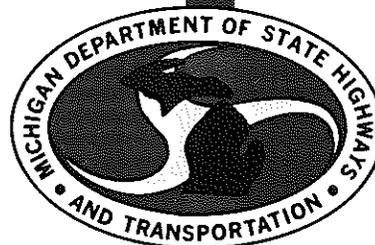


PREVENTIVE MAINTENANCE OF
CONCRETE PAVEMENTS - US 127

Progress Report



**TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION**

**PREVENTIVE MAINTENANCE OF
CONCRETE PAVEMENTS - US 127**

Progress Report

J. E. Simonsen

**Research Laboratory Section
Testing and Research Division
Research Project 72 F-123
Research Report No. R-1063**

**Michigan State Highway Commission
Peter B. Fletcher, Chairman; Carl V. Pellonpaa,
Vice-Chairman, Hannes Meyers, Jr., Weston E. Vivian
John P. Woodford, Director
Lansing, June 1977**

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INTRODUCTION

At the January 6, 1972 meeting of the Pavement Selection Committee, it was agreed that an experimental project be undertaken to determine the feasibility of preventive maintenance of concrete pavements. A proposal for an experimental project utilizing precast slabs, cast-in-place slabs, and relief joints in combination with grouting of existing joints, as prepared by the Research Laboratory, was approved by the Committee at its February 2, 1972 meeting.

The general purpose of the study was to evaluate the merits of preventive maintenance of concrete pavements. The specific objectives set forth in the proposal are:

- 1) Determine whether emergency repairs (of blow-ups) can be significantly reduced by repairing selected joints prior to actual failure.
- 2) Test the reliability of the method used to select joints for preventive maintenance repair.
- 3) Determine the feasibility of a pressure-grout type repair for use in a preventive maintenance program.

Because of the uncertainty involved in the procedure for grouting deteriorated joints, this type of repair method was investigated under a separate project. Research Report R-838 describes the grouting procedure and concludes that pressure grouting of deteriorated joints is not feasible. Because of the results of this project, Objective 3 was dropped from this study.

Construction project M 33-79, C1 (Control Sections 33031 and 33032) located on US 127 in Ingham County was selected for the study. The project POB is Sta. 730+00 and the POE is Sta. 1096+17 on the southbound roadway, and on the northbound roadway the POB and POE are at Sta. 730+00 and 1094+11, respectively. The southbound roadway was used for the experimental work and the northbound roadway designated as a control pavement.

The pavement was constructed in 1956 and consists of two 11-ft lanes of 9-in. thick reinforced concrete. The joints are spaced 99 ft apart and contain base plates and load-transfer dowels. The grooves were formed

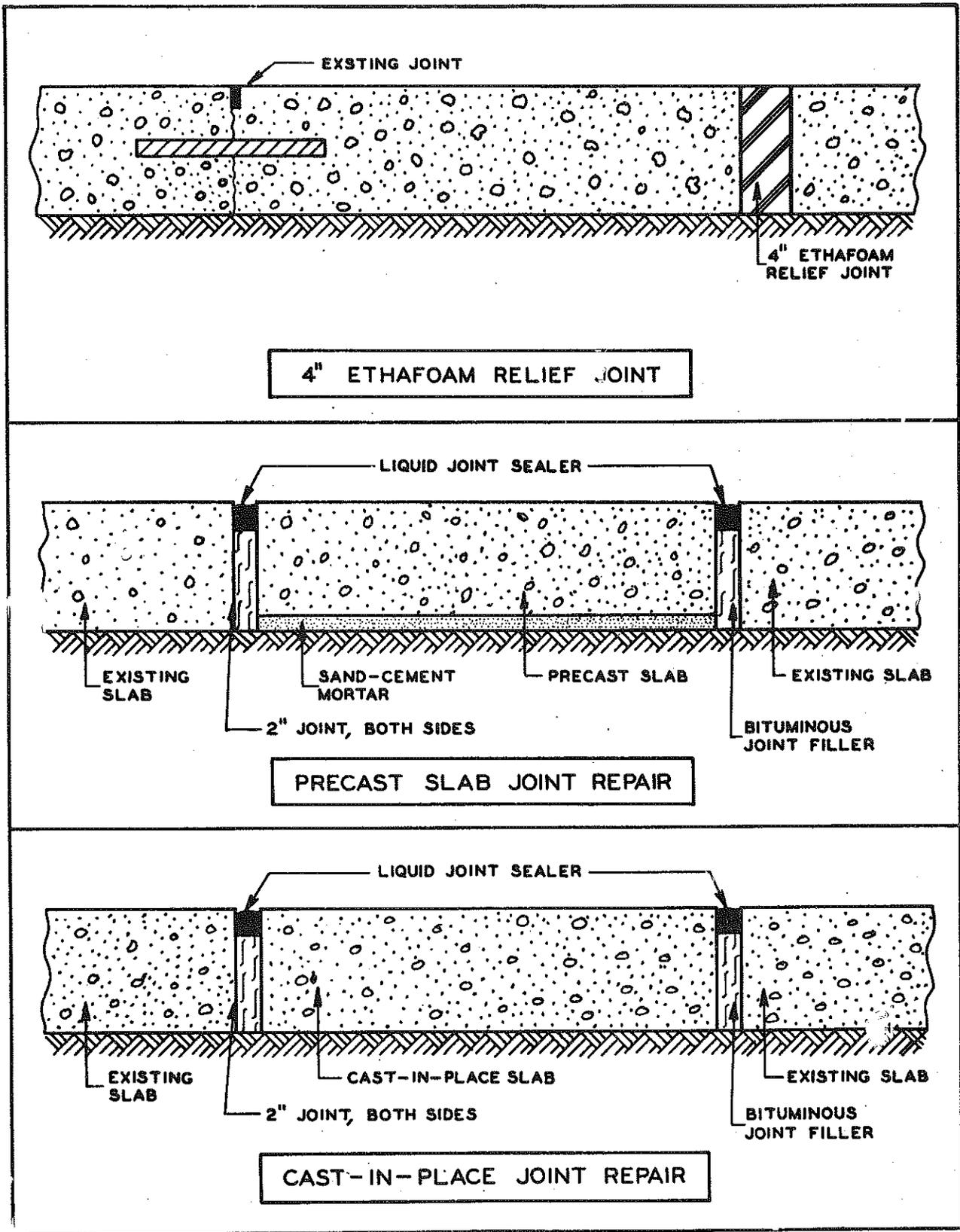


Figure 1. Repair Types

and were sealed with a hot-poured rubber-asphalt sealant. The pavement was in good condition for its age, and only three joints on the southbound roadway had been replaced with bituminous material.

A contract proposal (Project: Group Mm 2PC-8A) covering the experimental work was prepared by the Design Division in cooperation with the Maintenance and Testing and Research Divisions. The contract (covering the replacement of 10 joints with precast slabs, 20 joints to be replaced with cast-in-place concrete, and the installation of 18 relief joints) was awarded to the low bidder, Sargent Construction Co., on May 17, 1972.

The three types of preventive repairs are shown in Figure 1, and the layout of the repairs on the southbound roadway is shown in Figure 2. Pressure relief was provided at 48 locations at a spacing ranging from a minimum of 200 ft to a maximum of 1,200 ft. Precast slabs were installed at 10 locations, cast-in-place repairs were used at 20 locations, and at the remaining 18 locations a 4-in. relief joint was installed. The precast and cast-in-place repairs replaced badly deteriorated joints, while the relief joints were installed 6 ft from an existing joint.

Research Report R-859 describes the construction procedures used in repairing deteriorated joints and in installing relief joints. It also discusses the procedure used for selecting the locations for pressure relieving the pavement. This report deals with the performance of the pressure relieved southbound roadway and of the northbound roadway (control section).

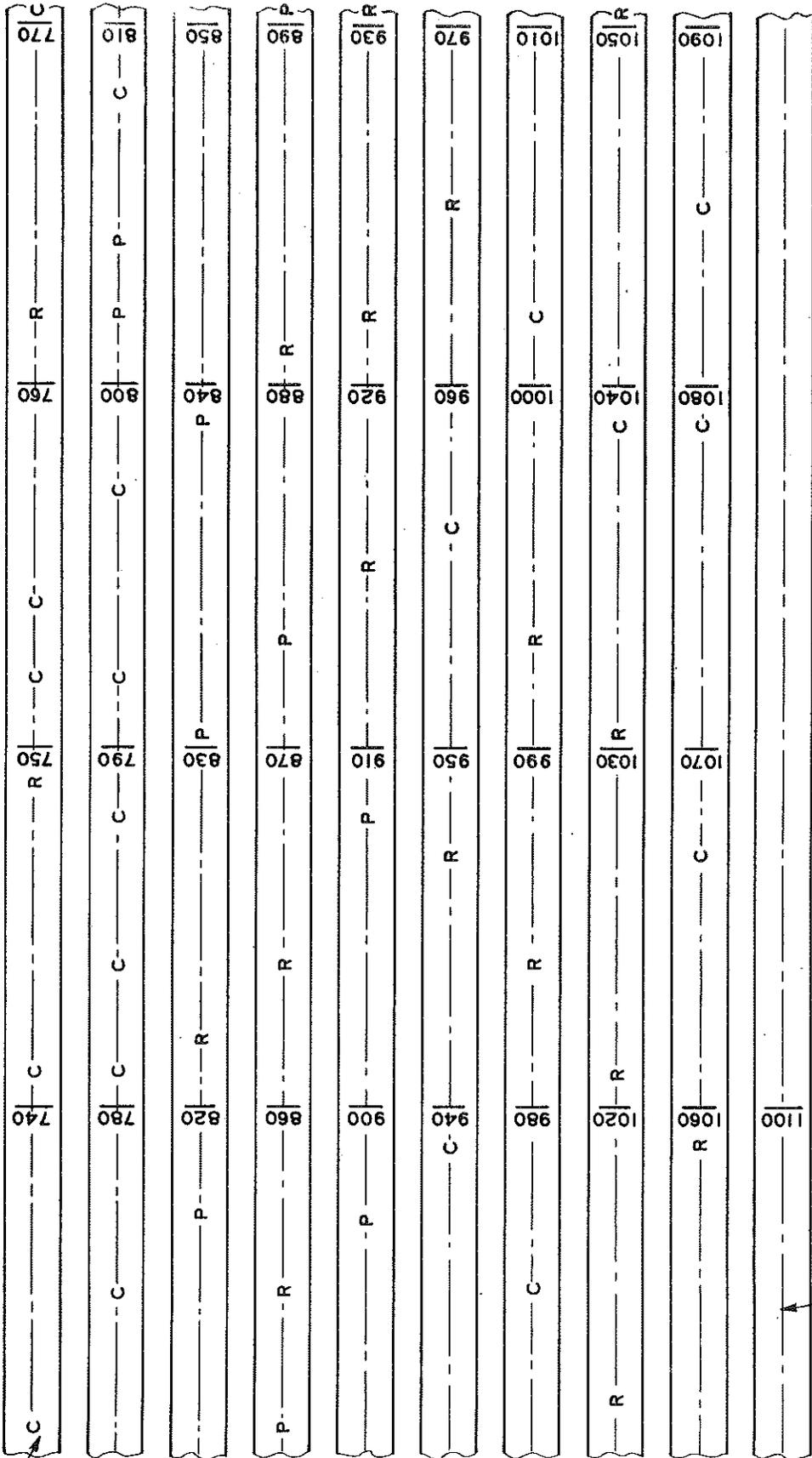
PERFORMANCE OF PRESSURE RELIEVED PAVEMENT

Reduction in Joint Blow-Ups

On the basis of observations of the performance of the test section it is evident that the blow-up problem can be controlled by incorporating expansion space into the pavement. The provision of expansion space at the 48 locations in the nearly seven mile test section has prevented blow-ups entirely for the past four years. In comparison, 25 full-depth repairs of failing joints were made on the northbound control section. However, since the test section has only been in service four years it is still too early to reach any conclusion concerning the number of years the section will remain in a blow-up free state.

Although this was the first project providing pressure relief by using a combination of repairs with expansion joints, and the use of 4-in. relief joints in relatively good sections of pavement, other projects utilizing the same principle have been pressure relieved under contract work with equal success. In addition, our maintenance forces have installed 4-in. relief

POB STA. 730+00



CODE:
P=PRECAST SLAB REPAIR
C=CAST-IN-PLACE REPAIR
R=PRESSURE RELIEF JOINT

Figure 2. Layout of preventive joint repair pavement section, (southbound roadway).

joints or provided expansion space at many joint repair locations in our concrete pavement. The effect of providing this expansion space is reflected in a decrease in the annual number of blow-ups occurring. The number of blow-ups for the years 1973 through 1976 as reported by the Maintenance Division are as follows:

Year	Total Number of Blow-Ups
1973	1,123
1974	805
1975	786
1976	391

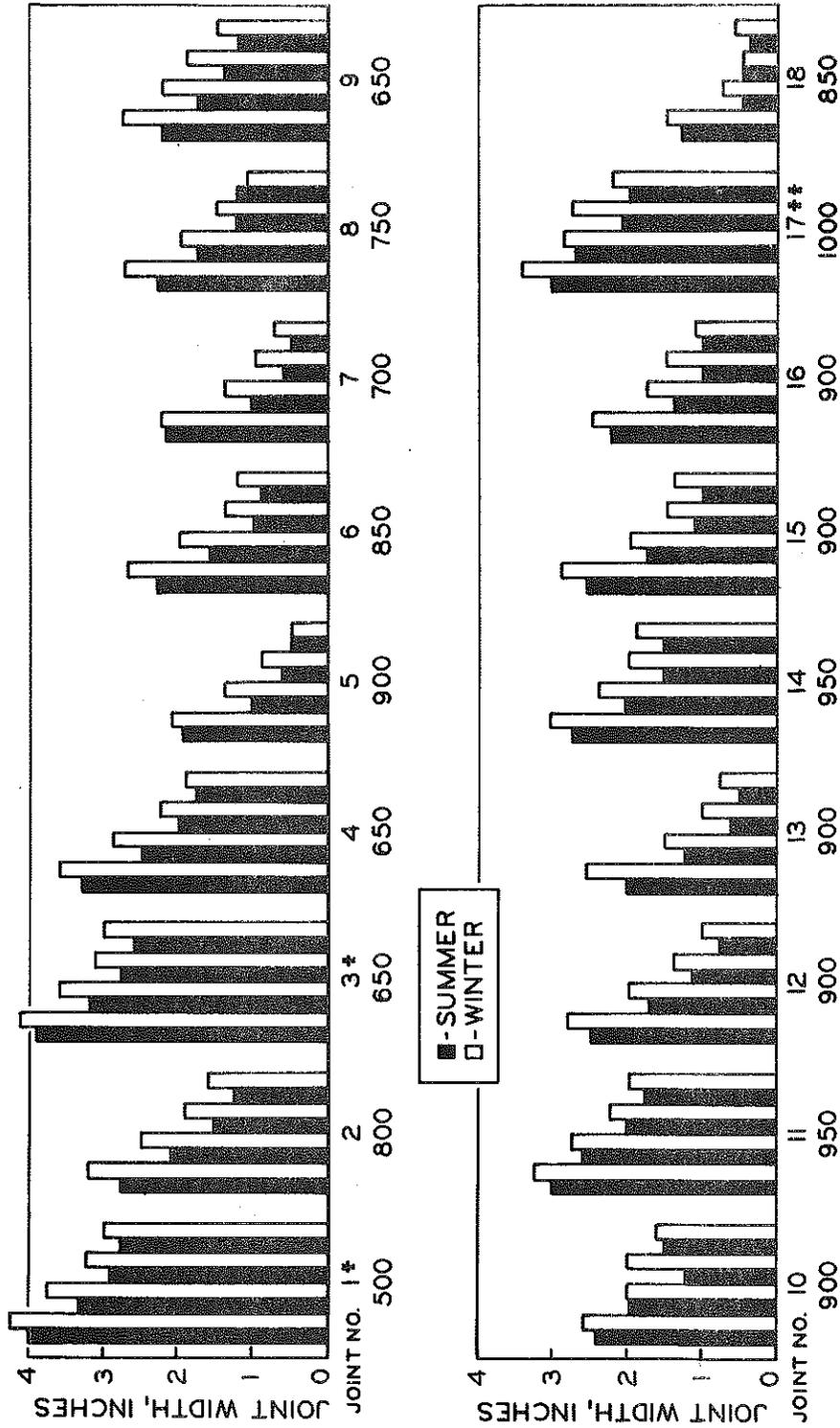
Some of the slightly more than 50 percent reduction in the number of blow-ups from 1975 to 1976 could have resulted from favorable moisture and temperature conditions existing during the blow-up season.

In addition to reducing blow-ups, the repair of joints prior to failure or the installation of 4-in. relief joints also eliminates the overtime pay for "emergency repairs." The cost of repairing a blow-up shortly after the emergency repair with a full-depth bituminous patch is also eliminated. Another benefit of preventive maintenance of the type discussed here, is that whether the work is done under contract or by maintenance forces, it can be planned ahead to take advantage of slack work periods.

The northbound control section of US 127 was maintained by our maintenance forces in accordance with normal procedures, which since about 1972 have incorporated expansion space in joint replacement maintenance. When this type of work is done under contract a relatively long section of pavement is pressure relieved in a short time. In contrast, pressure relief is provided by maintenance forces on a continuous yearly basis by replacing critically deteriorated joints wherever they are located throughout the pavement length. Three repairs were made on the control pavement in 1973, 1974, and 1975, and in 1976, 16 repairs were made.

Expansion Joint Closure

The closure of expansion joints installed in concrete pavements to relieve the pressure in the slab varies considerably from joint to joint.



* BITUMINOUS MATERIAL REPLACED WITH ETHAFOAM BETWEEN 3RD AND 4TH READINGS
 ** TWO FOOT OF FILLER MISSING - FILLED WITH BITUMINOUS MATERIAL

Figure 3. Annual movements at expansion joints during the past four years. Numbers below each joint indicate pavement length contributing to the joint movement.

Generally speaking, the expansion joints in new pavements close at a fairly uniform rate over the first few years until the provided space is used up. Then the expansion joints close and open in a manner similar to contraction joints.

The uniformity of closure of expansion joints in new pavement occurs because the compressive force is nearly of equal magnitude throughout the pavement. However, in older pavements being pressure relieved by using joint repairs or 4-in. relief joints, the compressive force varies greatly.

There are several factors that contribute to pressure change in the pavement slab. Two of the more important ones are open transverse cracks, and blow-ups. In slab areas with open cracks, incompressible materials enter the cracks during pavement contraction which then result in increased pressure during pavement expansion. In contrast, blow-ups reduce the pressure in the slab. Normally a bituminous patch is installed at a blow-up and serves as a relief point in the pavement. Considerable pressure may also be generated from incompressible materials entering the joints through failed seals.

Summer and winter measurements of the 4-in. relief joints have been made each year. The movement and permanent closure of each joint are shown in Figure 3. Note that filler problems at joint Nos. 1, 3, and 17 have impaired their function. The permanent closure of the remaining ones varies a good deal. The highest closure rate was encountered at joint Nos. 5, 7, 13, and 18, and these four joints may have ceased to be effective in relieving the pressure in the slab. At the remaining joints some additional closure is possible before pressure build-up will begin. A typical characteristic of expansion joints installed in older pavements is that the most permanent closure occurs the first year, unless a joint is installed close to a blow-up repair.

The length of pavement contributing to the closure of each expansion joint is shown in Figure 3 (assumed to be the sum of one-half the distance to the next relief point each side of the 4-in. relief joint). The length between relief points in a pavement certainly has an influence on the rate at which the expansion space is used up. However, the effect of length may be overshadowed by the effect that open transverse cracks and poorly sealed joints have on the consumption of the provided space. Therefore, if a pavement to be pressure relieved contains open transverse cracks, consideration should be given to install a repair with expansion joints at the crack locations, rather than using relief joints.

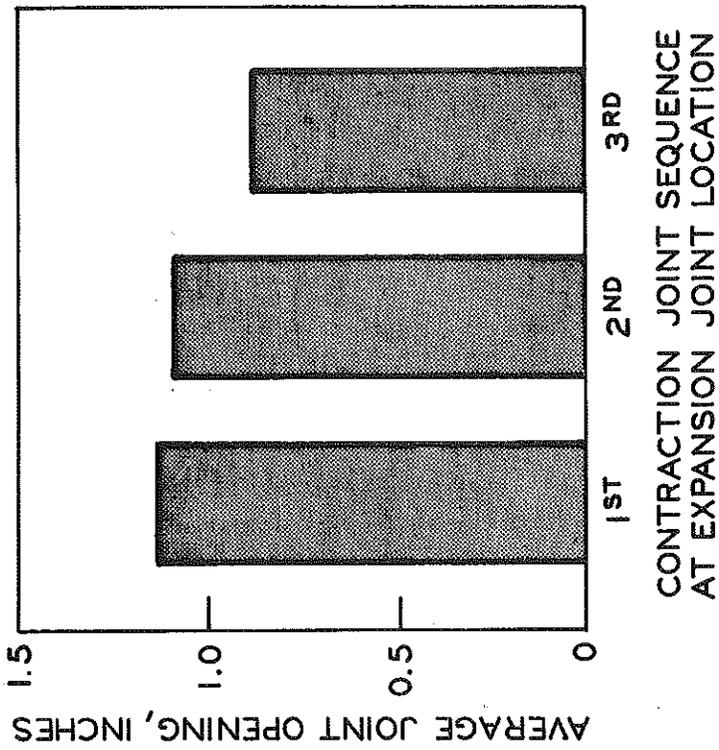


Figure 4. Average joint openings at the first, second, and third contraction joint away from expansion joint locations (measurements taken at 45 F).

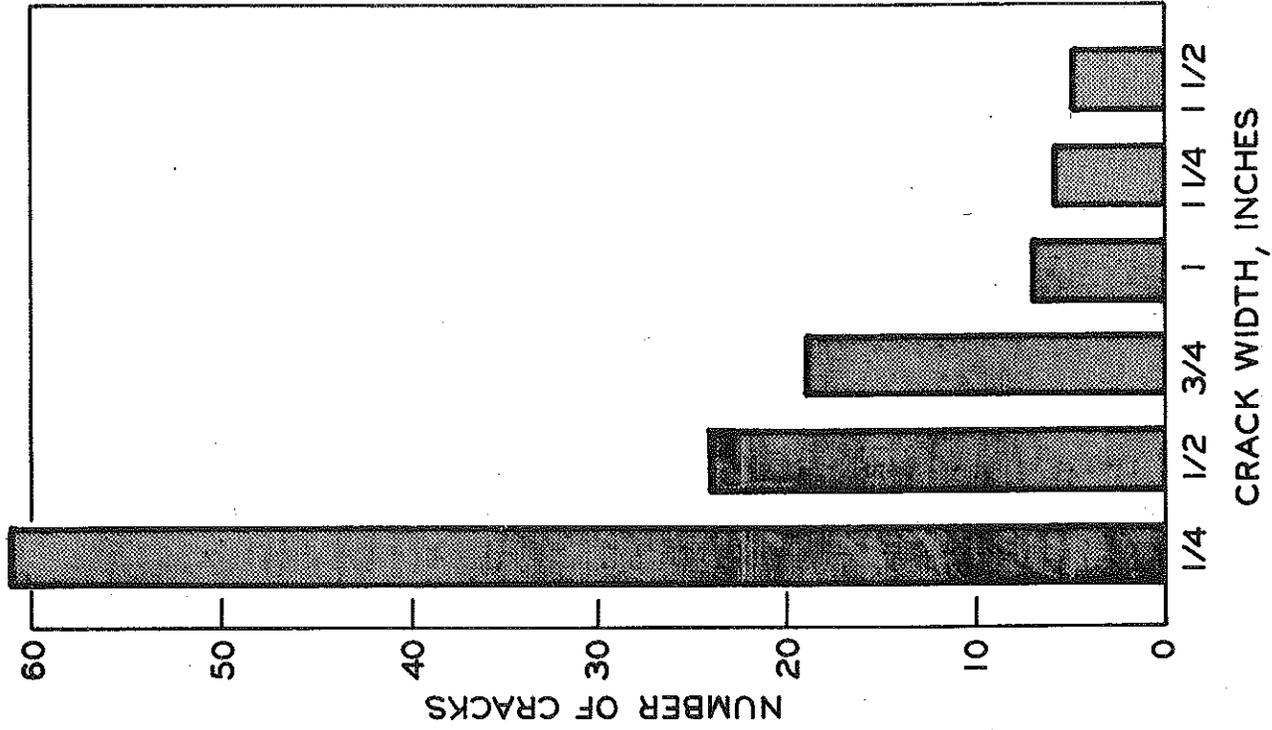


Figure 5. Number of cracks vs. estimated crack width.

Contraction Joint Movement

The pressure relief provided by installing expansion joints has an adverse effect on the movement of contraction joints in the near vicinity of the expansion joints. Apparently, lowering the compression in the slab allows the contraction joints near the expansion joints to open wider during subsequent contraction cycles of the slab. This in turn allows incompressible materials to enter the joints, resulting in more closure of the expansion joints during hot weather and increasing the rate at which the expansion space is used up.

The average opening measured at the first, second, and third contraction joint away from an expansion joint is shown in Figure 4. The opening shown is the average of 10 joint widths measured at 45 F, four years after the expansion joints were installed. At the ten selected locations the slabs were free of open transverse cracks. Assuming that the third joint is open the normal amount, and that the additional opening of the first and second joint has been filled with solid material during the four year period since the pavement was pressure relieved, then on the average nearly 0.8 in. of the expansion space at each location has been used to accommodate the length increase occurring at the adjacent contraction joints. To minimize the usage of expansion space resulting from permanent opening of adjacent contraction joints one could reseal the contraction joints to prevent infiltration.

Open Transverse Cracks

Open transverse cracks adversely effect a pressure relieved pavement. Whereas open cracks contribute to pavement growth which increases slab pressure until failure eventually occurs, the cracks in a pressure relieved slab increase the rate at which the expansion space is used up. Cracks in the vicinity of expansion joints have been observed to open more than cracks away from these joints, even though in both cases solids have unimpeded access to the crack.

A survey conducted in the fall of 1976 revealed that the southbound test section had 157 cracks open 1/4 in. or more. Figure 5 shows the number of cracks versus estimated crack width in 1/4-in. increments. The total width of the 157 cracks is just over 5 ft. Although the cracks will probably close somewhat during warm weather, one can very well imagine the adverse effect they have on the closure of expansion joints. As previously suggested, consideration should be given to the installation of a repair at open cracks when pressure relieving a pavement.

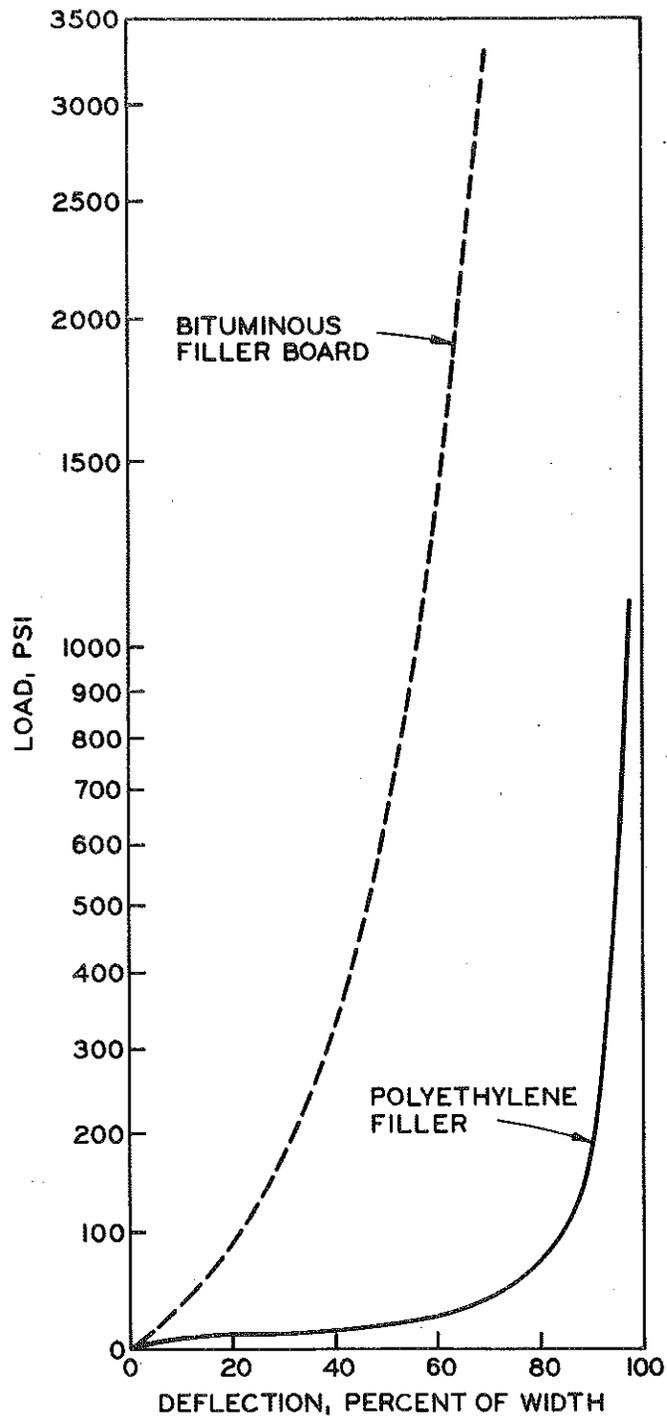


Figure 6. Typical load-deflection curves for bituminous and polyethylene joint fillers.

Repair or 4-in. Relief Joint

The condition of the pavement to be pressure relieved will dictate whether repairs or 4-in. relief joints should be used. The exclusive use of 4-in. relief joints in a pavement would be very unlikely unless the pavement is pressure relieved at a very early age. Normally a combination of joint repairs and relief joints would be prescribed to relieve pavement pressure. Either method would be equally effective in relieving the compression in the slab provided the filler material used is the same for each method. Otherwise, one material will provide more expansion space at lower pressure than the other one. Figure 6 shows that the compressibility of the two materials used (bituminous filler board and polyethylene filler) varies greatly. On the basis of the compression test results two 2-in. wide expansion joints using a bituminous filler can accommodate a 2.8 in. pavement growth before the pressure reaches 3,500 psi. A 4-in. relief joint with a polyethylene filler can provide for 3.8 in. length increase at a pressure of only about 1,000 psi. Obviously, it will be beneficial to use a highly compressible filler when pressure relieving a pavement.

Joint Faulting

Faulting across the 4-in. relief joints and across the joints at repairs does occur. Measurements of the faulting at the 18 relief joints installed on the test section, conducted in November 1976, showed that there was no faulting at two joints, whereas at the remaining joints the amount of offset varied from 1/8 in. to 1/2 in., the average for all joints was 1/4 in. Faulting across joints at repairs, as measured on other projects, is of about the same magnitude. If faulting were the only criteria used to determine whether a repair or an expansion joint should be used to relieve the pavement pressure, the expansion joint would be preferred, because there would only be one joint to develop a 'bump.' However, on most pavements being considered for pressure relieving some joints need to be replaced with a new slab to improve the rideability. To improve and maintain the surface smoothness of a pavement, by conducting pressure relief work, would require dowelled joints and tie-ins to the existing slab.

Joint Spalling

Joint deterioration in the form of spalling along the joint grooves continues on pressure relieved pavements. Each joint on both the southbound and northbound roadway has been inspected during yearly surveys and the length of spall more than 4 in. in width was estimated and recorded for each joint. The average spall length per joint was calculated for both roadways for each survey year and is presented graphically in Figure 7.

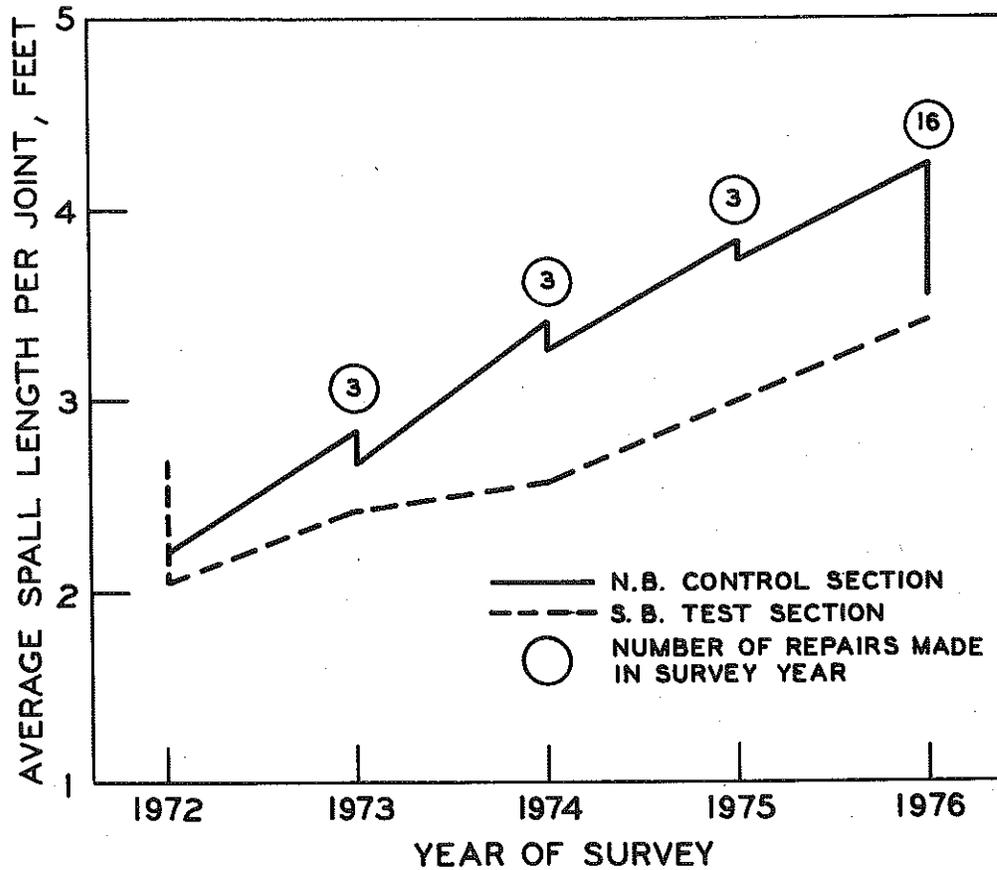


Figure 7. Average joint spall length before and after repair for each year since study began.

The average joint spall length on the southbound roadway was 2.7 ft in 1972 before pressure relieving this section. After repairing 30 joints (in 1972) the average joint spall length was reduced to 2.1 ft. On the northbound roadway the average spall length per joint was 2.2 ft in 1972. The increase in average joint spall length has occurred at a somewhat faster rate on the control section than on the test section. However, after replacing 16 joints in 1976 on the control section the average joint spall length is nearly the same on both roadways (3.4 ft on the test section compared to 3.5 ft on the control section).

Unfortunately, there is no solution to the joint spalling problem on the type of pavements under consideration for pressure relieving. However, if the joint spalling continues at the same rate on other pressure relieved projects as measured on the test section under study, it would appear that further pressure relieving, when needed, should be done by replacing badly spalled joints rather than recutting existing expansion joints, or installing new ones.

PROCEDURE FOR SELECTING JOINTS FOR PREVENTIVE MAINTENANCE REPAIR

Research conducted prior to initiating this study indicated that joint blow-ups can be predicted on the basis of visual surface defects. The pavement joints were divided transversely into five equal length sections. Visual defects present within these areas on 10 year old pavements were compared to the presence of blow-ups on the same pavements after five more years of service. It was found that the more sections on a joint exhibiting defects the more likely the joint would blow-up within five years. Since this method of grouping the defects did not require any physical dimensions of the surface deterioration, the seriousness of the defects could not be considered when selecting joints for repair. Therefore, it was agreed that data giving the total length of joint deterioration over 4 in. in width and the maximum width necessary to remove the deterioration on each side of the joint would be required on this project.

Results of the joint condition survey on the southbound roadway revealed that joints with considerable deterioration were not spaced evenly throughout the project length. For example, of the 375 joints on the southbound roadway, 13 percent had more than 4 ft of spall along their length, across the roadway, but about half of them were found to be either 100 or 200 ft apart. The data also showed that long sections of the pavement, in one case up to 6,200 ft, had joints with 4 ft or less of deterioration. With this information at hand it was necessary to decide which joints should be selected for replacement. It appeared that replacing joints with more than 4 ft of spall would be reasonable; however, in several cases adjacent joints would then be replaced. This would be costly and would contribute little toward pressure relieving the entire pavement length.

Although no rigid rules were established for the selection of joints to be replaced, the criterion of replacing all joints with more than 4 ft of spall was given up in favor of a more economical system that also appeared to provide protection against blow-ups. The procedure used was as follows:

- 1) All joints with 9 ft or more of deterioration were replaced with a repair having 2-in. expansion joints on each side.
- 2) On the pavement sections thus established, with lengths in excess of 1,200 ft, relief was provided by either a 4-in. relief joint or by replacing a joint having 4 to 9 ft of deterioration with a repair using 2-in. expansion joints on each side.

In general, a repair was specified if a joint within 200 ft of the required relief location had between 4 and 9 ft of spall. Using such a system results in variable spacing between relief location, and, of course, the pressure is not reduced to the same level throughout the pavement length involved. This appeared to be a better system than one that specified relief at a certain distance regardless of the condition of the pavement. It essentially removes joints most likely to fail and also allows for relatively longer spacing in sections of pavements having relatively good joints.

As mentioned previously 30 repairs and 18 4-in. relief joints were used on the southbound roadway. The spacings varied from 200 to 1,200 ft. Fourteen of the 30 repairs (46 percent) replaced joints having 9 ft or more of spall and the remaining 16 joints (54 percent) had between 4 and 9 ft of spall at the time they were repaired.

The amount of deterioration on each joint on the northbound roadway was also recorded in 1972. Thus, comparison of the amount of spall on the joints repaired since then to that on the joints selected on the southbound roadway, checks the reliability of the system used to select joints for replacement before failure.

On the northbound roadway there were 18 joints with 9 ft or more of deterioration in 1972. After four years 14 joints (77 percent) have been replaced with a repair. Three of the four joints in this deterioration group that were not replaced were adjacent to one that was replaced, and the remaining one was 200 ft, or two joints away, from a replacement. Being that close to a pressure relief point is probably why these four joints are still in service. Otherwise, 100 percent replacement likely would have occurred.

Of the other 11 joints replaced on the northbound roadway, eight joints (73 percent) had between 4 and 9 ft of deterioration. The remaining three replaced joints had between 1 and 4 ft of deterioration on them in 1972. There is no apparent reason for the replacement of these joints unless they had deteriorated more on the bottom than the adjacent ones.

The natural spacing of the repairs is quite similar to that of the selected joint repairs and relief joints on the southbound roadway. The spacing ranges from 200 to 1,400 ft except there are three long sections (0.5, 1.0, and 2.8 miles) where no joints have been replaced to date, and there are two locations where adjacent joints were repaired. On the three long sections without repairs the 1976 survey shows 18 joints with spalls 9 ft or more in length. It is anticipated that these joints will need replacement within one

or two years, thus essentially pressure relieving the northbound roadway over its entire length.

On the basis of the spacing between repairs and the length of deterioration on the joints replaced on the northbound roadway it appears that the procedure used to select joints for replacement and establish expansion joint locations on the southbound roadway was satisfactory. Since most pavement projects vary in their performance, the amount and spacing of expansion space needed on each project may also vary. From the information gathered on this study it appears that two-lane pavements, in similar condition as the US 127 portion involved in this study, can be pressure relieved in the following manner:

1) On the basis of joint condition surveys and past performance, determine the maximum spacing (plus or minus 200 ft) of relief points. The minimum spacing on badly deteriorated pavements will be one slab length.

2) Determine locations where the geometry of the alignment dictates the need for expansion space. If there is an open transverse crack or a joint with 4 ft or more of deterioration within 200 ft of the selected location, provide the space by using a repair at the crack or joint location. Otherwise, use a relief joint at the selected location.

3) Replace all joints having 9 ft or more deterioration with a repair.

4) Divide sections that exceed the maximum distance of relief points into lengths near the maximum allowed. At the locations thus established provide expansion space by replacing a joint with 4 to 9 ft of deterioration or an open crack if either one is within 200 ft of the selected location. Otherwise use a relief joint at the desired location.

The amount of expansion space to provide at repairs and at expansion joints will vary with the spacing of the relief locations and will depend on the condition of the pavement being relieved.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

On the basis of the information presented, the following conclusions appear warranted.

1) By providing expansion space in the pavement at spacings ranging from 200 to 1,200 ft, blow-ups have been prevented for the four-year period since the expansion joints were installed.

2) There was no evidence that provision of expansion space at repairs was better than providing space by installing 4-in. wide relief joints.

3) At most repairs and 4-in. relief joints, faulting has developed and ranges from 1/8 to 1/2 in.

4) Existing joints and transverse cracks with fractured steel in the vicinity of installed expansion joints increased permanently in width at a faster rate than those located in the interior section between expansion joints.

5) Spalling along the existing joints continued on the pressure relieved pavement. In this case, the average increase in spall length per joint was 1.4 ft over four years. The 1976 survey revealed 21 joints with 9 ft or more of deterioration on the section pressure relieved in 1972.

6) Based on the manner of repair required on the northbound roadway, the procedure used to select joints for repair and to locate relief joints on the southbound roadway appears reasonable.

Recommendations

Although pressure relieving a pavement by the use of undowelled expansion joints apparently has some adverse effects on the smoothness of the pressure relieved section, it does minimize the blow-up problem, and, therefore, continuation of the use of expansion joints to relieve pavement pressure is recommended.