PREVENTIVE MAINTENANCE OF CONCRETE PAVEMENTS - US 127
Final Report

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

PREVENTIVE MAINTENANCE OF CONCRETE PAVEMENTS - US 127
Final Report

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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 a preventive maintenance concept for 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 was prepared by the Research Laboratory and approved by the Committee at its February 2, 1972 meeting.

Most maintenance problems on concrete pavements develop at joints. The first signs of joint deterioration are spalling along the joint groove and corner breaks or cracks. These defects are fixed as they occur by filling with cold-patch materials; deterioration continues, however, and eventually the weakest joints fail either by crushing or blow-up. Unfortunately, many of the serious types of joint failures occur during hot weather in the late afternoon hours creating a hazard to drivers as well as causing traffic tie-ups. These joint failures must be temporarily repaired immediately which necessitates calling in maintenance personnel for overtime work. These repairs are generally referred to as 'emergency repairs.'

It is the general purpose of this study to evaluate the merit of preventive maintenance of concrete pavement joints. The specific objectives set forth in the proposal are as follows:

1) Test the reliability of the method used to select joints for preventive maintenance repair.

2) Determine whether emergency repairs can be significantly reduced by repairing selected joints prior to actual failure.

3) Determine the feasibility of a pressure grout-type repair for use in a preventive maintenance program.

Because of the special techniques and equipment involved in the procedure for grouting deteriorated joints, this type of repair method was investigated under a separate contract with the Structural Bonding Co. of Flint, Michigan. Research Report R-838 describes the grouting procedure and it was concluded that pressure grouting of deteriorated joints is not feasible.

Location and Description

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 was designated as a control section.

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

A contract proposal (Project: Group Mm 2 PC-8A) covering the experimental work was prepared by the Department's 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.

Research Report R-859 describes the construction and selection procedures used to determine pressure relief locations. A progress report (MDOT Research Report R-910) discusses the performance of the pressure relieved pavement after four years of service. This final report deals with the performance aspects as well as the selection process involved in determining pressure relief points in a pavement. Relevant portions or summaries of earlier reports are included herein where appropriate.

JOINT SELECTION PROCEDURE

The success of a program to prevent joint failures depends on the accuracy with which the joint most likely to fail can be selected. Although the more serious joint deterioration occurs on the bottom of the slab, there are indications that surface defects are related to the probability of joint failure. The more visible surface damage at a joint, the greater the chance that it will crush or blow-up in a given period of time. Thus, it would appear that selecting the joints with the greatest amount of observable defects should be the procedure to use in determining the joints to be repaired. Unfortunately, the joints with the most surface deterioration are normally not equally spaced throughout a project, but are found in groups or at close spacings. Therefore, if only the joints with the most surface defects were repaired to provide expansion space, the compressive forces would only be relieved in a short portion of the project.

In an attempt to develop a procedure for selecting the joints to be repaired on this project a joint condition survey was made. The survey recorded the estimated length of surface spalls more than 4 in. wide along each joint groove and the width of repair to remove the deteriorated concrete. A frequency distribution of joints with 0 to 22 ft of spall is shown in Figure 1. Of the 375 joints on the project, 13 percent (about 50 joints) had more than 4 ft of spall along their length. At first glance it would seem reasonable to replace these joints. However, as shown in Figure 2, 26 joints, or more than half of the joints with serious surface defects (more than 4 ft of spall), were found to be either 100 or 200 ft apart. The remaining joints in this group were spaced from 300 to 6,200 ft. Therefore, repairing only the joints with more than 4 ft of spall would result in large lengths of pavement without pressure relief.

On the basis of the survey data it was concluded that the best results in preventing blow-ups could be obtained by using a combination of joint repairs utilizing expansion joints and installing pressure relief joints in areas where the pavement joints were in good condition. The procedure used in determining repair and relief joint locations was as follows:

1) All joints with 9 ft or more of deterioration would be replaced with a repair slab.

2) On the pavement sections between repairs and over 1,200 ft in length, pressure relief would be provided by a relief joint or by replacing a joint having 4 to 9 ft of deterioration.

In general, a repair was specified at a joint if the joint was within 200 ft of the required relief location and had between 4 and 9 ft of spall. Using such a system results in variable spacing between relief locations, 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 regular spacing 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 (10 precast and 20 cast-in-place) and 18 relief joints were used on the southbound roadway. Two-inch expansion joints were used with the repairs and the relief joints were 4 in. wide. Figure 3 shows cross-sections of the repairs and relief joints.

The locations of repair types and relief joints are shown in Figure 4. As can be seen, the spacings of pressure relief locations vary 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 when they were repaired.

Figure 1. Frequency distribution of spalled joints.

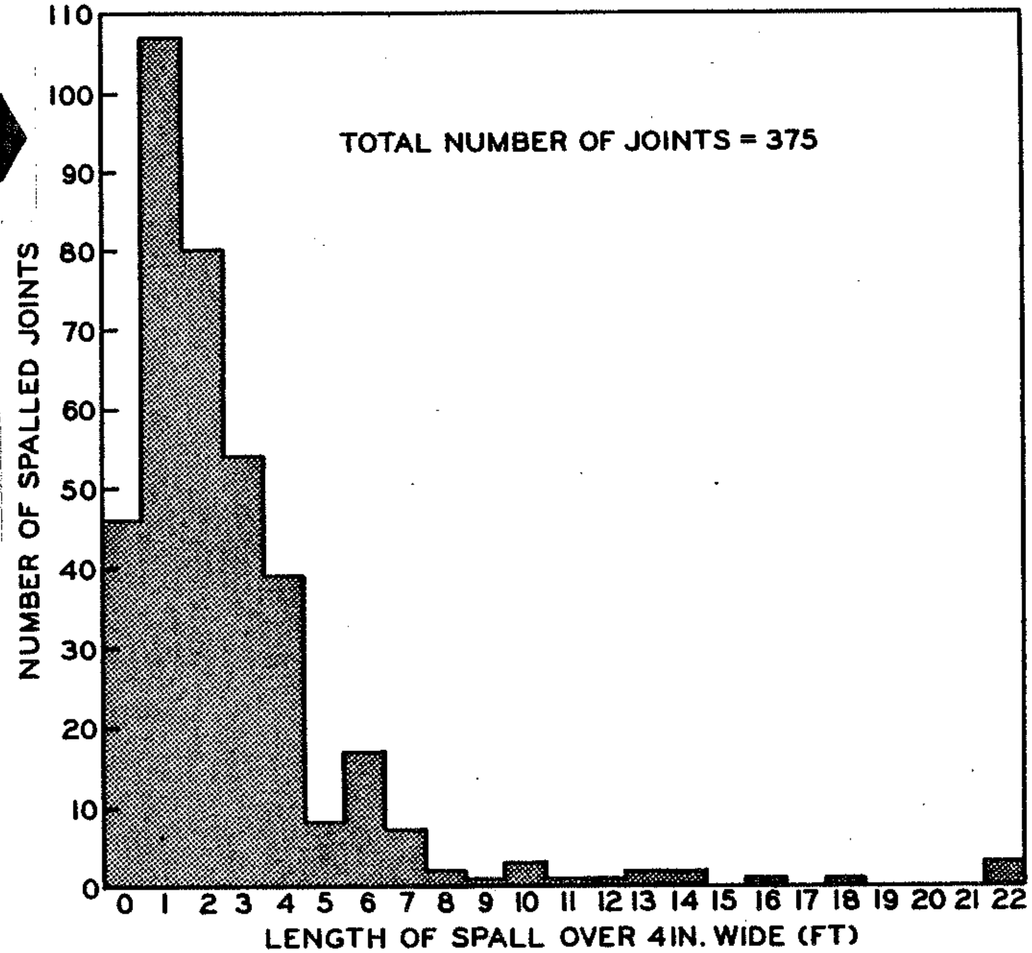
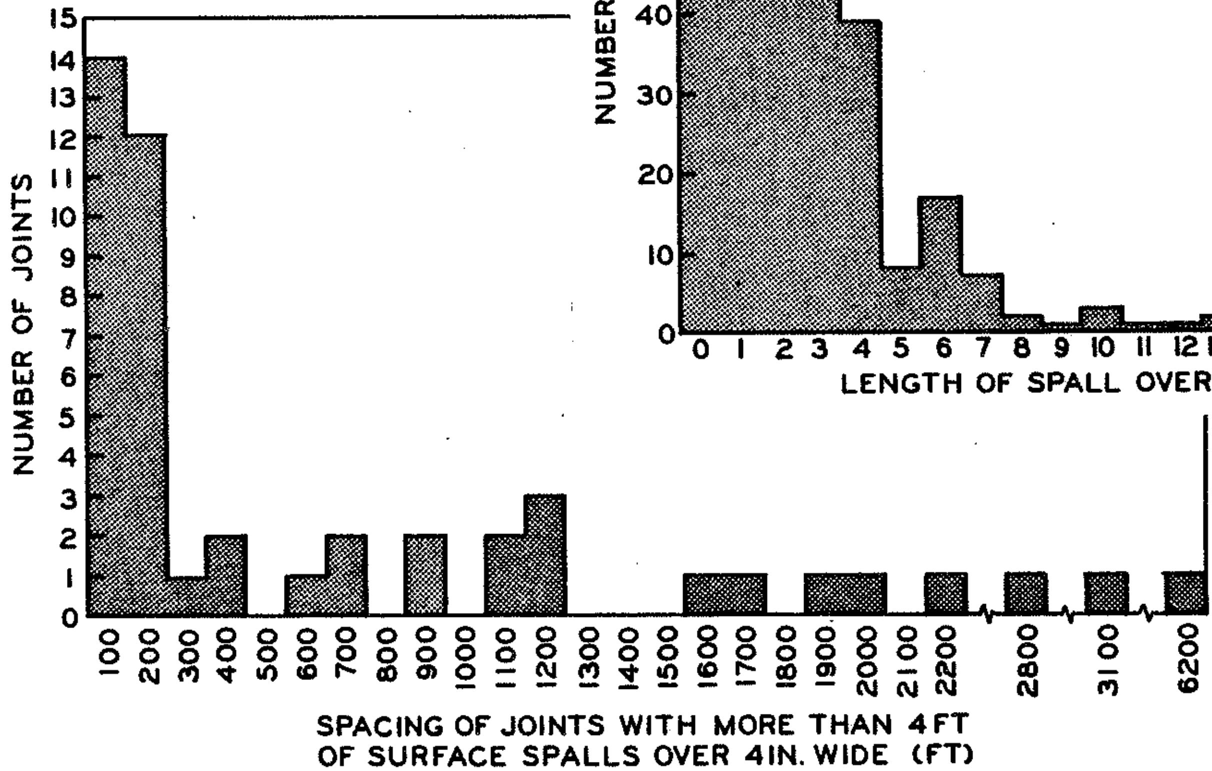


Figure 2. Frequency distribution of spacing of spalled joints.



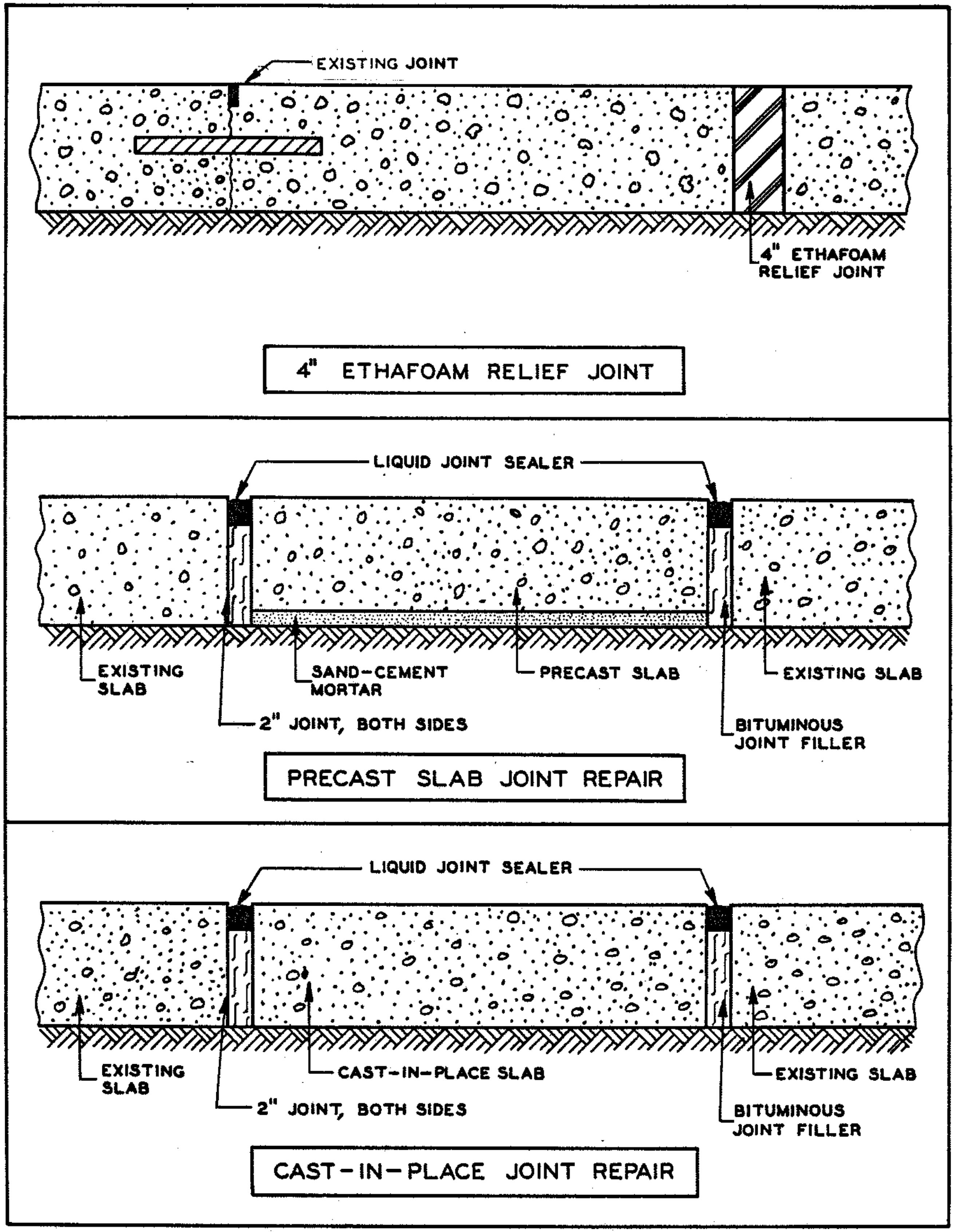


Figure 3. Repair Types

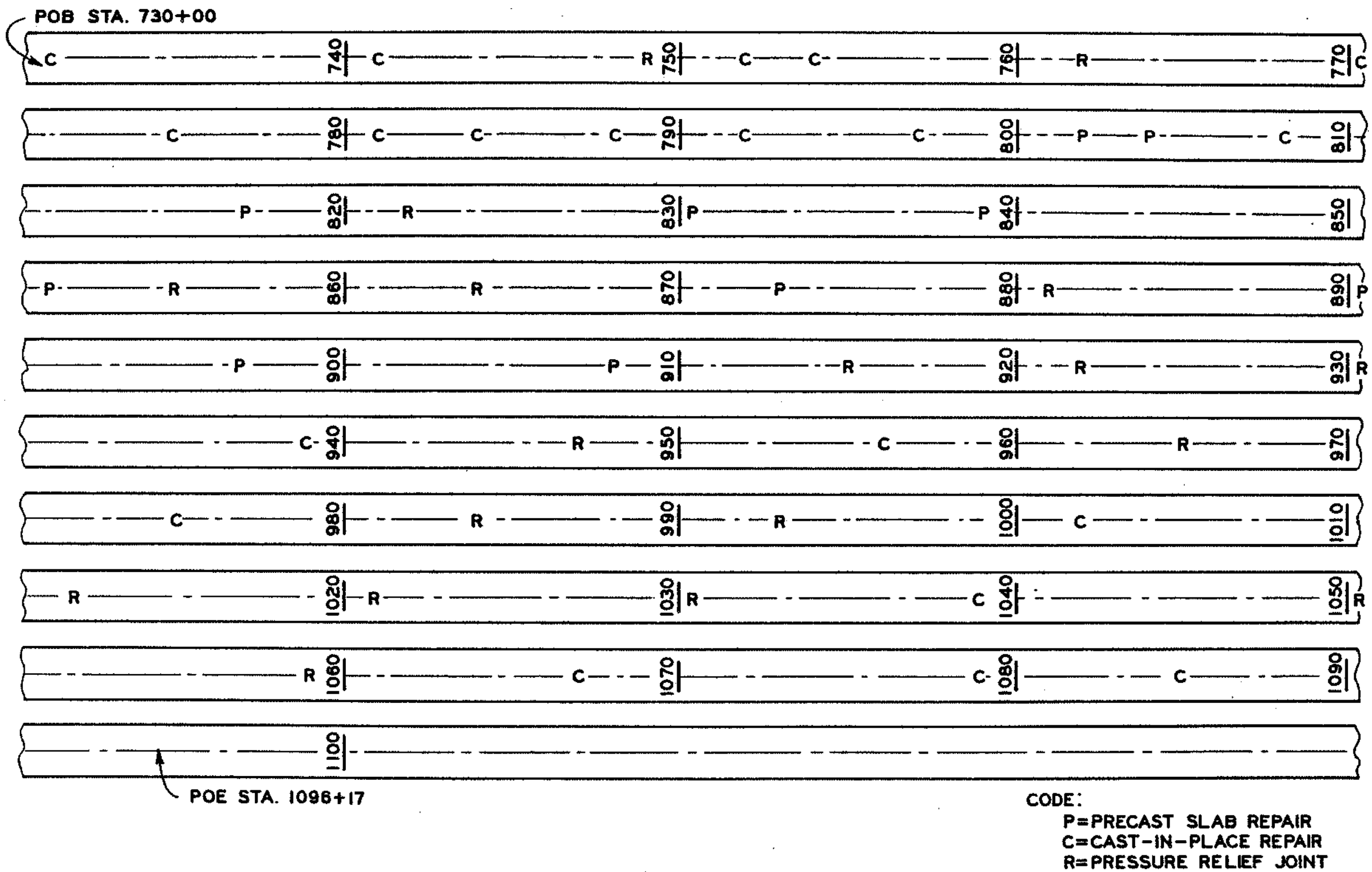


Figure 4. Layout of preventive joint repair pavement section, (southbound roadway).

CONSTRUCTION OPERATIONS

Precast Slab Repairs

The full-depth saw cuts were made in two stages. The first cut was made to a depth of about 5 to 6 in. with an 18-in. diamond blade and the remaining 3 to 4 in. was cut with a 24-in. diamond blade. Because of the severe compressive forces present in the slab during the replacement operation a carbide tipped 7-ft diameter saw (frost cutter) was used to make an initial 4-in. relief cut in the section of slab to be removed. All precast repairs were 6 ft 4 in. long.

The precast slabs were cast 6 ft long to provide 4 in. of total expansion space at each location. They were cast at the contractor's yard at an I 75 project in Oakland County and trucked to this project prior to beginning the installation.

The deteriorated concrete was lifted out by a crane, and the final cleanout was done by the careful use of a small backhoe and hand tools. The mortar was delivered to the site in ready mix concrete trucks. A frame and strike-off were used to obtain correct elevation of the mortar base. The precast slabs were installed by crane and the joints were constructed by inserting a bituminous filler in the gaps and sealing with hot-poured rubber-asphalt.

Cast-In-Place Repairs

Sawing of the repair limits and removing the deteriorated concrete was done in the manner described for precast slabs. The concrete was a 9-sack ready mix with calcium chloride added at the site to accelerate early strength gain.

Of the 20 repairs of this type, 14 were 6 ft long, two were 7 ft, two were 8 ft, one 10 ft, and one 14 ft long. A 2-in. thick by 7-1/2-in. high bituminous filler was placed against each end face of a repair and a 2 by 1-1/2-in. wood strip placed on top of the filler. The concrete was poured, vibrated, and finished in the normal manner for concrete patching. A membrane curing compound was sprayed on the slabs as soon as the concrete had set sufficiently. The groove forming wood strip was carefully removed after the concrete had hardened and the groove was sealed with hot-poured rubber-asphalt.

Relief Joint Installation

The location of the relief joints in all cases was 6 ft from an existing pavement joint. The joints were sawed full depth with a diamond blade. Two cuts, 4 in. apart, were made at each location. The concrete between the cuts was removed by use of air hammers and hand tools. A lubricant adhesive was applied to the joint walls and the filler pushed into the pavement gap. The polyethylene filler was 4 in. wide and 10-1/2 in. high. The filler extending above the pavement was cut off flush with the pavement surface by use of a hand saw.

PERFORMANCE OF PRESSURE RELIEVED PAVEMENT

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. However, the number of years a pressure relieved pavement will remain safe from blow-ups or crumbling joints depend to a large extent on the deterioration rate of the concrete slab. In this case, no concrete repairs were made from 1972 until 1979 when eight joints were replaced with cast-in-place slabs.

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 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 1978 as reported by the Maintenance Division are as follows:

Year	Total Number of Blow-Ups
1973	1,123
1974	805
1975	786
1976	391
1977	397
1978	189

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 that blow-up season. A recent inquiry to the Maintenance Division revealed that records of yearly blow-ups are no longer kept because blow-ups now occur relatively infrequently.

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 5. Note that filler problems at joint Nos. 1, 3, and 17 have impaired their function. The permanent closure of the remaining joints 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.

The length of pavement contributing to the closure of each expansion joint is also shown in Figure 5 (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. For example, a recent survey of the pressure-relieved section showed that there are now 406 open transverse cracks (fractured steel). At each of these cracks incompressible material is free to enter, especially during cold weather when the cracks are open more.

The effect on contraction joints from installing pressure relief was investigated four years after the pavement was decompressed. At 10 locations where the slabs were free of transverse cracks with fractured steel, the groove width of the first, second, and third contraction joint away from a relief joint was measured at a temperature of 45 F. The average groove width was 1.14, 1.04, and 0.88 in., for the first, second, and third joint, respectively. To minimize the permanent opening of adjacent contraction joints and transverse cracks, one could reseal the joints and attempt to seal the cracks.

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

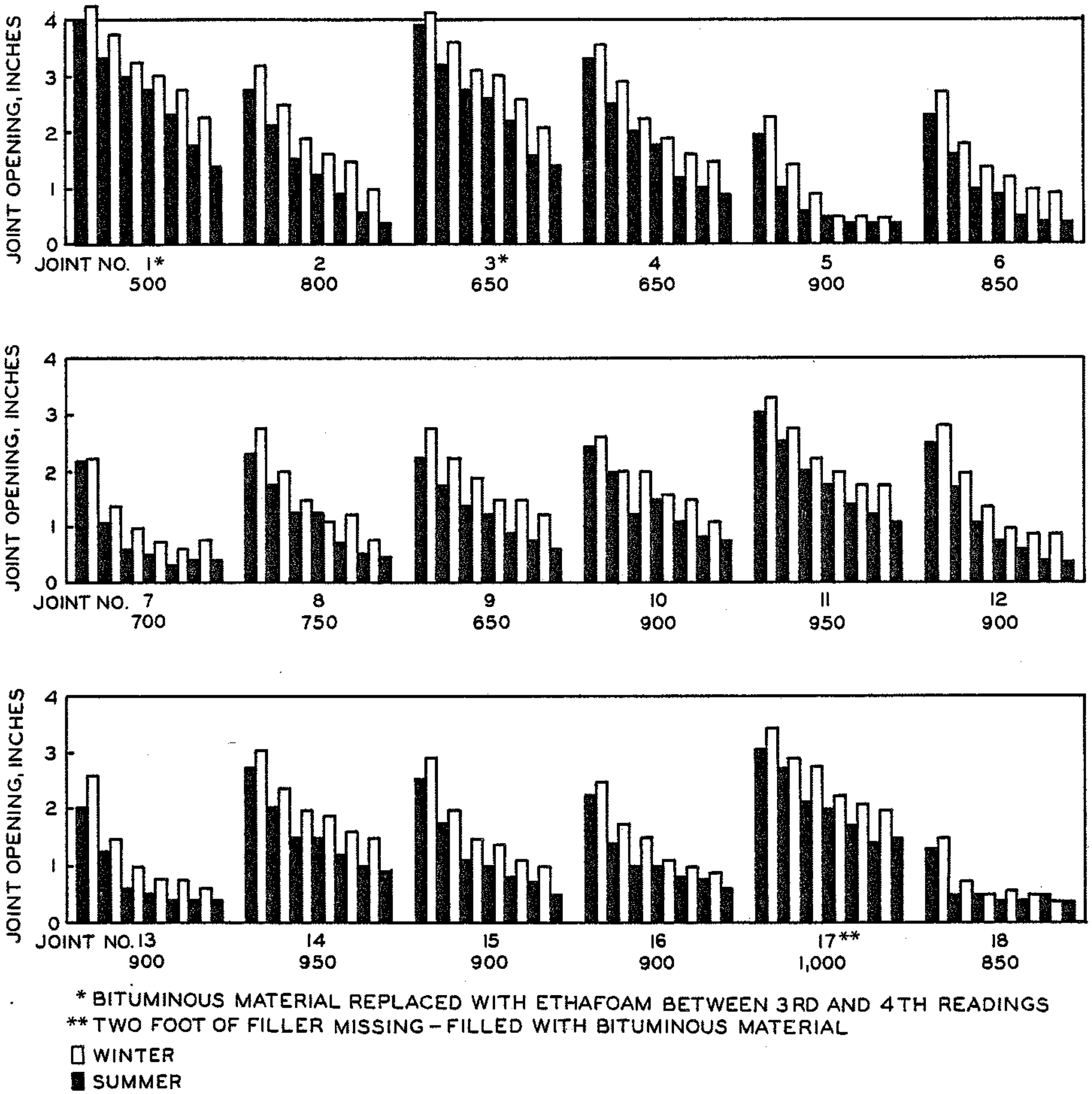


Figure 5. Summer-winter openings of relief joints from 1973 through 1979. (Numbers below each joint indicate pavement length contributing to the joint closure.)

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. On the basis of 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 pavement.

Measurements of the faulting at relief joints, at repair joints, and at cracks with fractured steel were made seven years after the pavement was pressure-relieved. Frequency distribution of the amount of faulting is shown in Figure 6. The largest average faulting (3/8 in.) was recorded at the trailing joint of repairs. This is three times as great as the average faulting at the leading joint. The average faulting at relief joints was 1/4 in. and at cracks with fractured steel it was 3/16 in. The largest fault measurement was 11/16 in. which was recorded at a cast-in-place repair. The faulting measurements indicate that, in time, pressure relieving a pavement increases the pavement roughness. To prevent this, dowelled or tied joints would be required.

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.

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 was nearly the same on both roadways (3.4 ft on the test section compared to 3.5 ft on the control section). The 1979 survey shows an average of 6.1 ft of joint spall on the control section compared to 5.0 ft on the joints on the test section after eight joints were replaced.

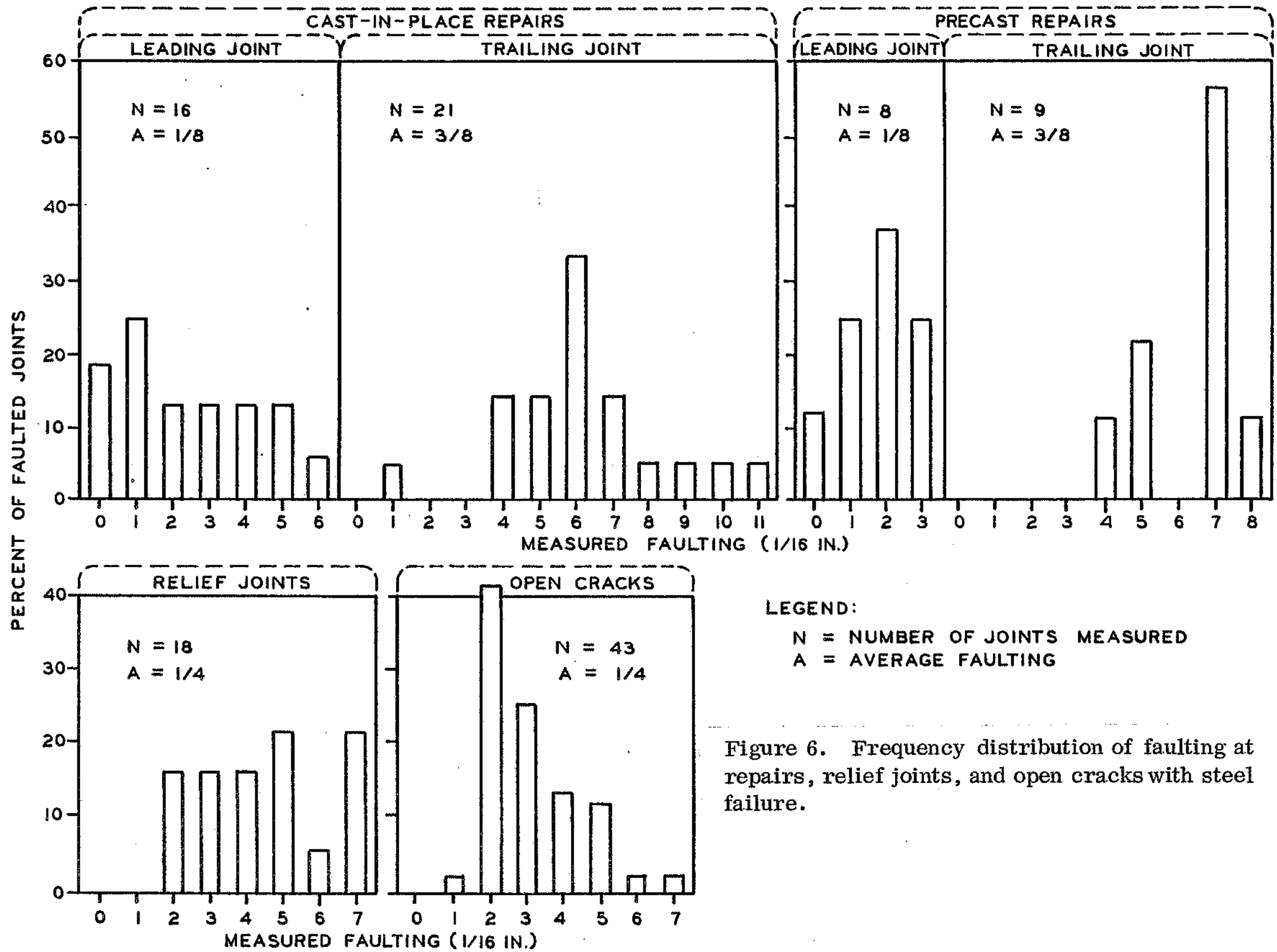


Figure 6. Frequency distribution of faulting at repairs, relief joints, and open cracks with steel failure.

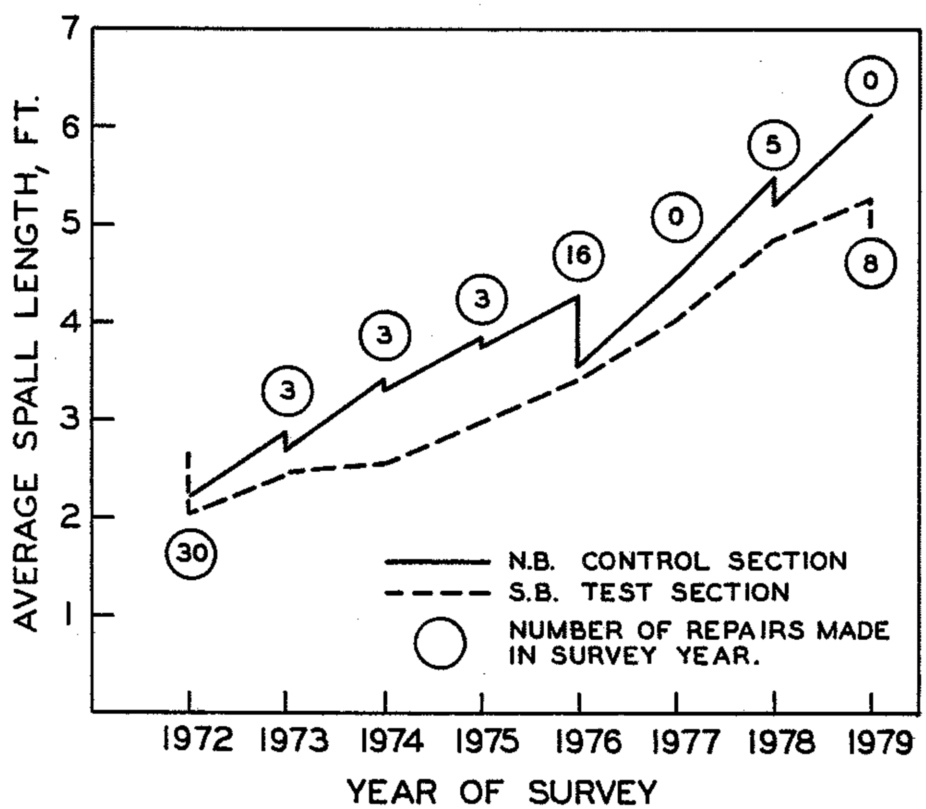


Figure 7. Average joint spall length before and after repair for each year since study began.

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.

Reliability of Procedure Used to Select Relief Locations

The procedure used to determine the pressure relief locations on the southbound roadway consisted of first selecting all joints with more than 9 ft of deterioration for replacement, then the pavement between these replacements was divided into sections not exceeding 1,200 ft and a relief joint specified except in cases where a joint within 200 ft either side of the section limit had 4 to 9 ft of deterioration, then a joint replacement was specified.

To check the accuracy of this procedure, the amount of deterioration on each joint on the control northbound roadway was determined in 1972 and yearly records of joint failures (repairs) on the northbound roadway were kept. Thus, the amount of deterioration in 1972 on the repaired joints would be known and could be compared to the deterioration on the joints selected for replacement on the southbound roadway.

By the end of 1979, 30 joints on the northbound roadway had been repaired by Maintenance personnel. In 1972, 18 joints had over 9 ft of spall. Of these, 14 joints or 78 percent have now been replaced with a repair. Eleven of the repaired joints had between 4 and 9 ft of spall in 1972. The remaining five joints had less than 4 ft of spall when repaired. This would indicate that the joints on the southbound roadway were selected with an 83 percent accuracy.

The spacing at which failures have occurred on the northbound roadway is quite similar to that of the selected repairs and relief joints on the southbound roadway. These spacings range from 200 to 1,400 ft. There are still four sections, however, each approximately 1/2 mile long which contain no repairs.

On the basis of the amount of deterioration on the joints that failed and were repaired on the northbound roadway, and the spacing at which the failures occurred, the procedure used to select joints for repair and to select pressure relief joint locations was reasonably satisfactory.

CONCLUSIONS

The use of pressure relief, either by installing expansion joints at repairs or 4-in. wide relief joints at a spacing of 1,200 ft or less, on the southbound roadway prevented blow-ups from occurring for a six-year period. Infiltration of incompressibles into contraction joints and cracks with fractured steel apparently caused most of the expansion space to be used. Spalling of the joints on the pressure relieved pavement continued to increase at nearly the same rate as on the non-relieved northbound pavement. Faulting of the repair joints averaged 3/8 in. after seven years service with 11/16 in. being the maximum recorded. At relief joints, the faulting averaged 1/4 in. which was 1/16 in. less than the average measured at cracks with steel fracture.

The procedure used to select deteriorated joints for replacement was found to be 83 percent accurate in comparison to the joint failures that occurred on the northbound control pavement.