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16. Abstract

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A majority of all joints contained debris, but distress was found to occur at the fixed joints more than ten times as frequently as at the expansion joints.

The high-pressure water-jet technique for cleaning joints appears to be more thorough in removing debris from the wider expansion joints than from the narrow fixed joints. Accordingly, alternative corrective measures applicable to the fixed joints in existing bridges are being considered.

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A SURVEY OF DISTRESS AND DEBRIS IN THE JOINTS OF PAN-FORMED CONCRETE BRIDGES

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Research Report No. 12-1

Improved Methods for Cleaning Joints
In Concrete Bridge Decks

Research Study 2-18-73-12

Sponsored by

The Texas Highway Department
In Cooperation with the
U. S. Department of Transportation
Federal Highway Administration

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TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

Preface

This is the first formal report issued under Research Study 2-18-73-12, "Improved Methods for Cleaning Joints in Concrete Bridge Decks."

The research was conducted at the Texas Transportation Institute as part of the cooperative research program with the Texas Highway Department and the United States Department of Transportation, Federal Highway Administration.

The authors wish to acknowledge their gratitude to all members of the staff of the Texas Transportation Institute who contributed to this research. Special thanks are expressed to Mr. C. E. Schlieker for his assistance in making the field surveys.

The support given by the Texas Highway Department personnel is also greatly appreciated, especially the advice and assistance provided by Mr. Don McGowan and Mr. Ralph Banks of D-18, Maintenance Operations Division, and the help in connection with the field survey provided by Mr. W. J. Byford, District 17 Maintenance Engineer.

The contents of this report reflect the views of the authors who are 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 or the Texas Highway Department. This report does not constitute a standard, specification, or regulation.

Abstract

Seventy-three pan-formed bridges, principally located within Texas Highway Department District 17, were surveyed to determine the prevalence of debris in the joints between adjacent spans and to detect visible manifestations of distress associated with the accumulation of this debris.

A majority of all joints contained debris, but distress was found to occur at the fixed joints more than ten times as frequently as at the expansion joints.

The high-pressure water-jet technique for cleaning joints appears to be more thorough in removing debris from the wider expansion joints than from the narrow fixed joints. Accordingly, alternative corrective measures applicable to the fixed joints in existing bridges are being considered.

KEY WORDS: Pan-formed bridges, Fixed joints, Debris, Joint-cleaning.

Summary

Damage and distress in multi-span, pan-formed bridges, attributable to the accumulation of debris in the joints, were found to occur principally at the fixed joints, which are joints formed by two adjoining spans both doweled to the same pier cap. Remedial measures to minimize further distress in existing structures, including a high-pressure water-jet cleaning technique, are continuing to be investigated.

Implementation Statement

The survey conducted in this study has revealed that damage and distress in multi-span, pan-formed bridges occur predominantly at the support where relative longitudinal movement between the beam and the pier cap is prevented, i.e., where two spans are doweled to one pier cap, thus forming a "fixed joint." Remedial measures for minimizing further distress are currently under investigation in this study. These measures have not yet progressed to the state of full implementation.

Table of Contents

List of Figures

List of Tables

1. Introduction

Deterioration of concrete at expansion joints in pavements and bridge decks frequently occurs when damaging pressure is developed in the adjacent concrete by expansion of the slabs in excess of the compressibility of the material in the joint. In cold weather, when slab contractions open joints, absent or inadequate seals allow entry of incompressible debris into the joints. With repeated expansion and contraction, these joints accumulate so much debris that damaging pressures finally develop.

This study, "Improved Methods for Cleaning Joints in Concrete Bridge Decks," was initiated because highway maintenance personnel have a need for a practical and effective technique for removing accumulated debris from existing joints. Such an improved technique was thought to be particularly needed for the maintenance of pan-formed bridges which have very deep and narrow joints.

This is an interim report which describes the results from a survey of seventy-three pan-formed bridges which was made to locate bridge expansion joints in need of cleaning. Such joints were sought in order to apply the techniques being developed in the course of this study. At the time it was made, this survey was not considered to be a major portion of the research effort; it was merely an effort to locate, for experimentation, suitable bridges convenient to the research headquarters. However, the findings of the survey are believed to be significant enough to justify this report. In fact, the authors believe that the findings point out a major problem facing the Texas Highway Department in the maintenance of pan-formed bridges.

2. Survey Results

Seventy-three multiple-span, pan-formed bridges were examined to locate expansion joints suitable for cleaning experimentation. All but two of the bridges were located in the Texas Highway Department Bryan District. The two exceptions were located in the adjacent Houston District. In addition to noting the amount of debris in joints, associated distress was noted for evaluating priority in the need for cleaning. Also, other facts pertinent to joint cleaning were recorded, such as the depth from the deck surface to the top of the pier cap and the width of the joint at the deck surface as well as at the pier cap. Typical bridge joint survey data sheets are contained in Appendix A.

Of the 382 joints between adjacent spans which were investigated, 302 were found to have accumulated appreciable amounts of debris due to the absence of any joint seal or because of deterioration of the sealing material. Table I shows the distribution of the debris with respect to the type of joint.

TABLE I: Debris Versus Type of Joint

	Number Without Debris	Number With Debris	Total Number	% With Debris
Fixed Joints	12	147	159	98.8
Expansion Joints	68	155	223	69.5
Total	80	302	382	79.0

It appears that the absence of seals at the fixed joints favors accumulation of debris there. Typically, the fixed joints are open about

1/4 inch wide at the top and closed at the bottom. The wedge shaped cavity thus formed provides a space for the debris to accumulate. See Figure 1.

The expansion joints were found, typically, to be about 3/4 inch wide and to contain a fiberboard filler beneath an asphaltic seal, as shown in Figure 2. In most cases, as seen in Figure 3, these seals had failed to prevent entry of debris. The high-pressure water-jet technique, which is under investigation in this study, appears well adapted to removal of debris, filler and deteriorated seal material from these expansion joints. For the narrower, tapered fixed joints, however, it appears that only the near-surface debris can be removed by this technique.

Indications of serious distress, such as cracked diaphragms or cracked pier caps, as shown in Figure 4, were seen in 26 of the 73 structures. Table II shows the distribution of the damage with respect to the type of joint at which it was observed to occur.

TABLE II: Distress Versus Type of Joint

	Number Without Distress	Number With Distress	Total Number	% Distressed
Fixed Joints	106	53	159	33.3
Expansion Joints	217	6	223	2.7
Total	323	59	382	15.4

From this Table, it is seen that the frequency of damage at fixed joints is more than ten times that at expansion joints.

In some of the structures surveyed, alternate spans were doweled to the pier cap at both ends, while the remaining spans were doweled only at one end. This pinning arrangement is shown in Appendix Figure B-1. Among

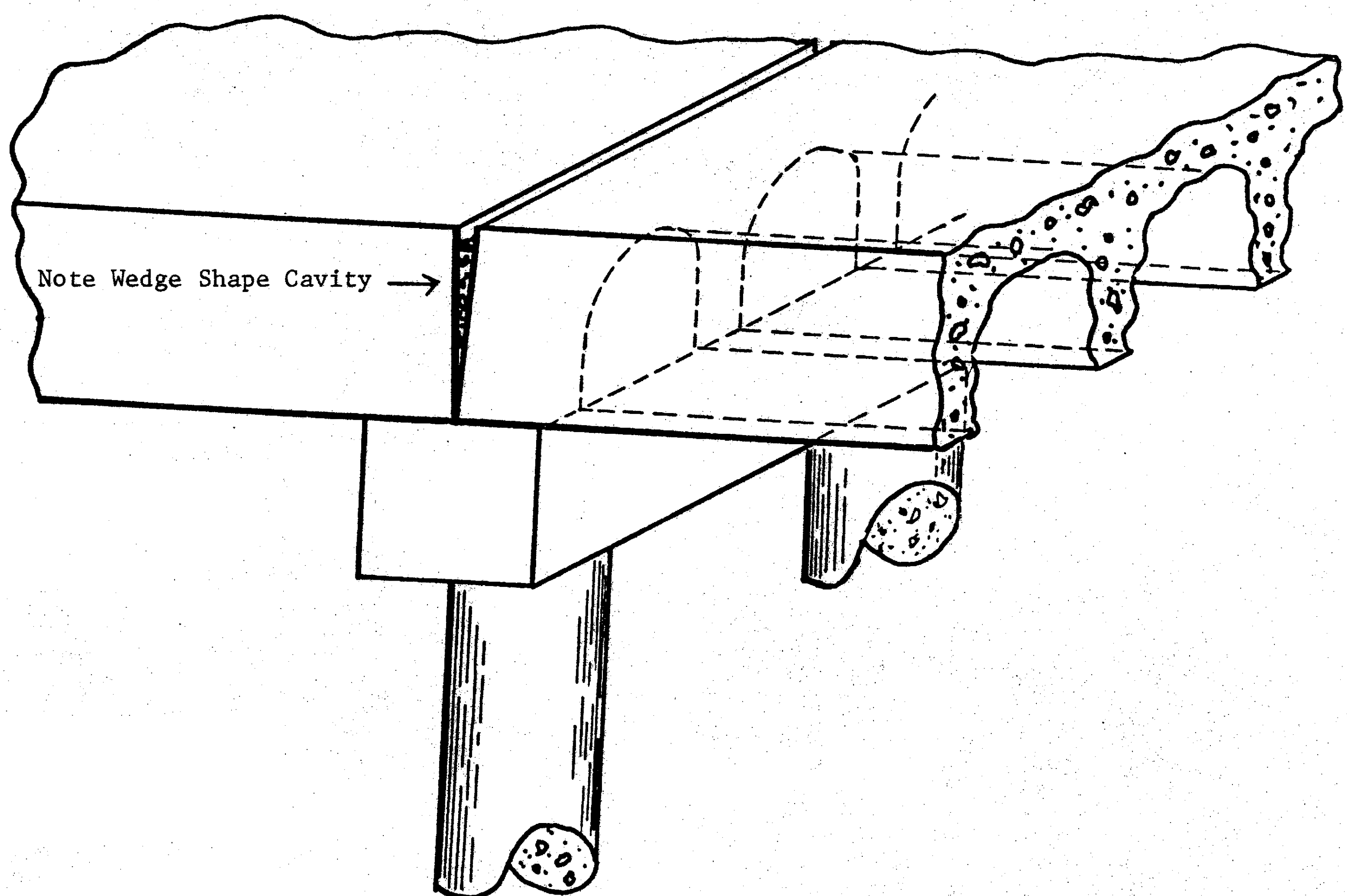


Figure 1: Fixed joints in pan-formed bridges are generally open about 1/4 inch at the top and completely closed at the bottom. Typically, adjacent spans are both doweled to the pier cap at these joints.

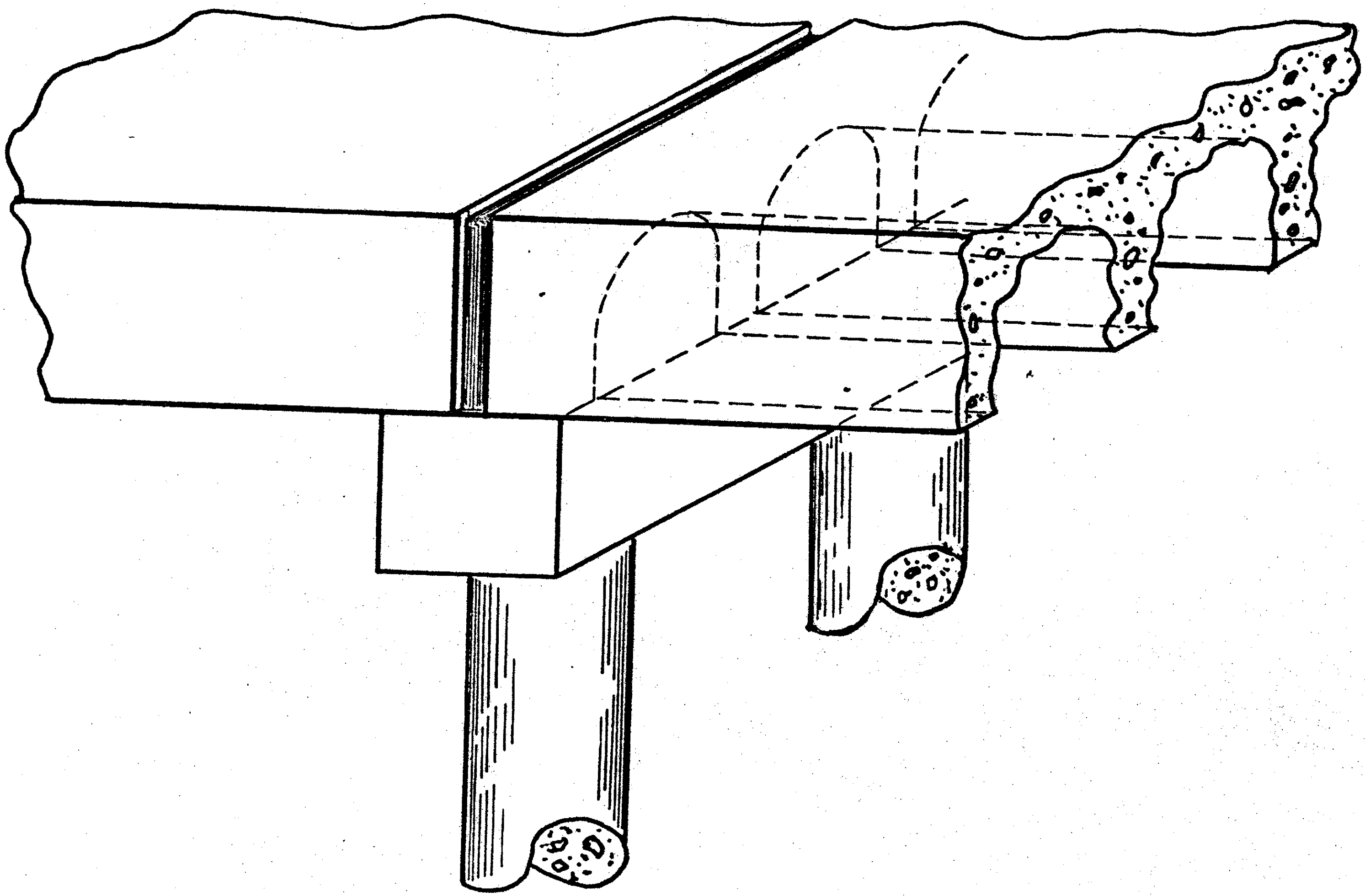


Figure 2: Expansion joints in pan-formed bridges are generally 3/4 inch wide and contain a fiberboard filler. Typically, only one of the adjacent spans is doweled to the pier cap.

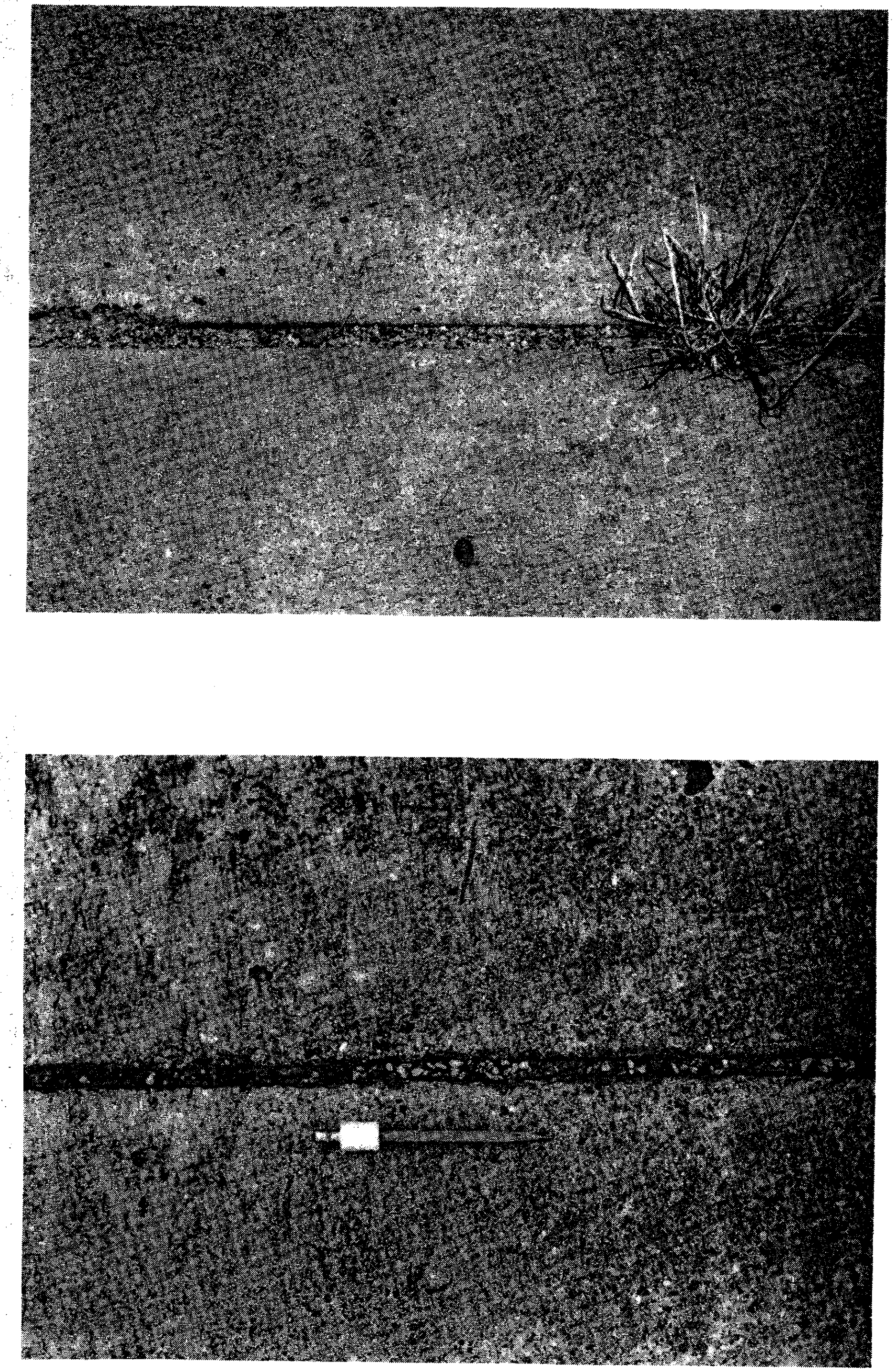


Figure 3: Ineffective joint seals in pan-formed bridges often allow the accumulation of incompressible debris.

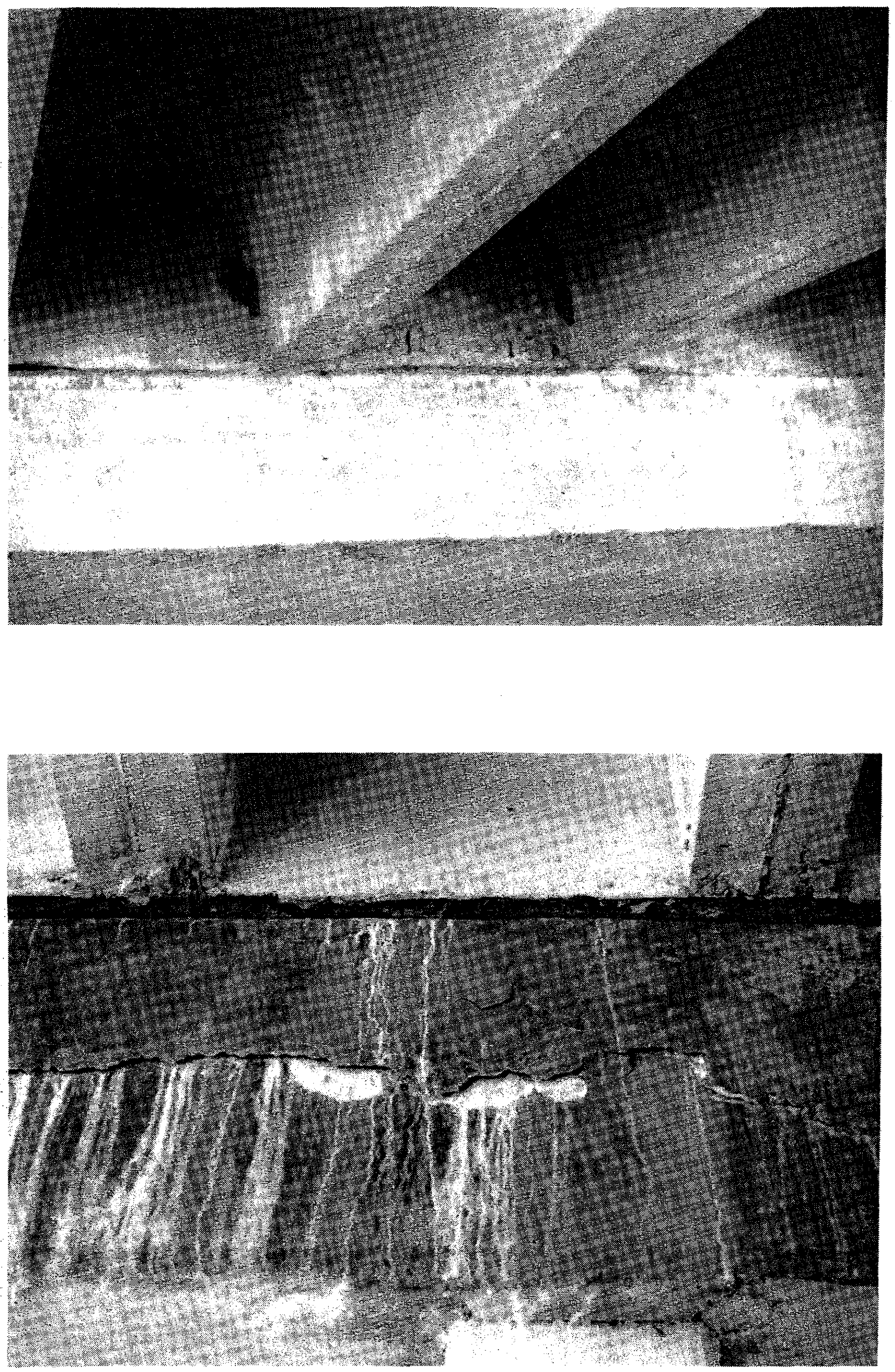


Figure 4: Distress at joints in pan-formed bridges results from damaging expansion pressures. The top photograph shows a ruptured diaphragm and the lower a ruptured pier cap.

such structures, when spalling of the face of the pier cap was present, it tended to occur predominantly on those pier caps to which two spans are pinned. Also, it usually occurred on the side of the pier cap toward the span which is pinned at both ends, rather than on the side toward the span whose opposite end is free. One possible explanation of this selectivity is presented in Appendix B.

In view of the finding that most damage occurs at fixed joints, it is apparent that measures are needed to relieve or prevent distress at these joints. Since typical fixed joints are open only about 1/4 of an inch wide at the top and completely closed at the bottom (24-26 inches deep), removal of the debris is difficult. There appear to be three possible remedial measures: (a) removing as much debris as possible from the accessible portion of the joint and providing a seal which will prevent further entry of debris, (b) cutting one set of dowel pins so that each span is pinned only at one end, and (c) widening the fixed joints by cutting a slot in the concrete to the bottom of the joint between adjacent slabs.

3. Possible Remedial Measures for Fixed Joints

This section contains a discussion of three possible remedial measures to relieve or prevent distress at fixed joints.

(a) Debris Removal and Sealing

The high-pressure water-jet technique, a joint cleaning method being examined in this study, is currently being used experimentally by maintenance personnel of several Texas Highway Department districts. See Figures 5 and 6. From the results to date, this technique appears highly effective for removing debris, filler and deteriorated seal materials from expansion joints. However, some pebbles are so firmly wedged in the joints that they can be removed only by breaking them into pieces. The water-jet is not able to do that. The narrow width and wedge shape of fixed joints severely limit the effectiveness of the water-jet. It is not possible in practice to remove all debris from such joints by the high-pressure water-jet technique. Even though it will not completely clean the narrow wedge joints, it may remove enough debris to relieve the joint and possibly prevent serious distress. Accordingly, its effectiveness for this purpose will be explored further.

In conjunction with debris removal, a practical method will be required for preparing the cleaned fixed joints to receive a seal. This aspect of the problem will be considered concurrently with further work on joint cleaning.

Figure 5: High-pressure water-jet being used to clean debris from joint. The jet "gun" has been mounted on a cart to facilitate operations.

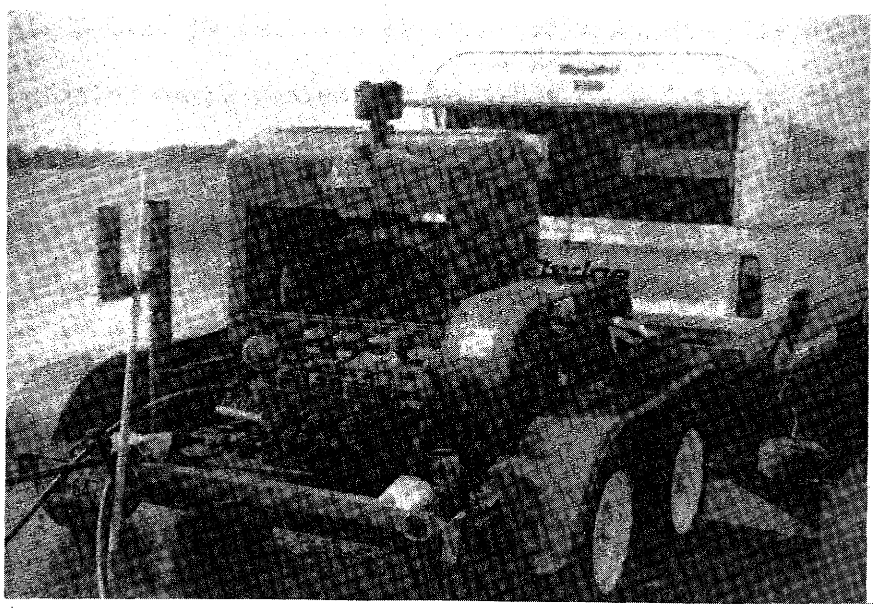


Figure 6: Trailer-mounted high-pressure pump used with the water-jet gun.

b. Cutting Dowel Pins

Binding at fixed joints can be relieved to some extent by cutting the dowels which join the beams to the pier cap. Several methods appear feasible for cutting these dowels under appropriate conditions. When the deck can be jacked up to expose part of the pins, a conventional cutting torch could be used to sever them. Without jacking up the deck, a horizontal circular diamond saw or the oxygen-iron, concrete-melting torch could be used. See Figure 7. With either of these latter methods, it is recognized that a certain amount of concrete will be cut away or damaged in the process of getting to the pins. However, it is believed that the loss of concrete would be acceptably small and that a satisfactory procedure might be developed along these lines.

c. Joint Widening

Three techniques for cutting concrete by sawing have been found which appear applicable to widening the narrow fixed joints. These techniques use the Ditch Witch (or the similar Vermeer) tractor-mounted device shown in Figure 8, the wire saw, and the circular diamond saw. The toothed wheels of the tractor-mounted devices cut an undesirably wide (4-inch) slot and their teeth are subject to rapid wear.

A wire-sawing technique, as used commercially in granite quarrying and in finish cutting of stone, has been considered. Based upon preliminary estimates, it appears that a major effort would be necessary to adapt the wire-sawing method to widening bridge deck joints and would result in a cumbersome mechanism. See Figure 9. While such a device appears to have

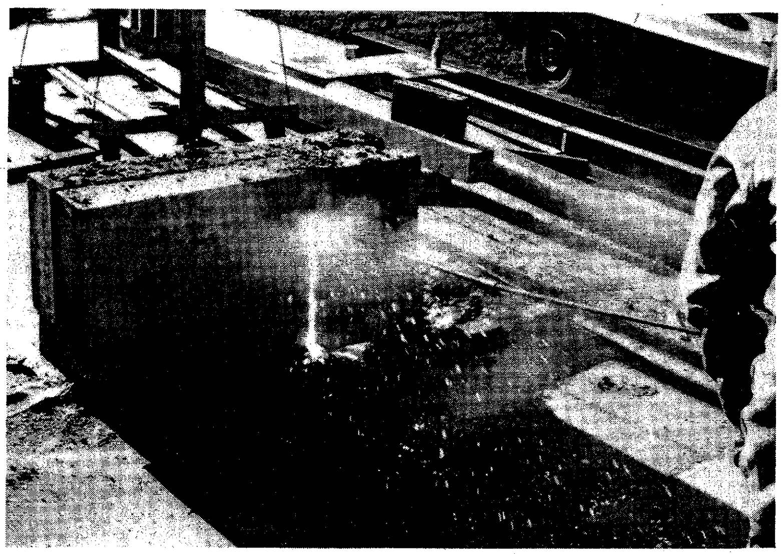


Figure 7: Oxygen-iron torch melting a hole through concrete.

Figure 8: "Ditch-Witch" tractor mounted concrete cutting saw.

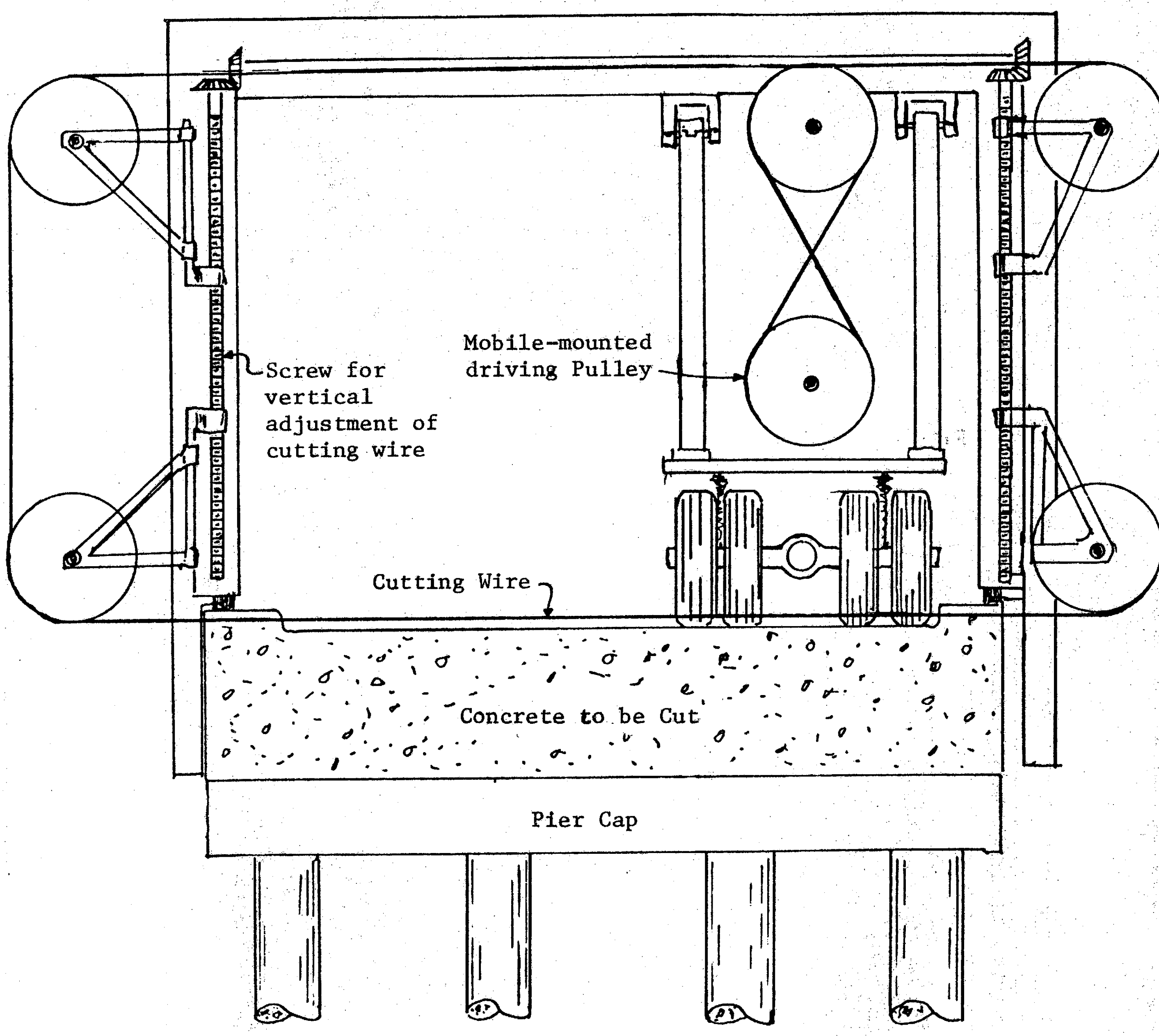


Figure 9: Conceptual sketch of wire-saw device for use on bridge decks.

the basic capability and certain advantages, its size and complexity would make it a very costly development which may not be warranted at this time.

An alternative which appears to be more attractive for the first attempt at joint widening is provided by the circular diamond saw which is also widely used in the building stone industry. For bridge slotting operations at depths up to 32 inches, a saw approximately 76 inches in diameter (a commonly available size) would be required. An 84-inch size is also available. Such blades have been attached in place of the toothed wheels normally used on the Ditch Witch or Vermeer tractors. A water supply for cooling the diamond saw must then be added.

The cutting rate is dependent upon the type of concrete, but it is estimated that a typical bridge joint might be cut in about two hours by this method. The cost of a 3/8 inch wide, 76-inch diameter blade is approximately $1,800 and its expected life is sufficient to slot about fifty joints. Accordingly, the circular diamond saw is considered to offer the best promise for bridge joint widening.

The debris removal and joint sealing technique appears to offer the least expensive approach for relieving and preventing distress at fixed joints. Accordingly, every effort will be made to achieve a satisfactory solution in this category before proceeding to examine the more costly pin-cutting and joint-widening techniques.

4. Conclusions

Widespread deterioration of seal materials at expansion joints in pan-formed bridges is permitting most of these joints to become filled with debris. The high-pressure water-jet joint cleaning method currently being investigated in this study may prove to be ample for cleaning such joints.

The absence of seals at the fixed joints, in combination with the tendency of these joints to open about 1/4 inch at the deck surface, makes them particularly prone to accumulate debris. Damage was observed in the surveyed bridges more than ten times as frequently at these joints than at expansion joints. It does not appear likely that cleaning only the expansion joints would appreciably diminish the distress at the fixed joints.

Although Texas Highway Department design changes have substantially eliminated fixed joints in new pan-formed bridge construction, the findings of this limited survey indicate that approximately 42% of the joints in existing pan-formed bridges are of the fixed type. A very high incidence of distress (about 33%) was found in this type of joint. Without some type of treatment like the remedial measures currently under investigation in this study, the incidence of distress in these joints can be expected to increase and cause severe future maintenance problems.

Appendix A

This appendix contains copies of two data sheets typical of those used in recording the field survey data. These examples have been copied, using a typewriter, to improve their legibility.

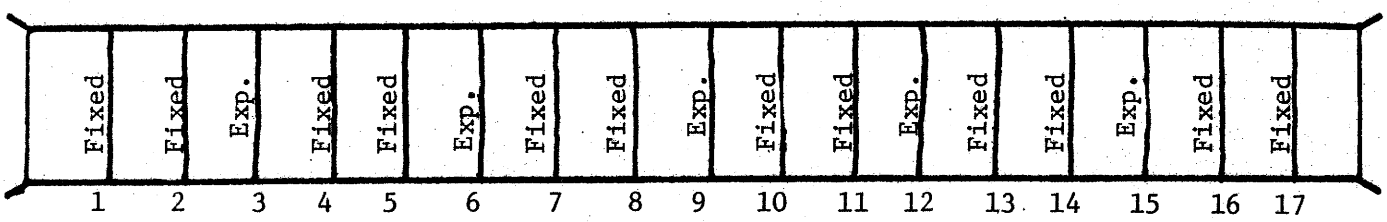
APPENDIX A

TYPICAL BRIDGE JOINT SURVEY DATA

County	Highway	Cont. & Sec.	Str. No.	Span Length	No. of Spans	Feature Intersected
Brazos	SH 30	212-03	13	30'	18	Navasota River Relief #2

Distance from deck to pier cap:

Type of Joints



Condition Survey Data:

Joint 1 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
2 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
3 width 1 inch at surface, 1/2 at bottom - Full of debris, no seal
4 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
5 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
6 width 3/4 inch at surface,1/2 at bottom - Full of debris, no seal
7 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
8 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
9 width 1 inch at surface, 1/2 at bottom - Full of debris, no seal
10 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
11 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
12 width 1 inch at surface, 1/2 at bottom - Full of debris, seal deteriorated
13 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
14 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
15 width 1 inch at surface, 1/2 at bottom - Full of debris, seal deteriorated
16 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal
17 width 1/4 inch at surface, 0 at bottom - Full of debris, no seal

Notes: Spalling on pier-caps 1, 6 & 10.

Appendix B

In multi-span, pan-formed bridges having alternating fixed and expansion joints, a trend has been observed for distress to occur in a specific pattern. Damage has been found predominantly on those pier caps to which two spans are doweled, rather than on those to which only one span is doweled, and predominantly on the side of such pier caps toward the span which is doweled at both ends, rather than toward the span whose opposite end is free. A possible explanation for this pattern of distress is offered in the following paragraphs.

Referring to Figure B-1, a rise in temperature will cause the concrete to expand. The closed joint at A prevents movement at A. Therefore, the far end of each span adjacent to A moves away from A. At the right end, movement to the right is possible if joint B is open, and no trouble occurs there. To the left, at joint C, a dowel restrains movement, but if movement takes place, it occurs either by bending the pier or by sliding on the pier cap with bending of the dowel. If the dowel bends, it is possible for it to cause spalling of the pier cap. However, spalling does not usually occur at C, it generally occurs at A.

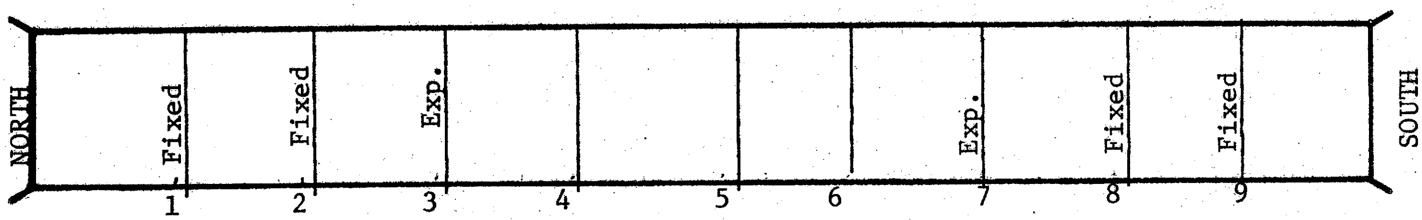
Now consider a drop in temperature. The concrete shrinks, but the expansion joint B permits sliding at B which relieves a portion of the tension in the slab between A and B caused by the temperature drop. However, at C no sliding can occur. Therefore, the span between A and C pulls the dowels at both ends toward the center of the span. This applies pressure on the vertical section between each dowel and the vertical face

BRIDGE JOINT SURVEY DATA

County	Highway	Cont. & Sec.	Str. No.	Span Lenght	No. of Spans	Feature Intersected
Robertson	US 190	49-8	66	30'	10	Campbell Creek

Distance from deck to pier cap: 25 inches

Type of Joints



Condition Survey Data:

Joint 1 width 1/2 inch at surface, 1/4 at botton - Full of debris, traces of seal

2 width 1/2 inch at surface, 1/4 at bottom - Full of debris, traces of seal

3 width 1 3/4 inch at surface - Full of debris, seal poor

4 width 7/8 inch at surface, 1/2 at bottom - Full of debris, little of seal remaining

5 width 1/2 inch at surface, 3/8 at bottom - Full of debris, little of seal remaining

6 width 1/2 inch at surface, 3/8 at bottom - Seal 70% gone

7 - Seal 30% gone

8 width 1/2 inch at surface, 3/8 at bottom - Seal 70% gone

9 width 1/2 inch at surface, 3/8 at bottom - Seal 70% gone

Notes: No fiberboard in any joints.

Pier caps 1, 2, 4, 5, 6, 8 & 9 repaired.

Pier caps 3, 7 O.K.

Several diaphragms patched, majority O.K.

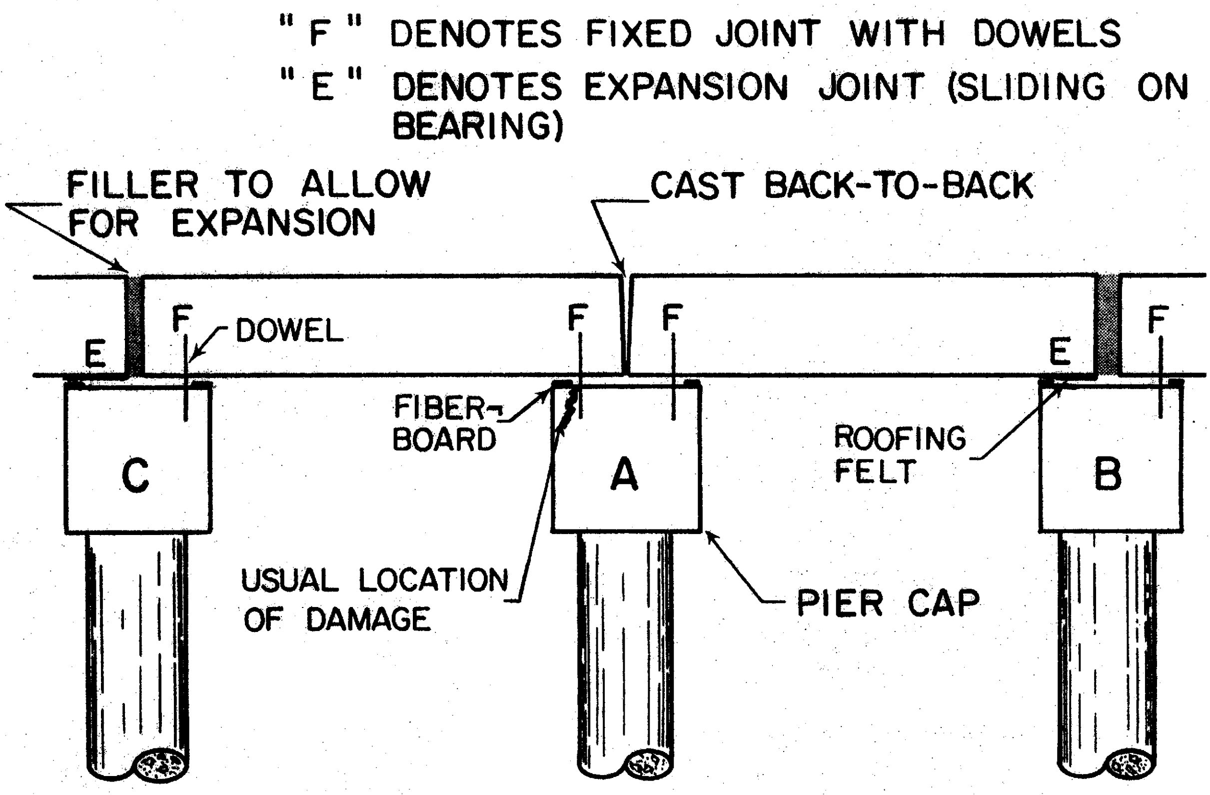


Figure B-1: Diagram of distress pattern.

of the pier cap. In an ideal case, equal pressures would occur at A and C which would give an equal chance for damage to occur at either location. It is observed, however, that damage occurs predominantly at A, very seldom at C.

Consider, in addition to the drop in temperature, the presence of debris in the joint at A, as shown in Figure 1. When traffic loads deflect the slab, the joint opens more at the top than at the bottom and loose debris drops farther into the joint. When the load leaves the span, the upward deflection tends to close the joint, but the debris which has worked its way down prevents closure. This develops pressure between the ends of the two slabs at A.

The combination of the pressure caused by the debris filled joint and that caused by shrinkage of the concrete due to a drop in temperature results in greater force on the left side dowel at A than on the right side. Thus, more outward force exists on the left dowel at A than on any other dowel, and that force is greatest when the temperature is lowest. Under these circumstances, the left side of the pier cap at A is the one most likely to be damaged.