EXPERIMENTAL INSTALLATION OF CHROME-ALLOY STEEL DOWELS

MICHIGAN DEPARTMENT OF
STATE HIGHWAYS AND TRANSPORTATION

EXPERIMENTAL INSTALLATION OF CHROME-ALLOY STEEL DOWELS

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In 1964 the Department, with the approval of the Federal Highway Administration, constructed a test road having load transfer assemblies containing chrome-alloy steel dowels. The objective of the study was to determine the field performance of this type of dowel bar as compared with standard steel dowels. Construction of the pavement was described in MDSHT Research Report R-505. However, for the reader's convenience pertinent information from the earlier report is included herein.

Location and Description

The experimental pavement, State Project I 41027A, C24, etc., consists of 4.9 miles of I 196, beginning at the Grand River then easterly through Grand Rapids to Fuller Ave (Fig. 1). Each roadway contains two 12-ft lanes of reinforced 9-in. thick concrete pavement. Through interchanges in the downtown area the pavement width is increased by one or two lanes to provide for the merging of traffic. The contraction joints are spaced at 71 ft 2 in. and expansion joints are located at structures, ramp gores, and at the beginning and ending of curves. The contraction joint grooves were formed using styrofoam inserts 1/2-in. wide by 2-in. deep. The expansion joints contain 1-in. wide bituminous filler material and the grooves were formed 1-in. wide by 2-1/4-in. deep by use of wood strips. All joints contain chrome-alloy steel dowels and galvanized steel base plates. Both types of joint were sealed with neoprene seals. However, the seals did not extend down the vertical edges of the slabs, but were terminated at the curb line or edge of metal.

Project I 41029A, C35, etc., a 2.6 mile section of I 196 immediately west of the experimental pavement was selected as control section. The design of this project was identical to the experimental section except that the joint spacing was 99 ft 0 in. and the joints were sealed with hot-poured rubber-asphalt.

Both projects were constructed during the summer of 1964 and opened to traffic in December of that year.

The 1973 average daily traffic (ADT) on the control section was 22,900 whereas on the experimental pavement the ADT varied from a low of 22,200 on the western end to a high of 43,000 in the downtown area.

Dowel Bar Requirements

Dowel bars for both the experimental and the control pavements were 18-in. long by 1-1/4 in. in diameter and were installed on 12-in. centers at mid-slab depth. The tensile requirements for both bar types and the

chemical properties of the standard dowels met the Departments Standard Specification. The chrome-alloy steel dowels met the following chemical composition:

Chemical	Percent
Carbon	0.18-0.23
Manganese	0.65-0.90
Phosphorus	0.025 max.
Sulphur	0.025 max.
Silicon	0.20-0.35
Chromium	3.00-3.50

Performance Evaluation

The performance of the two pavement sections has been evaluated by checking the corrosion and pull-out resistance of the two dowel bar types, by conducting condition surveys to determine transverse slab cracking, and by making periodic inspections of the pavement's general condition.

Dowel Bar Corrosion - Approximately two years after the pavements were constructed the condition of the dowels was examined by removing the seal and filler material above the dowels in expansion joints at two structures. Some rust and minor pitting were noted on both the chrome-alloy and standard dowels. In 1970 the outside dowel adjacent to the traffic lane shoulder was removed from a contraction joint on each project. Examination of the standard dowel revealed that the bar had corroded for a length of 1 to 2 in. in the joint crack area, and corrosion had penetrated to a depth of 3/32 in. at some spots in the corroded area (Fig. 2). The chrome-alloy dowel, shown in Figure 3, had a 2 to 2-1/2 in. length of corrosion in the joint crack area, and a maximum corrosion penetration of 1/8 in.

Dowel Bar Pull-Out Resistance - The dowels were removed in a block of concrete 12 in. wide, 24 in. long and with a thickness equal to the slab depth. Prior to breaking the concrete samples for corrosion examination of the dowels, pull-out tests were conducted to determine the maximum load occurring during a 1/2 in. movement of the dowel. The load recorded was 1,400 lb for the standard dowel and 8,400 lb for the chrome-alloy dowel. Comparing the pull-out test results to those obtained from dowels removed from other projects, indicates that the resistance of the standard dowel lies near the low end of the range of maximum load obtained during the 1/2 in. movement, whereas the load obtained for the chrome-alloy bar is close to the top of the load resistance range.

Transverse Slab Cracks - Dowel bar restraint along with loads, subgrade support, concrete quality, and slab length affect the formation of transverse cracks. Isolation of the affect that each of these factors has on transverse slab cracking is not possible and, therefore, the results of five and 10 year crack surveys shown in Figure 4 must be interpreted with this in mind. Since the control section has 99-ft slab lengths, the results of crack surveys on M 19, which has the same slab lengths and seal type as the experimental pavement and is of the same age, have been included in Figure 4. The M 19 pavement (Project F 50092A, C1) is 1.4 miles long and is located between I 94 and New Haven in Macomb County.

It is of interest to note that after 10 years of service over 90 percent of the slabs joined with chrome-alloy dowels remain without cracks, whereas only 15 and 5 percent are uncracked on the control pavement and on the M 19 project, respectively. Also, the highest number of cracks in any slab was two on the experimental pavement, seven on the control project and six on the M 19 project. On the chrome-alloy project there is 0.07 cracks per slab after 10 years of service. On the standard project with 99-ft slabs there are 2.4 cracks per slab and on the standard pavement with 71-ft slabs, on M 19 there are 2.5 cracks per slab. The 10 year condition survey lists no joint repairs for the experimental pavement but shows 12 lane repairs on the control section, and two lane repairs on the M 19 project. The ADT counts indicate that M 19 carries only about one-half of the traffic compared to the I 196 projects.

General Pavement Condition - Periodic inspections of the pavement sections have indicated that the experimental pavement has performed much better than the control section. As mentioned previously over 90 percent of the slabs are still uncracked and there have been no joint failures to date on the section with chrome-alloy dowels. Although not related to the type of dowels used, but to the design, joint problems are beginning to occur on the experimental section.

The design requirement for expansion joints at structures, at P.T.s, at ramp gores, etc., necessitated the installation of 77 expansion joints on the eastbound roadway and 72 on the westbound roadway. These expansion joints have undoubtedly contributed to the excellent performance of the pavement by relieving the compression in the slab. However, the compressive forces have now closed some of the expansion joints to the point where the neoprene seal is solid and severe spalling is occurring (Fig. 5). On a recent survey a total of 12 joints, six on each roadway were found to have spalled to the extent shown.

Another joint problem is the loss of seals in contraction joints. Currently, there are 67 joints with missing neoprene seals. Most of these seals are lost from joints near expansion joints. For example, 31 seals are missing in joints adjacent to expansion joints, and 17 are missing from the second joint following an expansion joint. The reason for losing the contraction joint seals near expansion joints is that the slabs compressive forces are smallest at these locations and, consequently, when the slab contracts, larger joint openings will occur, as compared to locations where the compressive forces are larger. Spalling along the joint groove can also result in the loss of seals. As shown in Figure 6, a spall may result in the seal losing its compression and eventually traffic will tear the seal apart and out of the groove. Regardless of which way the seals are lost, the result is that the open plane-of-weakness crack fills with incompressible materials. As a result the compressive forces increase more rapidly to the point where joint failures may occur.

Conclusions

1. On the basis of the results of limited tests on pull-out resistance of dowels and examination of samples for corrosion, the chrome-alloy dowels are not performing any better than standard steel dowels.

2. With respect to transverse cracking and general pavement condition, recent surveys indicate that the experimental pavement is out-performing the standard pavement. This may in part be due to properly functioning dowels and to the relatively large number of expansion joints installed on the experimental section. Although it may be difficult to determine the exact reasons why this pavement shows better than average performance an investigation may be in order.

3. Severe spalling at some expansion joints is a sign of large compressive forces building up in the pavement which could cause joint failures to occur soon. The loss of more than 10 percent of the contraction joint neoprene seals results in infiltration of incompressible materials into the open plane-of-weakness cracks, further aggravating the problem of excessive slab compression.

Recommendations

Although the experimental pavement is in much better condition structurally than the standard section, there is no evidence that the chrome-alloy dowels are more corrosion resistant than steel dowels. Moreover, the Department is considering using only coated or stainless steel sleeved dowels. For these reasons further evaluation of the chrome-alloy dowels is not recommended.

The evaluation, however, revealed that problems at expansion joints sealed with neoprene have developed and a relatively large number of contraction joint seals are missing. To prevent further deterioration of the experimental pavement and possibly eliminate expansion joint problems of the type discovered it is recommended that:

1. The experimental section be used in a study to determine procedures for resealing joints with missing seals and where spalling has resulted in loss of compression in the seals.

2. The spalled expansion joints be replaced to provide new expansion space.

3. On projects where curves, ramps, and structures necessitate the installation of a relatively large number of expansion joints, consideration should be given to spacing the expansion joints to provide the most benefit, rather than installing several in sequence at structures. Also, the design of joint groove and seal in contraction joints adjacent to expansion joints could possibly be redesigned to maintain a properly functioning seal in these joints where larger than normal joint openings apparently occur in time on some pavement.

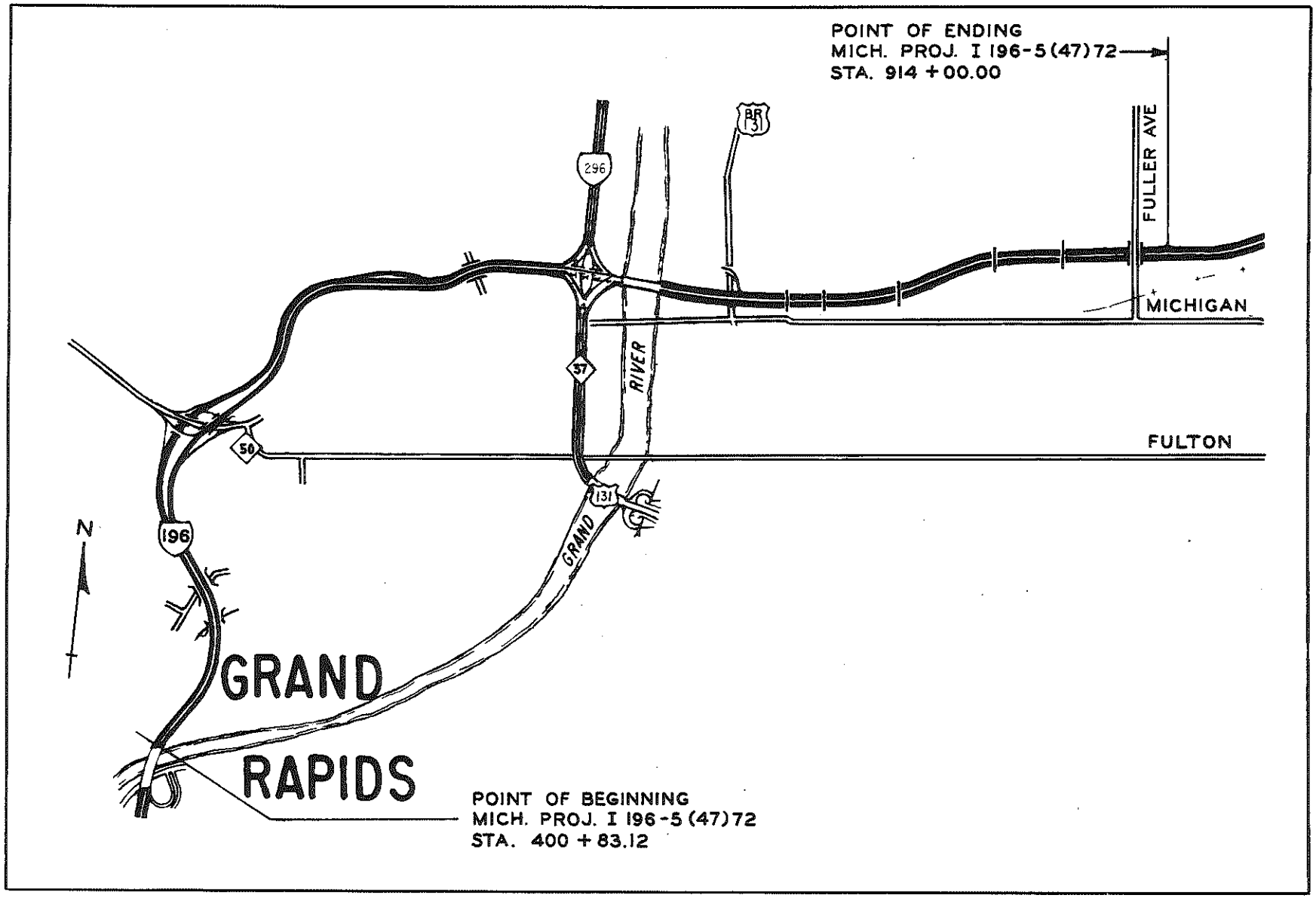

Figure 1. Locations of contracts containing experimental dowel bars.

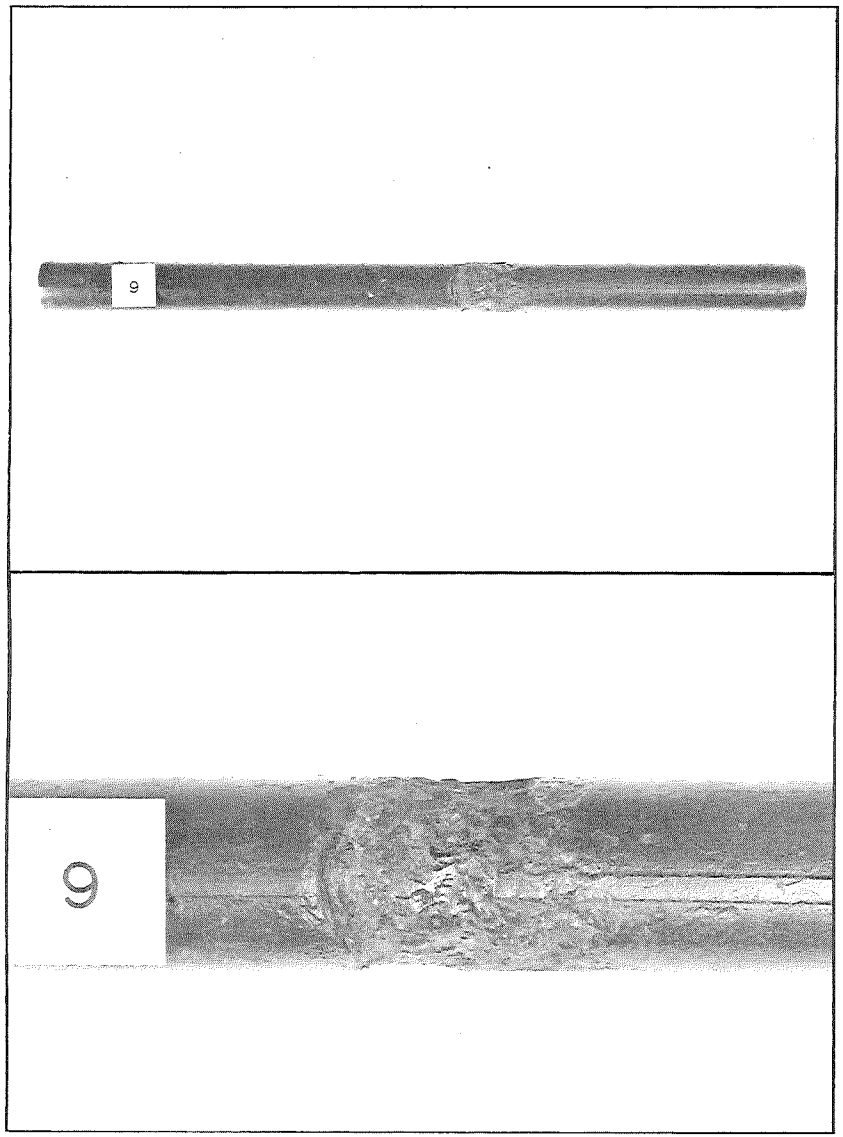

Figure 2. Corrosion condition of a six-year old standard dowel removed from a contraction joint in the control pavement.

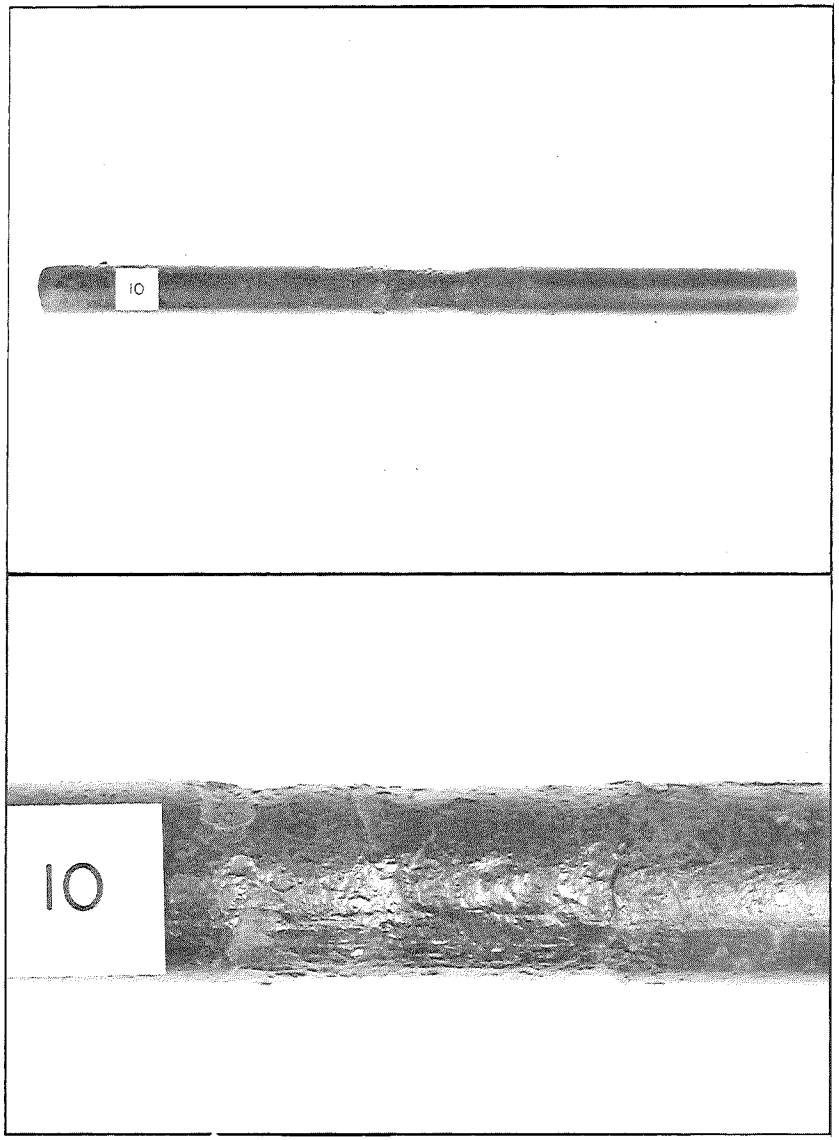

Figure 3. Corrosion condition of a six-year old chrome-alloy dowel removed from a contraction joint in the experimental pavement.

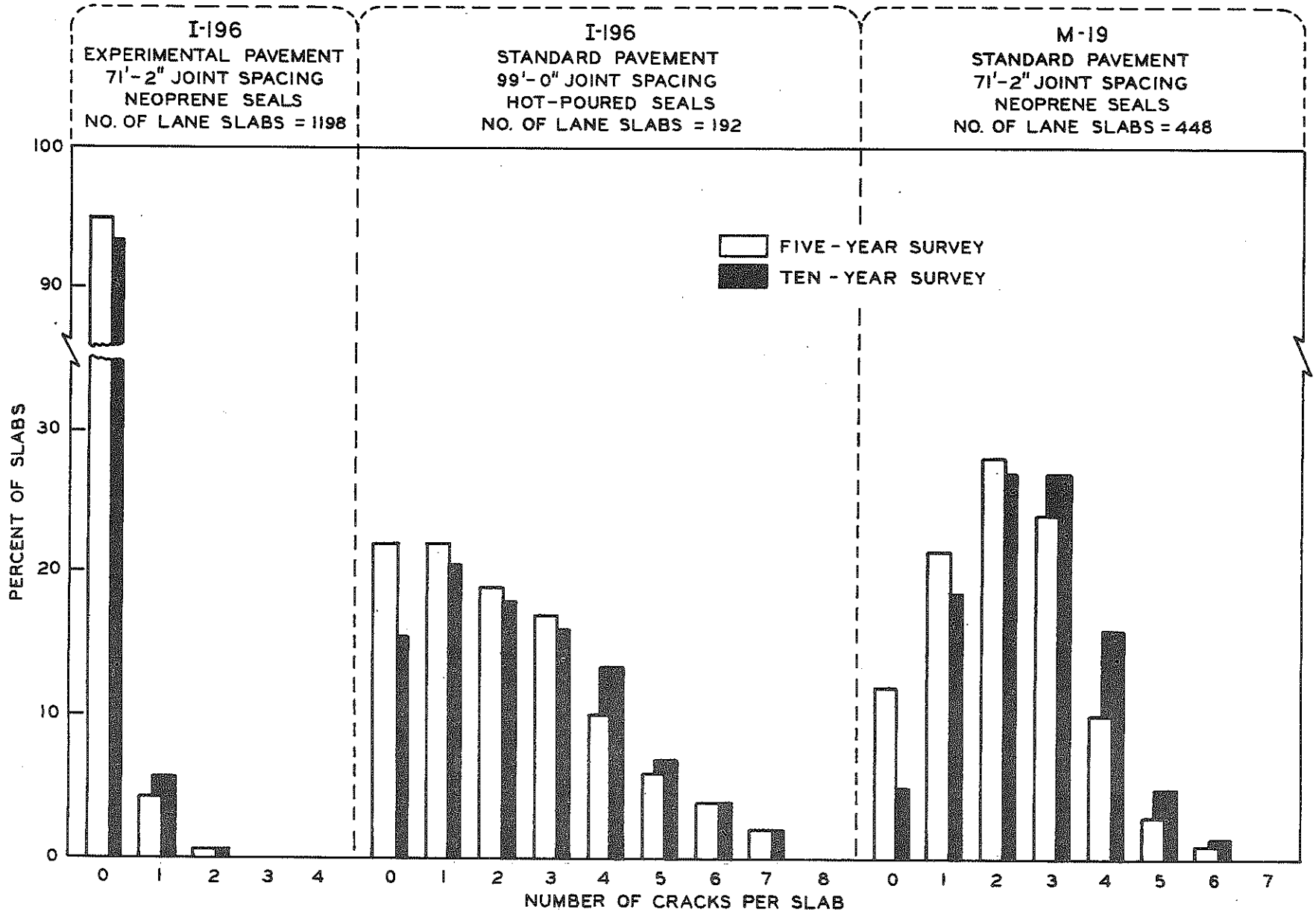

Figure 4. Histograms of transverse cracks per slab for experimental and standard pavements after five and ten years of service.

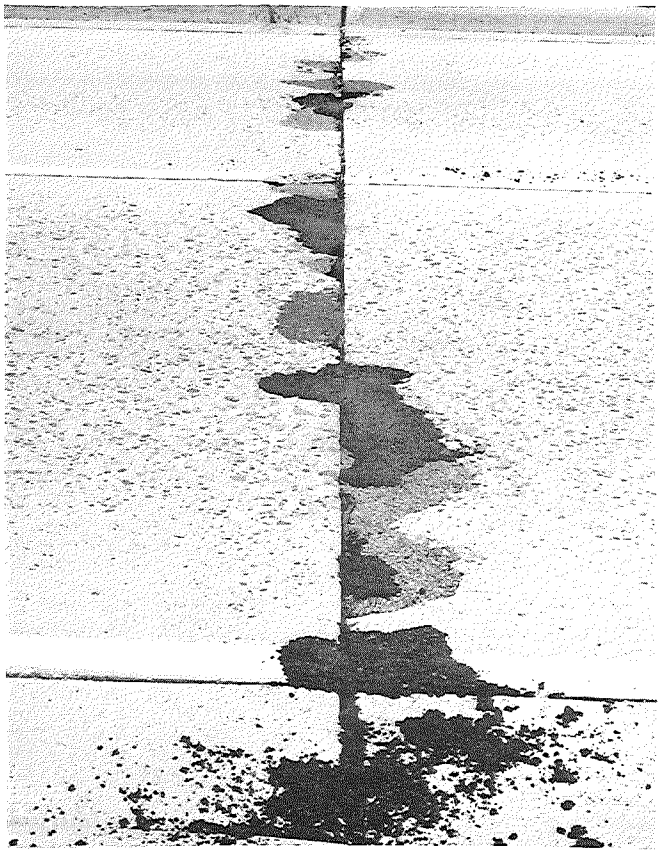

Figure 5. Condition of expansion joint where compressive forces have caused spalling to occur.

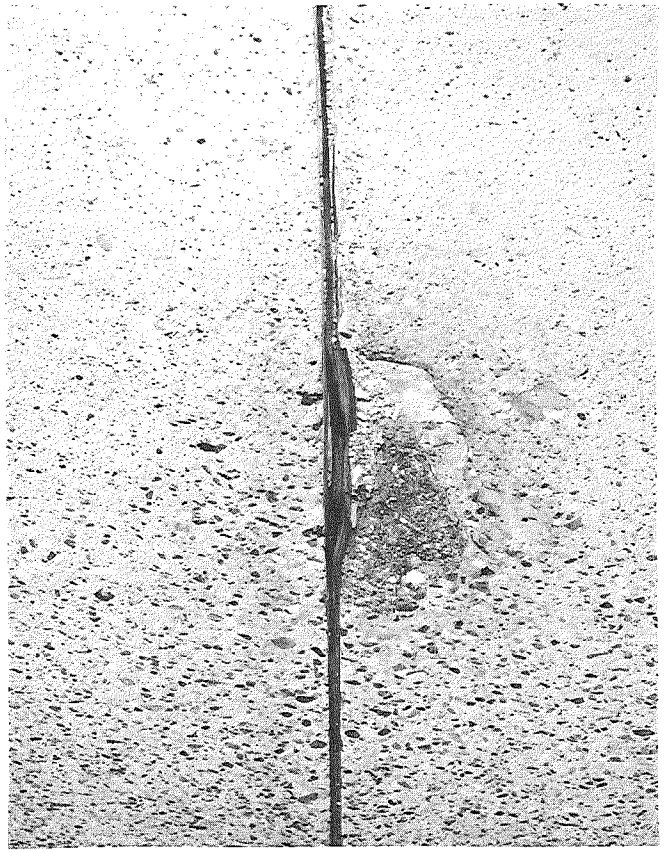

Figure 6. Neoprene seal being torn apart by traffic in a spalled area.