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PREVENTIVE MAINTENANCE OF CONCRETE PAVEMENTS



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PREVENTIVE MAINTENANCE OF CONCRETE PAVEMENTS

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Research Laboratory Section  
Testing and Research Division  
Research Project 72 F-123  
Research Report No. R-859

Michigan State Highway Commission  
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Vice-Chairman, Claude J. Tobin, Peter B. Fletcher  
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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 was prepared by the Research Laboratory and approved by the Committee at its February 2, 1972 meeting. The construction phase of the project has been completed and is covered in this report.

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 material; 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 jams. 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 uncertainty involved in the procedure for grouting deteriorated joints, this type of repair method was investigated under a separate project. Because of the results of this project, objective 3) was dropped from this study. 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.

Figure 1. Frequency distribution of spalled joints.

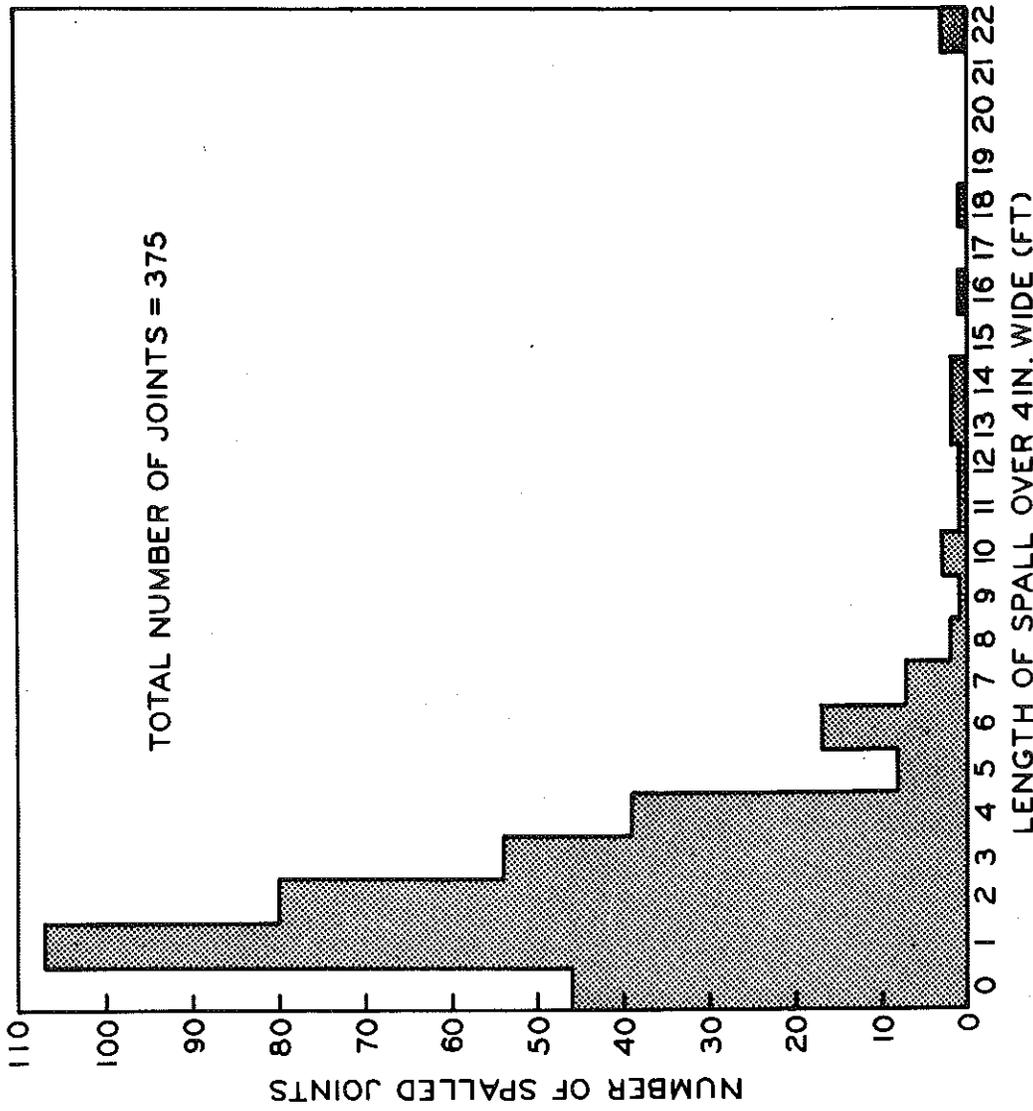
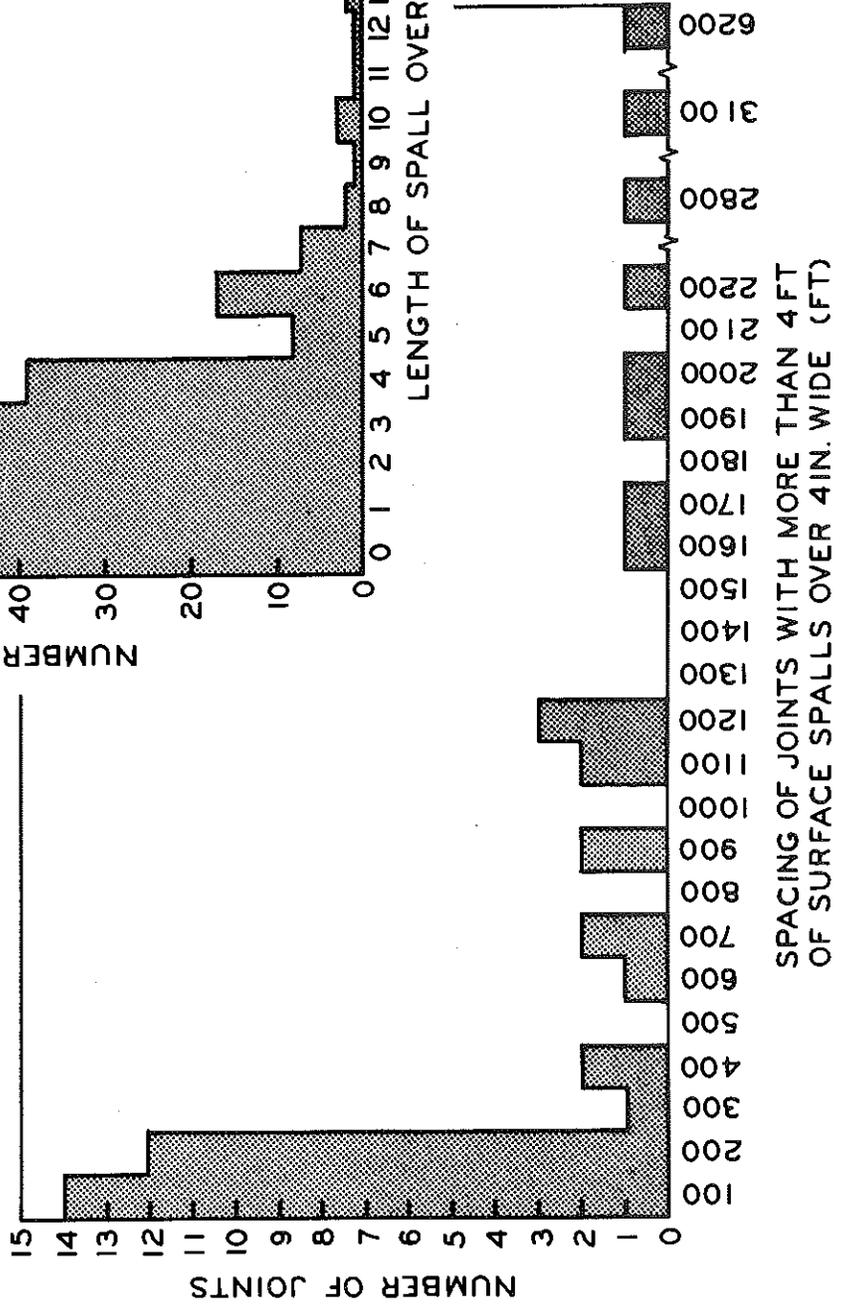


Figure 2. Frequency distribution of spacing of spalled joints.



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 Design Division in cooperation with the Maintenance and Testing and Research Divisions. The contract (covering the replacement of 10 joints with precast slabs, 18 joints to be replaced with cast-in-place concrete, and the installation of 19 relief joints) was awarded to the low bidder, Sargent Construction Company, on May 17, 1972.

### 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 time period. 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.

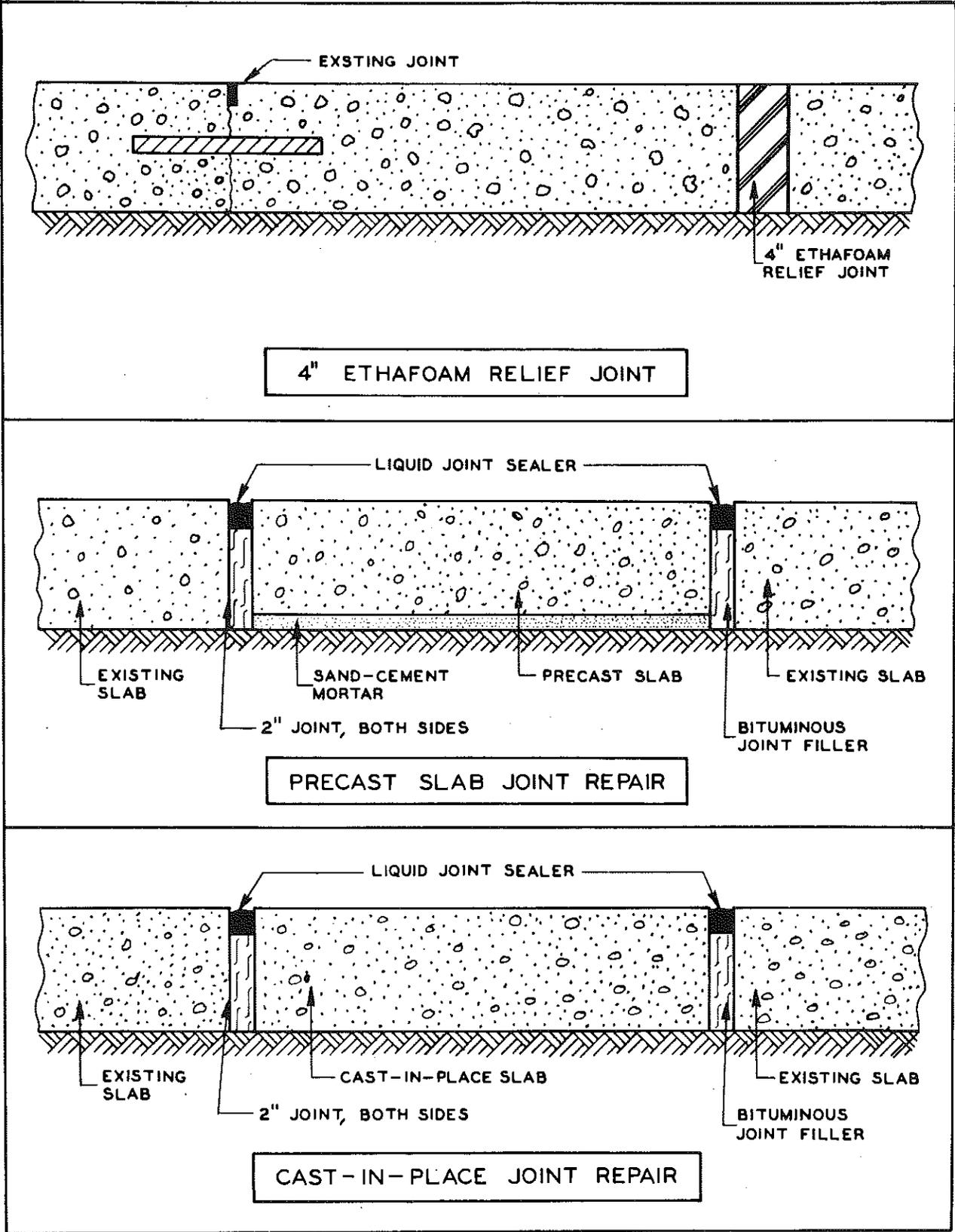


Figure 3. Repair Types

On the basis of the survey data it was decided that best results in preventing emergency repairs could be obtained by providing pressure relief in the pavement at a spacing consistent with the pavement condition. Pressure relief was provided by replacing badly spalled joints with either precast slabs or cast-in-place repairs. In areas where the pavement was in relatively good condition 4-in. wide relief joints were utilized. At all locations a total of 4 in. of expansion filler was provided.

The three types of preventive repairs are shown in Figure 3, and the layout of the repairs on the southbound roadway is shown in Figure 4. 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 a badly deteriorated joint, while the relief joint was installed 6 ft from an existing joint.

#### Construction Operations

Precast Slab Repairs - The contractor, Sargent Construction Co., subcontract the precast slab repairs to Titus Construction Co. The full-depth sawing operation was begun July 31. The 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 severe compressive forces in the slab a Vermeer saw was used to make a relief cut in the patch 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 the 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 clean-out 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 bituminous filler in the gaps and sealing with hot-poured rubber-asphalt. The 20 lane slabs were installed in two days.

Cast-In-Place Repairs - Sawing of the repair limits began September 4, 1972, and was carried on intermittently until completed. As in the case of the precast slab repairs, a Vermeer saw was used to make relief cuts in the repair area, and the deteriorated concrete was removed in the manner described for precast slabs.

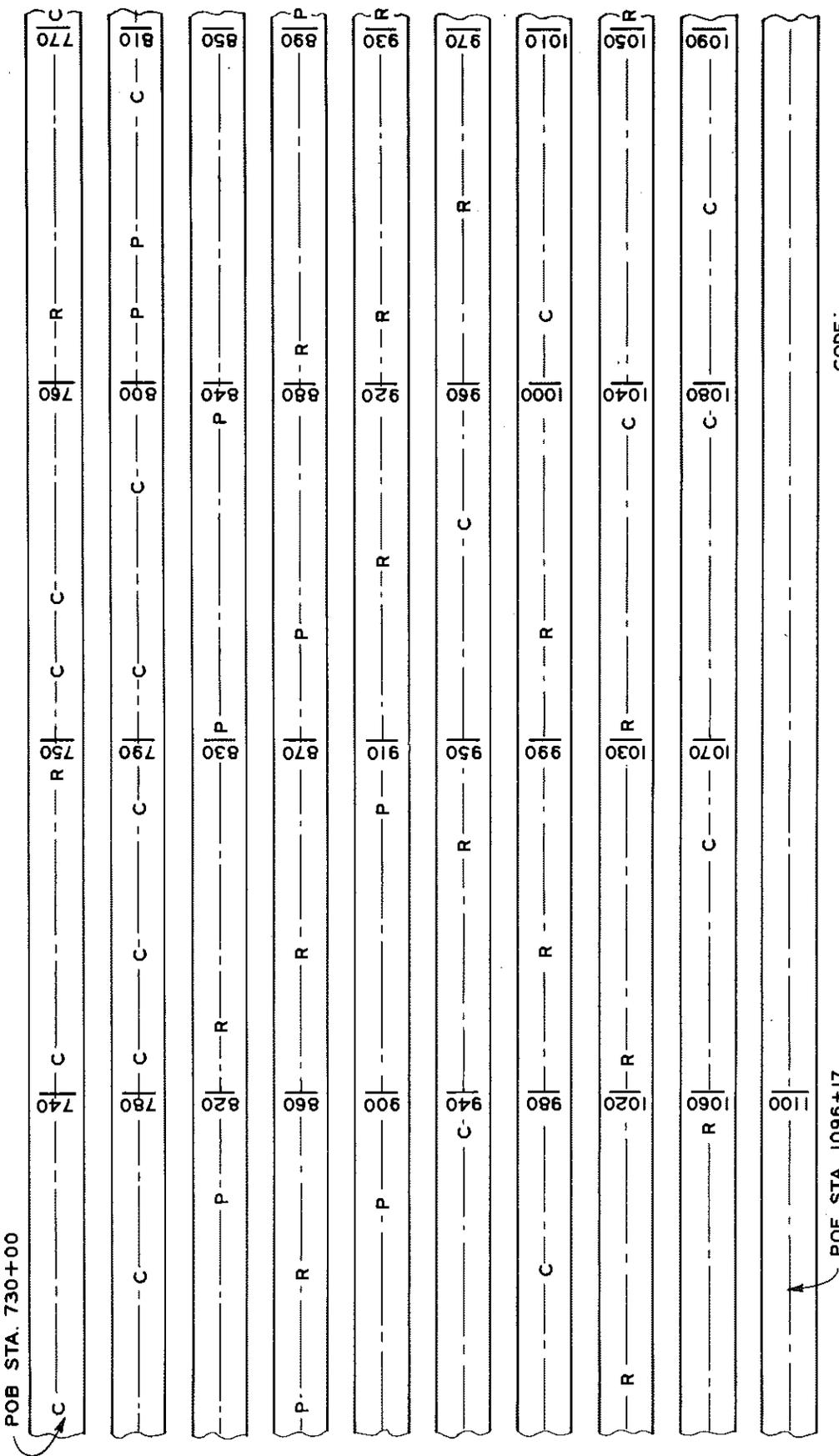


Figure 4. Layout of preventive joint repair pavement section, (southbound roadway).

The concrete was a 9-sack ready mix and calcium chloride was added at the site. The prescribed addition rate was as follows:

| <u>Air Temperature, F</u> | <u>CaCl<sub>2</sub> per cu yd of mix, lb</u> |
|---------------------------|--|
| Less than 45              | 36   |
| 45 to 65                  | 27   |
| above 65                  | 18   |

The CaCl<sub>2</sub> was added to the mix in dry form just before use and the mix was given about 20 revolutions at mixing speed. Sixteen pours were made in the 45 to 65 F range and three pours were made at temperatures above 65 F.

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 about 1/2 hr after the concrete was poured.

The initial set of the 9 sack concrete mix took place about 20 min. after addition of the CaCl<sub>2</sub>. By careful scheduling of the pouring operations and personnel assignment the contractor was able to have the concrete delivered in sufficient quantity to pour two repairs from each load. The pouring operation began September 27, 1972 and was completed October 24, 1972. The contractor began concrete removal operations in the early morning in order to have as much time as possible before pouring operations were suspended at 1 p.m. as specified. The 1 p.m. cut-off point for concrete placement was specified to allow 7 hr of daylight curing time. No lane closure at night was allowed.

The flexural strength of the concrete was specified at 300 psi before the repairs could be opened to traffic. In all cases the required strength was obtained 7 hr after pour and in only two cases was it below 300 psi at 6 hr after pour. The average flexural strength of 19 beam tests conducted 4, 5, 6, and 7 hr after pour was 270, 290, 340, and 350 psi, respectively. The test beams were sprayed with curing compound and left at the site until tested. The tests were done with a portable beam breaker.

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 (Dow Chemical Co. Ethafoam) 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.

Photographs of all construction operations are shown in the Appendix.

### Costs

The unit bid prices were as follows:

|                       |                    |
|-----------------------|--------------------|
| Precast Slab Repairs  | \$59.00 per sq yd  |
| Cast-in-Place Repairs | \$43.00 per sq yd  |
| Relief Joints         | \$15.00 per lin ft |

The lump sum bid for maintaining traffic was \$10,500.00.

### Evaluation

The test section and control section will be surveyed yearly to determine the lineal length of deterioration on each joint. The location and number of joint failures on each section will also be recorded. From these data it will be determined whether joint surface deterioration can be used to predict joint failures.

The number of emergency repairs required each year in each section will be recorded. Thus, a comparison of the number of failures occurring in each section requiring emergency repair should reveal if the provided pressure relief in the experimental section will significantly reduce pavement maintenance.

In addition, the cost of maintaining the pavement on each section will be recorded to obtain information on the net worth of this type of pavement maintenance.

### Discussion

The following discussion is based on the construction phase of this project and on concrete pavement behavior in general. It is presented here for consideration in the design of either preventive maintenance projects or routine maintenance contracts.

1) Some of the ethafoam filler installed in the relief joints came out during the past winter, because the joints did not close sufficiently before the onset of cold weather. It is felt this problem can be eliminated by restricting the use of 4-in. wide relief joints to jobs completed before September. From September through April a relief joint width of 3-1/2 in. could be used. The 3-1/2-in. width may require an installation tool to insert the 4-in. filler in the 3-1/2 in. groove.

2) Unfortunately the cost of repairs alone cannot be used to determine the type of repair for maintaining a concrete pavement. The length of time a lane or lanes may be closed is a vital factor in the selection of a suitable repair type. Basically, there are two types of repair available for concrete pavement maintenance: precast slab repairs, and fast setting cast-in-place repairs. The precast slab repairs are for locations where the closure time is limited to 4 to 8 hr, and the cast-in-place repairs are suitable for lane closure times of 8 to 24 hr.

3) One way of reducing the cost of concrete pavement maintenance may possibly be through the use of pressure relief joints. At this time the cost of a minimum size lane repair (6 by 12 ft) is about \$500, whereas a relief joint costs about \$240 per 12-ft lane. Thus, for about the same amount of money, twice as long a section of pavement can be pressure-relieved by using expansion joints rather than repairs. However, if only expansion relief joints were used, the pavement would need to be in the 7 to 10 year age group, and exhibit none or only minimal surface deterioration at the joints. It would seem logical to begin preventive maintenance when it will do the most good for the least cost.

4) Although the surface condition of the joints appears to be related to the probability of joint failures, this project demonstrated that considerable judgement is required to determine which joints need to be replaced. It appears that the best preventive maintenance system of a concrete pavement should provide pressure relief in the full length of the pavement. This approach was followed in determining the location of repairs and relief joints on this project. Of course, by doing preventive maintenance before surface defects of the joints are visible, the selection of relief locations would be simplified.

APPENDIX

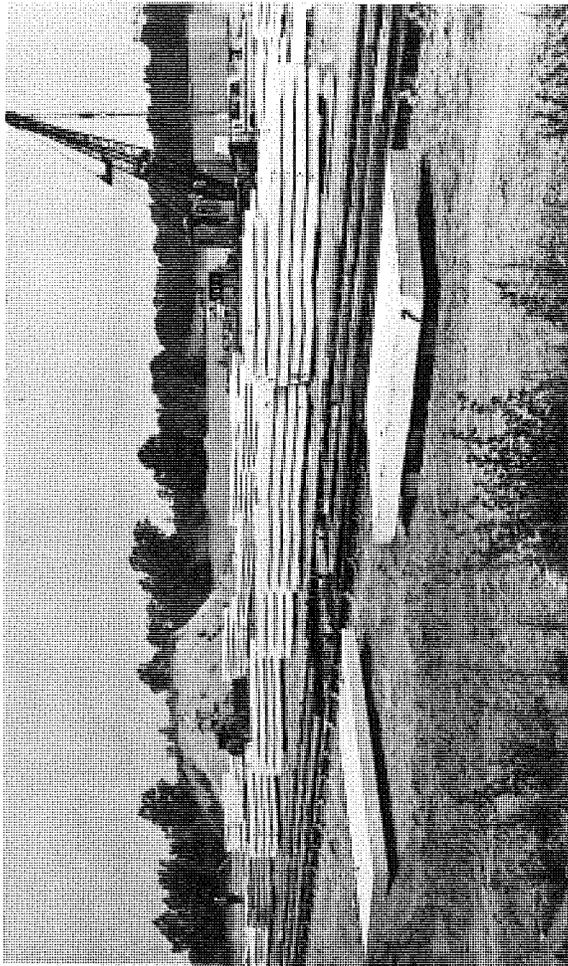


Figure 1. The slabs were cast at the contractor's yard on an I 75 job and transported to this project.

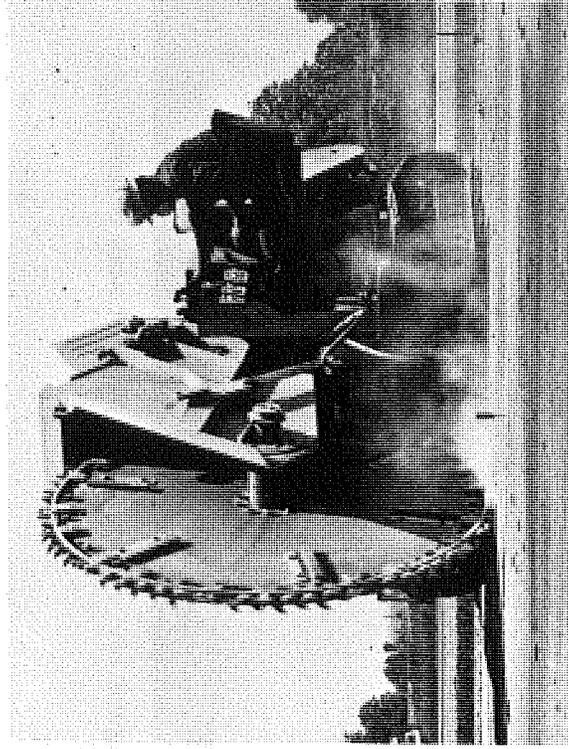


Figure 2. A Vermeer saw was used to make a relief cut in the area to be removed.

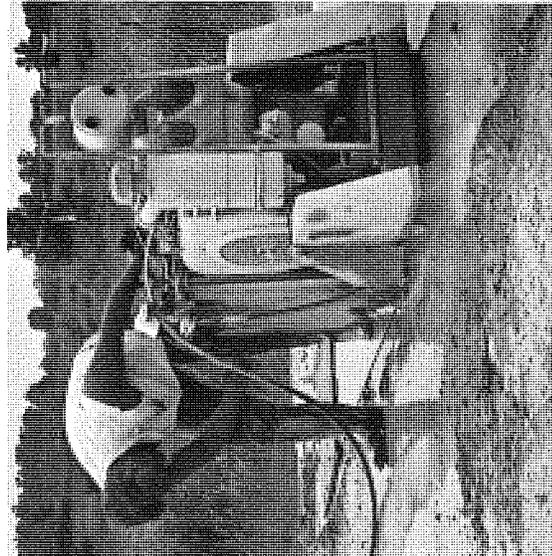


Figure 3. The repair limits were sawed full depth with a diamond blade saw.

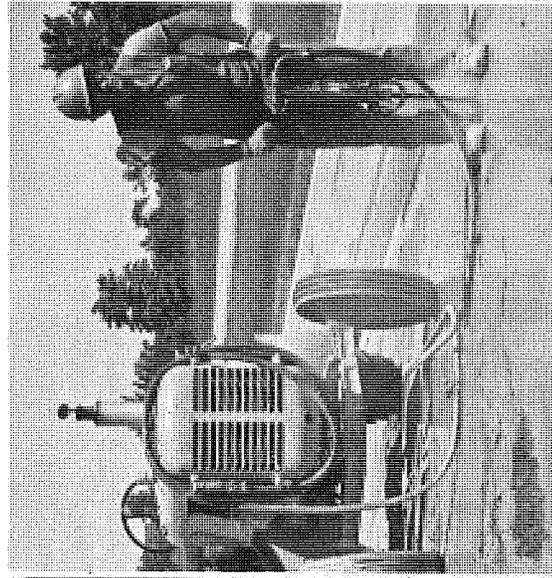


Figure 4. Holes were drilled through the slab for inserting lift pins.

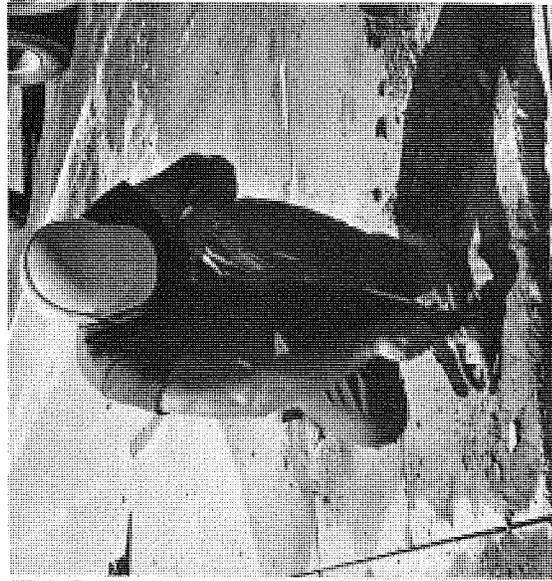


Figure 5. The lift pins were inserted in the holes.

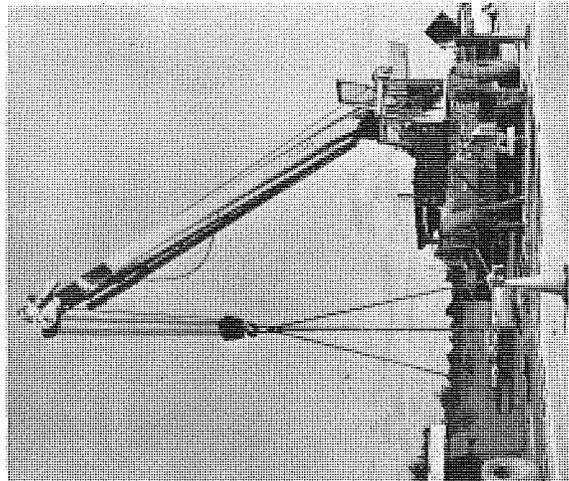


Figure 6. The deteriorated joint area was lifted out.

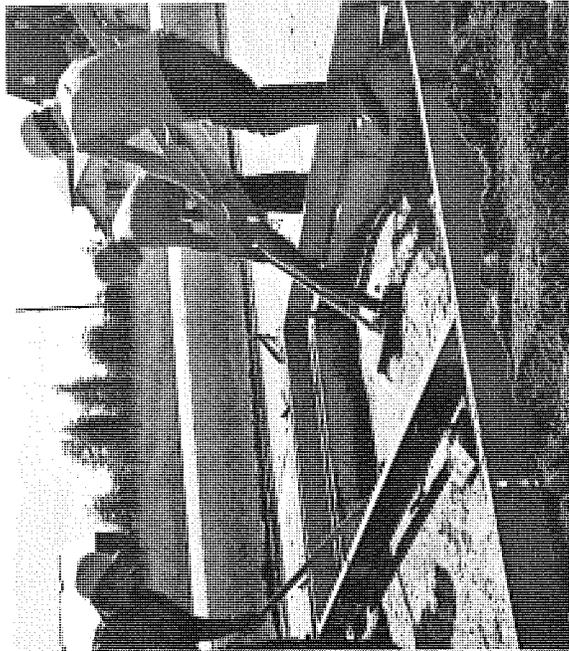


Figure 7. Mortar was poured and struck-off to the correct elevation by use of a frame and strike-off guide.

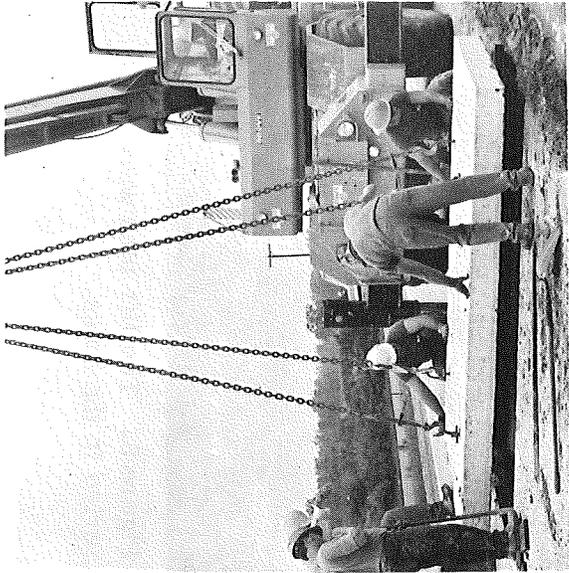


Figure 8. The precast slab is installed.

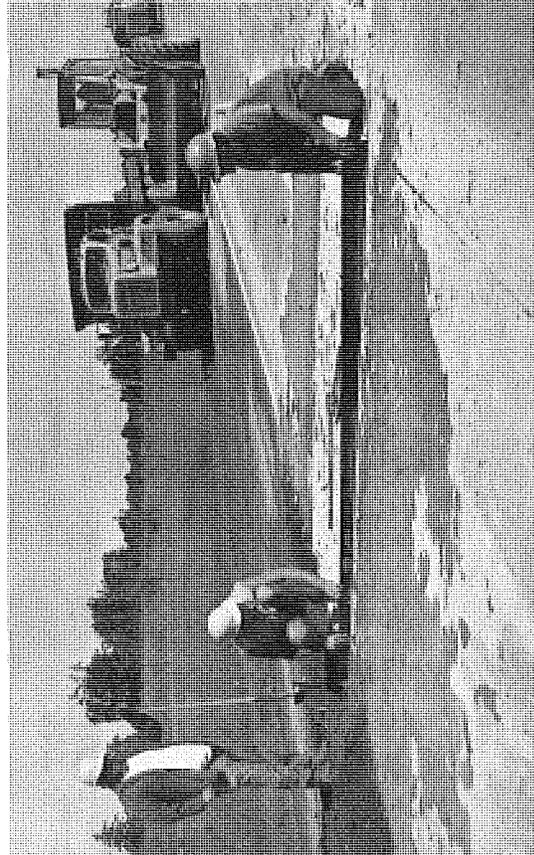


Figure 9. The bituminous filler is installed in the joint and, once in place, the joint is sealed.

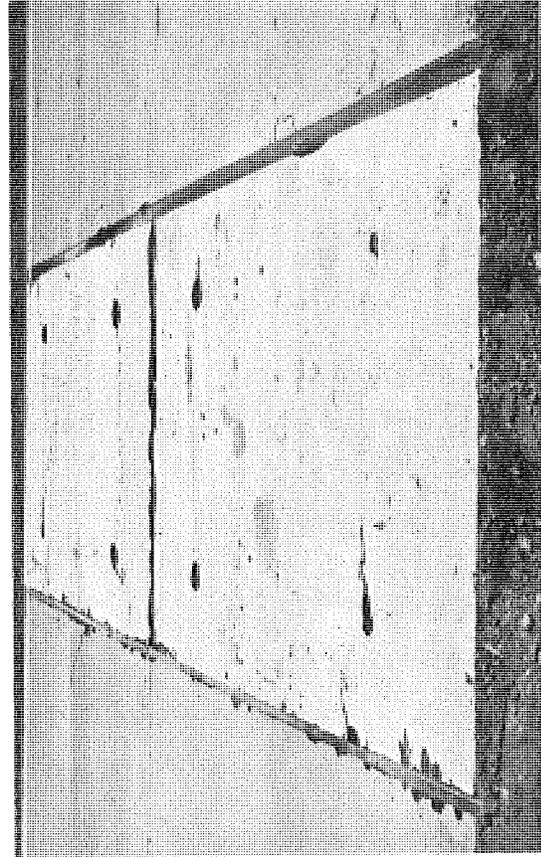


Figure 10. A completed precast slab repair.

126 174  
3 97 5



Figure 11. The sawing and removalal operations were the same as for precast slabs. Here the filler has been placed and the wood forming strip is being oiled.

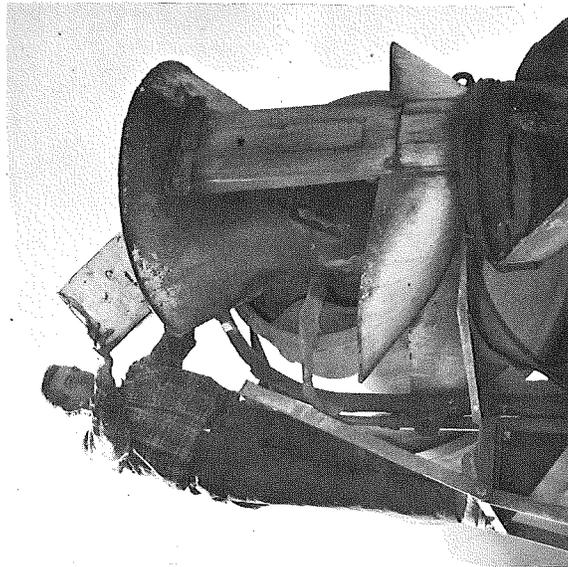


Figure 12. The  $\text{CaCl}_2$  was added to the mixer at the site just prior to pouring.

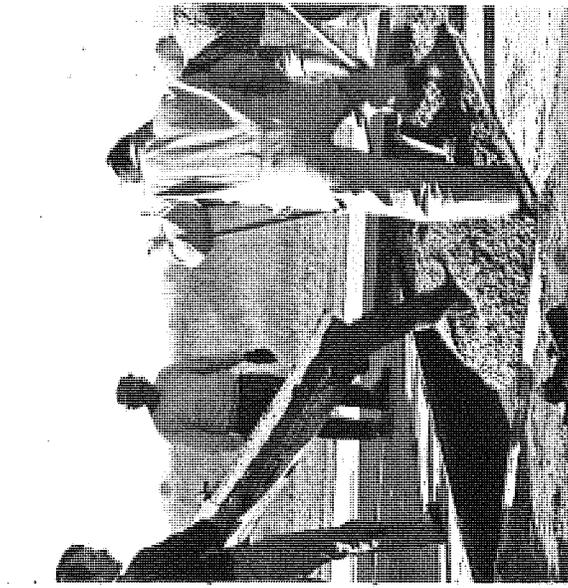


Figure 13. The concrete is poured into the prepared area.

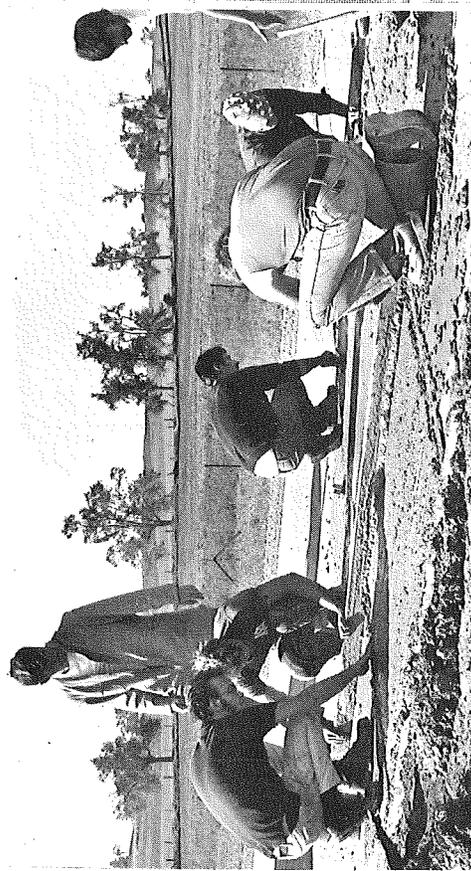


Figure 14. The concrete is struck-off to height of existing slab.



Figure 15. The concrete was finished with hand trowels.

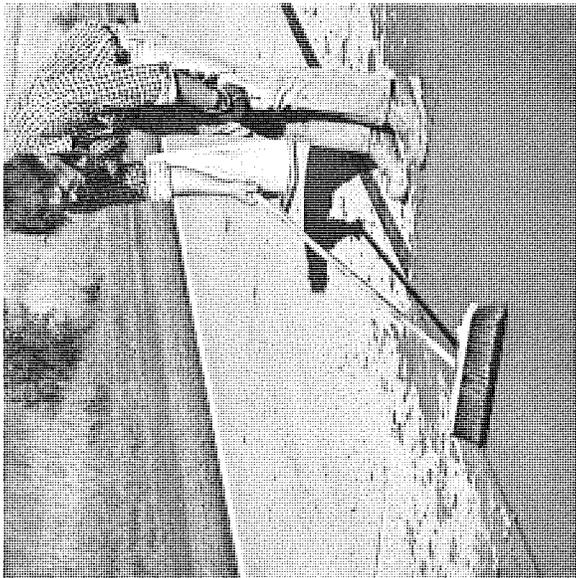


Figure 16. The concrete was broomed to obtain a rough surface.



Figure 17. An edging trowel was used along the wood strip.

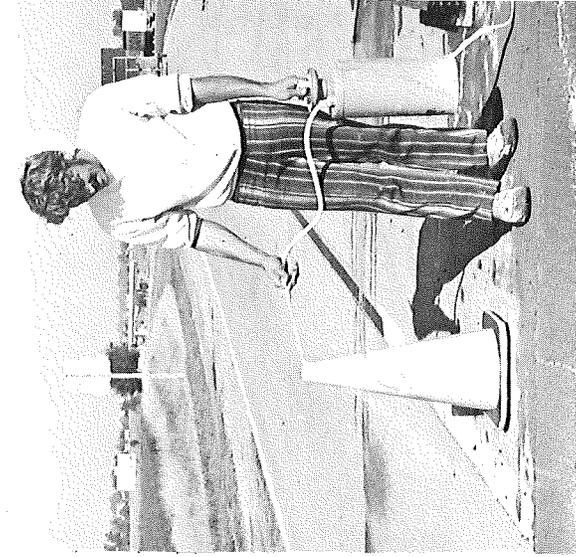


Figure 18. The slabs were cured with a membrane curing compound.

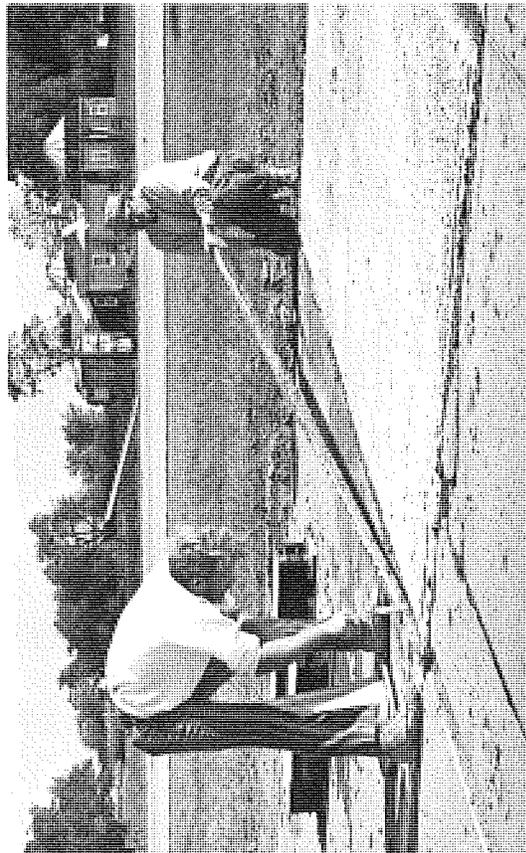


Figure 19. The wood forming strip was removed 15 to 30 min. after the repair was finished.



Figure 20. A completed cast-in-place repair.

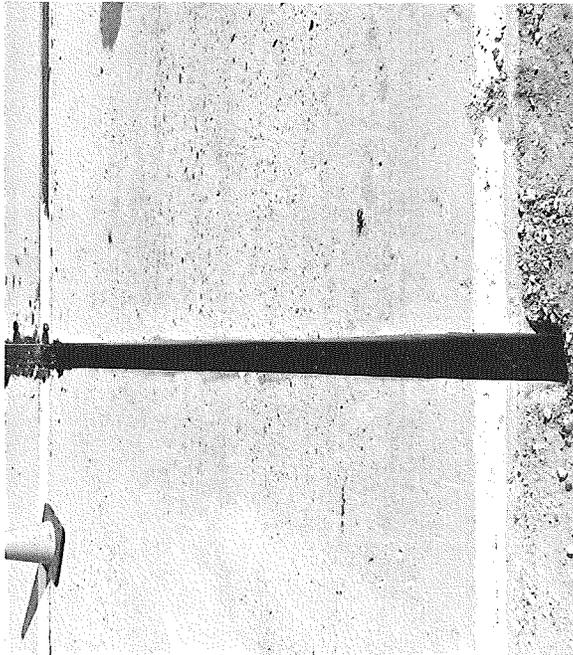


Figure 21. Full-depth diamond blade cuts were made 4 in. apart and the concrete removed to form a joint.

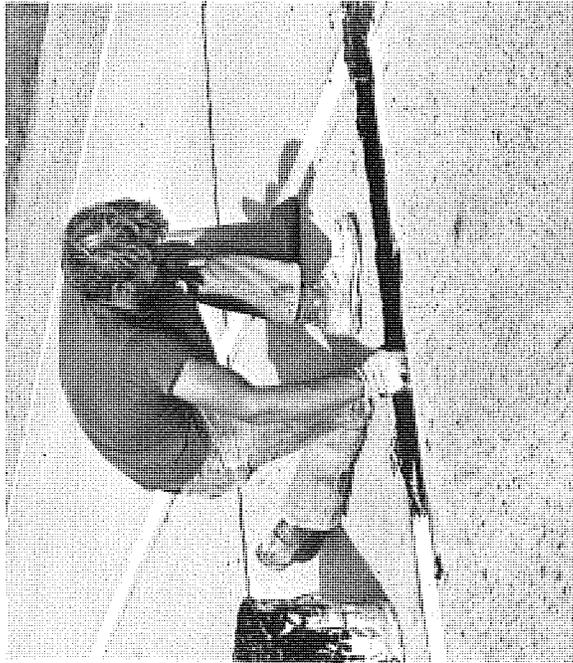


Figure 22. The joint walls were coated with a lubricant adhesive.



Figure 23. The filler was inserted into the joint.



Figure 24. Excess joint filler was sawed off flush with the pavement surface.

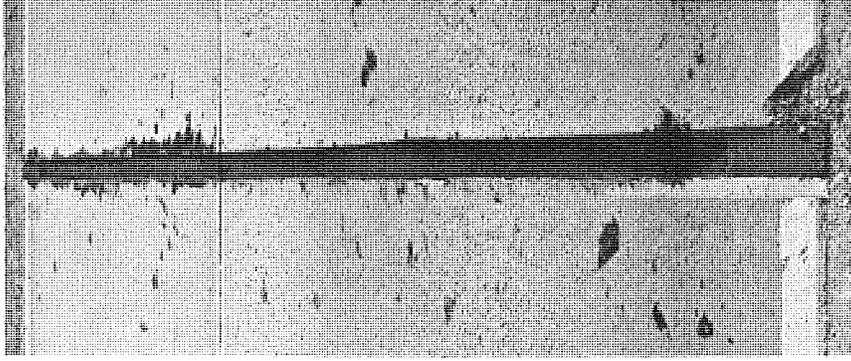


Figure 25. A completed relief joint installation.