

AN APPRAISAL OF TRANSVERSE JOINT BASE PLATES

Research Laboratory Division
Office of Testing and Research
Research Project 39 F-7 (14)
Research Report No. R-582

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State of Michigan
Department of State Highways
Lansing, June 1966

REFERENCE: Finney, E. A. "An Appraisal of Transverse Joint Base Plates." Michigan Department of State Highways Research Report No. R-582, June 1966.

ABSTRACT: Metallic base and end plates for transverse joints were introduced into Michigan concrete pavement design in 1946, with the intent of reducing infiltration of fine inert materials into the joint space from the pavement surface, shoulders, or base. However, joints excavated after varying periods of service indicate that the plates themselves produce serious problems, through entrapment of inert materials and moisture within the joint space, particularly after failure of the joint sealant. Contraction joints frequently display characteristic patterns of deterioration, which may not be visible at the pavement surface until the final stages of joint failure; expansion joints, however, seldom show deterioration attributable to base plates. Deletion of the plates from Michigan pavement design is recommended, relying instead on preformed compression sealants to protect the joint at the top and sides.

KEY WORDS: transverse joints, base, plates.

FOREWORD

Research Project 39 F-7 (14), "Performance of Postwar Pavements," was established in 1946 as a sub-unit of the parent project, 39 F-7, "Concrete Pavement Design." When Michigan adopted its current postwar concrete pavement design practice in 1946, based on the findings of the Michigan Test Road and on recommendations set forth in Research Laboratory Report No. R-68 "The Design of Concrete Pavements for Postwar Construction," this subproject was established for the express purpose of studying the general performance of postwar pavements, particularly in relation to the new design principles and practices incorporated in their construction.

Over the years, numerous reports have been submitted under this project number, pertaining principally to various abnormal manifestations found to be directly attributable to design or construction factors. This report is the latest in this series. More are contemplated in the near future on the subject of transverse joint design.

HP&R Research Project 39 F-7 (15), entitled "Concrete Pavement Design," now nearing completion, will present a comprehensive evaluation of the performance of postwar concrete pavements based on data systematically gathered since 1946, the first year of postwar construction under current design practice. Briefly, performance will be evaluated as affected by traffic, soil, construction, and materials variables. This quantitative evaluation of performance of over 15 years of pavement construction will help Department administrators in making future decisions with reference to required improvements in major and minor design features.

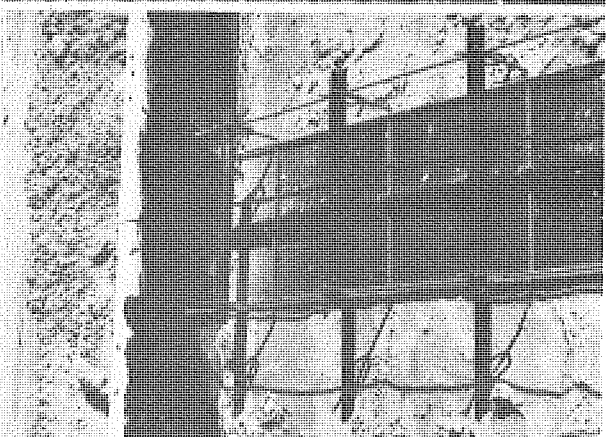
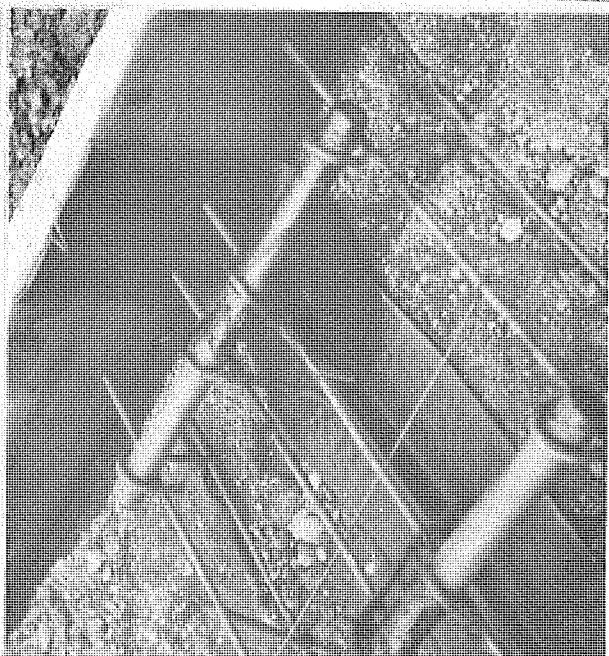
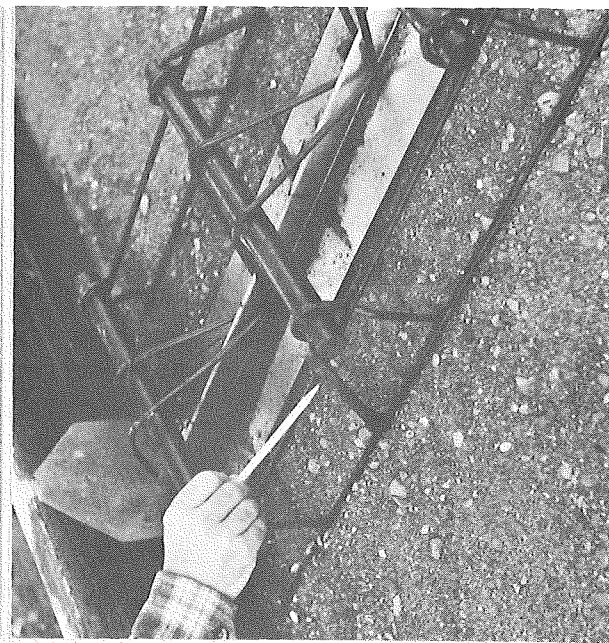
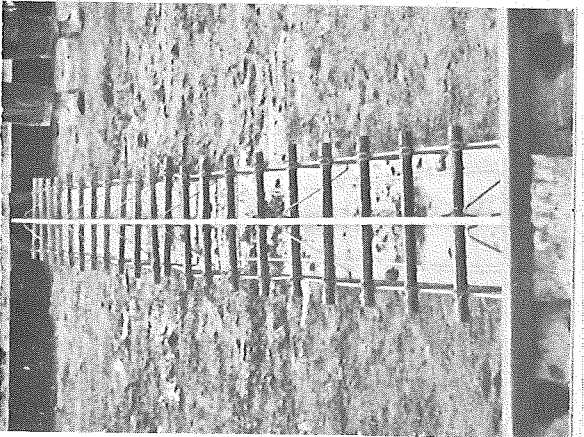
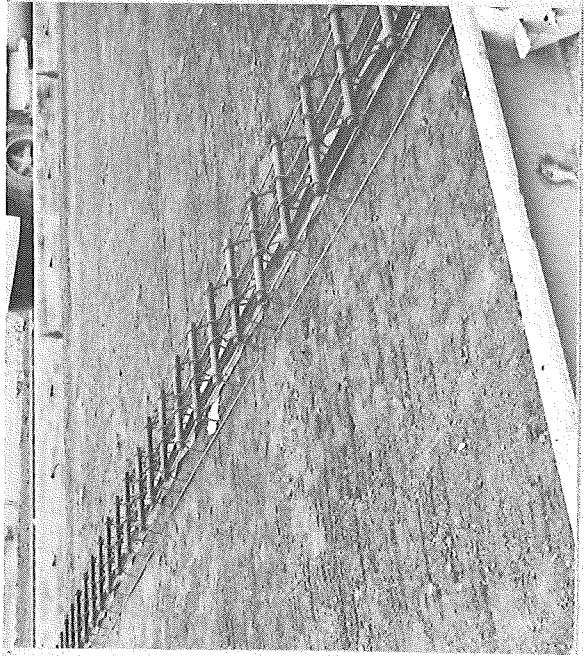
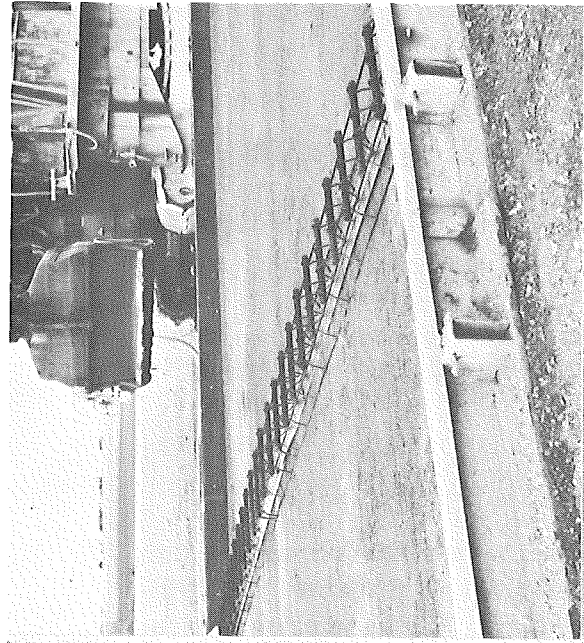
AN APPRAISAL OF TRANSVERSE JOINT BASE PLATES

This appraisal of Michigan's experience in the use of base plates for transverse joints in concrete pavements was prepared at the verbal request of W. W. McLaughlin. Recently, Department personnel have expressed concern about whether base plates should be continued as a feature of transverse joint design, in view of three recognized factors: 1) improvements in base course construction over the years may have reduced the need for base plates, 2) in spite of their presence, joints continue to fail, and 3) no other state has adopted them.

The base plate system, including two end plates extending up the slab edges at either side of the joint, was first adopted as a feature of Michigan joint design in 1946, for two purposes. First, the base plate system was intended to prevent infiltration of fine inert particles from base course and shoulder materials into the joint opening, and second, the base plate itself was to serve as a support for the dowel assembly in place of 6- by 6-in. sand plates or 2-in. wide continuous bearing plates attached to wire supports of the assembly. Further, the base plate could also furnish support for a 1-in. high parting strip placed directly under the surface groove to control direction of cracking at the joint. Finally, in adopting base and end plates, the Department was influenced by joint failure experience encountered on pre-war pavements, and by results of the joint design studies included in the Michigan Test Road (1).

The Test Road's performance suggested that in order to seal a transverse joint effectively against infiltration of inert material, it might be necessary to encase the sides and bottom of the joint in a metal sleeve, constructed in conjunction with the dowel assembly in such a manner as not to impede movement of abutting slabs. Also, it was necessary to provide an adequate seal at the top of the joint. It was thought that the hot-poured, rubber-asphalt joint sealing compounds appearing on the market about 1940, at the beginning of Test Road studies, would adequately seal the top of the joint for a long period (2).

Over the years since 1946, several changes have been made in design and materials of base and end plates (Fig. 1). The width of base and end plates was narrowed from 11-1/4 in. to the present 7-1/2 in. At the outset, bituminous-impregnated fiber board was permitted as an alternate for metal. In the 1950's, rubber and plastics were approved as substitutes



Bituminous-impregnated fiber board (11-1/4 in.).

Rubber-plastic materials (7-1/2 in.).

Galvanized sheet metal (7-1/2 in.).

Figure 1. General view and close-up of base plate installations typical of the period 1947-1966. Note contrast in base soil texture between 1947 photos (left) and more recent photos (center and right).

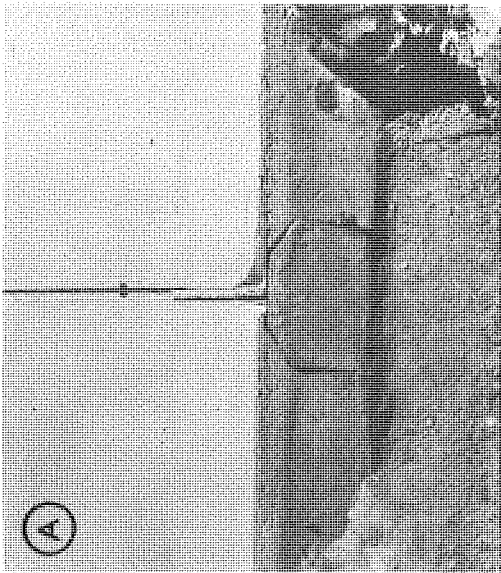
for steel, but for various reasons all these alternates were eventually discarded as unsatisfactory. Galvanized steel plates were then required and are in use at present. With the advent of preformed neoprene joint seal material in 1964, the end plates were omitted, and the joint ends have been sealed since then by extending the neoprene sealant continuously in a prepared groove down the edge of the pavement to the bottom of the slab.

Also, during this period changes in base course construction were made to upgrade physical characteristics, both in quality of material and depth of structure. Present standard base course specifications require two layers of granular materials totaling 15 in. in depth. The top layer, 3 to 4 in. thick, consists of select surfacing material such as 22A, with a definite limitation on fines. A porous material (Grade A) is permitted in the balance of the base course. The whole structure is consolidated to a uniform density. It is believed that with this type of base course, infiltration of soil material will be reduced.

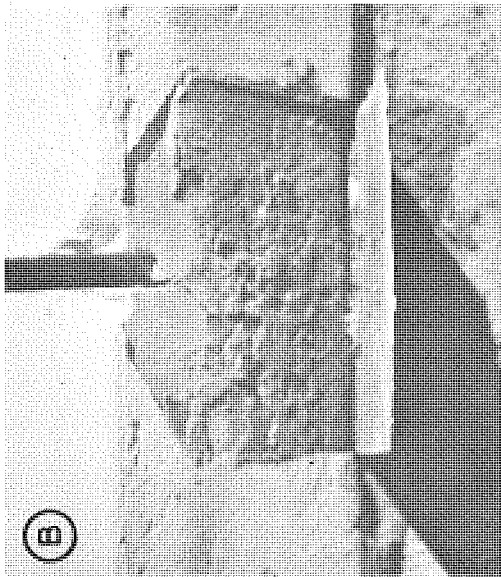
Until the advent of preformed neoprene compression sealants, the weakest component of the joint sealing system was the liquid-type rubber-asphalt sealant. Field studies have conclusively demonstrated that material of this type in general use in the past has not been able to perform satisfactorily for more than about two years, after which free water and inert materials have ready access into the joint.

Field studies have also disclosed a contraction joint construction feature permitting early infiltration of fine solid materials--the use of preformed materials such as styrofoam to form the plane of weakness groove. Much fine material entered the joint by way of the opening that always developed alongside the preformed material, caused by normal shrinkage of the concrete, contraction due to temperature change, or both. This condition is clearly illustrated by the sequence of views in Figure 2 of a contraction joint in a new project which had stood over one winter without traffic and had still not been opened when the examination was made (3). Figure 2A shows the opening beside the styrofoam material, through which fine soil particles filtered downward to the base plate (Figs. 2B, C, D, E). The metal base plate was permanently depressed from the bottom of the slab, as much as 1/4 in. (Figs. 2D and E), and the void filled with fine soil particles. Figure 2F shows soil material found in the joint groove when the styrofoam was removed.

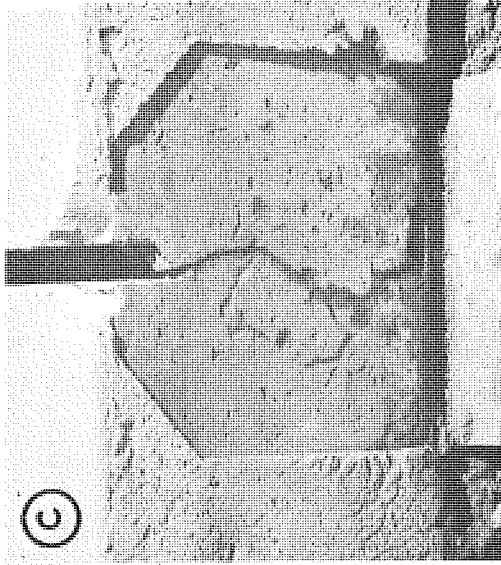
The fact that base plates in one form or another have been used on all postwar projects complicates the problem of determining their effec-



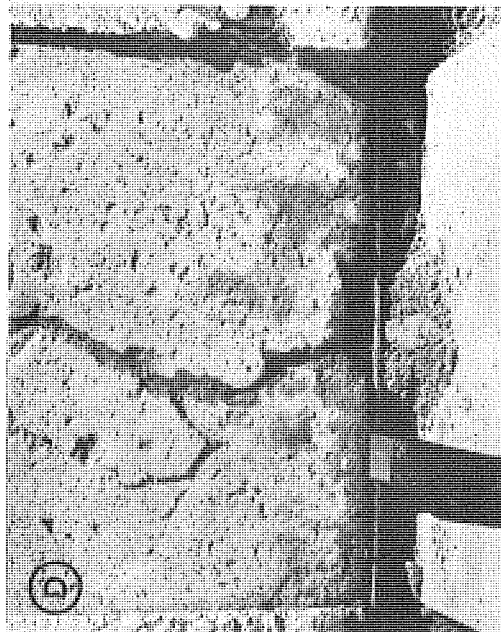
The shoulder face of a transverse joint was excavated.



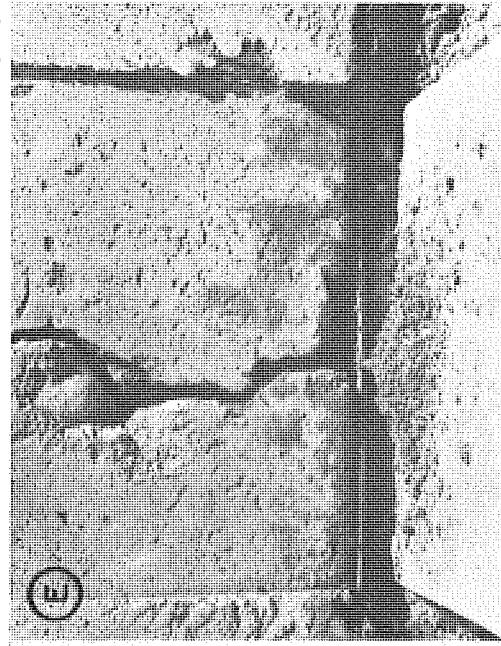
The steel end plate was turned down, revealing a deposit of packed fine sandy soil.



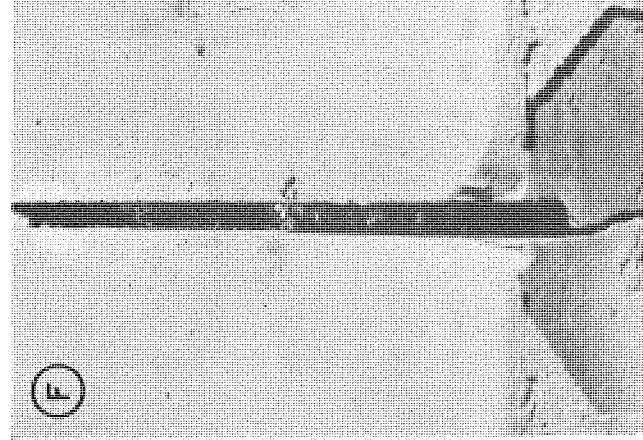
When this excess soil was removed, additional compacted soil was found in the joint crack.



The base plate was found to be depressed, and the space between the plate and slab filled with fine soil.



The joint crack after removal of soil material near the slab edge.



Additional material was found to have filtered in around the styro-foam material in the joint groove.

Figure 2. Examination of a joint ready for sealing on a new project: Sta. 298+76, Project 23-17, C14RN; constr. 1956, sealed 1957.

tiveness, as compared to their omission, since direct comparisons cannot be made on similar pavement built without them in the same project. Thus it is necessary to draw conclusions from the many field inspections of distressed joints occurring in projects built since 1946.

FIELD SURVEYS OF POSTWAR JOINTS

Since 1946, numerous field surveys have been made to examine base plate performance specifically, and to study joint failures in general. In this report, pictorial evidence is included from reports on several of these earlier surveys, and in addition results are presented from more unreported surveys made since this particular report was started. In the eight surveys reported, the age of examined pavement ranges from three to twenty years.

Survey 1

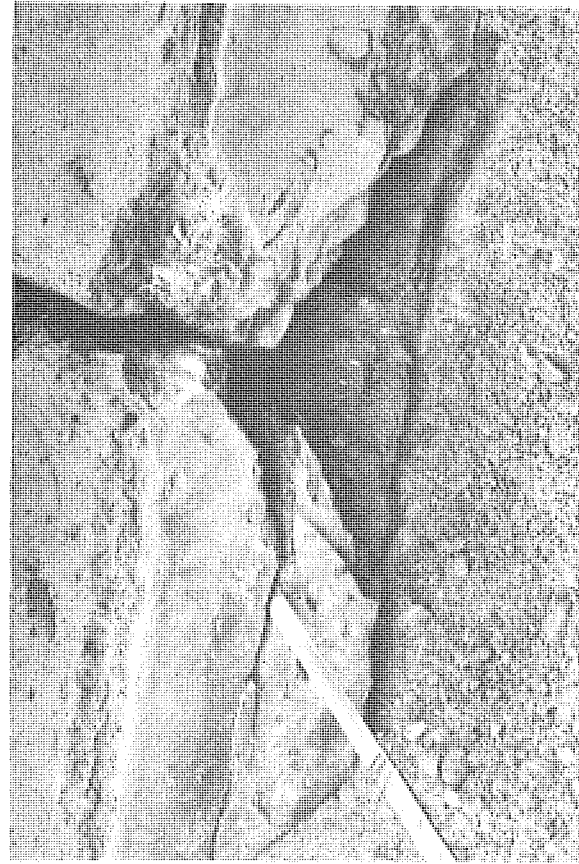
Examination of contraction joints on several projects (3), revealed various degrees of slab spalling and concrete deterioration at the bottom of the joint, as illustrated in Figure 3. In all cases, pavement condition above the base plate could not be surmised from physical appearance of the surface. The degree to which the base might have contributed to the situation in each case would be difficult to ascertain. However it is quite obvious that due to failure of the joint seal to accomplish its intended function, the joint space had become filled with soil material which was then trapped by the base plate. The characteristic cone or wedge shaped void at the bottom of the joint (at lower right in Fig. 3) evidently results from complete disintegration of concrete in the area, and has been observed on many other projects during field surveys.

Survey 2

A 1963 survey of several construction projects to observe rusting of metal base plates revealed certain additional pertinent facts (4). Figure 4 shows condition of a joint after three years in service, before and after removing the end plate. When this plate was pulled away, the joint opening and void above the base plate were full of fine sand material, which was removed before the "after" picture was taken. Figure 5 shows a 6-year-old joint before and after removing the end plate. Although everything looks serene at the surface of this latter joint, deterioration has begun in the area above the base plate.



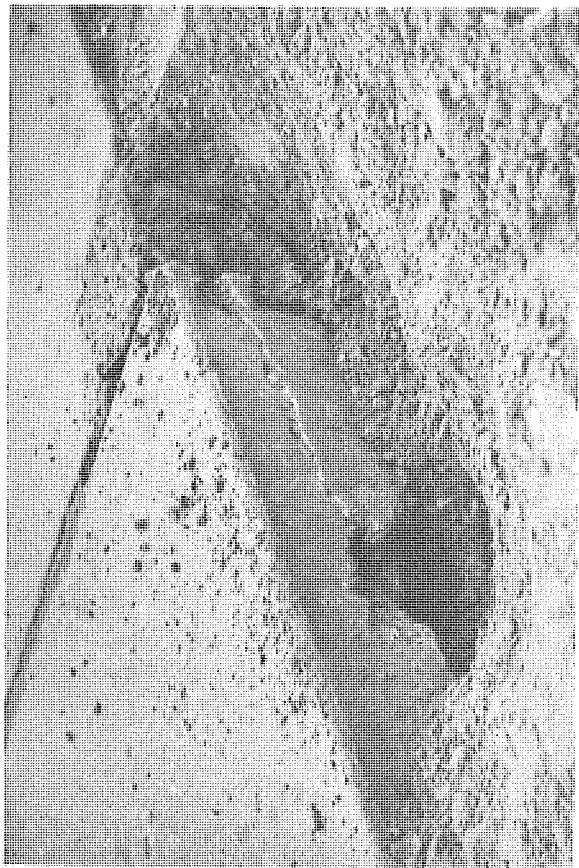
Sta. 876+00, Project 39-40, C4; constr. 1953



Sta. 207+09, Project 47-26, C6; constr. 1948

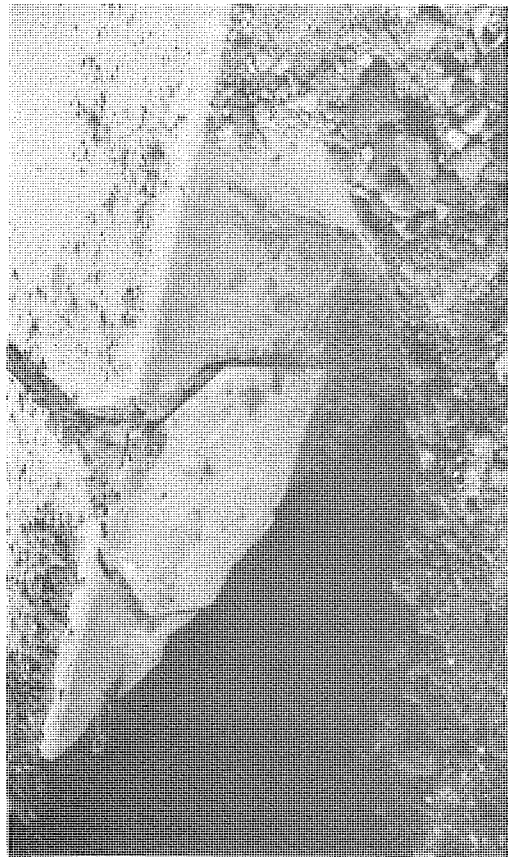


Sta. 1067+81, Project 39-40, C4; constr. 1953

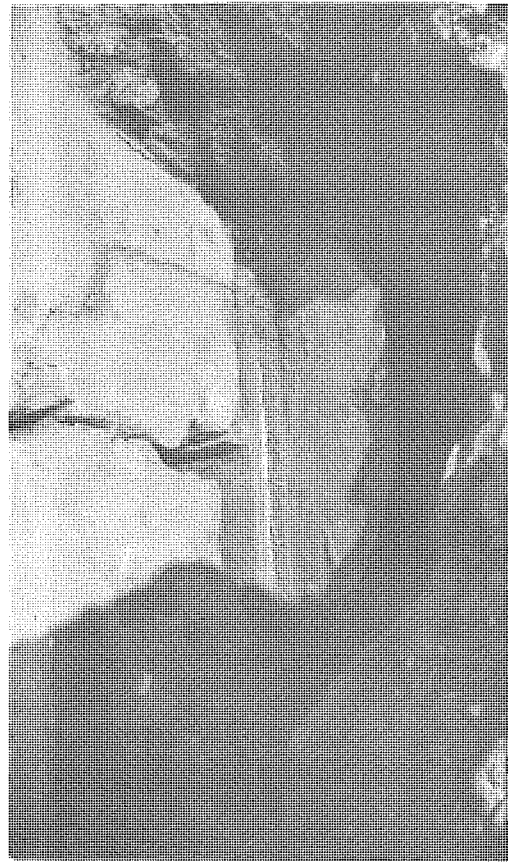


Sta. 262+25, Project 72-7, C5; constr. 1947

Figure 3. Slab bottom spalling at four joints exposed by excavating; pavement ages of 3, 4, 7, and 8 years (from upper left).



Before removing end plate.



After removing end plate.

Figure 4. Three-year-old base plate; Project 39-40, C4; constr. 1953.



Figure 5. Six-year-old base plate; Project 23-17, C11; constr. 1952.



After removing end plate.

Survey 3

A 1965 survey of joint failures on a 12-year-old project (5) disclosed further evidence that base plates may contribute to deterioration of concrete at the bottom of a joint. Figure 6 shows photographically and schematically an area of complete deterioration below a dowel system, as observed during repair of numerous other failed joints.

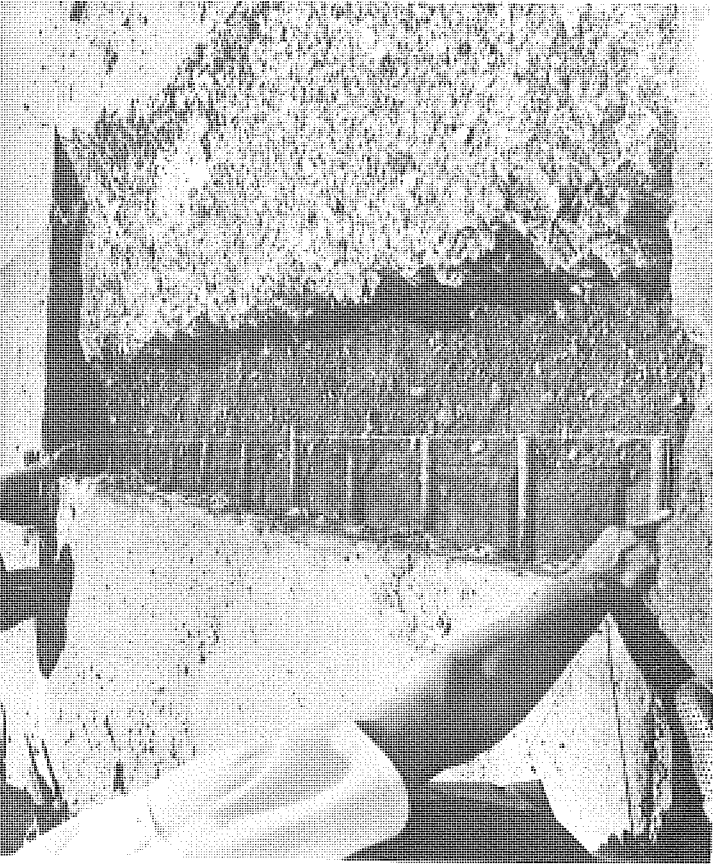
Survey 4

Another 1965 survey of joint failures (6), on US 127 between Hudson and the Ohio state line, revealed that in the case of the joints inspected, concrete above the base plate had disintegrated in the characteristic wedge shape, tapering to a point at the dowel bars. On a 1947 project there, Figure 7 shows that concrete above the dowels had also fractured into small pieces as though subjected to severe compressive stresses. In contrast, the joints on an adjoining 1949 project generally looked normal on the surface, but upon further examination the concrete immediately above the base plate was found to be badly disintegrated (Fig. 8).

Samples of crumbly concrete material were taken from joints in both of these US 127 projects and analysis indicated 0.34 lb of free sodium chloride per ton of concrete in the 1947 project, and 0.62 lb per ton in the 1949 project. These results support the theory that concrete deterioration immediately above the base plate is aggravated by penetration of salt solutions from de-icing chemicals into the joint, due to faulty sealants, with subsequent impoundment on base plates.

Survey 5

By arrangement with the Office of Maintenance, in September 1965 two joints were examined on M 46 just east of M 83 in Saginaw County. This pavement was constructed in 1947 and contained joints apparently in excellent condition, as well as many in the imminent failure category. The examination consisted of carefully removing concrete from both sides of two joints, one of which was in a bad state of disintegration (Fig. 9A), and the other apparently in good condition from the appearance of the surface (Fig. 9B). In Figure 9C, note the characteristic triangular wedge of completely deteriorated concrete immediately above the base plate. Concrete in the area of the dowels and above is badly crushed. In Figure 9D, showing the apparently good joint, also note the disintegrated triangular wedge of concrete immediately above the base plate, although concrete above the dowel system is still sound. Conceivably, with pres-

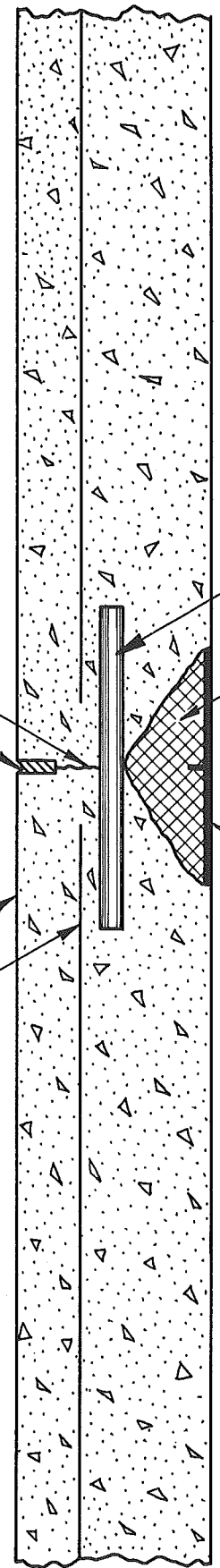


9" UNIFORM REINFORCED CONCRETE

STANDARD REINFORCED MESH

1/2" X 2" SEALED JOINT GROOVE

PLANE OF WEAKNESS CRACK



15" X 1" DIA. DOWEL BAR

DETERIORATED CONCRETE

1/4" WIDE METAL BASE PLATE

Figure 6. Dowel and joint groove misalignment were observed during repair of this 12-year-old joint (upper left), and concrete deterioration below the dowel bars (upper right); Sta. 327+03 EB, Project 38-48, C9.

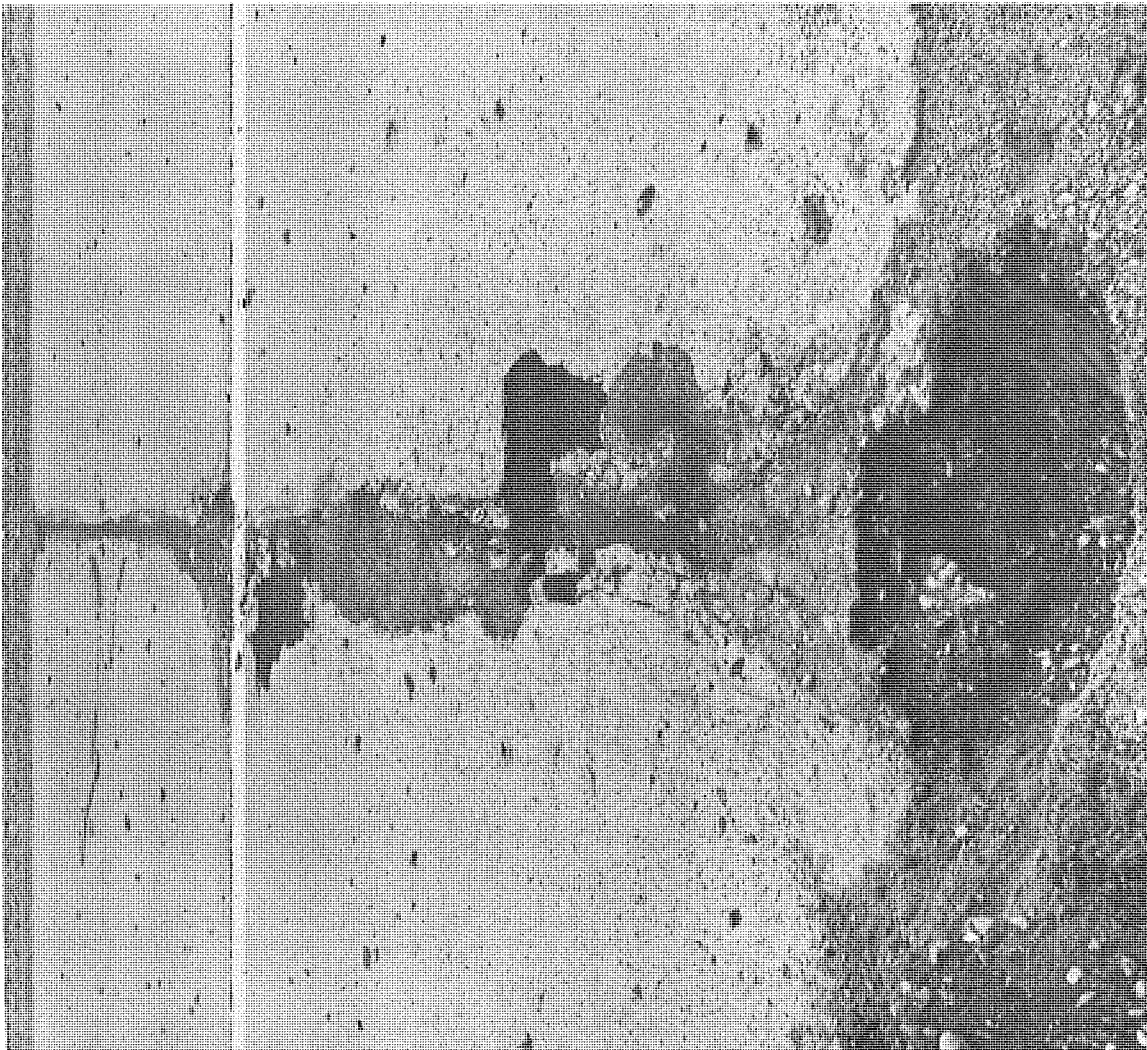
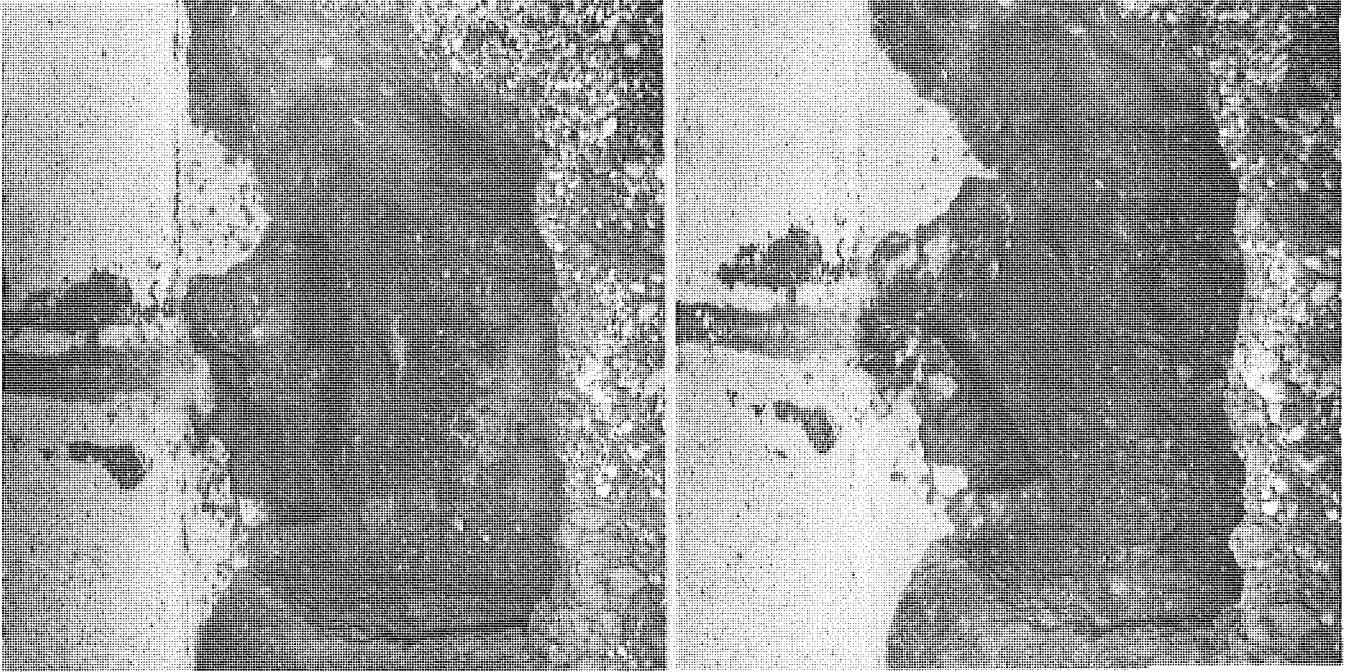


Figure 7. Distressed 18-year-old joint with end exposed; Project 30-04, C3.

Figure 8 (right). End view of sound 16-year-old joint in Project 30-04, C5, before removal of end plate (top) and after removal of end plate (bottom). Note disintegration of concrete above base plate.

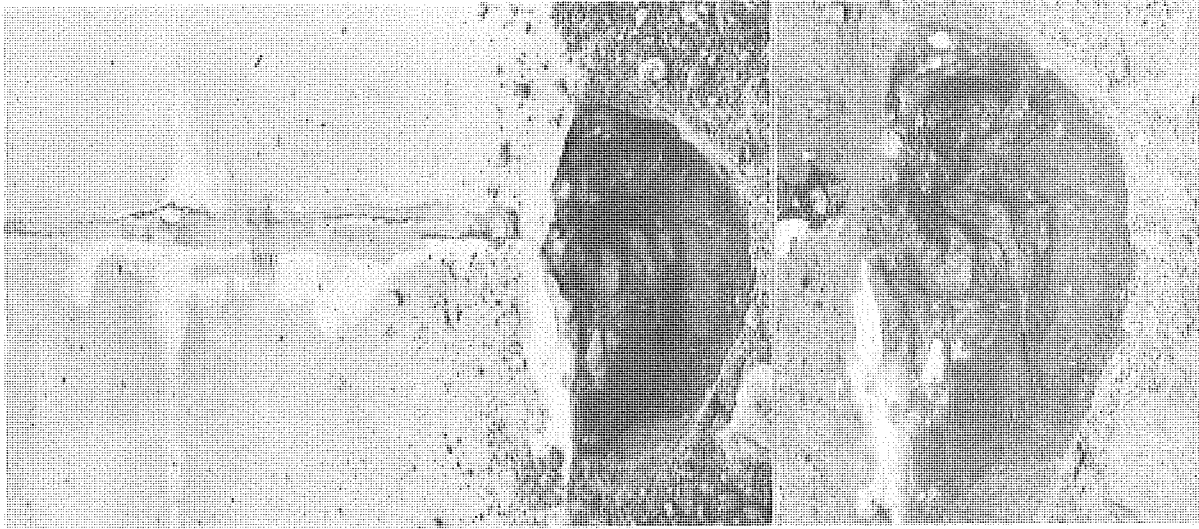


Figure 10. Two views of a deteriorating 18-year-old joint at Sta. 577+00 on Project 23-6, C4.

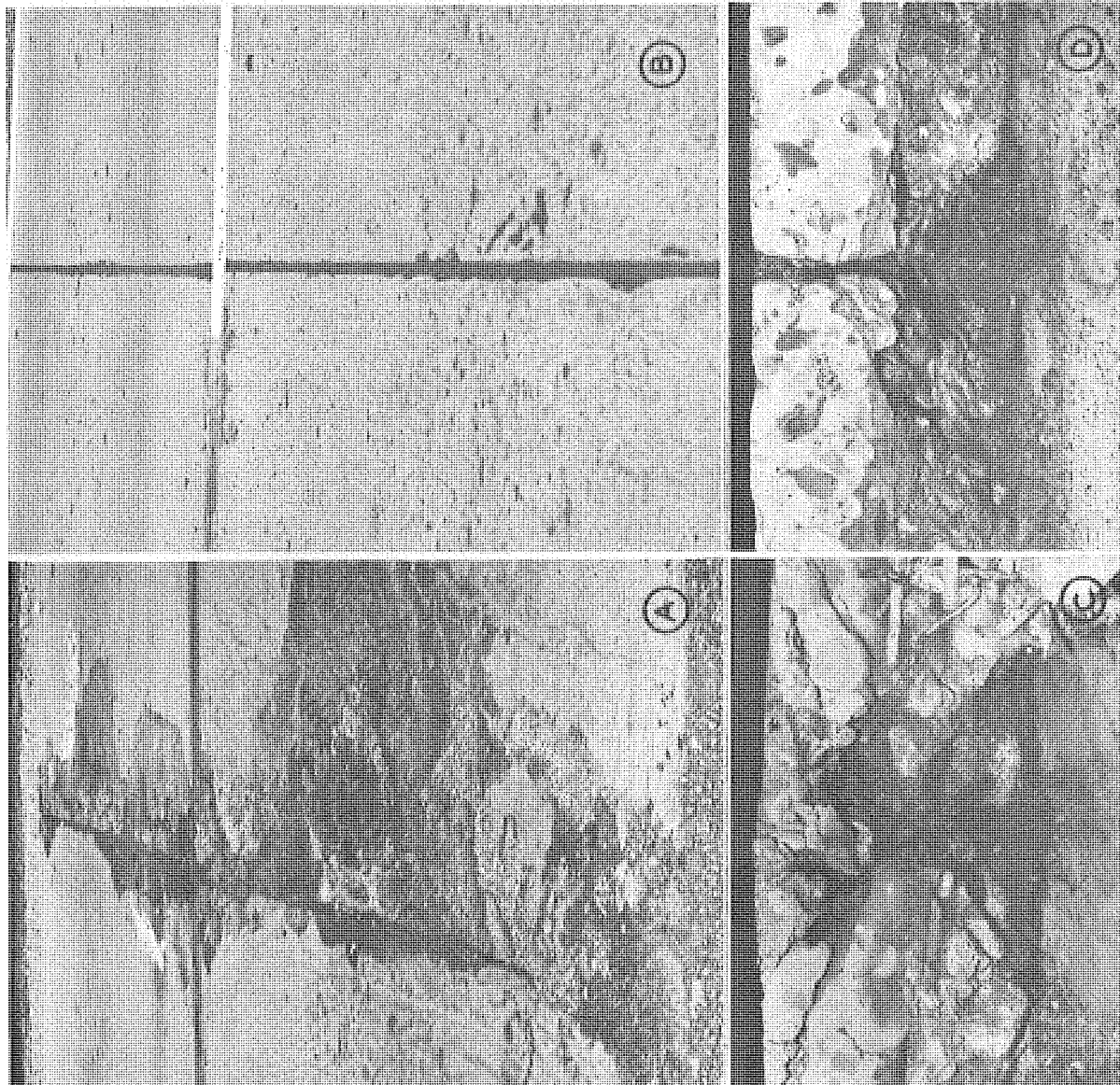


Figure 9. Characteristic deterioration above the base plate found in two 18-year-old joints, but not necessarily reflected in pavement surface condition (Project 73-30, C4).

Sta. 563+17

Sta. 559+23

sure buildup at the joint faces due to loss of bearing area, the sound concrete at the surface in Figure 9B would eventually have failed in the manner shown in Figure 9A.

Survey 6

A joint on M 43 west of Grand Ledge, also constructed in 1947, is shown in Figure 10 as it appeared in an April 1966 inspection. Although the pavement surface appears sound, initial crushing of joint faces was evident, the worst area being immediately above the base plate. Also, note in the close view of the slab edge the two longitudinal cracks at left, running out from the joint face and indicating the presence of large internal forces at some time during the life of the pavement.

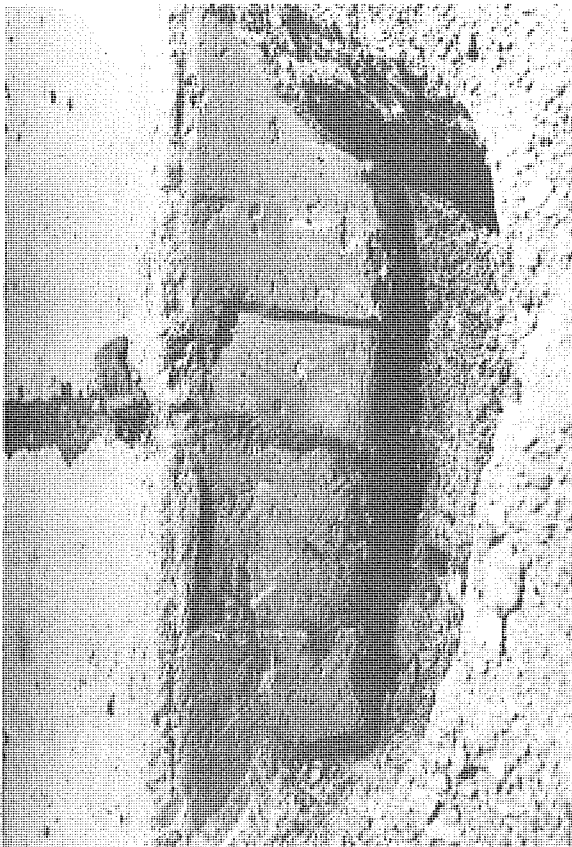
Survey 7

In May 1966, additional surveys were made to determine the state of concrete deterioration above the base plate at expansion joints as compared to contraction joints. First, on a 1946 project on US 27, Figure 11 shows concrete at a typical expansion joint to be in excellent condition the full depth of the joint and the filler material to be compressed practically to refusal. In the same figure, note typical concrete disintegration above the base plate at a contraction joint 100 ft north of the expansion joint.

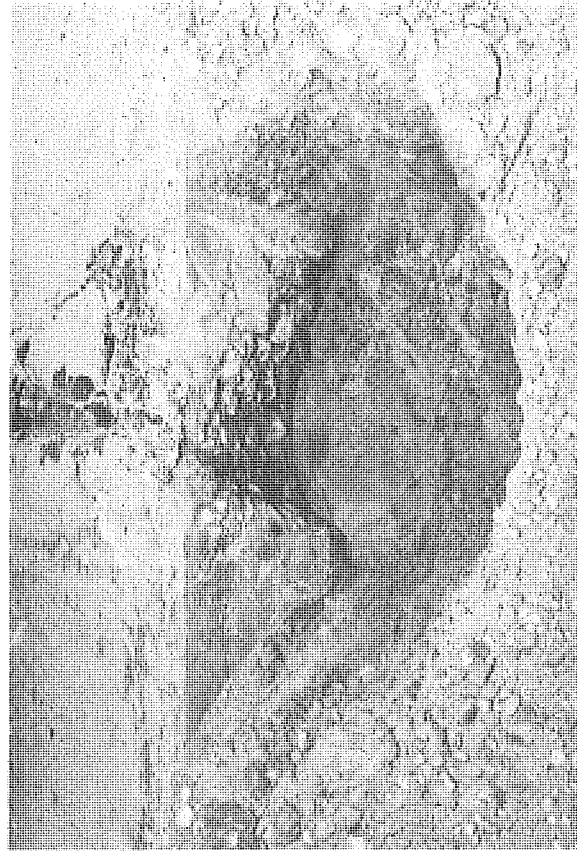
The same contrast was found on a more recent US 27 project, built in 1956. With reference to Figure 12, here again note the difference in concrete deterioration above the base plate in the two different types of joints. The fine concrete material (shown on the paper) taken from wedge area above the base plate was analyzed for chloride content and gradation. The sodium chloride content was 0.7 lb per ton of concrete, or 0.035 percent by weight. Approximately 96 percent of this material passed the 3/8-in. sieve and 19 percent the No. 200 sieve.

Survey 8

Widening operations on I 96 west of I 696 in May 1966 afforded an excellent opportunity to examine the condition of many joints exposed during earthwork operations. Figure 13 shows three contraction joints undergoing typical concrete deterioration above the base plate. A crack and an expansion joint with a base plate are shown in Figure 14, where the absence of concrete deterioration may be noted in both cases.

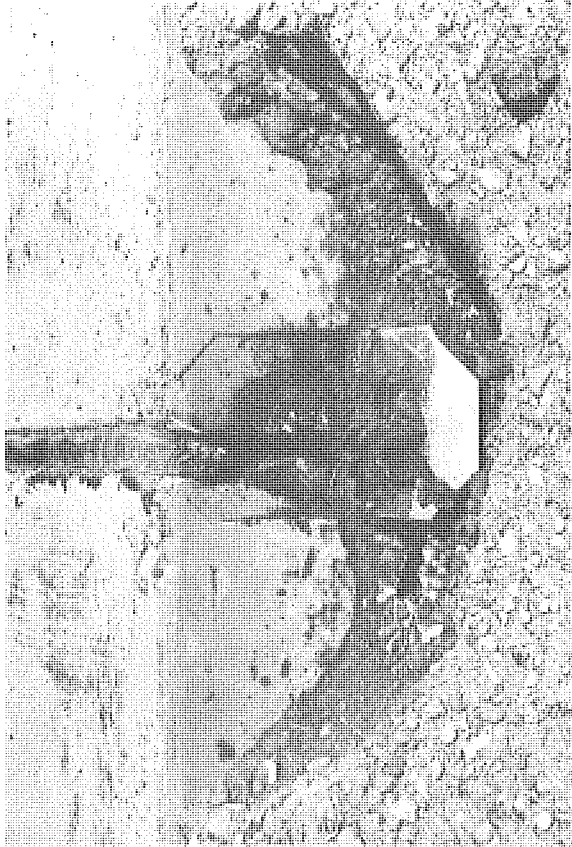


Expansion Joint



Contraction Joint

Figure 11. Comparative performance of two 20-year-old joints on southbound US27 near the Looking Glass River bridge; Project 19-41, C1; constr. 1946.

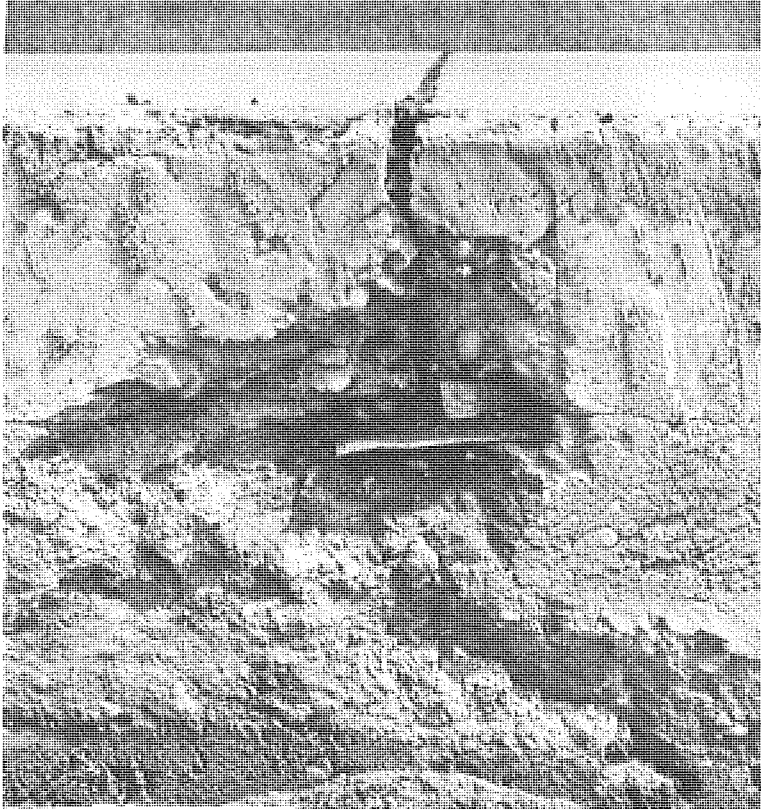


Expansion Joint (Sta. 539+00)

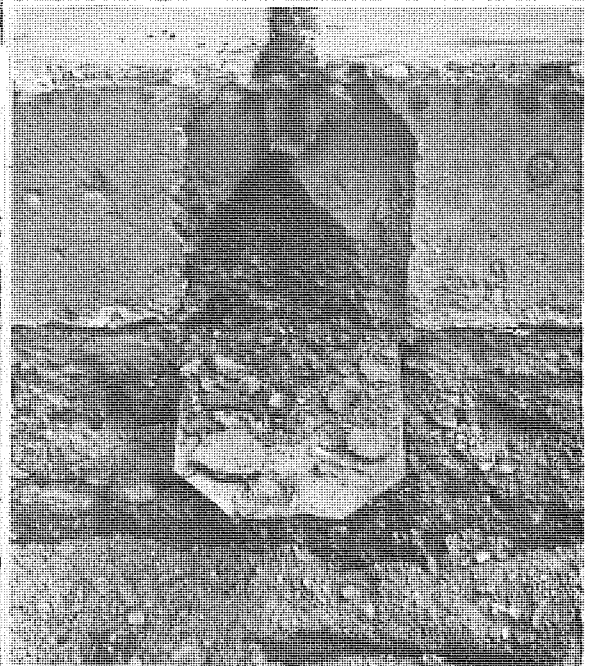
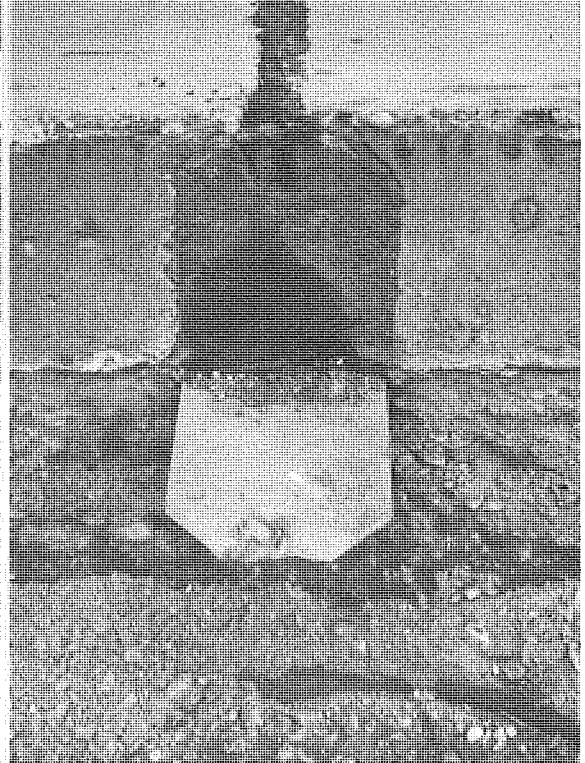


Contraction Joint (Sta. 540+00)

Figure 12. Comparative performance of two 10-year-old joints on northbound US27 near the Maple River bridge; Project 29-17, C9; constr. 1956.



Sta. 470+59 WB

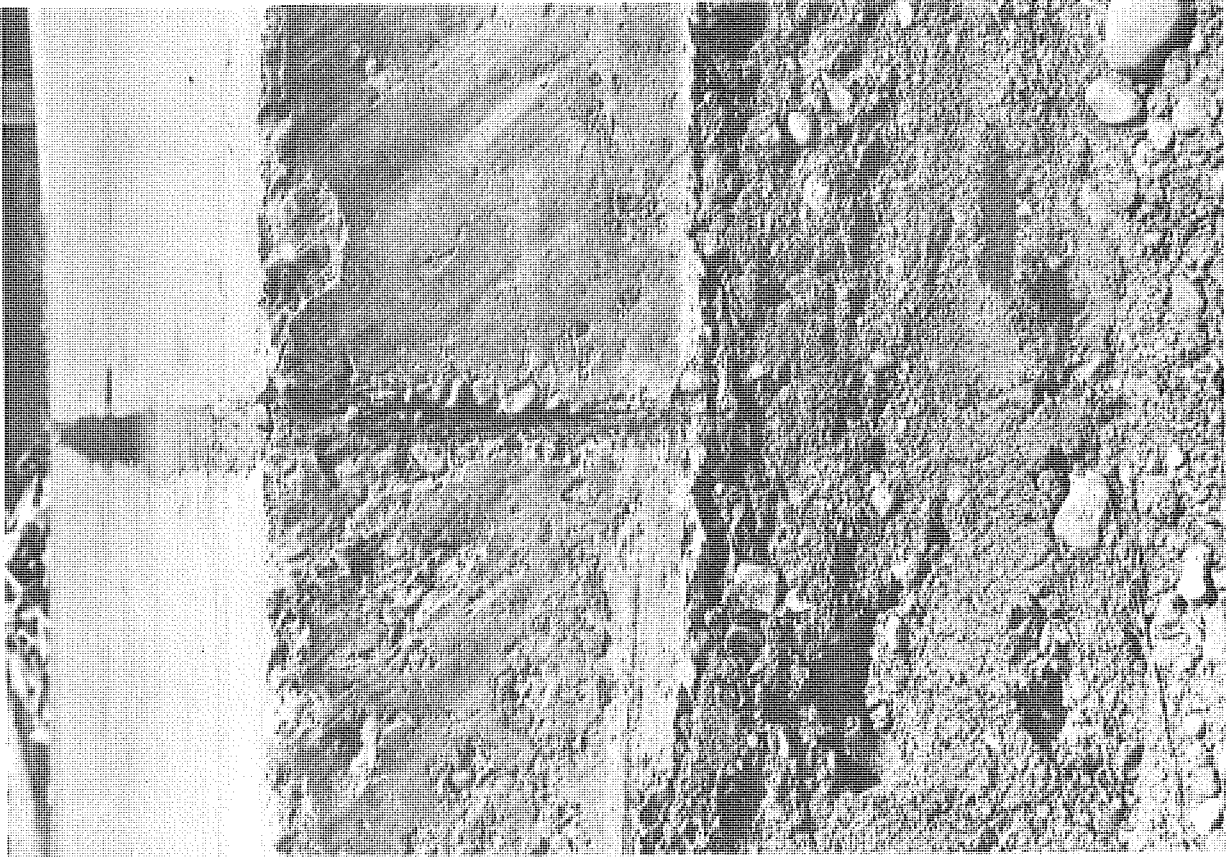


Sta. 510+50 WB

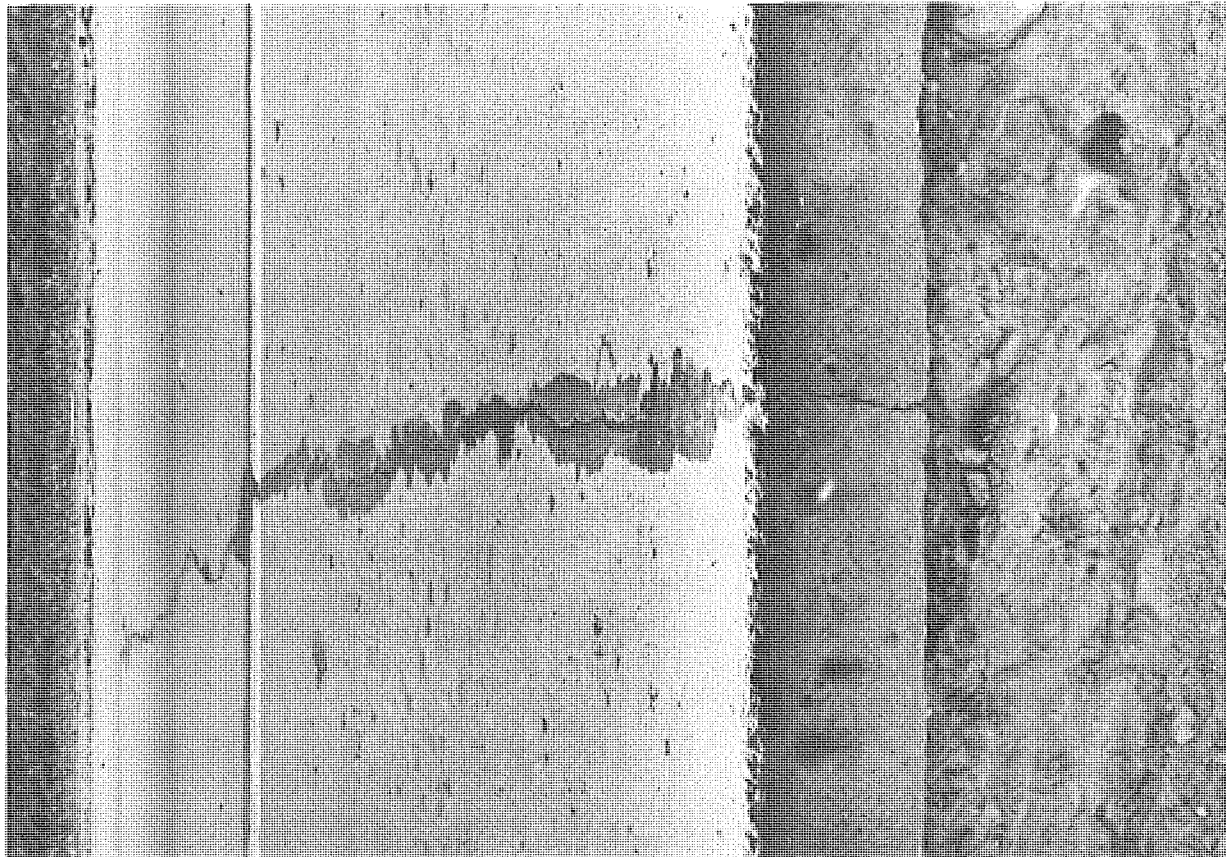


Sta. 581+84 EB

Figure 13. Characteristic deterioration above base plate at three 10-year-old I 96 contraction joints; note moistness and quantity of infiltrated, entrapped material held in place by end plate at Sta. 510+50 WB; Project IN 63-29, C10; constr. 1956.



Sta. 533+94 WB



Sta. 582+45 EB

Figure 14. Note similar good condition of lower slab at crack and at expansion joint with base plate, both on 10-year-old I 96 pavement; Project IN 63-29, C10; constr. 1956.

SUMMARY

Although base plates were intended to act as a barrier preventing infiltration of base course material into the bottom of the joint, the evidence presented conclusively indicates that they also trap inert materials which penetrate the joint through faulty joint seals, as well as water and chloride solutions resulting from snow and ice removal operations. Alternate freezing and thawing, coupled with the detrimental effect of chloride solution on concrete, accelerates deterioration of concrete at joint faces below the dowels, resulting in the characteristic wedge of disintegrated concrete. As a result, the concrete area available to resist normal compressive forces is greatly decreased, thus contributing to further failure of concrete, and ultimately resulting in complete pavement failure in the joint area.

This is particularly true in the case of contraction joints. Such failures do not seem to occur at expansion joints. Measurements show that the few expansion joints required under present pavement construction methods continue to close with age, and the compressed filler material tends to reduce infiltration to an insignificant factor.

It might be argued that the recent adoption of preformed neoprene compression joint sealants could entirely alter the situation, provided that they succeed for a reasonable period in sealing the joint against penetration of fine soil materials and saline solutions, as well as rain water. If this is the case, then the joint sealing system envisioned in 1946 may be realized, and joint failures of the types described here theoretically might not occur in the future. At present, however, there is no assurance that such a situation will ever develop.

In any event, it is obvious that the base plate constitutes a trap for any inert materials or liquids penetrating the surface seal or joint ends. Weighing this factor against any anticipated trouble that could possibly develop from infiltration of base course material upward into the joint with the base plate absent, it is apparent that the base plate constitutes the greater of the two evils, and consequently should be deleted from Michigan's joint design. However, sealing the ends of joints should continue, by extending the preformed joint sealant downward from the pavement surface to the bottom of the slab.

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