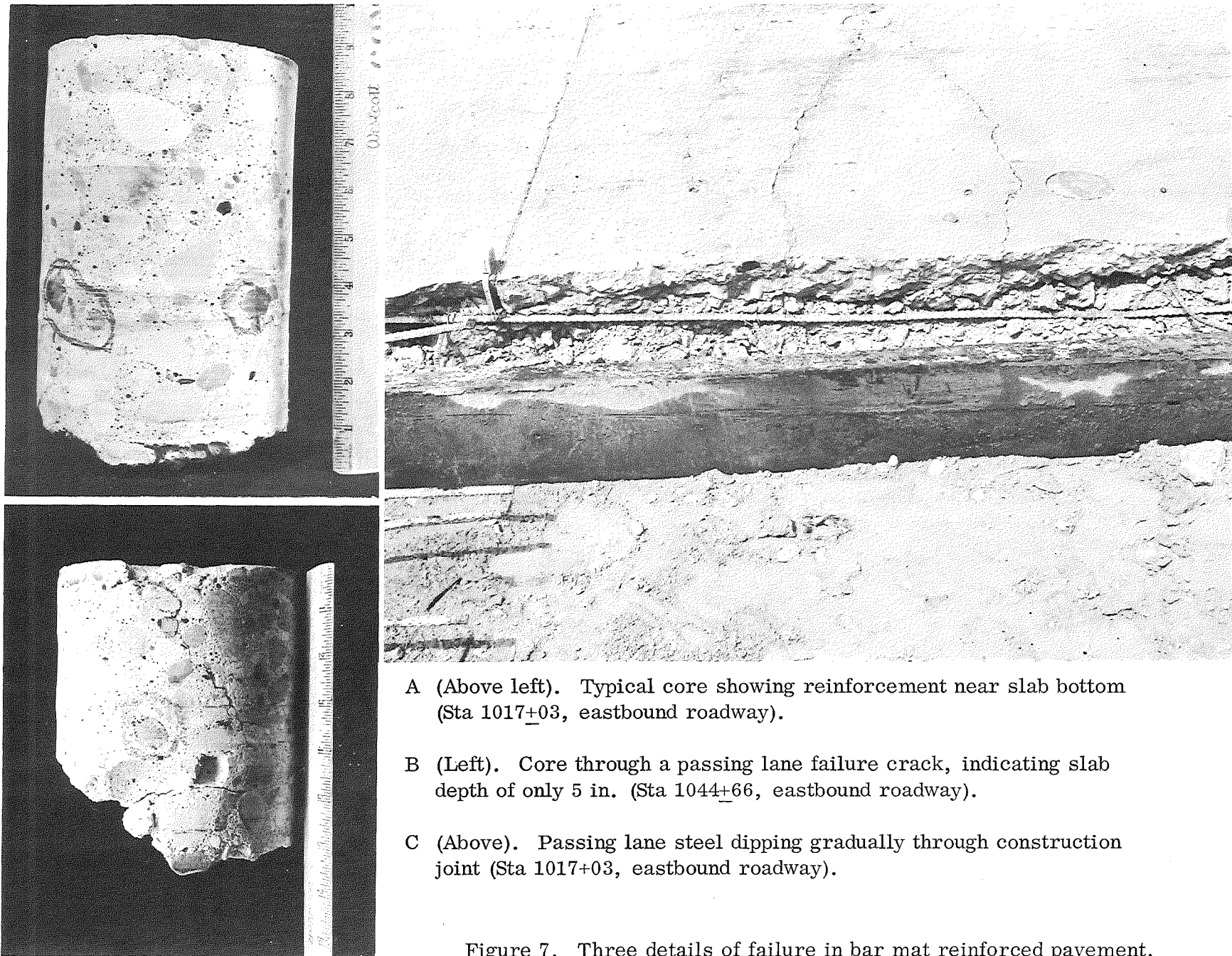


A (Above left). Core through failure crack in traffic lane, indicating a Type 1 failure.

B (Left). Core through section at end of longitudinal steel lap in traffic lane, indicating a Type 1 failure.

C (Above). Fractured longitudinal steel in passing lane.

Figure 6. Traffic lane cores and passing lane repair excavation at Sta 875+90, eastbound roadway.



A (Above left). Typical core showing reinforcement near slab bottom (Sta 1017+03, eastbound roadway).

B (Left). Core through a passing lane failure crack, indicating slab depth of only 5 in. (Sta 1044+66, eastbound roadway).

C (Above). Passing lane steel dipping gradually through construction joint (Sta 1017+03, eastbound roadway).

Figure 7. Three details of failure in bar mat reinforced pavement.

and tested in September 1960, when the concrete was approximately 3 years old, revealed the following:

1. Station 1017+03. Four of the seven cores which could be tested had a mean ultimate compressive strength of 3660 psi, with a high of 6140 and a low of 2450 psi.

2. Station 1044+66. Three of the eight cores which could be tested had a mean ultimate compressive strength of 3450 psi, with a high of 3860 and a low of 3030 psi.

It should be emphasized that the area of concrete at the beginning of the day's pour in a continuously reinforced slab is a critical one with respect to crack development. Concrete of the previous day's pour has attained sufficient strength and continuity to react to shrinkage and temperature-induced volume changes, placing correspondingly greater restraint forces on the more recently poured section. Observations during repair indicated the following:

Sta. 1017+03, Eastbound Roadway. The reinforcement extended 5 ft 4 in. through the construction joint. The steel depth below the slab surface at the end of the extended steel through the joint was measured to be 5-3/4 in. The dipping of the steel caused a vertical offset in the steel of better than 2 in. at the lap. Poor consolidation of the concrete was indicated throughout the area by the fact that while concrete was removed during repair, the mortar broke away from the aggregate quite readily.

Sta. 1044+66, Eastbound Roadway. The steel extended 7 ft through the construction joint. At the point where this steel ended, its depth below the slab surface was measured to be 6-1/4 in. Again, this dip caused a vertical difference in the reinforcement at the lap of about 2 in. The concrete in this area showed evidence of poor consolidation and the concrete in the bottom layer was of poor quality. Pockets of unmixed aggregates ranging in diameter from 6 to 12 in. were found at various locations throughout the distressed area.