

**REPAIR OF CONTINUOUSLY REINFORCED PAVEMENT  
I 96: Portland Road to M 66**

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**Research Laboratory Division  
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**Michigan State Highway Department  
John C. Mackie, Commissioner  
Lansing, January 1963**

## REPAIR OF CONTINUOUSLY REINFORCED PAVEMENT I 96: Portland Road to M 66

### Synopsis

This report outlines the construction procedures employed in repairing five failures of the continuously reinforced experimental pavement incorporated into I 96 between Portland Road and M 66 in Ionia County, constructed in the late fall of 1958. Based on the experience gained from this type of repair, certain recommendations for future repairs are included.

Research Report No. R-397, titled "Failures of Continuously Reinforced Pavement: I 96, Portland Road to M 66" (November 1962), described the causes of failure at each of five locations--three in welded wire mesh sections (at Stations 1071+90 and 1045+70 westbound and Station 875+90 eastbound), and two in bar mat sections (at Stations 1017+03 and 1044+66 eastbound).

The basic requirement in replacing part of a continuously reinforced pavement is that continuity of the steel be maintained throughout the replaced area and the immediately adjacent original pavement. To ensure this, it is necessary to establish the location of the lap in the original reinforcement so that a set limit can be determined on the distance from the center of the lap to the end of the concrete to be replaced. The existing reinforcement also must extend intact into the area where concrete is to be replaced, to provide adequate anchorage and lap length for the new reinforcement.

Since this was to be the first pavement repair of this type attempted in Michigan, a standard procedure was developed for determining the extent of the area to be replaced. In addition, recommendations were prepared regarding procedures for removing concrete and steel from the failed area, and placing new reinforcement.

#### Procedure for Determining Area to be Replaced

The procedure developed for determination of the extent of the area to be replaced is as follows:

1. The lap location in the existing reinforcement is determined by taking cores through pavement near the failure. General pavement condition in the immediate area of the failure is also noted.

2. The distance from the center of the lap in the existing reinforcement to the end of the concrete area to be replaced will be a minimum of 3 ft. This length is the same prescribed originally in the design of this project for minimum embedment in the completed slab at a construction joint, and provides sufficient and adequate anchorage.

3. The existing reinforcement is retained intact for 3 ft beyond the end limits of the concrete to be replaced. This is equal to about twice the lap length recommended for unstaggered longitudinal reinforcement by the CRSI Committee on Continuously Reinforced Pavement\*. It is felt that this additional length is justified, considering the factors involved and the consequences thereof.

Using this procedure, information was obtained at the I 96 failure sites indicating that the repair areas could be proposed as shown in Figs. 1 and 2.

#### Procedure for Replacement Operations

The procedure developed for repair and replacement of the five failures is as follows:

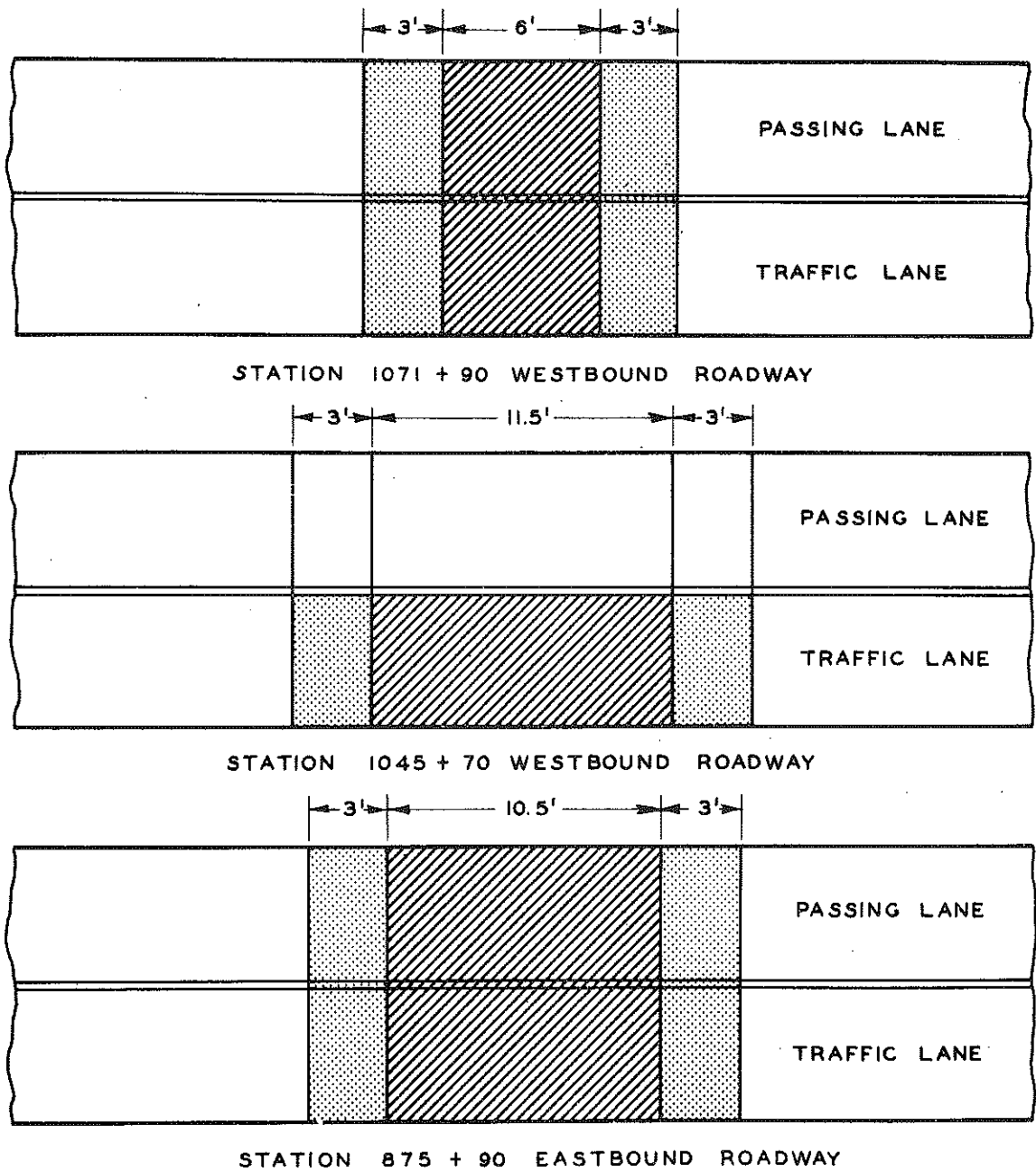
1. At the end limits of the concrete area to be replaced, a sawcut 1-1/2 in. deep is to be made to provide a neat straight joint across the pavement.

2. At the end limits of the area where both concrete and steel are to be removed, a full depth sawcut is to be made. This full depth sawcut separates the two areas, ensuring that existing reinforcement remains intact for the 3-ft length required for the splice.

3. The replacement longitudinal steel is to consist of No. 5 deformed bars in bar mat sections and No. 4 deformed bars in welded wire mesh sections. All transverse bars are to consist of No. 3 deformed bars. All replacement steel must meet the requirements for hard grade steel in ASTM Specification A-15.

4. Longitudinal bars are to extend the entire length of the new concrete area and lap the existing reinforcement a full 3 ft at each end. In bar mat sections, No. 5 bars are to be placed adjacent to each existing

\* "Design of Continuously Reinforced Concrete Pavement for Highways." Chicago: CRSI Committee on Continuously Reinforced Pavement, Bulletin No. 1 (December 1960).



LEGEND



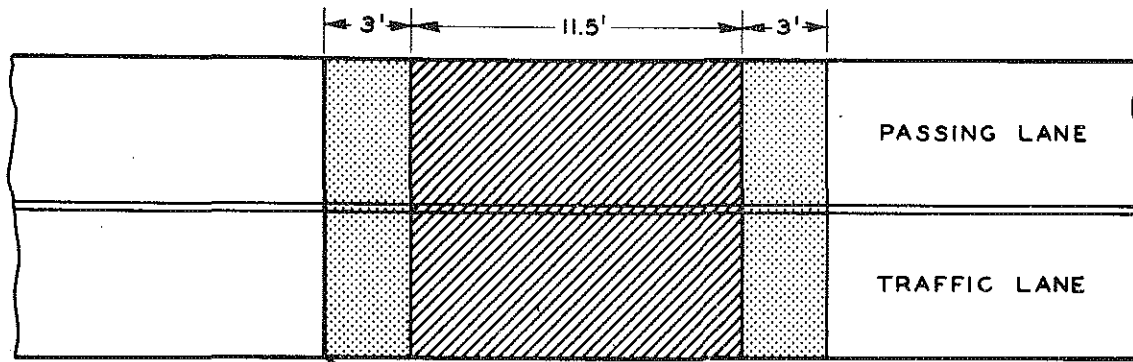
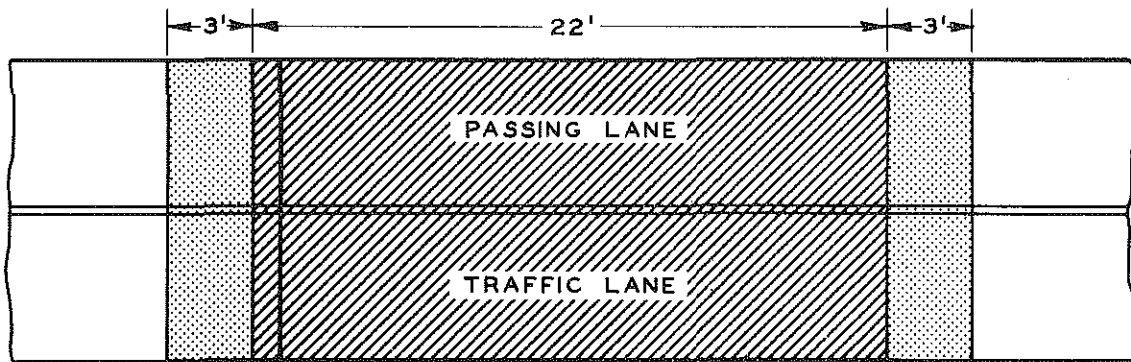
	REMOVE CONCRETE AND STEEL FROM THIS AREA
	REMOVE CONCRETE ONLY FROM THIS AREA

Figure 1. Proposed areas to be replaced in welded wire mesh pavement.



CONSTRUCTION JOINT  
STATION 1044+66 EASTBOUND ROADWAY



CONSTRUCTION JOINT  
STATION 1017+03 EASTBOUND ROADWAY

- LEGEND
-  REMOVE CONCRETE AND STEEL FROM THIS AREA
  -  REMOVE CONCRETE ONLY FROM THIS AREA

Figure 2. Proposed areas to be replaced in bar mat pavement.

bar and welded together, with four symmetrically spaced 2-in. long fillet welds. In wire mesh sections, the No. 4 bars are to be placed adjacent to each existing wire and welded at the crosswire locations of the existing wire mesh reinforcement. The transverse No. 3 bars are to be tied to the longitudinal bars at 2 ft 3 in. centers in both the bar mat and wire mesh sections.

5. The replaced steel is to be supported on wire chairs and maintained level at the required 3 in. depth from the surface.

6. Where both lanes are to be replaced at the same time, standard procedures are to be followed for tying lanes together and sawing the longitudinal centerline. Where lane-at-a-time construction is to be used, standard longitudinal centerline joint hookbolts are to be used. Where only one lane is replaced, the existing 1/2-in. diam tie bars are to be left in place, if feasible; otherwise, approved anchor bolts are to be used as lane ties.

7. To reduce the adverse effect of temperature change, it is preferable that the work be done in the fall when cooler temperatures prevail, thus minimizing the chances of extreme temperature variation.

#### Field Pavement Repair: Removal Operations

The failed areas were repaired under contract on a competitive bid basis. Construction operations began April 19, 1962, and were completed May 25, 1962. Lane-at-a-time construction was employed at each of the five locations, so as to maintain traffic during the construction period. The repair of all areas in one lane was in progress simultaneously.

The dimensions of the three repairs in welded wire mesh sections were as originally proposed (Fig. 1). Dimensions of the two bar mat repairs, however, were somewhat larger than originally proposed (Fig. 2), because of the following changes:

1. At Station 1017+03 eastbound, the length of the area to be replaced was increased by 5 ft at the west end of the passing lane only. This increase resulted from an error in interpretation of the end limit by the contractor's personnel. Existing reinforcement was left intact in this added area.

2. At Station 1044+66 eastbound, the west end limit of the proposed area coincided with a construction joint. During removal of concrete in the traffic lane, it was discovered that existing reinforcement at this

construction joint had corroded to the extent that continuity of the steel was greatly impaired. Therefore, an additional 3 ft of concrete was removed in both lanes at this end of the patch.

Removal of concrete and steel included the following five operations:

1. Sawing 1-1/2 in. deep sawcut at the designated locations.
2. Breaking and removing concrete to expose reinforcement at the ends of the area where both concrete and steel were to be removed.
3. Cutting existing reinforcement at the required distance from the end limits of the patch.
4. Breaking and removing the concrete and steel in the center of the patch.
5. Breaking and removing only the concrete at the two end regions of the patch, while leaving existing reinforcement intact.

As a preliminary step in removing the concrete and steel, the 1-1/2 in. deep sawcuts were made across the slab at the end limits of each whole patch area. At the end limits of the central portion from which both steel and concrete were to be removed, the contractor elected the following method for separating the three areas:

1. A 1-1/2 in. deep sawcut was made across the slab at the point of separation.
2. Two to three passes with the breaker set at minimum stroke were made across the slab at the sawcut (Fig. 3). A typical trench made across the passing lane in the welded wire mesh section in this manner is shown in Fig. 4.
3. The broken concrete was removed by hand tools and the exposed reinforcement cut (Fig. 5).

Once the two areas had been separated, pavement in the center of the patch was removed without difficulty (Fig. 6). However, removing only the concrete from the remaining 3 ft at each end of the patch required extreme care to prevent bending the steel and undercutting the slab at the vertical end face. In traffic lane patches, the breaker set at minimum stroke was used to break the concrete away from the steel. Several passes were made across the slab, with the final pass adjacent to the sawcut.



Figure 3. Breaking concrete with Arrow breaker.

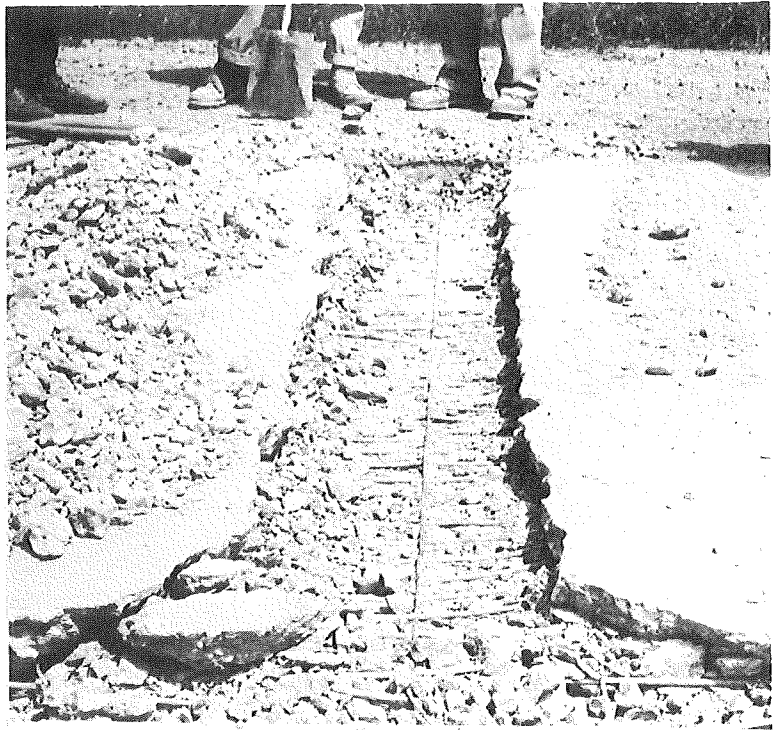


Figure 4. Exposed reinforcement in trench made with breaker.



Figure 5. Cutting bar mat with acetylene torch (left), and welded wire mesh with wire cutters (right).







Figure 6. Removing concrete from a failed area, where both concrete and steel are to be replaced.

Figure 7. Breaking concrete with air hammer at the end of a patch, where 3 ft of original steel is to remain.



Figure 8. Condition of typical patch locations after removal of failed pavement, in bar mat section (top) and a welded wire mesh section (bottom).



The broken concrete was then removed by hand tools. This method was very expedient, but the steel was bent extensively and the vertical pavement edge undercut excessively. Therefore, the procedure for removing concrete from these 3-ft end areas was changed for the passing lanes. The breaker was again set for minimum stroke, but the final pass was made about 1 ft away from the sawcut. The remaining concrete was then broken out with an air hammer (Fig. 7). Although this procedure was time-consuming, the steel was not damaged as extensively and undercutting of the pavement edge was less severe. Fig. 8 shows the condition of typical patch areas in bar mat and wire mesh sections after removal of the failed pavement.

#### Field Pavement Repair: Replacement Operations

Replacement of the removed concrete and steel included the following seven operations:

1. Leveling and compacting subgrade, setting forms, and placing steel.
2. Delivering and spreading concrete.
3. Vibrating concrete along edges and forms with hand vibrator.
4. Striking off concrete with vibratory screed.
5. Final hand finishing of concrete surface.
6. Applying burlap drag finish to concrete surface.
7. Applying white membrane curing compound.

The steel reinforcement conformed to the sizes and grade as recommended. All longitudinal bars were of such length as to bridge the full distance of the patches and provide a 3-ft lap at each end. Individual chairs were used to support the reinforcement at the required level. Standard pavement hookbolts were used to tie the lanes together, except at Station 1045+70 westbound where the existing 1/2-in. diam tiebars were left intact.

The new reinforcing bars were welded to the existing reinforcement in the traffic lane patches as recommended. According to continuous temperature measurements at the site, a temperature rise of approximately

30 deg occurred between the time the new steel was welded, and final readiness for placement of the concrete. This severe temperature rise caused the exposed steel to buckle to such an extent as to make concrete pouring useless. In addition, with the traffic lane removed, this temperature rise was sufficient to cause the badly deteriorated passing lane sections to buckle at Station 1071+90 westbound and Station 1044+66 eastbound. To maintain the reinforcement in the required horizontal plane, the steel was cut and spliced in the center of the patched area just before pouring the concrete. Because of the prevailing high temperatures during this time, the new steel in the passing lane patches was not welded but tied to the old reinforcement in the end extremities of the patches. Fig. 9 shows the steel arrangement in typical patches in passing lanes of the bar mat and wire mesh sections.

A high-early-strength, transit-mixed concrete was used with a constant cement content of 7 sacks per cu yd. The addition of Darex AEA provided average concrete air contents of 5.4 and 7.5 percent in the traffic and passing lane patches, respectively. The average slump of the concrete was 2-1/2 in. Concrete placement and finishing are shown in Figs. 10 through 12.

The concrete in the traffic lane patches was poured at temperatures from 82 to 92 F, while those in the passing lane were poured at 70 to 74 F. Although a temperature drop of 30 deg was recorded during the first 24 hr following concrete pouring, only ordinary crack patterns developed except at two locations where the passing lane had buckled. In these traffic lane patches, the resulting forces set up by the temperature drop, coupled with complete ineffectiveness of the passing lane in resisting these forces, apparently caused a bond failure which resulted in excessive slippage and formation of large single cracks near the center splice. Fig. 13 shows the condition of these cracks at Stations 1071+90 westbound and 1044+66 eastbound six days after pouring.

Beams for modulus of rupture tests were taken at each of the five locations, including one per lane at the four two-lane patches. Data from beams tested at 3, 7, and 14 days are shown in Table 1, with recorded temperatures at the times of pour.

#### Plugs for Relative Joint Width Movement

A set of gage plugs was placed at one of the formed joints in each patch, 12 in. from the pavement edge in the traffic lane and 4 in. each side of the joint centerline. The plug in the replaced concrete was placed

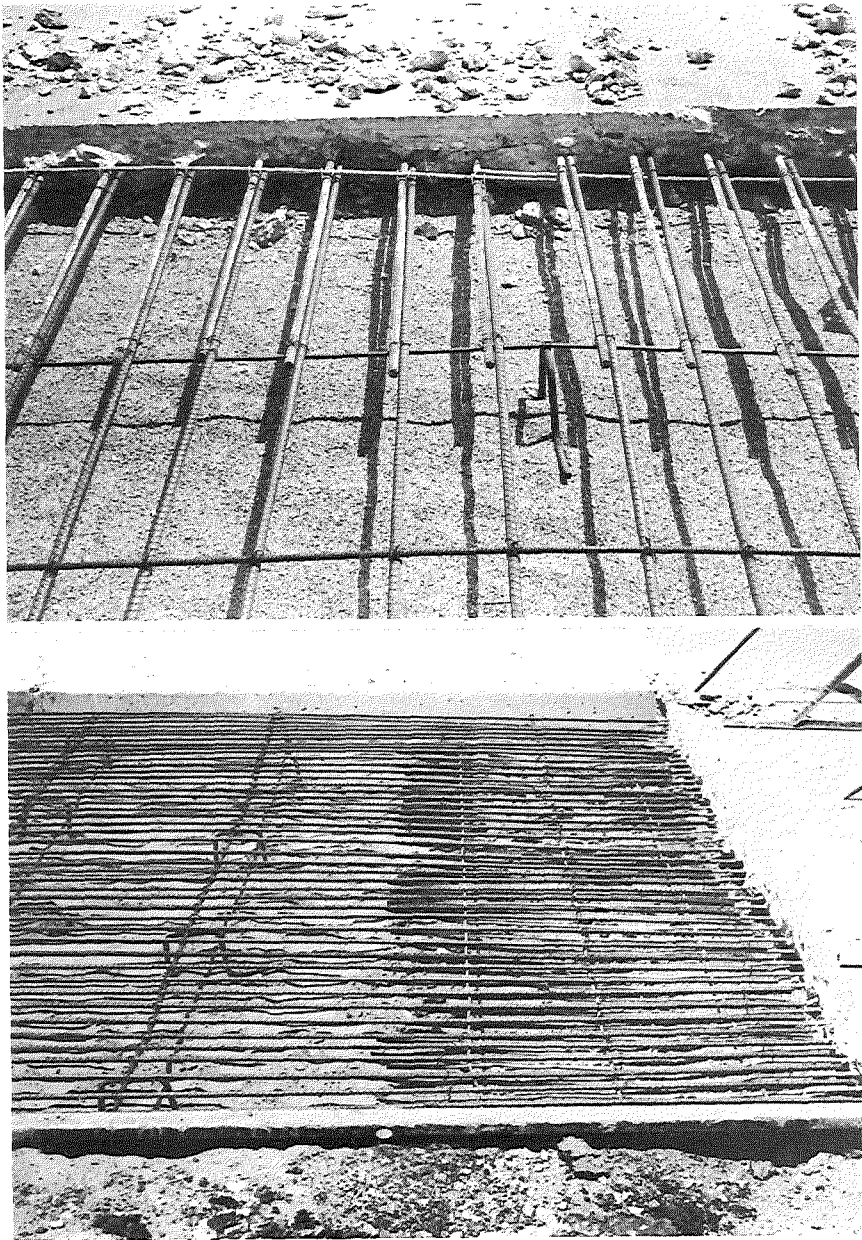


Figure 9. Steel arrangement in typical patches (passing lanes) in a bar mat section (top) and in a welded wire mesh section (bottom).

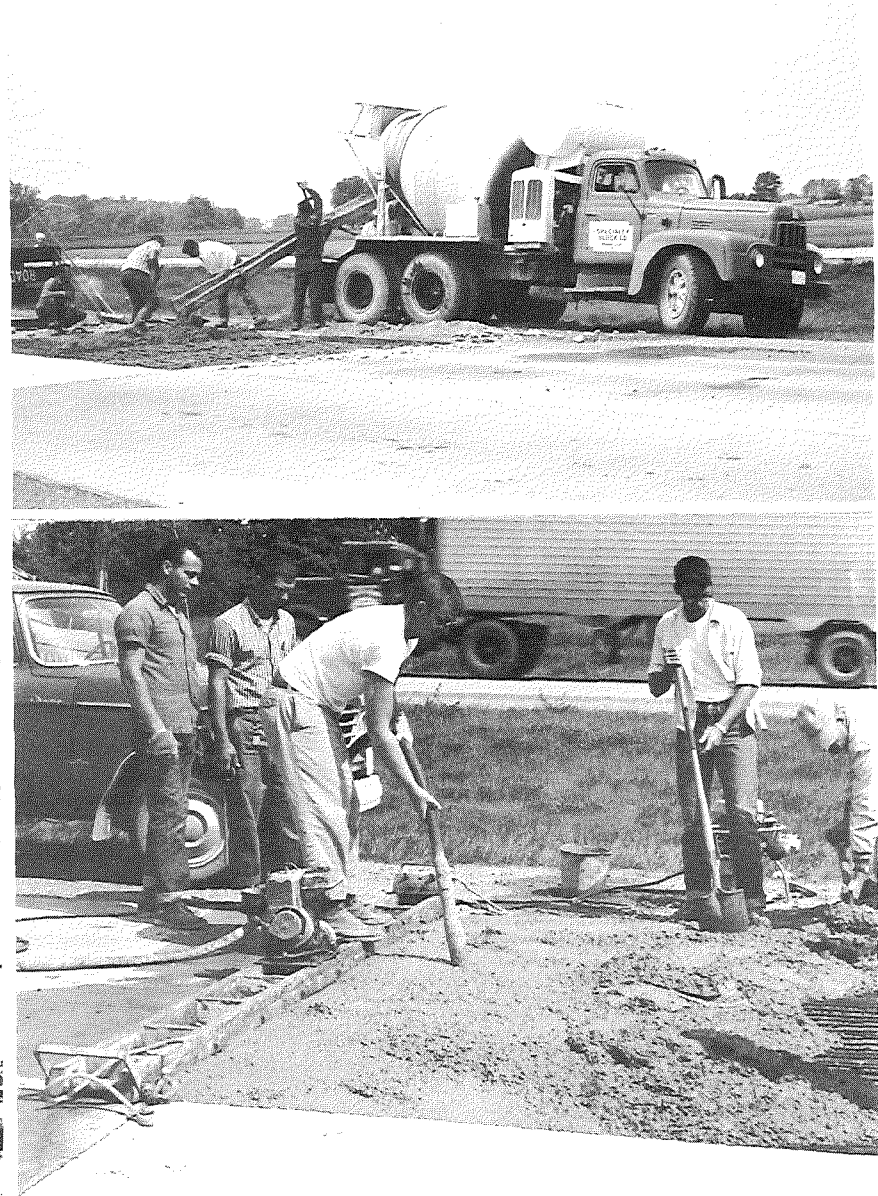
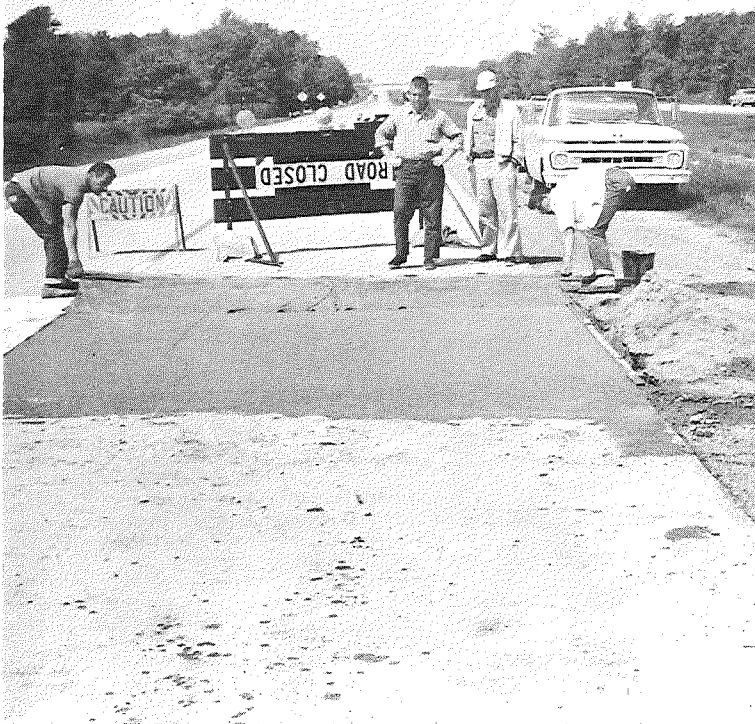
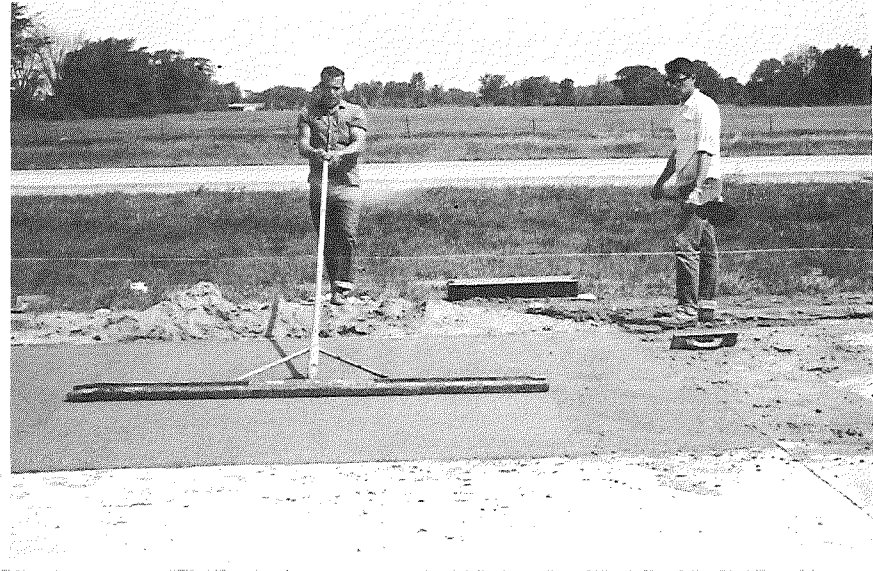


Figure 10. Concrete delivered and spread (top) and vibrated with electric vibrator (bottom).



**Figure 11. Finishing operations** included initial pass with vibratory screed (top left), final hand finishing of the surface (top right), and application of burlap drag (bottom left).



**Figure 12. Application of white membrane curing compound** (right).

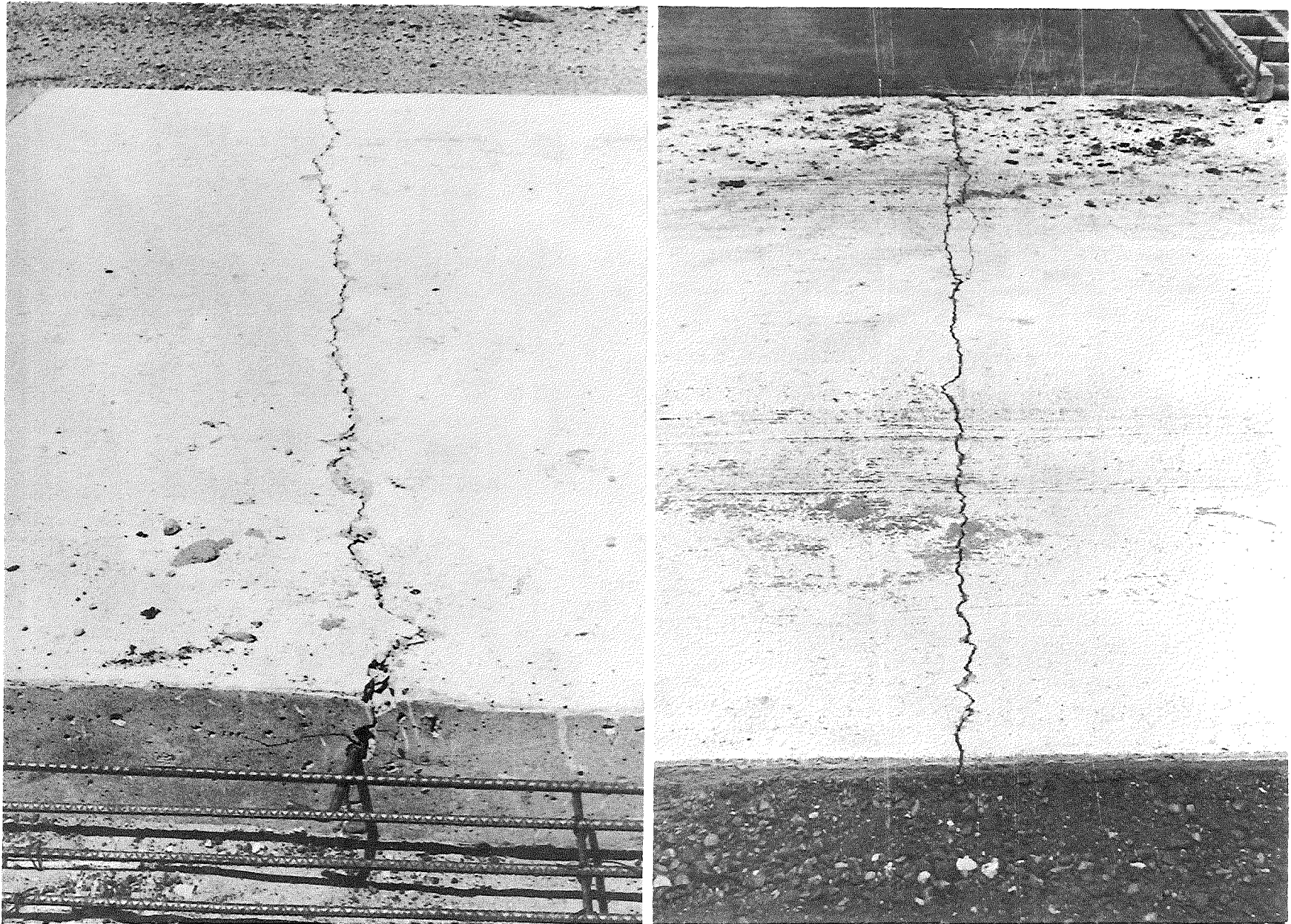


Figure 13. Failure cracks six days after pour in traffic lane patches at Station 1071+90 westbound (left), and Station 1044+66 eastbound (right).

just after the burlap finishing and the one in the existing pavement was set in Armstrong Type A-1 cement. The initial reading was taken with a 0.001-in. vernier caliper as soon as the plugs were firmly embedded. Subsequent measurements will be taken at the regular scheduled quarterly intervals at which the joint width readings are taken for the original instrumented joints.

TABLE 1  
CONCRETE PROPERTIES AT REPAIR LOCATIONS

	Roadway	Station	Lane	Modulus of Rupture, psi			Air Temp, F
				3 day	7 day	14 day	
Poured 5-15-62	Eastbound	875+90	Traffic	---	797	---	82
	Eastbound	1017+03	Traffic	---	---	760	84
	Eastbound	1044+66	Traffic	614	---	---	92
	Westbound	1045+70	Traffic	---	670	---	90
	Westbound	1071+90	Traffic	522	---	---	87
Poured 5-25-62	Eastbound	875+90	Passing	591	---	---	72
	Eastbound	1017+03	Passing	632	---	---	74
	Eastbound	1044+66	Passing	---	870	---	74
	Westbound	1071+90	Passing	---	---	786	74

### Conclusions

The primary objectives in repairing the experimental pavement were restoration of continuity and riding quality in the failed areas. This was accomplished, except at the two locations previously mentioned. It appears that complete success can be obtained by employing construction procedures that tend to minimize the adverse effect of temperature changes. It also became apparent that since lane-at-a-time construction is necessary to maintain traffic during repair of this type, the repair should be done if possible before the failed area has deteriorated to such an extent that one lane cannot withstand the forces arising from temperature changes. The procedure described here for determining the area to be replaced at a failure proved to be satisfactory.

### Recommendations

The recommendations made before the repair concerning construction procedures to be used seem satisfactory in light of the field operations,

except for the full-depth sawcut suggestion. Since this is rather an expensive process, a shallower 1-1/2 in. sawcut establishing the proper line will suffice. Once this line is established, the concrete on each side can be broken, and after its removal, the steel can be cut off at the required 3 ft length. Additional recommendations based on the experience gained are as follows:

1. To achieve the best possible results, construction procedures must be very flexible so that any changes necessary can easily be made as work progresses. Therefore, it is recommended either that the Office of Maintenance perform any future repair of this type or that the work be done under contract on a force account basis.

2. When failures have occurred at more than one location, in addition to lane-at-a-time construction the repair should also be on a patch-at-a-time basis. This would minimize the expansion-contraction cycles to which the pavement is subject, which in turn would reduce the severity of the additional forces acting on the one remaining lane. It would also minimize the probability of buckling or blowup failures, and allow for proper welding of the reinforcement to maintain the necessary steel continuity.