DEVELOPMENT OF PROCEDURES FOR REPLACING JOINTS IN CONCRETE PAVEMENT
Final Report

MICHIGAN
RESEARCH LABORATORY SECTION

MICHIGAN DEPARTMENT OF
STATE HIGHWAYS AND TRANSPORTATION

DEVELOPMENT OF PROCEDURES FOR REPLACING JOINTS IN CONCRETE PAVEMENT
Final Report

J. E. Simonsen

A Final Report on a Highway Planning and Research Investigation Conducted by the Testing and Research, and Maintenance Divisions of the Michigan Department of State Highways and Transportation in Cooperation with the U. S. Department Of Transportation, Federal Highway Administration

Research Laboratory Section
Testing and Research Division
Research Project 70 F-118
Research Report No. R-1020

Lansing, September 1976

ABSTRACT

The performance of precast and cast-in-place slabs used for repair of concrete pavements is described. The development of the repair procedures was discussed in an interim, MDSHT Report No. R-968, dated August 1975. Briefly, the procedures require full-depth diamond blade sawing of the repair limits, removal of the distressed concrete area without disturbing the existing base, placement of the slab, and installation of sealed joints between new and old slabs. A previously sawed concrete area, up to 10 ft long, and one-lane wide, can be replaced with a precast slab and opened to traffic in approximately 1-1/2 hours. A similar size area can be repaired with fast-set concrete and opened to traffic in six to eight hours.

Evaluation of the performance of the repairs indicates that both repair types will perform reasonably well for at least five years and it is expected that the majority of the repairs will continue to give good service for 10 years. Some faulting develops at the joints, but deflection at the joints under load, and slab rocking, do not appear to have any serious effect on the performance of the repairs. The installed expansion joints close permanently at various rates at different repair locations, and existing joints and transverse cracks adjacent to repairs were noted to open permanently.

The developed repairs are suggested for use as interim repairs on roadways scheduled for overlays, rehabilitation, or reconstruction within five to ten years. For repair or rehabilitation work where the smoothness of the joints is to be maintained a doweled joint between new and old slab should be used.

In 1969 the Michigan Department of State Highways and Transportation began an experimental program to develop procedures for repairs of concrete pavement joints that could be done rapidly and would be long lasting. The initial development work resulted in the use of precast slabs for repairs on experimental installations in 1970 and 1971. On the basis of the excellent results of these experimental installations an expanded program to further develop the precast slab repair method and to investigate the use of fast-setting cast-in-place repairs was initiated in July 1971 with the approval of the Federal Highway Administration. This program had the following objective:

"To develop procedures for replacement of distressed joints with permanent type repairs that can be opened to traffic within a few hours after installation."

To meet this objective the first three years of the five-year project were devoted to the development of repair procedures and initial performance evaluation. Work during the remaining two years was concerned only with evaluating the performance of the various types of repair. The development of procedures and initial performance results are described in interim Report R-968. Except for a brief description of the developed repair procedures this report deals with the performance of the various repair types.

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Repair Procedures

The experimental repairs are located on I 96 between the Lowell exit and the Thornapple River in Kent County, and on temporary I 69 between Shaftsburg and Perry. The 1973 ADT values were 13,400 and 16,700 for the I 96 and I 69 locations, respectively. Both pavements are reinforced concrete, 9 in. thick, and each roadway contains two 12-ft lanes. Doweled joints sealed with hot-poured rubber-asphalt are spaced at 99-ft intervals. The pavements were placed on a 14-in. granular base overlaying a subgrade of moderately granular material. The I 69 pavement was constructed in 1957 and the I 96 pavement was built in 1960.

TABLE 1
SUMMARY OF JOINT REPAIR DETAILS

Section	Repair Type	No. of Repairs	Repair Length, ft	Base Support	Joint Type	Filler Material	Nominal Joint Width, in.
I 96 Westbound Roadway (1972)	Precast	1	10	Mortar	Contraction	Mortar [1]	0
	Precast	1	10	Sand	Contraction	Mortar	0
	Precast	1	10	Mortar	Expansion	Bit. Filler [1]	1-1/2
	Precast	1	10	Sand	Expansion	Bit. Filler	1-1/2
	Precast [2]	1	10	Mortar	Expansion	Bit. Filler	1-1/2
	Precast [2]	1	10	Sand	Expansion	Bit. Filler	1-1/2
	Cast-in-Place	1	10	Ex. Base	Contraction	None	0
	Cast-in-Place	1	10	Ex. Base	Expansion	Bit. Filler	1-1/2
	Cast-in-Place [2]	1	10	Ex. Base	Expansion	Bit. Filler	1-1/2
	Cast-in-Place [3]	1	10	Ex. Base	Expansion	Bit. Filler	1-1/2
I 96 Eastbound Roadway (1973)	Precast	2	10	Sand	Expansion	Polyethylene	2
	Precast	2	8	Sand	Expansion	Polyethylene	2
	Precast	2	6	Sand	Expansion	Polyethylene	2
	Cast-in-Place	1	14	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place	5	10	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place	2	8	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place	2	6	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place [3]	2	5	Ex. Base	Expansion	Polyethylene	2
	Cast-in-Place [3]	2	4	Ex. Base	Expansion	Polyethylene	2
I 69 Westbound Roadway (1974)	Cast-in-Place	1	12	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	1	12	Ex. Base	Expansion	Bit. Filler	1
	Cast-in-Place	2	10	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	2	8	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	6	8	Ex. Base	Expansion	Bit. Filler	1
	Cast-in-Place	4	6	Ex. Base	Expansion	Polyethylene	1-1/3
	Cast-in-Place	4	6	Ex. Base	Expansion	Bit. Filler	1

1 Contraction joints, and expansion joints constructed with bituminous filler, were sealed with hot-poured rubber-asphalt sealant.

2 Load transfer provided by installation of steel dowels on 12-in. centers.

3 These repairs have one hook-bolted joint and one expansion joint. The expansion joint with the 1972 repair of this type is doweled.

A total of 50 two-lane joints were repaired in three sequences. Ten joints were repaired on westbound I 96 in 1972, 20 on eastbound I 96 in 1973, and 20 on the westbound roadway of I 69 in 1974. Table 1 summarizes the variables involved in each repair sequence. As can be seen, both precast and cast-in-place repairs were used in 1972 and 1973, whereas only cast-in-place repairs were placed in 1974. All slabs constructed in 1972 were 10 ft long. In 1973 slab lengths ranged from 4 to 14 ft and in 1974 from 6 to 12 ft. The precast slabs were placed on a thin cement mortar or sand base whereas the cast-in-place repairs were poured on the existing base. Doweled and undoweled expansion joints and undoweled contraction joints were tried in 1972. Undoweled expansion joints were used in the remaining repairs except four short repairs in the 1973 sequence were constructed with one joint hook-bolted. The joint filler material was either a bituminous impregnated filler board or a polyethylene plank. Joints containing a bituminous filler board were sealed with hot-poured rubber-asphalt. No seal was used at repairs using the polyethylene material as a filler. The width of the filler materials were 1-1/2 in., 2 in., and 1 and 1-1/3 in. for the 1972, 1973, and 1974 repairs, respectively.

As a result of difficulty in obtaining proper fitting dowel holes and the relative large amount of time required to drill 22 holes at each lane repair, it was concluded, on the basis of our experience, that doweled joints on large scale projects would not be feasible using available drilling equipment. The repair procedure is as follows:

<u>Precast Slab Repair</u>

1. The limits of the concrete area to be removed are sawed full-depth with a diamond blade saw.

2. The larger sections of the deteriorated slab are lifted out by a crane and smaller debris carefully removed by machine or hand to avoid disturbing the existing base.

3. A thin base (about 1 in.) of either sand-cement mortar or of sand is placed on the existing base and struck off to the correct elevation so the new and old slab surface will match each other.

4. The precast slab is lowered into the gap and positioned so each joint is about equal in width.

5. Bituminous impregnated filler boards are installed in the joint gap when an expansion joint is required. If a contraction joint is desired the

gap is filled with sand-cement mortar to within about 1-1/2 in. of the surface. Both joint types are sealed with a hot-poured rubber-asphalt sealant.

Cast-In-Place Repairs

1. The concrete is sawed and removed in the same manner as for precast slab repairs.

2. A joint filler is positioned against the repair ends when expansion joints are required.

3. A fast-set concrete (9-sack mix with calcium chloride added for set acceleration) is poured and finished in the normal manner specified for this type of concrete work.

4. The repair is sprayed with curing membrane compound and cured until specified strength is reached. When the air temperature is below 65 F, 2-in. curing blankets are required.

5. A hot-poured rubber-asphalt seal is installed in grooves formed in the fresh concrete when either an expansion joint with a bituminous filler or a contraction joint is used. Where a polyethylene filler is installed no seal is used.

A previously sawed 10-ft long lane repair can be removed, replaced, and opened to traffic in approximately 1-1/2 hours using the precast slab repair procedure. An equal sized repair utilizing the 9-sack fast-set concrete mix can be completed and opened to traffic in about 6 to 8 hours. Since the precast slabs must be poured away from, and later transported to, the repair site this type of repair is approximately 25 percent more expensive than cast-in-place repairs. The Department has utilized the cast-in-place repair procedure since 1972.

Performance Evaluation

The performance of the repairs is evaluated by measuring joint movements, joint faulting, slab rocking, and deflection under load. In addition, periodic surveys are conducted to visually monitor the condition of the repairs.

Semi-annual condition surveys were conducted to record any visual changes in the performance of the repairs. Specific factors checked on each survey were: joint spalls, corner breaks, joint seal condition, and slab cracks.

A common problem with repairs where the end limits were not sawed full-depth and the concrete was removed by breaking it with a demolition ball, was the early occurrence of spalling and general breakup of the old slab along the joint. Also, the breaking of the deteriorated slab section occasionally resulted in hairline cracks forming in the old slab. These cracks would open with time and in extreme cases contribute to the early failure at the repair. Examination of the experimental repair joints revealed no spalls of any consequence at any of the repairs in the 1972, 1973, and 1974 construction sequences, nor have any corner breaks or cracks in the immediate joint vicinity occurred. It appears that full-depth sawing and removal of the concrete by lifting it out in large pieces results in good joint faces on the old slab, provided the limits of the repair are located in sound concrete. Otherwise, deterioration as shown in Figure 1 may occur. The joint shown is tied with expansion anchors and hook-bolts. When installing the anchors it was noted that a horizontal hairline crack existed at the steel level. The installation of the anchors plus the effect of traffic probably caused the surface layer to fail.

At another hook-bolted repair a spall developed in the summer of 1975 in the old slab at the outside edge of the repair. The spall is believed to be caused by the polyethylene filler being of less thickness at the corner. Thus, when the pavement expanded the compressive force at the corner was of sufficient magnitude to cause the spall and also to crack the slab longitudinally. Figure 2 shows the spall and longitudinal crack as it appeared during the 1976 survey.

The hot-poured rubber-asphalt seals performed well the first winter. However, during the second winter, adhesion failures began to develop. These failures were of sufficient magnitude to allow infiltration of liquids and fine incompressible materials into the joint (Fig. 3). In the summer the expansion of the pavement and the action of tires "reseals" the joints. The polyethylene filler used at some joints does not in all cases exert sufficient pressure on the joint walls to prevent liquids and fine sand from entering the joints during the winter (Fig. 4). During expansion of the pavement the filler is compressed and seals out foreign material. The overall appearance of a typical repair with hot-poured seals and one with polyethylene filler is shown in Figure 5.

The repair slabs have not as yet developed any serious deterioration. Some of the precast slabs cracked during handling and transportation, but since they are reinforced the cracks are of no concern. As mentioned previously, one of the cast-in-place slabs cracked longitudinally as a result of high localized compressive forces. A transverse crack has developed at about the mid-point of the 14-ft long traffic lane repair on eastbound I 96.

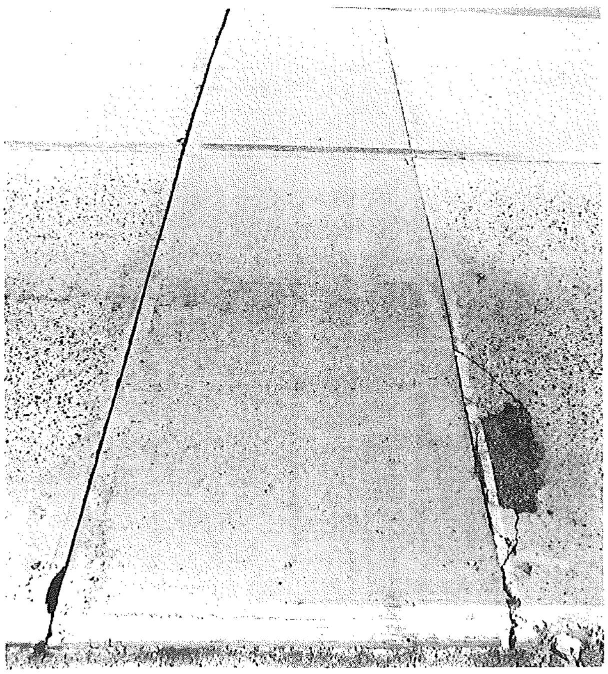


Figure 1. Failure in old pavement slab along hook-bolted joint resulting from locating repair limit in unsound concrete.

Figure 2. Spall and longitudinal crack in 4-ft wide repair slab apparently caused by excessive compressive forces at the spalled corner.

Figure 3. Adhesion failure in hot-poured rubber-asphalt sealer after two years service.

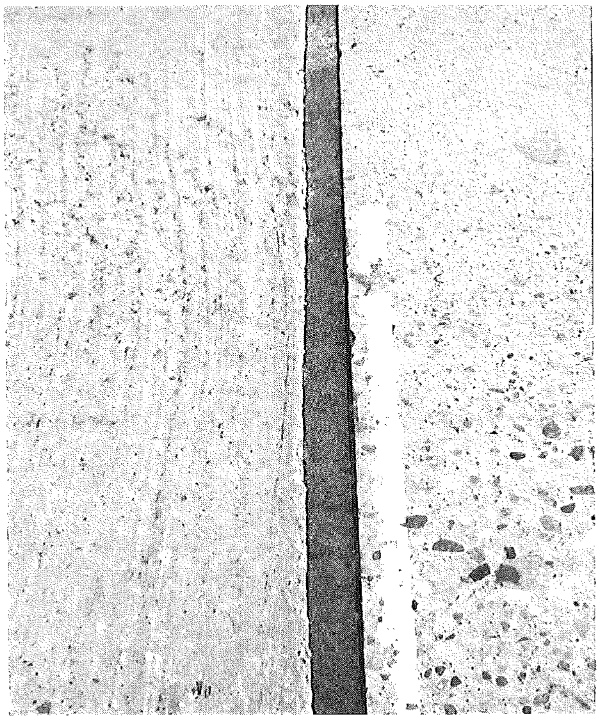


Figure 4. Failure of the polyethylene filler to exert sufficient pressure on the groove walls during cold weather results in foreign materials entering the joint.

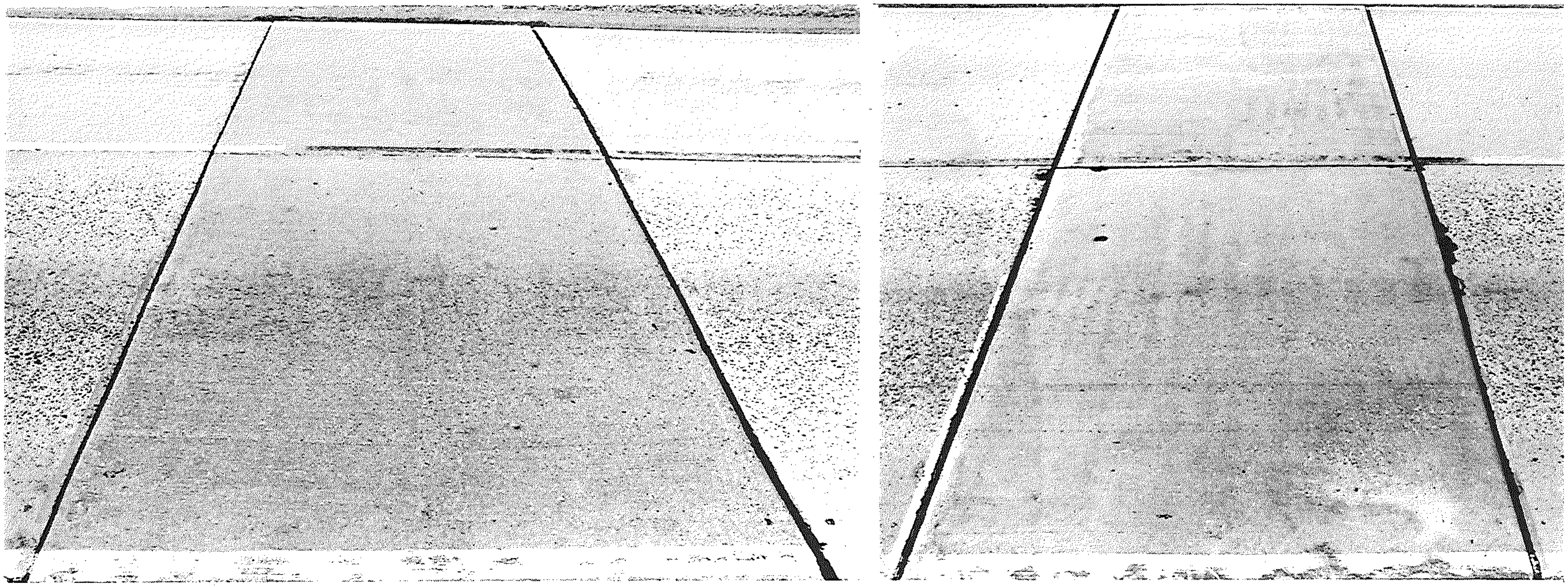


Figure 5. Overall condition of typical repair with hot-poured seals (right) and with polyethylene filler (left) each four and three years old, respectively.

Figure 6. Faulting along existing pavement centerline joint at repair on eastbound I 96 in the winter of 1976.

Cracking of cast-in-place repairs made under contract was noted to be more prevalent than on the experimental repairs and a survey was conducted on contract repairs on I 75, I 94, and I 696. A total of 1,292 lane repairs were inspected after about one year of service. It was found that longitudinal cracking was confined to slabs 6 to 10 ft long. Of 1,127 lane repairs less than 10 ft long, 5.6 percent had cracked longitudinally and of the remaining 155 lane slabs over 10 ft long, 29.6 percent had cracked in the transverse direction. Although no serious faulting or spalling of the cracks were noted the problem was considered of sufficient magnitude to reinforce all repairs over 10 ft long with standard steel mesh reinforcement. The problem of longitudinal cracking will be further investigated to determine if cracks continue to form in uncracked slabs to the extent that reinforcement may be needed in slabs less than 10 ft long.

Another problem noticed is the faulting of the longitudinal centerline joint adjacent to some failed or repaired joints. In all cases the traffic lane settles with respect to the passing lane. Since there is no load transfer at failed or repaired joints the load stresses approach those of a free slab edge. Apparently this increase in load stresses eventually causes failure of the centerline joint in the existing slab. On the experimental repair sections the 1976 winter survey revealed faulting of the longitudinal joint at 12 repairs. Figure 6 shows the faulted joint at a repair on eastbound I 96.

Joint Width Changes

Contraction Joints - Prior to the development of the repairs described herein the Department used a "plug" type concrete repair which utilized unsealed contraction joints. Consequently, when the pavement contracted, incompressible materials would enter the open joints. Open transverse cracks and joints with failed seals would also become contaminated with foreign materials during the contraction cycles of the pavement. Since contraction joints do not provide for expansion of the pavement beyond its original length the additional compressive force resulting from contaminated cracks and joints plus "growth" of the slab would cause new failures to occur in the repaired pavement the following year. Therefore, it appears that the use of only contraction joints when repairing a pavement should be reserved for projects where the existing joints have retained their full cross-section or otherwise the repairs should be spaced so that the compressive force in the slab between repairs can be held to a level commensurate with the available cross-section. In either case, sealing of joints and cracks would help to minimize the occurrence of new failures.

The contraction joints installed at repairs on westbound I 96 in 1972 were sealed with hot-poured rubber-asphalt. The groove dimensions were approximately 1-1/2 by 1-1/2 in. The movement experienced at the leading and trailing joint of each repair from summer to winter is shown in Figure 7. It can be seen that the leading joint at repair No. 1 acts like an expansion joint. Apparently the mortar installed in the gap between the precast slab and the existing slab was not sufficiently consolidated to withstand the compressive force developed during expansion of the pavement. The seals have worked fairly well in preventing the infiltration of incompressible materials but the permanent openings recorded at the trailing and leading joint of repairs No. 6 and 7, respectively, would indicate failure of the seals in these cases. The small movements recorded at the trailing joint of repair No. 1 are the result of an open transverse crack that formed close to the repair in the existing slab.

Expansion Joints - Unlike a contraction joint, an expansion joint allows a pavement to increase in length during periods of expansion and to increase permanently in length as long as the provided expansion space is not used up. By the provision of expansion space the compressive forces in the slab are reduced which minimizes the occurrence of blow-ups. However, observations of existing joints near repairs with expansion joints revealed that joints with failed seals and open transverse cracks increase permanently in width. Apparently the introduction of expansion space in a pavement that has been under compression for several years causes more than normal joint and crack openings during slab contraction, because of the sudden and drastic reduction in the compressive force in the area near repairs. Although expansion joints have this undesirable effect it is offset by the protection against blow-ups they provide. Once the provided expansion space has been used up, it is, of course, necessary to install additional expansion fillers to maintain the pavement in a "no blow-up" state. The average seasonal and yearly joint width changes occurring at each repair installed on westbound I 96 in 1972 are also shown for undoweled and doweled expansion joints in Figure 7. Except for joint No. 8 these joints showed the most permanent closure the first year. Thereafter, the amount of permanent closure has decreased each year. The summer readings appear to have reached their maximum indicating that pressure may be building up in the adjacent slab. Joint No. 8 has not closed nearly as rapidly as the other joints and the seasonal movement has remained close to the same each year. These movements and closure mode are interpreted to result from the repair being located in an area where the pressure in the existing slab is lower than at the other repair locations.

The movements at joints of both precast and cast-in-place repairs installed in 1973 on eastbound I 96 are shown in Figure 8. The joints at both

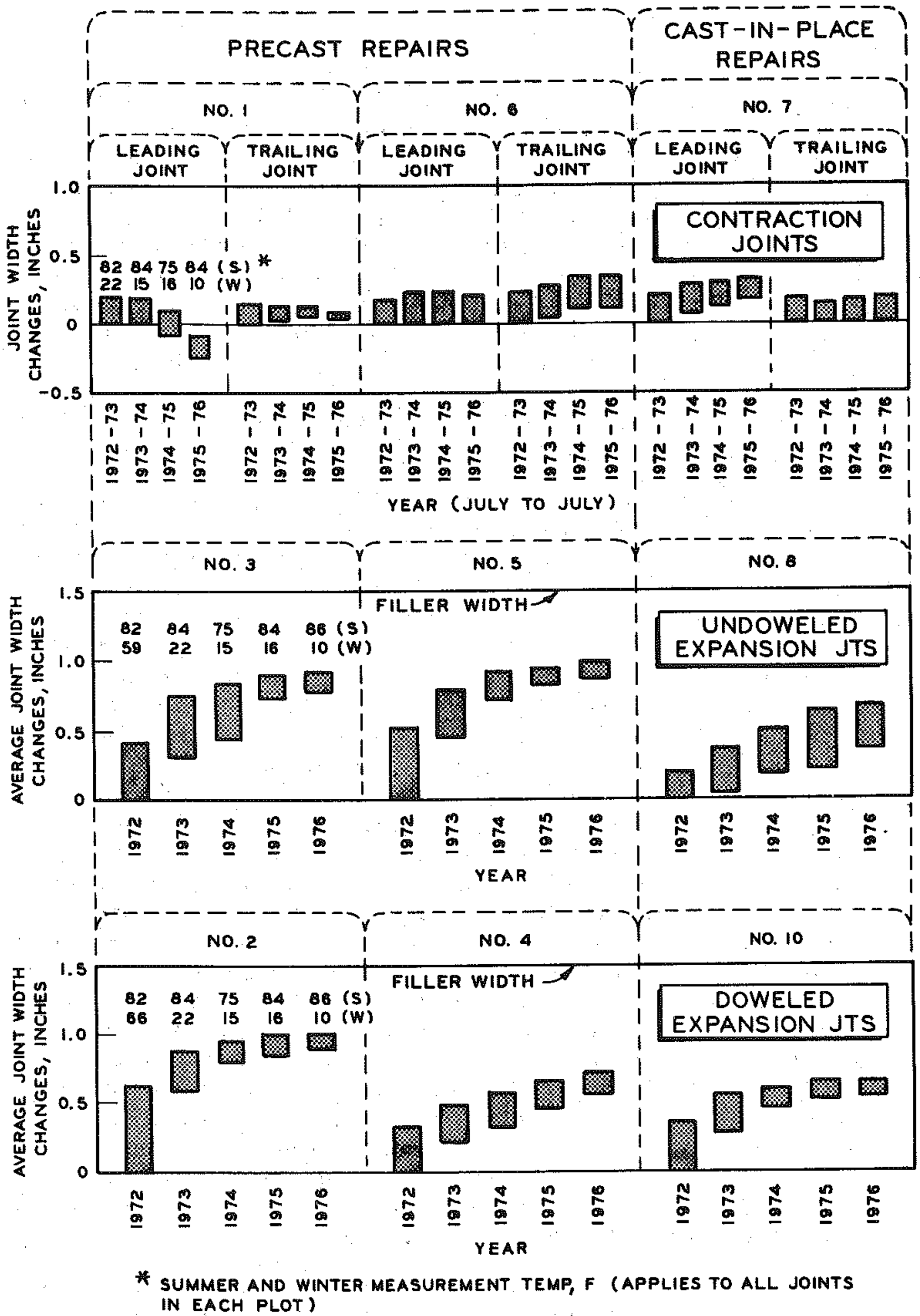


Figure 7. Average seasonal and yearly joint width changes at repairs installed on westbound I 96 in 1972.

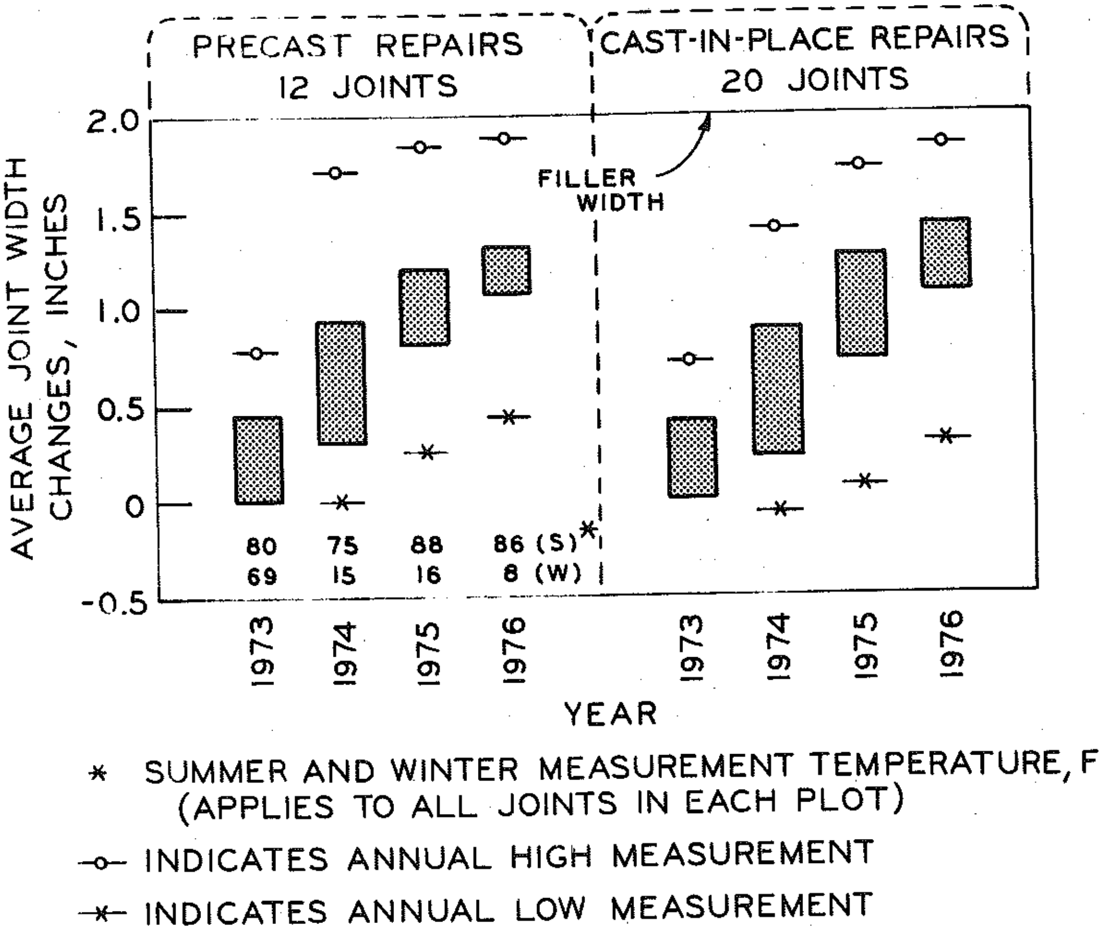


Figure 8. Average seasonal, yearly, and yearly high-low joint width changes at repairs installed on eastbound I 96 in 1973.

types of repair were constructed by use of polyethylene filler materials, and the summer-winter measured movements are nearly the same for both repair types. The progressive closure of the joints and the reduction in the amount of yearly movement are also close to the same for the two repair types. The average permanent closure after three years is just over 1 in. and the high summer reading indicates that pavement pressure may soon begin to increase at some repairs during hot weather.

Figure 9 shows the changes in joint widths of repairs installed on westbound I 69 in 1974. These repairs were all cast-in-place, but both bituminous and polyethylene fillers were used. However, there is not much difference in the average movement at both types of joints. As in the case of the 1972 and 1973 repairs the average yearly movement is decreasing

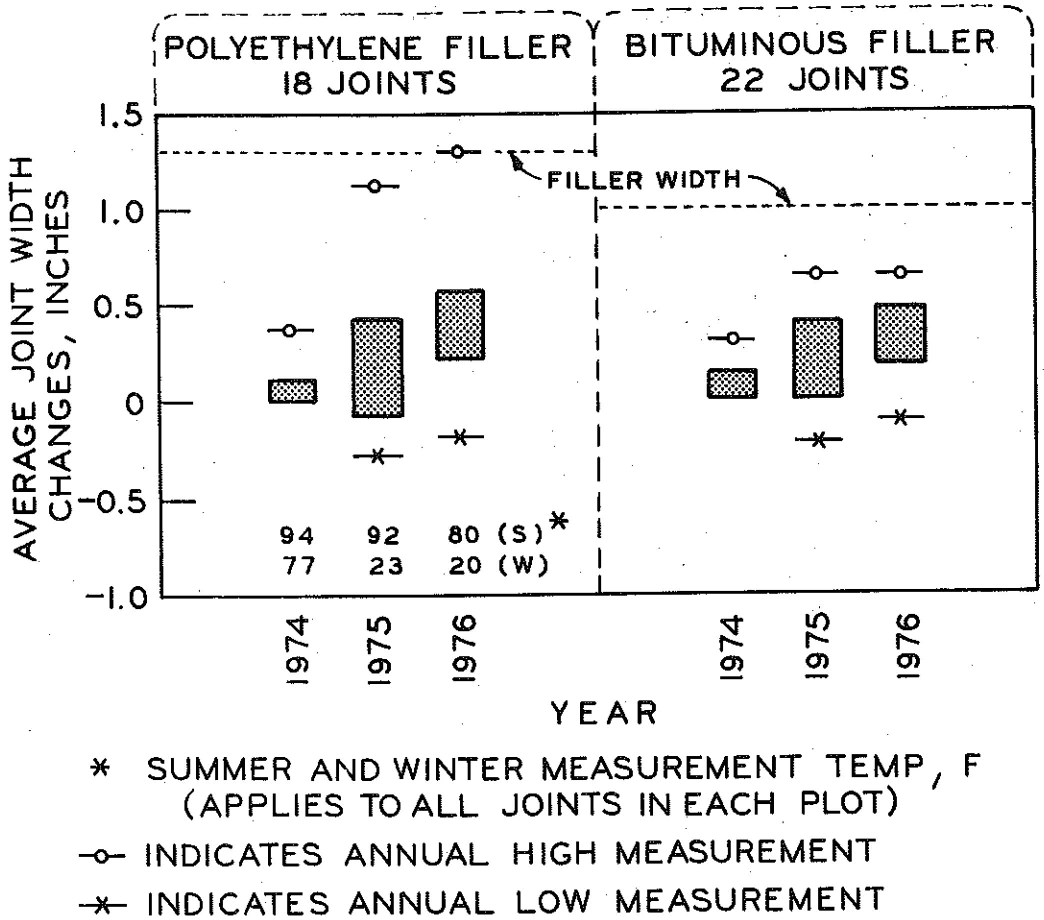
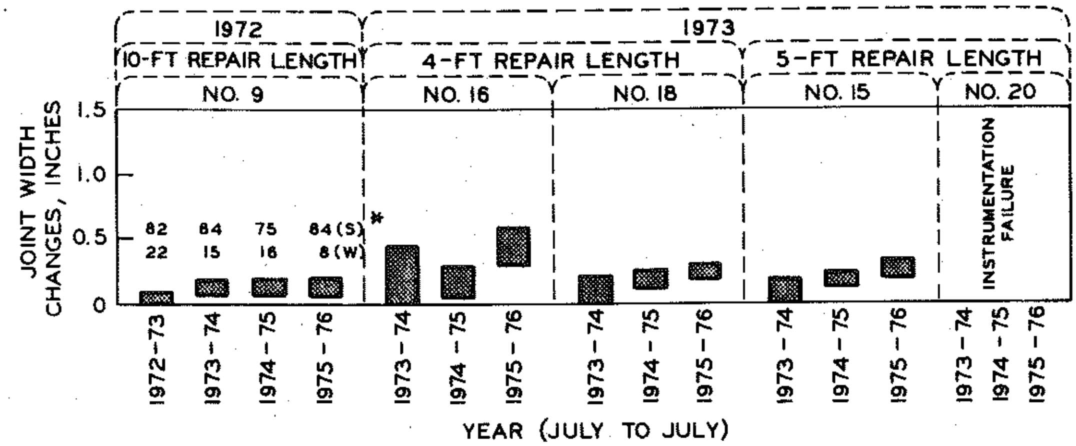


Figure 9. Average seasonal, yearly, and yearly high-low joint width changes at repairs installed on westbound I 69 in 1974.

and the summer readings indicate that the compressive force at some joints may soon increase rapidly as no more expansion space is available.

Hook-Bolted Joints - During construction of the first repair sequence in 1972 one joint was made by use of hook-bolts. The purpose was to learn about the construction feasibility and performance of this type of joint. To further investigate hook-bolted joints four more were included in the 1973 repairs. The 1972 joint was used with a 10-ft long slab, whereas the 1973 joints were used with 4 and 5-ft long slabs. It was felt that the main use of this joint type would be with short slabs to prevent rocking under traffic. Each joint consisted of six 5/8 in. self-drilling expansion anchors with 8-in. long hook-bolts installed at slab mid-depth and at 24-in. centers.

Although the installation of the expansion anchors was done without too much difficulty their performance is very disappointing. As can be seen in Figure 10 all joints opened the first winter and the winter openings have increased each year. Since the anchors failed to hold the joints together no other performance tests were made on these repairs.



* SUMMER AND WINTER MEASUREMENT TEMP, F (APPLIES TO ALL JOINTS IN EACH PLOT)

Figure 10. Seasonal and yearly movements at hook-bolted joints.

Joint Faulting

The amount of joint faulting or changes in elevation across the repair joints was measured in the summer and winter of each year. The measurements were obtained by taking elevation readings of stainless steel plugs embedded in the concrete surface, 4 in. each side of the joint centerline. An initial reading was taken shortly after construction operations of a repair sequence were completed. This reading was used as a "zero faulting" elevation and the difference between the zero reading and subsequent readings is the amount of elevation change across the joint. The elevation changes recorded at the leading and trailing joints of the 1972, 1973, and 1974 repairs are shown in Figures 11, 12, and 13, respectively. In averaging and plotting the elevation changes no consideration was given to whether or not the changes resulted in a "step-up" or "step-down" with respect to crossing over the joints in the direction of traffic.

1972 Repairs - The joint faulting measurements recorded during the summer and winter of each year are shown in Figure 11. Since several variables were involved, the faulting at the leading and trailing edge of each repair is shown. For comparison purposes, the performance of the three different types of joints are shown in each group. The figure shows that

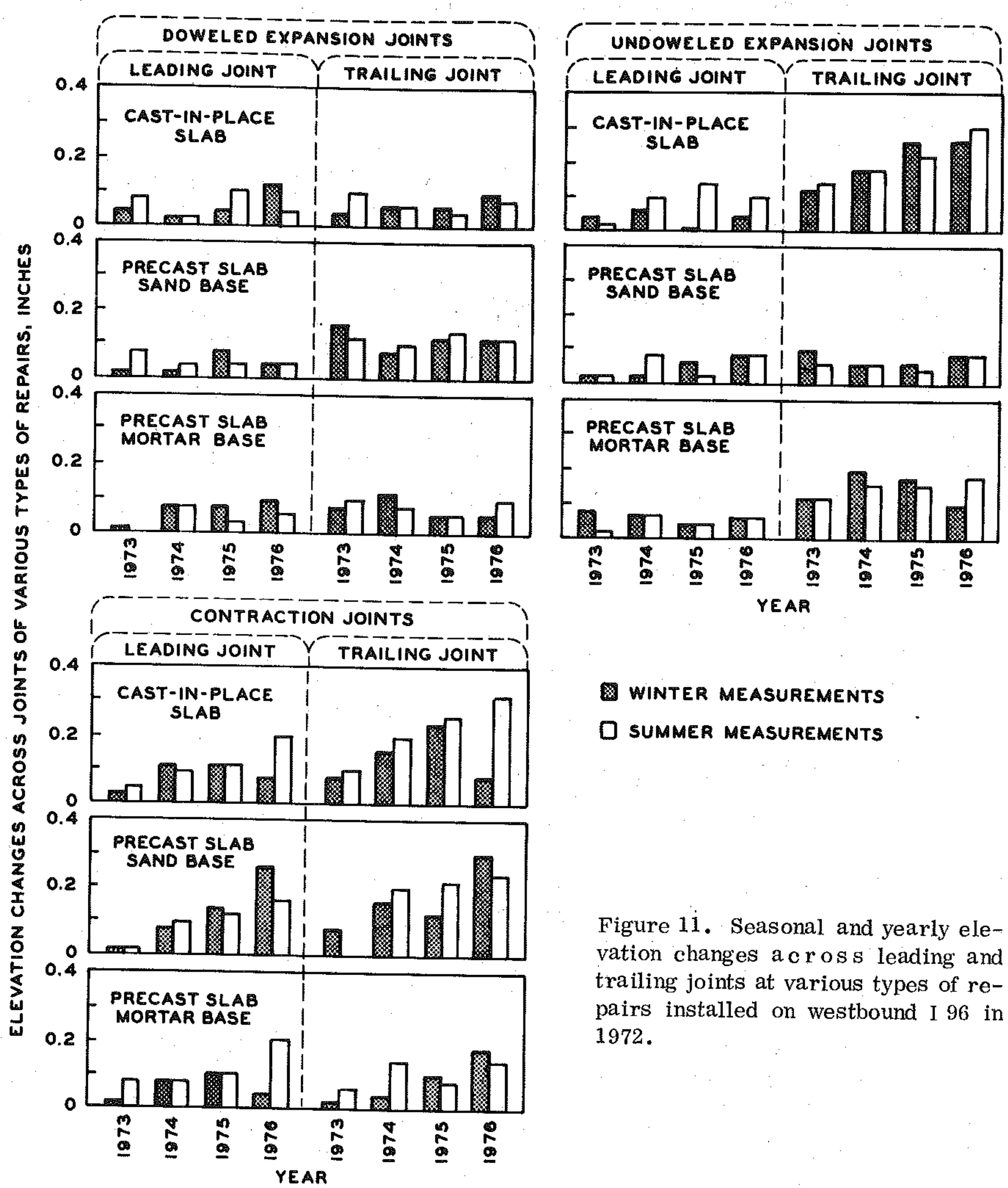


Figure 11. Seasonal and yearly elevation changes across leading and trailing joints at various types of repairs installed on westbound I 96 in 1972.

the doweled joints have faulted somewhat less than the undoweled joints. The amount varying from approximately 0.02 to 0.10 in. over the years since construction. Both the precast and cast-in-place repairs have performed about equally well.

The performance of the undoweled expansion and contraction joints is nearly equal. In both cases it appears the leading joint faulted less than the trailing joint. For example, the amount varied from 0.06 to 0.20 in. at the leading joints in the summer of 1976 whereas at the trailing joint the variation for this date was 0.08 to 0.32 in. The rate of increase in faulting with time varies from one repair to another. Basically there has been no increase in the amount of faulting at the doweled expansion joints, nor at the precast repairs with undoweled expansion joints. However, at the remaining repairs the faulting has increased over the years, especially at the trailing joints. The reason for the variation in the amount of faulting is believed to be differences in the support and drainability of the base at the various repair locations.

1973 Repairs - These repairs were all constructed with undoweled expansion joints using polyethylene filler material. The average faulting for 6, 8, and 10-ft long repairs of both the precast and cast-in-place types is shown in Figure 12. For the precast slab repair the three length groups have performed almost equally well. There has generally been little variation in the semi-yearly amount of faulting and there has been very little increase in the amount of faulting with time. The 1976 average summer measurements at the leading joint for 6, 8, and 10-ft repairs were 0.16, 0.10, and 0.12 in., respectively, and 0.14, 0.20, and 0.14 in. at the trailing joint of the 6, 8, and 10-ft repairs.

The elevation changes across the leading joint in the three length groups of cast-in-place repairs have been small and have varied little with time. After three years of service the elevation changes for 6, 8, and 10-ft slabs were measured to be 0.06, 0.04, and 0.06 in., respectively. The elevation changes at the trailing joints have been larger than those at the leading joints and some increase with time can be noted. The latest readings indicate an average elevation change of 0.16, 0.26, and 0.20 in. for the 6, 8, and 10-ft long repairs, respectively.

1974 Repairs - Only one type of repair (cast-in-place) was used in this repair sequence. Four slab lengths, 6, 8, 10, and 12 ft were used and the measured elevation changes across the leading and trailing joints for each repair length are shown in Figure 13. Since these repairs have only been in service for two years the data do not as yet indicate any specific trends

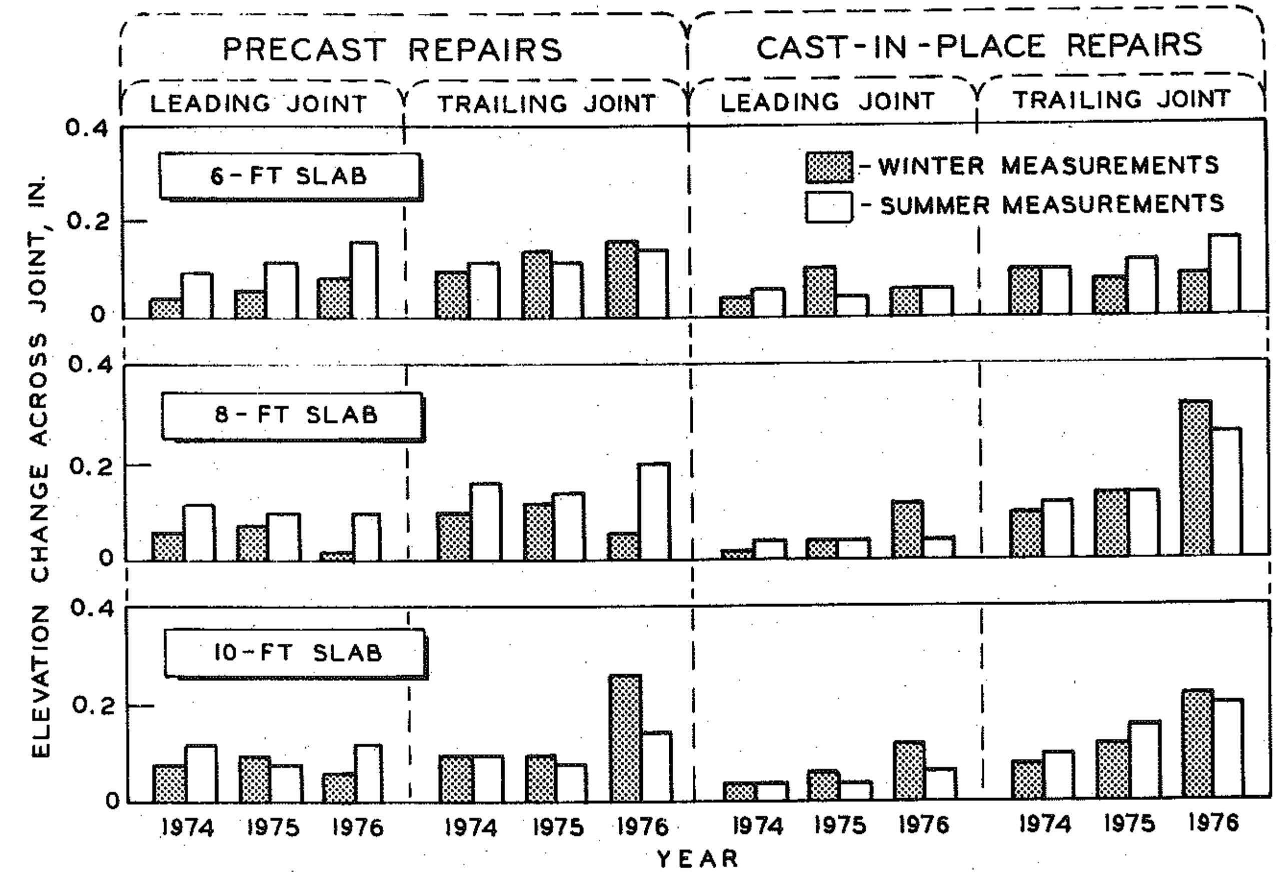


Figure 12. Average seasonal and yearly elevation changes across leading and trailing expansion joints at 6, 8, and 10-ft long precast and cast-in-place repairs installed on eastbound I 96 in 1973.

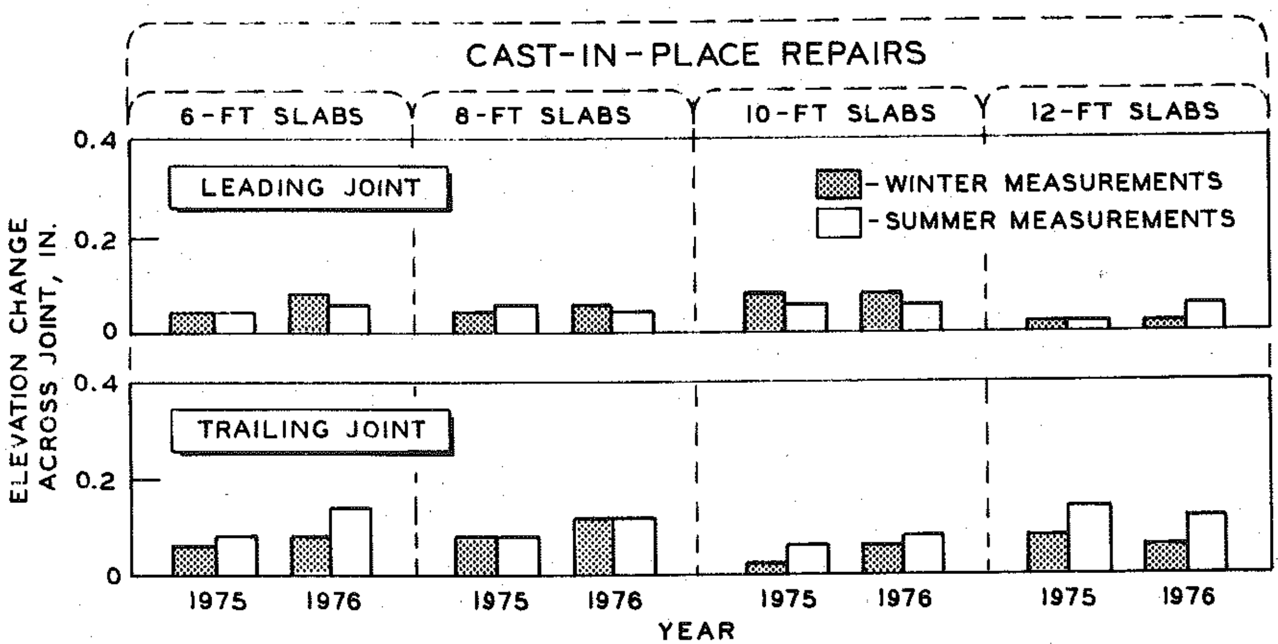


Figure 13. Average seasonal and yearly elevation changes across leading and trailing expansion joints at 6, 8, 10, and 12-ft long cast-in-place repairs installed on I 69 in 1974.

with respect to variation in the amount of faulting with time, nor are there any indications if one length of repair will perform better than any other one. At the leading joints the highest average change to date has been 0.08 in. and at the trailing joints it has been 0.14 in.

Load Deflection Test

The daytime deflection of the existing pavement and the repair slab at the leading joint of each repair caused by an 18,000-lb axle load was measured in the summer of each year. The load passed over the joint at creep speed at a distance of 12 in. from the pavement edge. The deflection was measured with linear variable differential transformers, suspended from a cantilever truss, with the core resting on the pavement. The movement of the core as the load passed was recorded on a two-channel oscillograph. The deflection was measured at the point 2 in. from the pavement edge and 2 in. each side of the joint, and two trials were made at each repair. Since nearly all the repair joints are undoweled and without aggregate interlock, there is no load transfer as such across the joint. Even at the few doweled joints the load transfer effectiveness would be low because the dowel holes in the existing slab were drilled 1/16 in. oversize. Therefore, the measured deflections are basically a check on the base's capacity to maintain its support strength with time.

1972 Repairs - The measured deflection at each repair for each of the five years since construction is shown in Figure 14. There appears to be no significant differences in the performance of the three types of joints. The deflections have been close to 0.01 in. throughout the five year service period, except for one 1973 and a few 1974 measurements. These unusual large deflections could possibly have been caused by instrumentation problems since subsequent readings are back in the normal range. The deflections at the doweled joints are about of the same magnitude as those at undoweled joints, which would indicate that dowels installed in 0.06 in. oversized holes have little effect on deflections of the magnitude measured.

1973 Repairs - The average deflections measured at the leading joint of 6, 8, and 10-ft precast and cast-in-place repairs during the past four years are shown in Figure 15. As in the case for the 1972 repairs the deflections measured at the leading edge of the precast repairs for 1973 and 1974 are unusually large. Otherwise, the deflections have ranged from 0.008 to 0.012 in. at the existing pavement, and from 0.010 to 0.014 in. at the repairs. For all three length groups in the cast-in-place category the deflections have been somewhat smaller through the years than those recorded at the precast slab repairs. For the existing pavement the deflections have varied from 0.005 to 0.010 in. and for the repairs the range

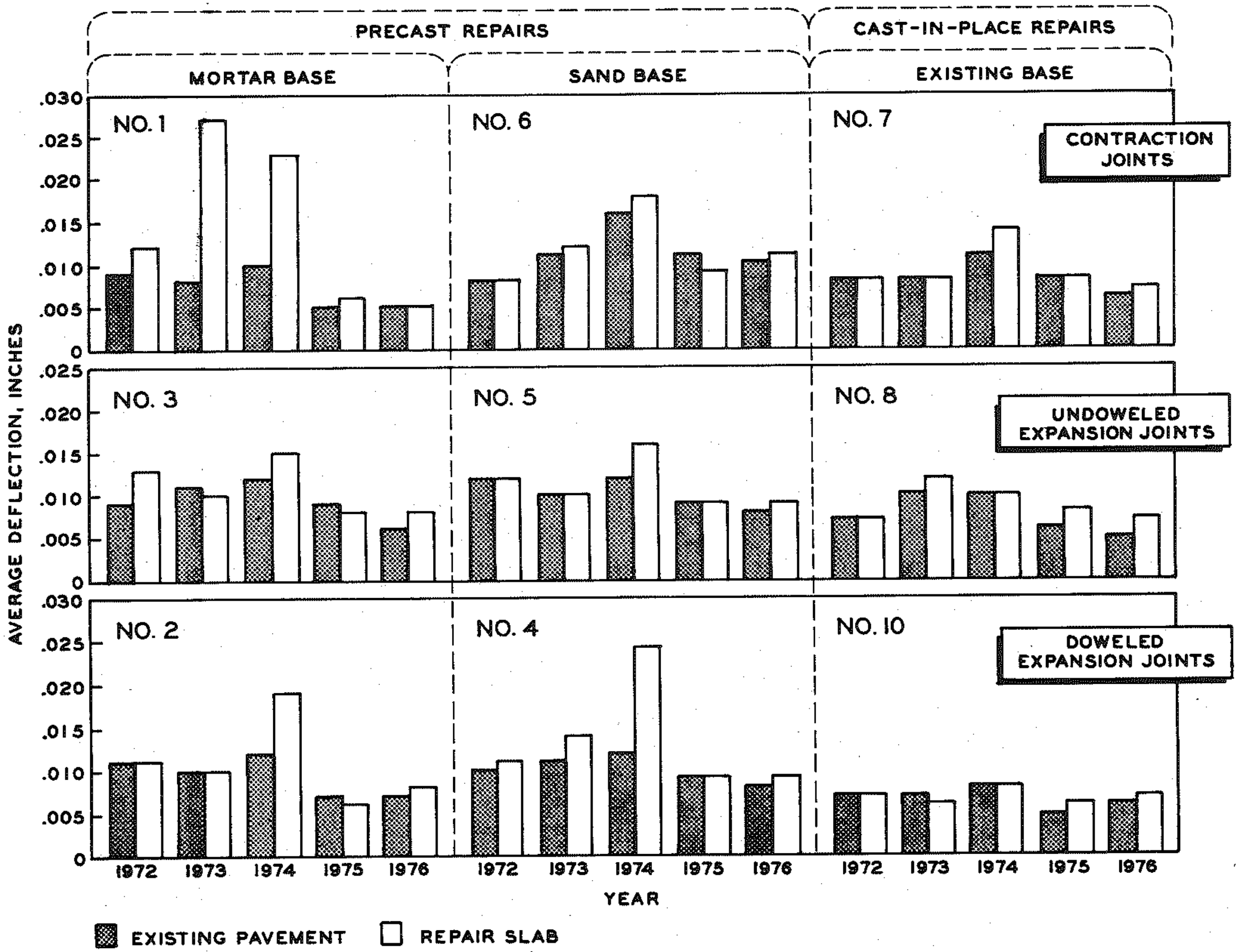


Figure 14. Daytime load deflection versus time at the leading joint of precast and cast-in-place repairs on westbound I 96.

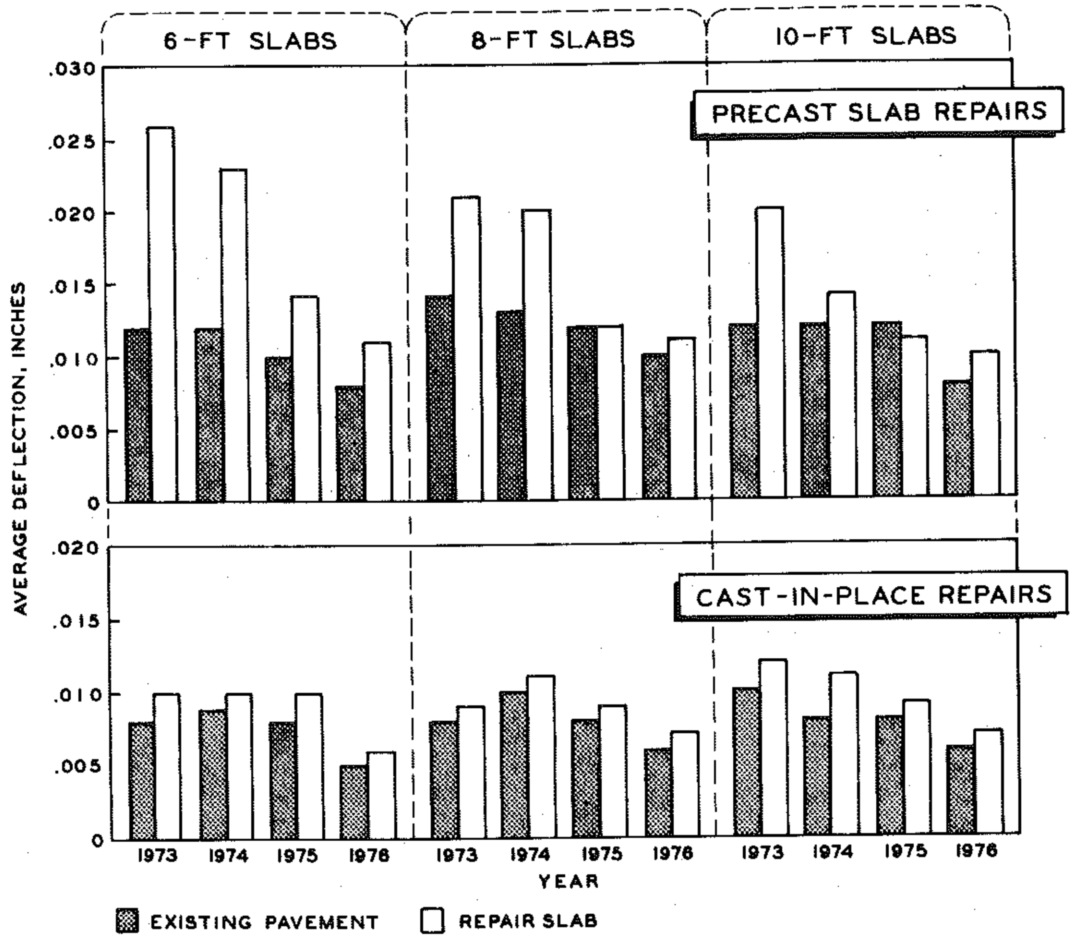


Figure 15. Average daytime load deflection versus time of the leading joint of precast and cast-in-place repairs on eastbound I 69.

has been from 0.006 to 0.012 in. It appears that the deflections measured in the summer at the two repair types and for all repair lengths used, do not increase with time.

1974 Repairs - The average deflections measured at these repairs (Fig. 16) are in about the same range as those measured at the cast-in-place repairs in 1972 and 1973. Also, the various lengths of repairs deflect about the same amount and there are no indications that the deflection will increase as the repairs get older.

Slab Rocking

In order to determine if the repair slabs are rocking under load, the downward deflection of the leading edge of a repair, and the upward movement at the trailing edge resulting from an 18,000 lb axle load moving onto

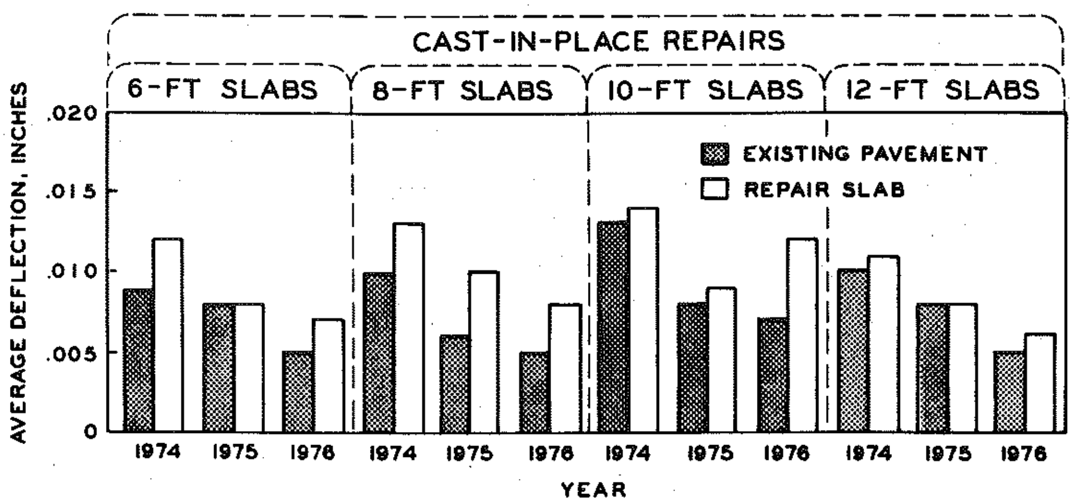


Figure 16. Average daytime load deflection versus time of leading joint of cast-in-place repairs on westbound I 69.

the slab, were measured at the time the load deflection tests were performed. The results of this type of test on the westbound I 96 repairs indicate that neither the precast slabs nor the cast-in-place slabs show any significant amount of rocking. As previously mentioned all these repairs are 10 ft long.

On the eastbound roadway, repairs of 6, 8, and 10-ft lengths were used. Some amount of rocking was noted, especially at the precast slab repairs (Fig. 17). As can be seen, the amount of rocking decreases as the length of repair increases. It can also be noted that the slabs appear to "settle down" after a few years service. For the cast-in-place repairs on eastbound I 96 (Fig. 17) and for the same type of repairs on I 69 (Fig. 18) there is not much variation in the amount of rocking for 6, 8, and 10-ft slabs. The 6, 8, and 10-ft long repairs all show a slight upward movement (maximum average of 0.003 in. in 1976 at 8-ft slabs on I 69). Only the 12-ft long repairs on I 69 have not shown any rocking during the years they have been in service.

Conclusions

The following conclusions are based on the results of the experimental work described in interim Report No. R-968 and concern the construction phase of the project.

1. A previously sawed lane repair, up to 10 ft long, can be completed and opened to traffic in an average time of 1-1/2 hours using a precast slab with undoweled joints and utilizing the developed repair procedures.

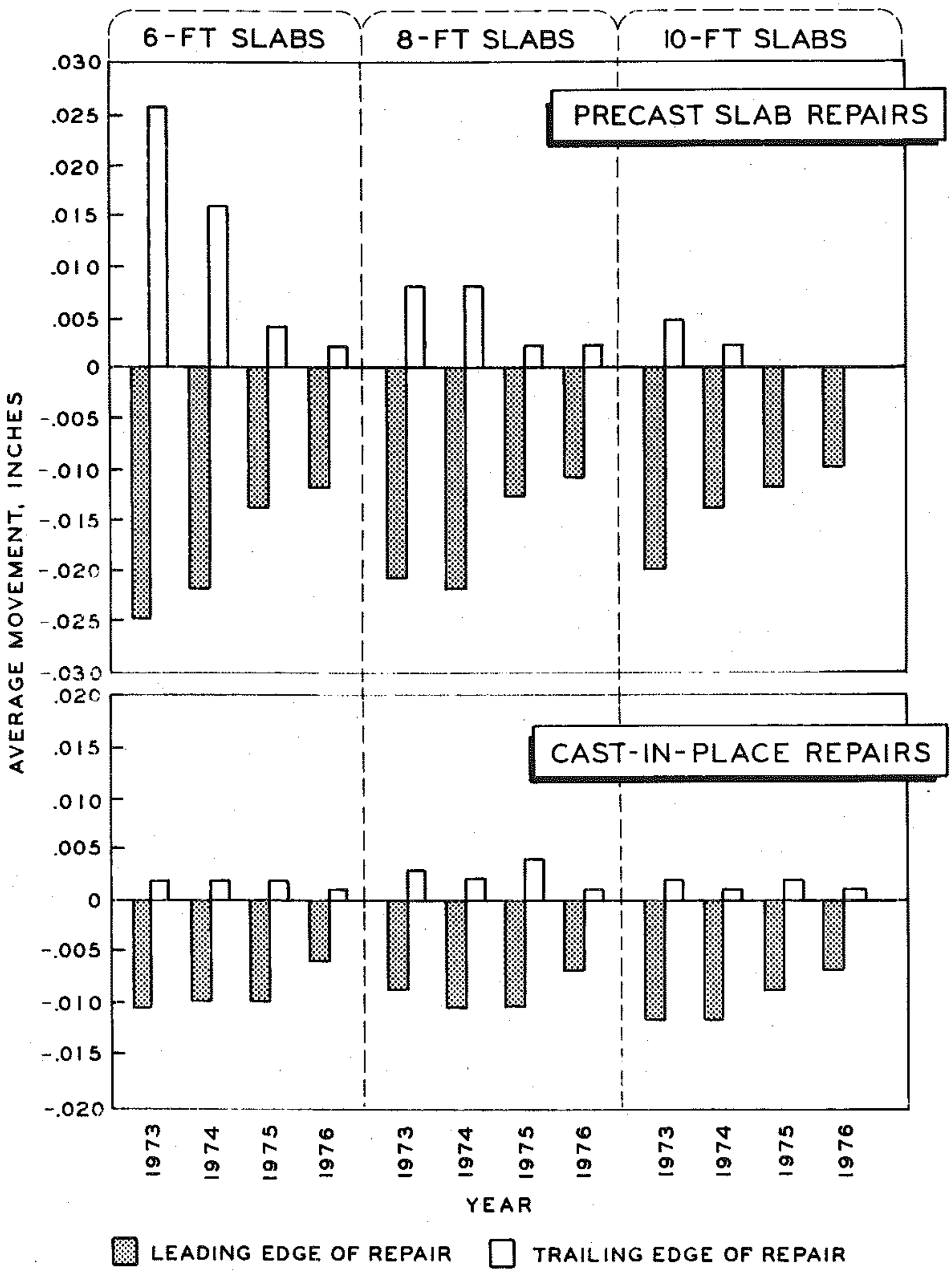


Figure 17. Rocking of repair slabs on eastbound I 96 precast repairs (top) and cast-in-place repairs (bottom).

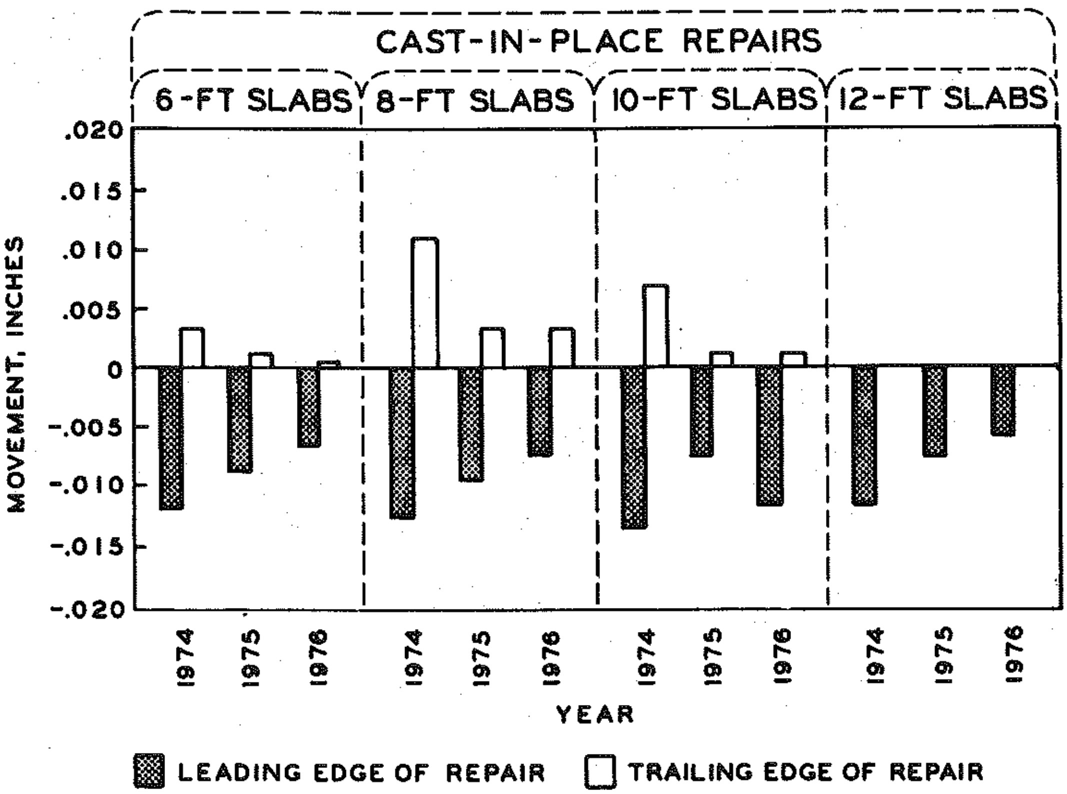


Figure 18. Rocking of repair slabs on westbound I 69.

2. A repair of equal size constructed with a 9-sack concrete mix with calcium chloride added for set acceleration, using undoweled joints and the methods developed, can be finished in an average time of 1-1/2 hours. However, an average minimum curing time of 4-1/2 hours results in a lane closure time of 6 hours minimum.

3. The use of doweled joints will add approximately 35 minutes and 1-1/4 hours to the lane closure times for cast-in-place and precast slabs, respectively. Although the additional time required to install dowels may not seem excessive compared to the total lane closure time, many problems were encountered installing the dowels. On the basis of the experience from these experimental repairs, it appears that there is no simple and inexpensive method to install dowels at the present time, and to install properly functioning dowels on a production basis, sophisticated equipment needs to be developed.

4. In general, the repair costs increase as the permitted lane closure times decrease. In the case of precast slabs, a 75 percent reduction in lane closure time appears to result in an approximately 25 percent increase in cost. This additional cost of precast slabs results from the necessity of casting the slabs away from the construction site and later transporting them to the repair area.

Conclusions concerning the performance of the repairs are as follows:

1. On the basis of the evaluation measurements conducted during the service life of the repairs, both precast and cast-in-place repairs have performed reasonably well. From the data it appears that at least five years of trouble free service can be expected and it is anticipated that a majority of the repairs will give good service for 10 years.

2. Some faulting develops at the joints. For undoweled contraction and expansion joints after four years of service the largest fault measurement was 0.32 in. For the doweled expansion joints with the same service life the maximum fault was 0.12 in. For undoweled expansion joints with three years service the highest average fault was 0.26 in., and for the same type of joint with two years service the maximum average fault was 0.14 in.

3. The rate at which expansion space is used up varies at different repair locations. At some repairs the space was utilized after two to three years. If the repair joints are counted on to relieve pressure in the pavement, resawing for installation of additional expansion material at the repair or in its vicinity need be considered. Although no measurements were made, inspection of existing joints and open transverse cracks in the vicinity of repairs with expansion joints revealed that they both increase permanently in width.

4. The downward deflection caused by an 18,000-lb load as it passes over the joints at repairs, is nearly the same for the existing slab and the repair slab. The tests indicate that the deflections do not increase with time.

5. The slabs rock a small amount when trucks pass over them. The test results indicate that the amount of rocking does not increase with time and in some cases actually decreases. No amount of rocking was recorded at the 12-ft long slabs.

6. The limits of the repairs must be located in sound concrete, otherwise premature failure of the joint edge in the existing slab may occur.

7. Although the hot-poured seals and the polyethylene filler failed to completely exclude foreign material from the joints for the duration of the project it appears that sufficient reduction in the amount of infiltration occurs to warrant sealing of repair joints. If polyethylene filler planks are used provision for anchoring them in place must be made.

8. Neither transverse nor longitudinal cracking of the unreinforced slabs has caused problems. Only one slab (14 ft long) has cracked transversely and one slab (5 ft long) has cracked longitudinally. However, on contract projects transverse cracks developed, as mentioned in the text, and reinforcement is now required in slabs 10 ft or longer.

Recommendations

There are many factors that affect the performance of pavement repairs, such as: condition of the existing pavement slab; the support and drainability of the base; the amount of commercial traffic using the facility; the length of closure time available to complete and cure the slabs; the amount of care used in constructing the repairs; the type of joint used between new and old slabs, etc. With so many variables affecting the performance it would be difficult to recommend a repair type for use in all possible situations.

The developed repairs are suggested for use as interim repairs on facilities scheduled for overlays, rehabilitation, or reconstruction within five to 10 years. Expansion joints are recommended where pressure relieving of the old slab is necessary. The amount of expansion space to install depends on the condition of the pavement under repair and must be designed accordingly. The base must be equivalent to or better than, the 14 in. of granular base used under the pavement repaired in this experiment.

Because the joints fault to some degree the repairs are not recommended for restoring or rehabilitating a pavement to its original smoothness. For such work properly doweled joints between new and old slabs would appear to be needed.