EVALUATION OF CAST-IN-PLACE JOINT REPAIRS IN CONCRETE PAVEMENT

MICHIGAN DEPARTMENT OF TRANSPORTATION

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RESEARCH LABORATORY SECTION

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Evaluation of
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EVALUATION OF CAST-IN-PLACE JOINT REPAIRS IN CONCRETE PAVEMENT

C. A. Zapata

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The Problem

During the 1970's, it became more and more evident by current rates of expenditure, that Michigan's highway system was deteriorating each year at a rate that exceeded replacement and repair. It also was evident that improved repair methods would aid in maintaining the serviceability of the existing roadway system. The experiment evaluated here deals with one small facet of this problem.

'Ethafoam' foamed urethane joint fillers, used in pavement relief joints during the mid-1970's on early contract joint repair projects, developed considerable extrusion and, in some cases, loss of the filler occurred. Also, some repair contracts were let with joint design details that were developed for preventive maintenance jobs; thus, excessive amounts of expansion space were provided when joint repairs were close together. Joint repairs on more recent contracts have been limited in the amount of expansion space provided.

At the time this project was initiated, an additional repair joint option detail was added to provide for sealed joints without filler. Improved procedures were required for selecting joint design details to fit each particular situation. Joint designs properly selected and built should aid in maintaining better riding surfaces on repairs and longer life for repaired roadways.

Research personnel felt that there was sufficient evidence to indicate the necessity for some expansion relief and seals at repair joints. However, there were no sound data on how nearby expansion space would affect the rate of opening of unsealed contraction joints at repairs, or on the performance of different types of seals in contraction joint repairs. Moreover, the performance of the different types of repair joints with respect to faulting was not quantified. Therefore, this experimental project was proposed to develop data concerning relative performance of the various types of repair joint design details for future use on repair contracts. Details included 1-in. and 2-in. expansion joints with filler and seals, contraction joints with seals, contraction joints without seals, and base with and without shoulder drains. None of the joint details included load-transfer.

During the life of this experimental project, there have been numerous developments in techniques of repair, pavement rating and management, preventive maintenance, and pressure relief. Also, it has become more and more obvious that repairs without load-transfer develop objectionable faulting in a few years. Therefore, the Department has recently changed the design of repairs to require load-transfer. This report has been prepared as the final report regarding pavement repairs with no load-transfer provision and no further evaluations are intended.

Scope

This investigation included the construction, instrumentation, and evaluation of a major concrete pavement repair contract on a badly deteriorated freeway. It compares the reaction and performance of various types of joints and seals. The project included 335 lane repairs totaling about 5,600 sq yd.

Objectives

The objectives of this study were to develop data on the movement and relative performance of six different types of joint design details, with and without shoulder drains (French drains), in order to choose suitable designs for future repair contracts. Mainly, the investigation was expected to determine:

1) Whether joint seals for contraction joints at repairs might help prevent build-up of compressive stresses in a 15 to 20 year old jointed pavement,

2) Whether preformed neoprene seals performed better than cold-poured seals placed in expansion repair joints,

3) Whether joint faulting was more extensive and severe at expansion repair joints or contraction repair joints,

4) Whether preformed neoprene seals performed better than hot-poured seals at contraction repair joints,

5) Whether any superiority of one sealer type over another might be established between cold and hot-poured seals at repair joints.

Background

In 1969, the MDOT began an experimental program to develop practical and economical methods of joint repair on concrete pavements (1). The program was expanded to study the relative performance of various types of joint repairs and seals on a badly deteriorated concrete pavement. Thus, in January 1976, the Department approved an experimental work plan for this study. The joint repair work, located on I 75 south of Flint, began September 14, 1976 and was completed April 28, 1977.

Contraction joints are designed to control cracking attributable to frictional restraint, thermal and moisture changes, and the combined effects of load and warping stresses. Contraction joint movements depend on slab length, temperature or moisture changes, and location and distance between expansion joints (2, 3).

Expansion joints in new pavements are usually transverse joints designed to relieve compressive stresses by providing space for pavement expansion, and to reduce pressure on bridges. During early pavement life, expansion joints close at a relatively uniform rate, but after the expansion space is used up (about seven years or more after construction) they behave as contraction joints (2). Expansion joint movement is influenced by the total pavement length between the expansion joints, the concrete temperature at time of initial set, the coefficient of expansion, D-crack expansion rate of the particular concrete aggregates involved, and the number of intermediate contraction joints and transverse cracks. Eventually, all original expansion space will be utilized by the pavement, and additional expansion space at repairs should be installed to relieve some of the expansive pressure on nearby joints that also are deteriorated.

Many factors affect the performance of repair joints such as: existing pavement condition, previous and subsequent maintenance practices, foundation support, base drainability, commercial traffic volume, joint repair type, spacing of repairs, and workmanship. Furthermore, it is evident that maximum, as well as minimum, amounts of expansion space should be specified for a given length of pavement. Therefore, where repairs are closely spaced, or placed only in one lane, a joint detail without joint filler is required. This presents a problem, since the joint is a contraction joint at the end of a long slab and cannot be adequately sealed for long service life with ordinary poured sealants. If it is left unsealed, experience has demonstrated that the joint will fill with incompressible material and progressively increase in width, thereby adding to pavement "growth" and increasing pressure on nearby joints. Since load transfer devices are in existing pavement joints and not in the repair joints, and since corrosion makes such pavement joints difficult to open, joint openings at the repair slabs tend to be wider than otherwise would be expected.

There is ample evidence that one major culprit in concrete pavement deterioration is water in the joints and under the slabs (4, 5, 6). Another highly significant factor is lack of freeze-thaw durability of the coarse aggregates which causes deterioration of the joint faces (4, 7, 8). Baseplates under joint load transfer assemblies in pavements built between 1946 and 1967 have severely increased the rate of deterioration of D-crack susceptible aggregates. Crushing of poor joint faces is accelerated by infiltration of incompressible materials. Therefore, it seems reasonable to provide the best possible seals when doing pavement construction or repairs.

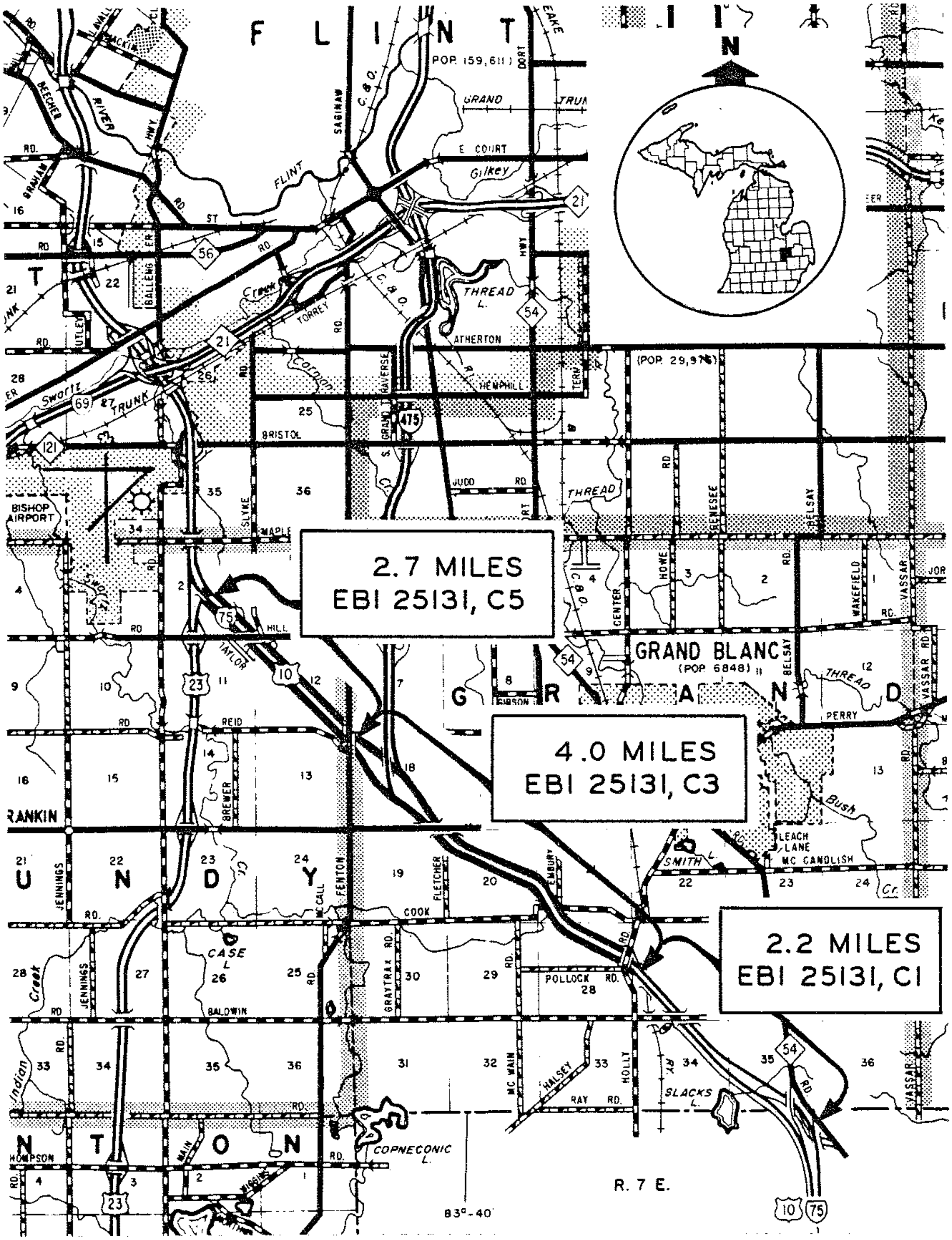


Figure 1. General location of experimental repair on I 75, mileage, and construction projects involved.

Only preformed compression type seals have the theoretical capacity to effectively seal contraction joints in 99-ft pavement slabs from the infiltration of incompressible materials. This requires, of course, that they be placed in such a way as to remain in the joints. There may be objections to placement of neoprene seals at repairs in an old pavement that had hot-poured seals to begin with. However, based on the magnitude of the joint movements that may occur, and the possible consequences of the infiltration of water and incompressibles, it seemed worthwhile to include the experimental installation of neoprene compression seals in this repair contract for comparison with joints sealed with poured sealants.

The experimental joint repairs were located on a heavily traveled and badly distressed four-lane divided section of I 75, just south of Flint from Maple Ave southeasterly to Ray Rd in Genesee County. The selected area included three construction projects (EB I 25131 C1, C3, and C5) built in 1963 and totaling 8.75 miles (Fig. 1).

The jointed, reinforced concrete pavement, which carried an average daily traffic volume of 21,500 vehicles in 1980, is 9 in. thick. Each roadway has two 12-ft lanes. Dowelled joints with baseplates were sealed with hot-poured rubber-asphalt and spaced at 99-ft intervals. This section has not been resurfaced with bituminous concrete.

A 1978 pavement condition survey showed typical distress patterns (joint spalling and disintegration, transverse and corner cracking, joint filler extrusion, and bituminous patching) found in many concrete pavements at 15 to 20 years of age (1, 7, 9).

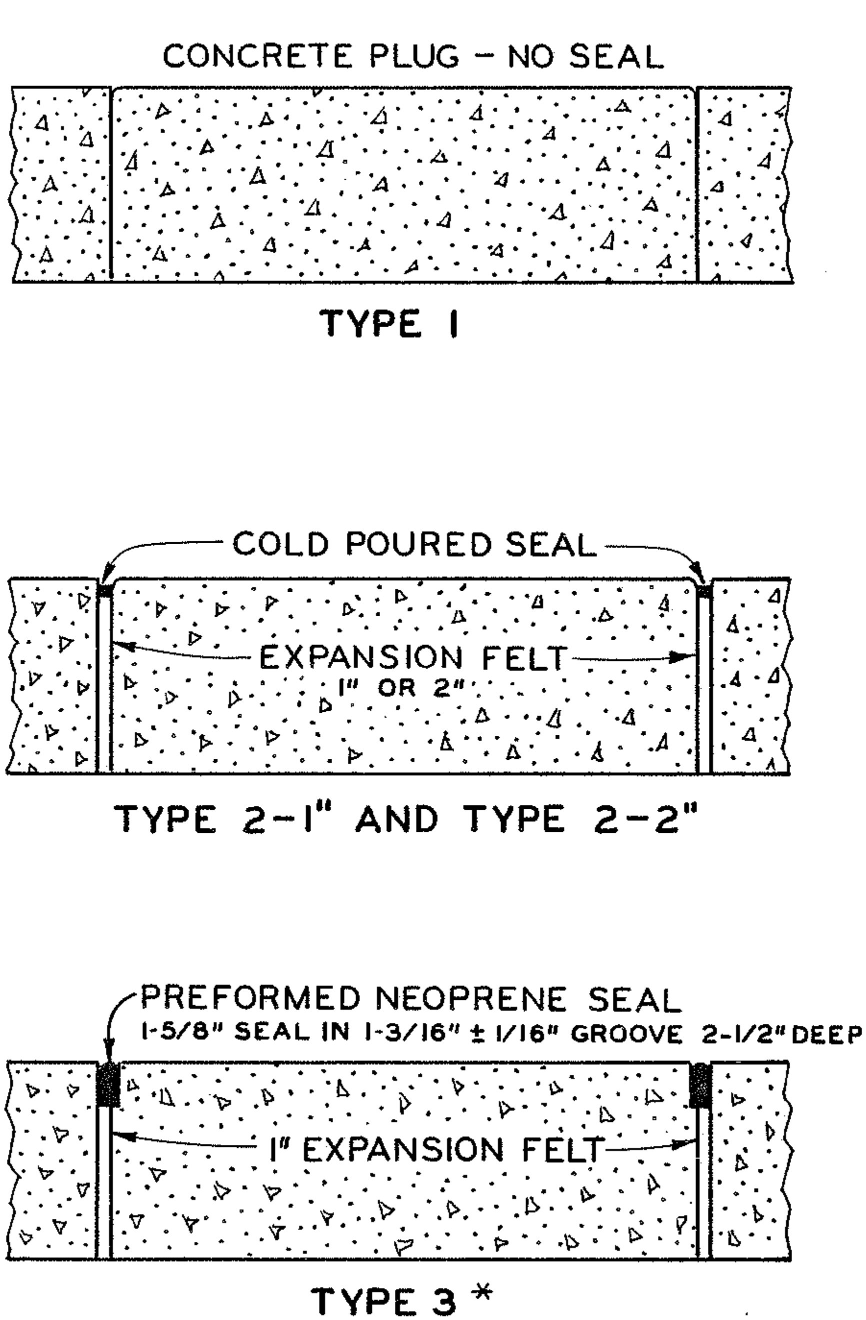
Investigative Procedure

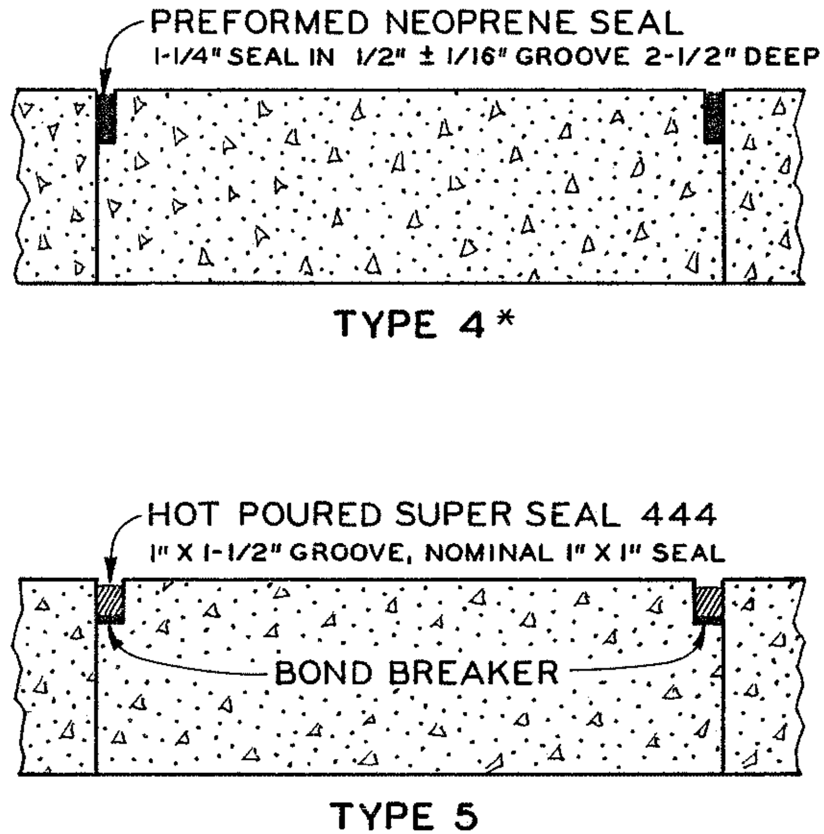
The general plan of action at the project site was to:

1) Conduct a pavement condition survey to determine which distressed joints were to be replaced, the total number of repairs, and the precise locations of the repairs.

2) Determine the type of repair to be placed at each distressed joint so as to provide the most comparable field conditions possible for the six types of joint repairs under study (Fig. 2). A joint rating technique developed by the MDOT Research Laboratory was used in the selection of joints for repairs (5).

3) Place a crushed-rock drain (at approximately one-half of the repairs of each type) along the patch edge and through the shoulder to determine whether deleterious effects of water under the concrete slab can be





* Seal to be extended down edges of pavement, and installed with one component lubricant adhesive per 8.16.04-C-2.

Figure 2. Experimental joint details at 1976-77 repairs on southbound I 75 south of Flint, Genesee County.

reduced by such shoulder drains. Figure 3 shows the details of the experimental shoulder drain at a full-depth, cast-in-place concrete patch.

4) Continue semi-annual surveys and field inspections of the experimental area to document and evaluate the relative performance of the repairs. Appendix A gives the location, joint type, and area in square yards of the repairs under study. One-hundred twenty repairs were instrumented to measure horizontal and vertical movements of the joints. Distress factors visually inspected and recorded in each field survey included joint spalling, faulting, slab cracking, and joint seal failure.

Joint Repair Types

The full-depth, cast-in-place concrete pavement repair with fast-set concrete was used for the experimental patching according to a special provision of the 1973 MDOT Standard Specifications (Appendix B). For pavement removal, full-depth saw cuts were made with diamond blades according to the sawing diagram shown in Appendix B. Appendix B also includes a drawing of a lifting device used to remove the distressed concrete slab.

Of the total 335 cast-in-place repairs installed in the experimental project, 214 repairs were placed with contraction joints (repair types T_1, T_4, and T_5) with 100 to 200-ft spacings and 121 repairs with expansion joints (repair types $T_{2-1''}$, $T_{2-2''}$, and T_3) spaced randomly from 300 to 2,935 ft. Furthermore, 35, 32, and 11 percent of the total 335 repairs were full-depth concrete patches measuring 6 by 12 ft, 6 by 24 ft, and 6 by 36 ft, respectively. The remaining 22 percent of the joint repairs included concrete patches of different length and width. One-hundred twenty of the 335 repairs were randomly selected for seasonal condition surveys and joint movement measurements of the six types of joint repairs under investigation (Fig. 2).

Spacing between repairs with contraction joints varied from 100 to 200 ft. One to five contraction joint repairs were placed between expansion joint repairs spaced 300 to 2,935 ft. Of the 120 full-depth repairs selected for joint measurements, 66 repairs were instrumented for contraction joint movements; 22 for repair Type 1, 25 for Type 4, and 20 for Type 5, and 54 repairs were instrumented for expansion joint movements; 30 repairs for Type 2, and 24 repairs for Type 3 (Table 1). Expansion joint repairs were randomly located throughout the experimental project.

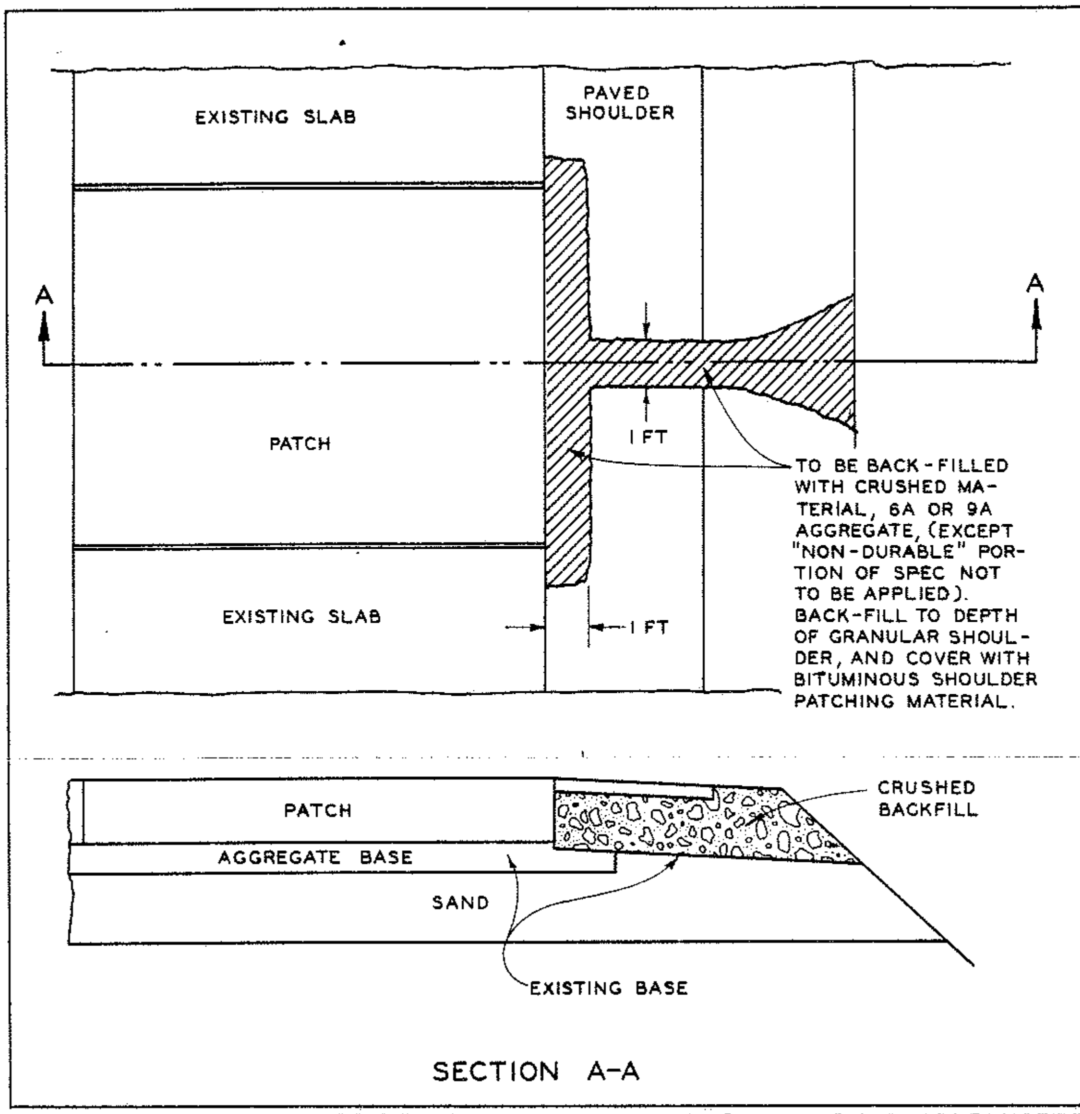


Figure 3. Details of shoulder drain at full-depth, cast-in-place concrete patch.

Minor vertical differential movement between adjacent slabs usually occurs at joints under normal service conditions. But excessive movement is frequently associated with defective load transfer conditions (deteriorated joint faces, no load-transfer, undersized dowels, abraded aggregate interlock, excessive joint opening), leading to numerous problems such as severe faulting, pumping action, joint sealant failure, and related detrimental effects (8, 9). Since no load-transfer was included in the repairs being evaluated here, the question is one of whether changes in other aspects of the joint detail made any difference in the performance of the repairs.

Table 1 summarizes the joint repair details evaluated in this experimental concrete patching work.

TABLE 1
SUMMARY OF JOINT REPAIR DETAILS AT 1976-77 REPAIRS ON SOUTHBOUND I 75 SOUTH OF FLINT, GENESEE COUNTY

Repair Type	No. of Repairs*	Joint Type	Joint Details
1 WD	7	Contraction	Concrete plug, no seal, shoulder drain
1 ND	15	Contraction	Concrete plug, no seal, no drain
2-1" WD	7	Expansion	Cold-poured seal, 1 in. felt filler, shoulder drain
2-1" ND	7	Expansion	Cold-poured seal, 1 in. felt filler, no drain
2-2" WD	8	Expansion	Cold-poured seal, 2 in. felt filler, shoulder drain
2-2" ND	8	Expansion	Cold-poured seal, 2 in. felt filler, no drain
3 WD	12	Expansion	1-5/8 in. neoprene seal, 1 in. felt filler, shoulder drain
3 ND	12	Expansion	1-5/8 in. neoprene seal, 1 in. felt filler, no drain
4 WD	10	Contraction	1-1/4 in. neoprene seal, no filler, shoulder drain
4 ND	15	Contraction	1-1/4 in. neoprene seal, no filler, no drain
5 WD	5	Contraction	Hot-poured Super Seal 444, no filler, shoulder drain
5 ND	15	Contraction	Hot-poured Super Seal 444, no filler, no drain

LEGEND: WD - with drain; ND - no drain

* For joint movement measurements and condition surveys.

Repair Costs

Bid prices of the three lowest bidders for the 8.7 miles of joint repair work are given in Appendix C. The contract was awarded on May 19, 1976 to the lowest bidder, Sargent Construction Co. The unit costs for the six types of repairs were as follows:

Type 1 - concrete plug, no seal (T_1)	— $20/sq yd
Type 2 - 1 in. felt and cold-pour seal ($T_{2\text{-}1''}$)	— $23/sq yd
Type 2 - 2 in. felt and cold-pour seal ($T_{2\text{-}2''}$)	— $23/sq yd
Type 3 - 1 in. felt and 1-5/8 in. neoprene seal (T_3)	— $31/sq yd
Type 4 - no filler, 1-1/4 in. preformed neoprene seal (T_4)	— $24/sq yd
Type 5 - no filler, hot-pour seal (T_5)	— $21/sq yd

In addition, other costs were as follows: $17/sq yd for old pavement removal, $80 for each shoulder drain, and $20,840 lump sum for traffic control and mobilization. The total bid price was $257,588 for 5,647 sq yd, bringing the total average cost to $45.62/sq yd for the entire project. More recent projects have been awarded at approximately $50/sq yd.

PERFORMANCE EVALUATION

The relative performance of the experimental cast-in-place repairs was evaluated by measuring joint width changes and elevation differentials across the 'approach' and the 'leave' joints at the instrumented concrete patches. For this purpose, stainless steel plugs were embedded in the concrete surface about 4 in. each side of the joint centerline (Fig. 4). The distance between the steel plugs across the joint was measured semi-annually with a precision caliper to monitor joint width changes. Elevation changes across the joint were measured with an elevation differential device called a fault gage and were referenced to the same two plugs at each location. Furthermore, in the 1982 condition survey of the repaired area, distress factors such as joint spalling, slab cracking, and joint seal failure, were also recorded and included in the final evaluation procedure.

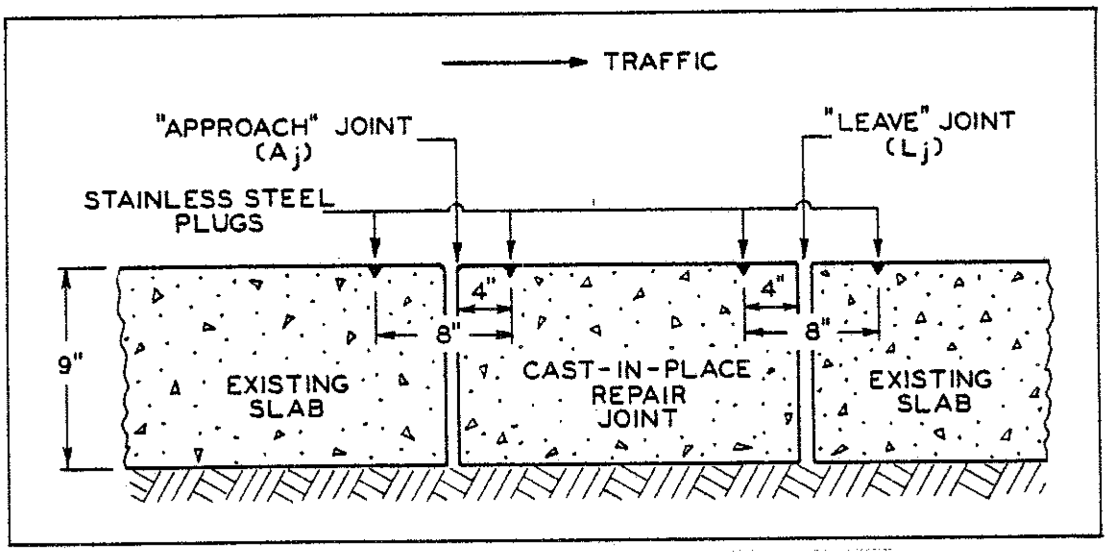


Figure 4. Stainless steel plugs embedded in the concrete surface as reference points to monitor joint movements at the approach (A_j) and leave (L_j) joints of each concrete patch. Both joint width and faulting measurements were made using these reference points.

The joint movement data (horizontal and vertical movements) were stored in a central computerized file and retrieved by a remote terminal for data treatment. To eliminate time-consuming tabulations, the field data were analyzed graphically providing four diagrams for each joint type repair, with and without shoulder drains, as test parameters. Computerized results and joint distress data still required additional computations and statistical tests to complete the joint repair evaluation.

The standard statistical T-test was found useful for testing differences in joint opening measurements, vertical joint movements, and joint faulting.

Also, differences in proportion defective, expressed as percentages within grouped repairs, were used to test the statistical significance of joint distress types such as joint spalling, transverse cracking, and joint sealer damage. Computed and estimated values were tested by using the customary 95 and 99 percent probability or significance levels (10, 11).

To determine whether the neoprene seal for expansion joints remained in better condition in joint T_3 than the cold-poured seal placed in joints T_{2-1}" and T_{2-2}", joint sealant defects or deficiencies were defined in terms of physical conditions as follows:

1) Cold-poured seal (joints T_{2-1}" and T_{2-2}") — Adhesion failure: seal developed crack(s) and pulled away from joint edges. Cohesion failure: seal developed crack(s) or tearing apart of the sealant as the joint expanded.

2) Preformed neoprene seal (joint T_3) — Seal failure: loss of seal, joint stripping, joint filler protruding above joint edges (sealer extrusion).

Elevation changes across the joint at each end of the concrete patch (A_j and L_j) were measured with an elevation differential device (fault gage).

The standard T-test was applied to field data from 120 instrumented repairs (54 for expansion joints and 66 repairs for contraction joints) to compare differences in vertical movements or joint faulting.

RESULTS

Contraction Joints

Joint movement data were separated into two main categories: joint repairs with shoulder drains (WD) and no shoulder drains (ND) with each category evaluated separately at the approach joint (A_j) and the leave joint (L_j) of each repair. Figures 5 and 6 summarize the seasonal changes in joint openings from 1977 to 1981. To determine whether joint seals for contraction joints at repairs might prevent lengthening or growth of a 19-year old jointed pavement, the standard T-test was applied to field data from 66 instrumented repairs to compare differences in horizontal joint movement. The results indicated the following:

1) Joint comparisons T_1 vs. T_4, T_1 vs. T_5, and T_4 vs. T_5 were tested for differences in joint openings and resulted in no statistical significance at the 95 percent level. Therefore, the relative differences in joint openings for contraction joints were attributed to chance or random variations

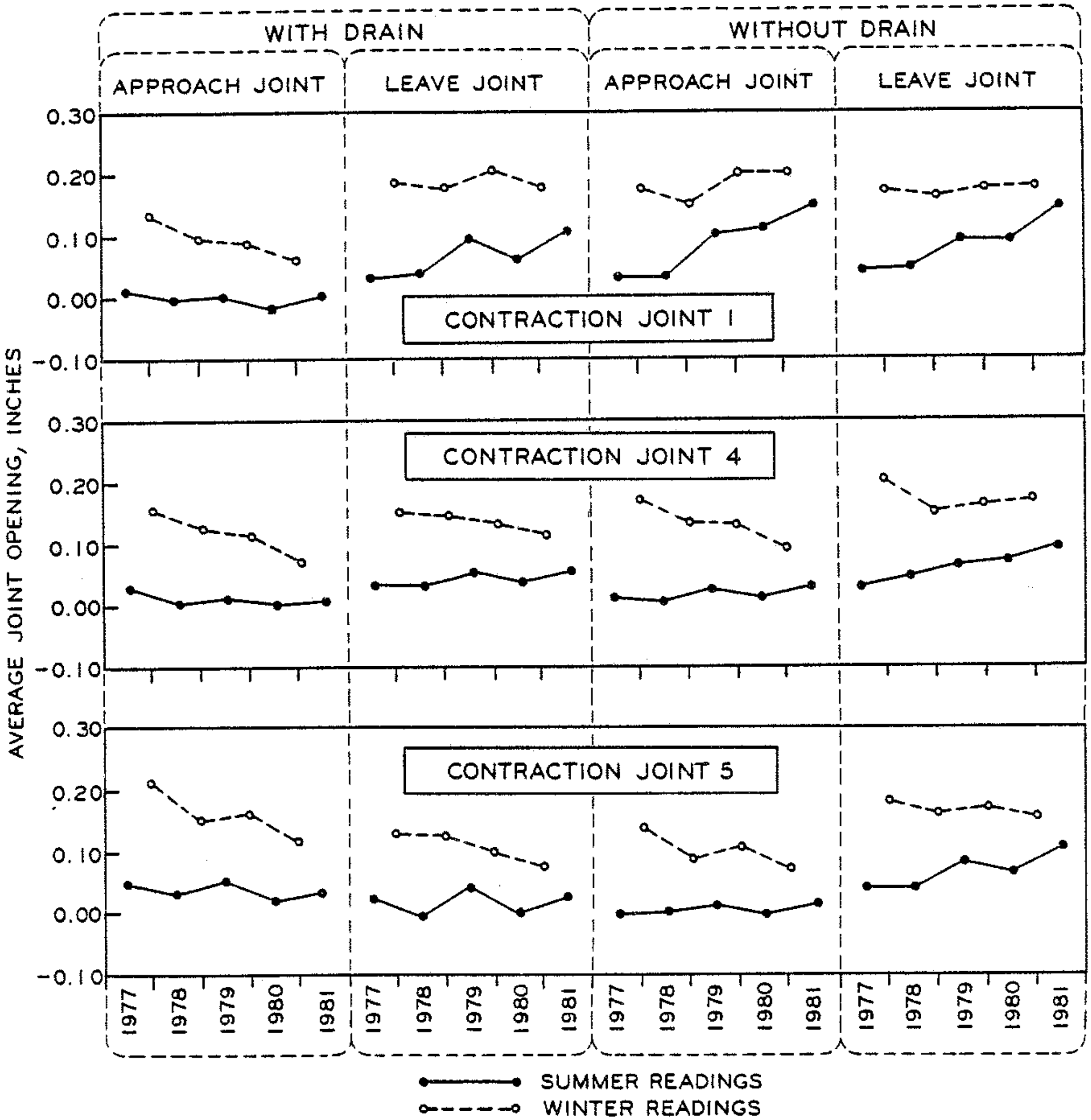


Figure 5. Average seasonal and yearly joint width movement for experimental contraction joints at repairs located on I 75 south of Flint.

rather than to joint seal performance at repairs. This means that no significant association between pavement growth and joint seal performance at repairs was statistically established. Since infiltration is known also to depend on availability of incompressible materials, it seems likely that the freeway road type and paved shoulders would have some effect, and the above conclusion may not apply to different types of roadways.

2) Overall, contraction joints (T_1, T_4, T_5) under study showed progressive changes in width (opening and closing) that might eventually reach an average permanent joint opening somewhere between 0.06 and 0.12 in. (Fig. 6).

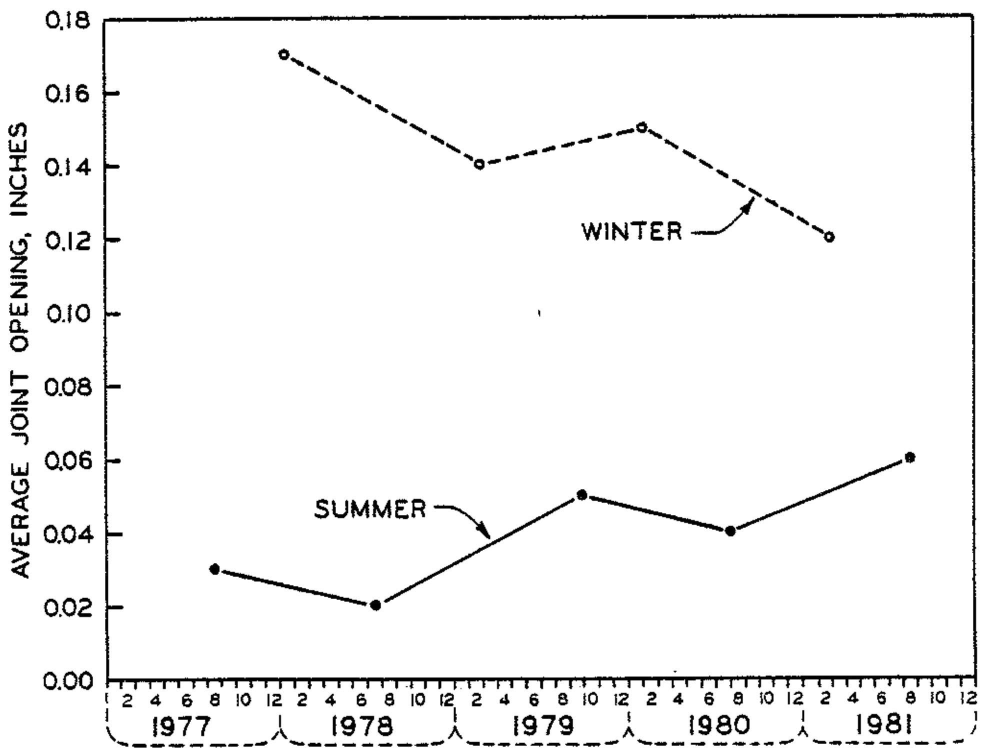


Figure 6. Overall progressive changes in width for experimental contraction joints (T_1, T_4, T_5) at repairs.

Expansion Joints

Similar to the contraction joint data, the expansion joint data were separated into two main categories: joint repairs with shoulder drains (WD) and without shoulder drains (ND) with each category evaluated at both ends (A_j and L_j) of each repair.

Figures 7, 8, and 9 summarize the seasonal joint closure trends at repairs from 1977 to 1981.

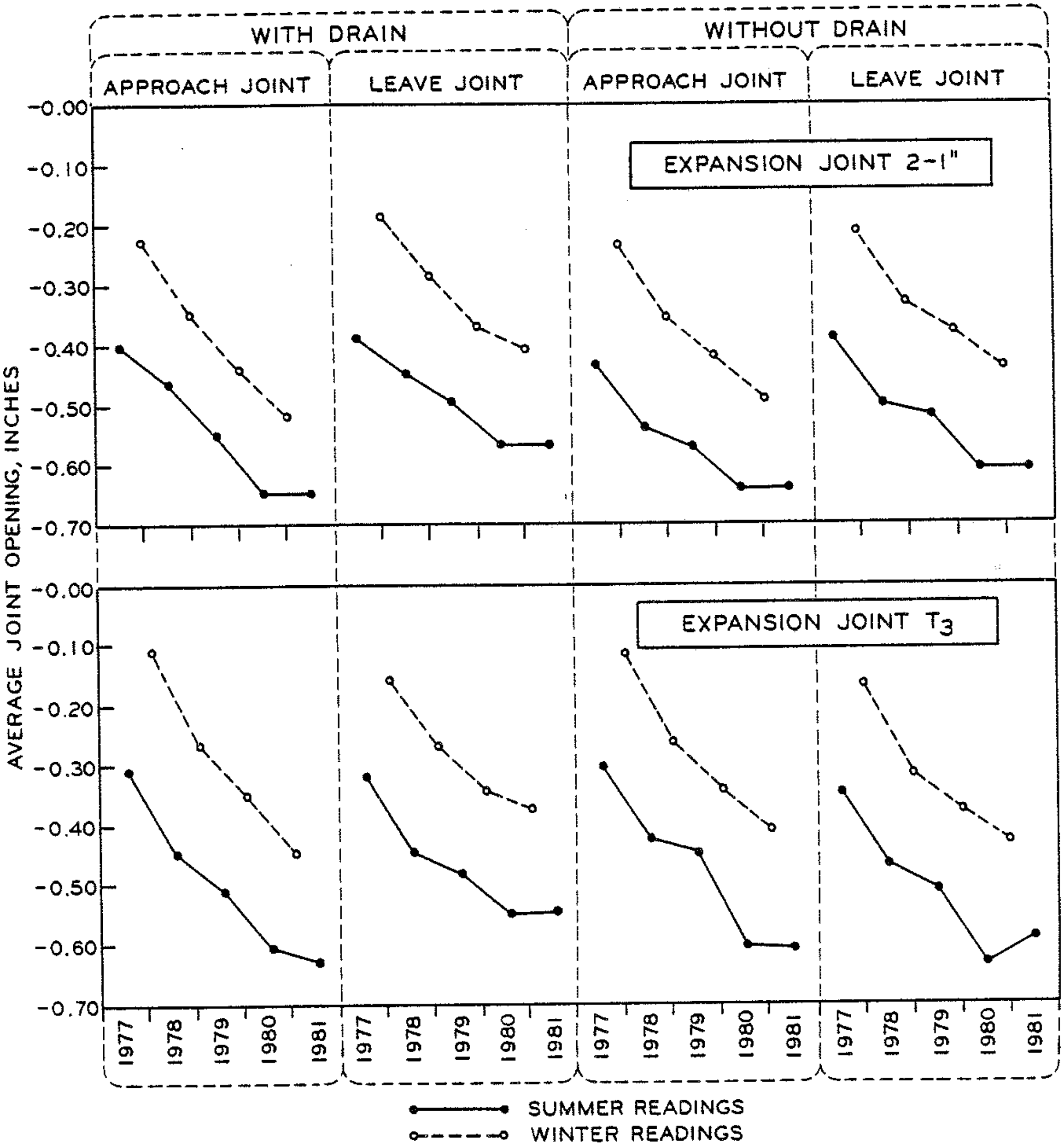


Figure 7. Average seasonal and yearly progressive closing of experimental expansion joints ($T_{2-1''}$ and T_3) at repairs.

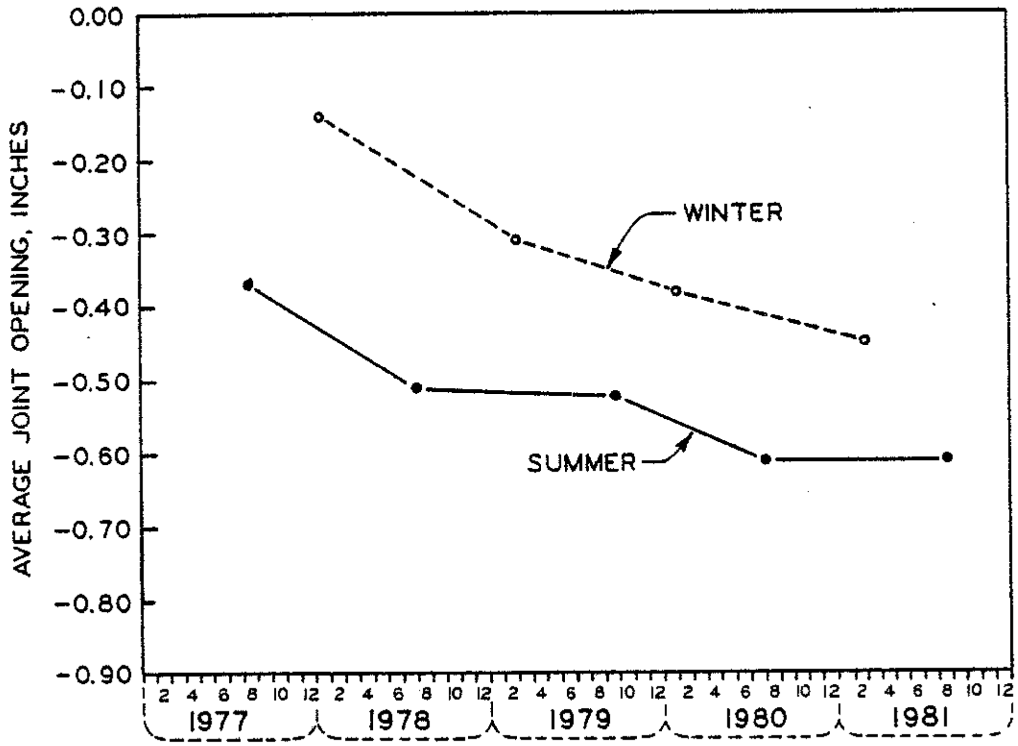


Figure 8. Overall progressive closing of expansion joints $T_{2-1''}$ and T_3 at repairs.

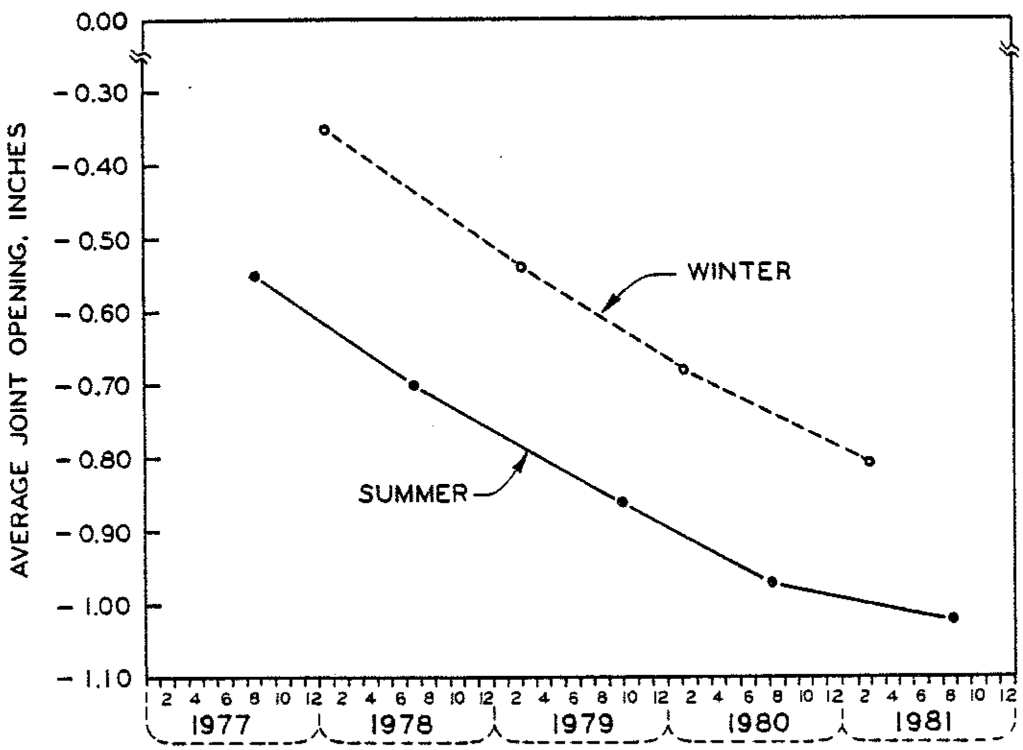


Figure 9. Progressive closing of expansion joint $T_{2-2''}$ at repairs.

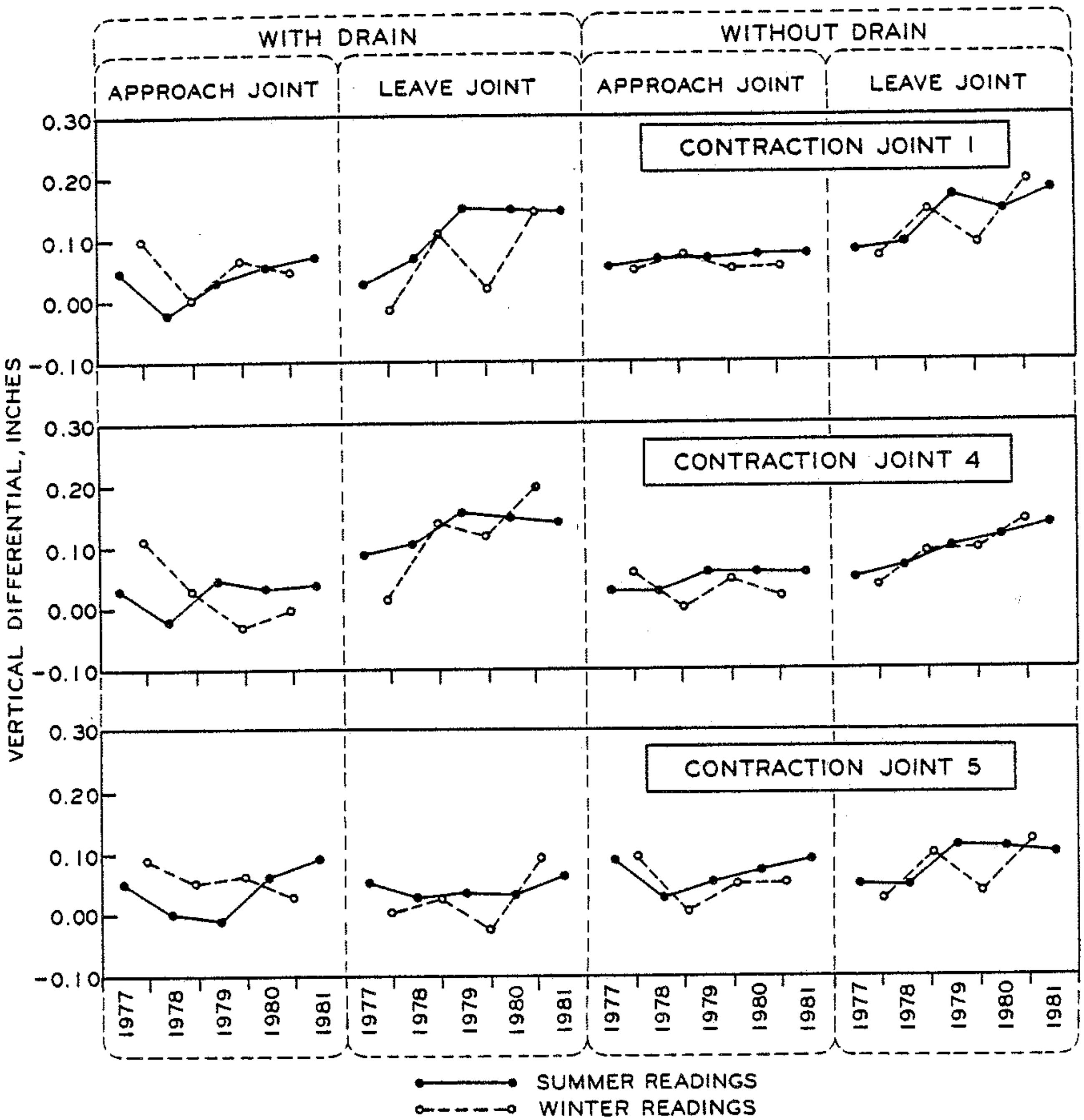


Figure 10. Average seasonal and yearly vertical joint movement of experimental contraction joints at repairs.

To estimate sealer performance, it was convenient to deal in terms of 'proportions' of faulty joint sealer (proportion defective as percentage within grouped repairs) on a joint-by-joint basis rather than 'number' or length in feet of faulty joint sealer over each repair. Statistical tests for differences between proportion defectives were applied to field data from 54 instrumented repairs, and the results indicated the following.

The proportion of faulty joint sealer for cold-poured seal was significantly greater than that for neoprene sealer, well beyond the 95 percent level of confidence. Therefore, in terms of physical appearance, neoprene sealer performed significantly better than cold-poured sealer in expansion joints.

Vertical Movement

To determine whether joint faulting was more severe and extensive at expansion rather than at contraction joints, the computed values were tested by using the customary 95 and 99 percent probability levels. Figures 10, 11, and 12 summarize the seasonal changes in vertical movements from 1977 to 1981. The results indicated the following.

1) The presence or absence of shoulder drains at repairs did not show any significant difference at the 95 percent level among the trends of vertical movement for the six different types of joint repairs being compared.

2) At the approach joints (A_j) at repairs, the average vertical differential for all joint types was 0.05 in. for the 1980-81 winter/summer results. In contrast, at the leave joints (L_j) at repairs, the average vertical differential was 0.18 in. for the 1980-81 winter/summer results. Thus, in terms of joint faulting, the difference was significantly greater for the leave joints (L_j) than for the approach joints (A_j) at the 99 percent level of confidence. Furthermore, at the leave joints (L_j) at repairs, the vertical differential trend continued increasing at an average rate of 0.03 in./year (Fig. 12).

3) With the exception of joint Type T_5, faulted joints were noted in 46 out of 66 repairs (70 percent) with contraction joints (T_1, T_4) as compared with 24 out of the 54 repairs (44 percent) with expansion joints (T_3, $T_{2-1''}$, $T_{2-2''}$). Thus, in terms of joint faulting, the difference in proportions was significantly greater for contraction joints than for expansion joints at the 95 percent level of confidence. On the other hand, the average vertical differentials for all joint types, including approach and leave joints, ranged between 0.01 and 0.18 in. for the field data from the instrumented repairs without indicating any significant difference in relative severity (depth) of joint faulting between contraction and expansion joints. In other words, more contraction joints than expansion joints exhibited faulting, but the amount of depth of faulting was about the same for both.

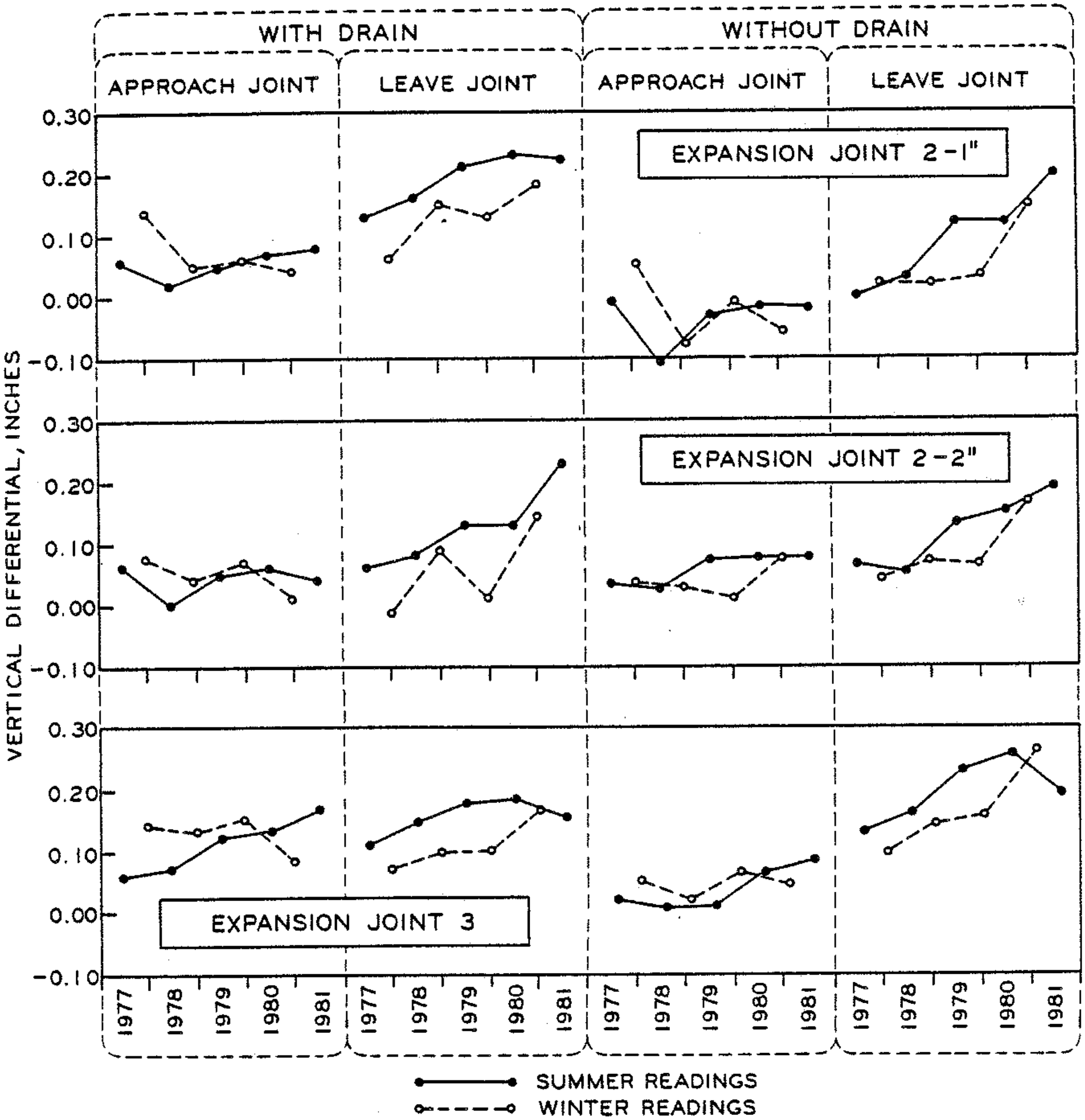


Figure 11. Average seasonal and yearly vertical joint movement of experimental expansion joints at repairs.

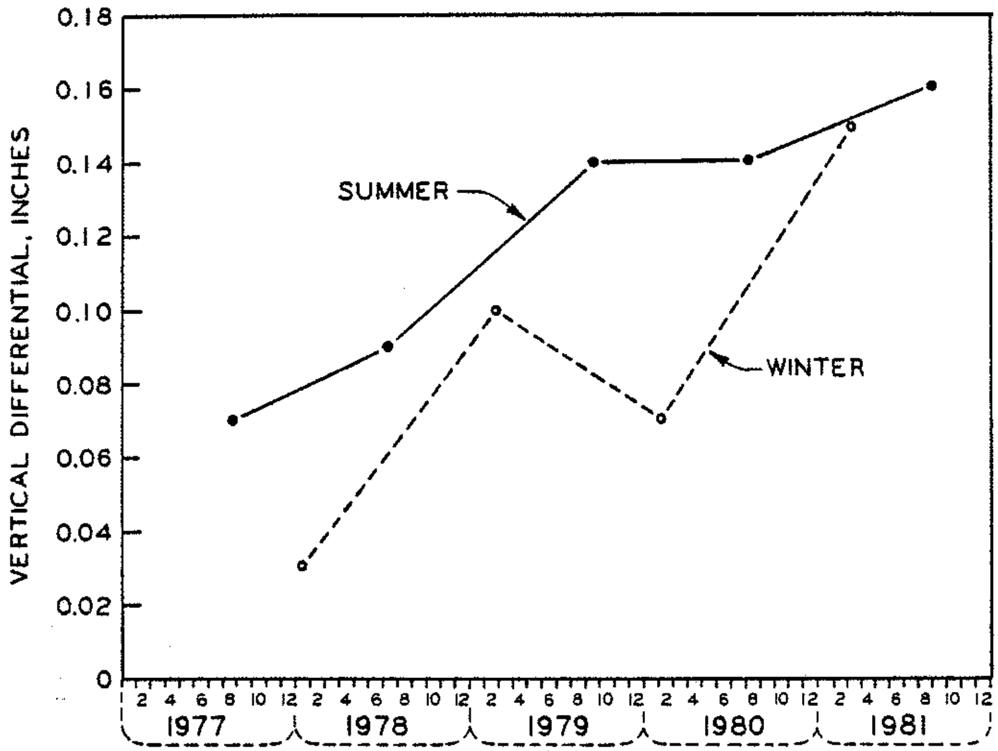


Figure 12. Overall vertical differential at leave joint (L_j) at repairs increasing at the average rate of 0.03 in./year.

Distress Types

The 120 cast-in-place instrumented repairs selected to monitor horizontal joint movements were also visually inspected for such major distresses as joint spalling, cracking, and joint faulting. Besides these three major distresses, joint sealer damage (extrusion, stripping, or missing) was considered a potentially harmful distress and therefore included in all visual inspections. Similar to the classification of joint movements discussed previously, the repair performance data were separated into two main categories: those joint repairs with shoulder drains and those without drains, so that each joint repair type could provide four different groups for detailed data treatment. For each distress type, the relative joint deterioration was estimated as the proportion defective within grouped repairs (sample size) and expressed as a percentage. The estimated differences in proportions were tested by using the 95 to 99 percent probability levels. Figure 13 summarizes the results of the 1982 visual condition survey for the 120 instrumented repairs.

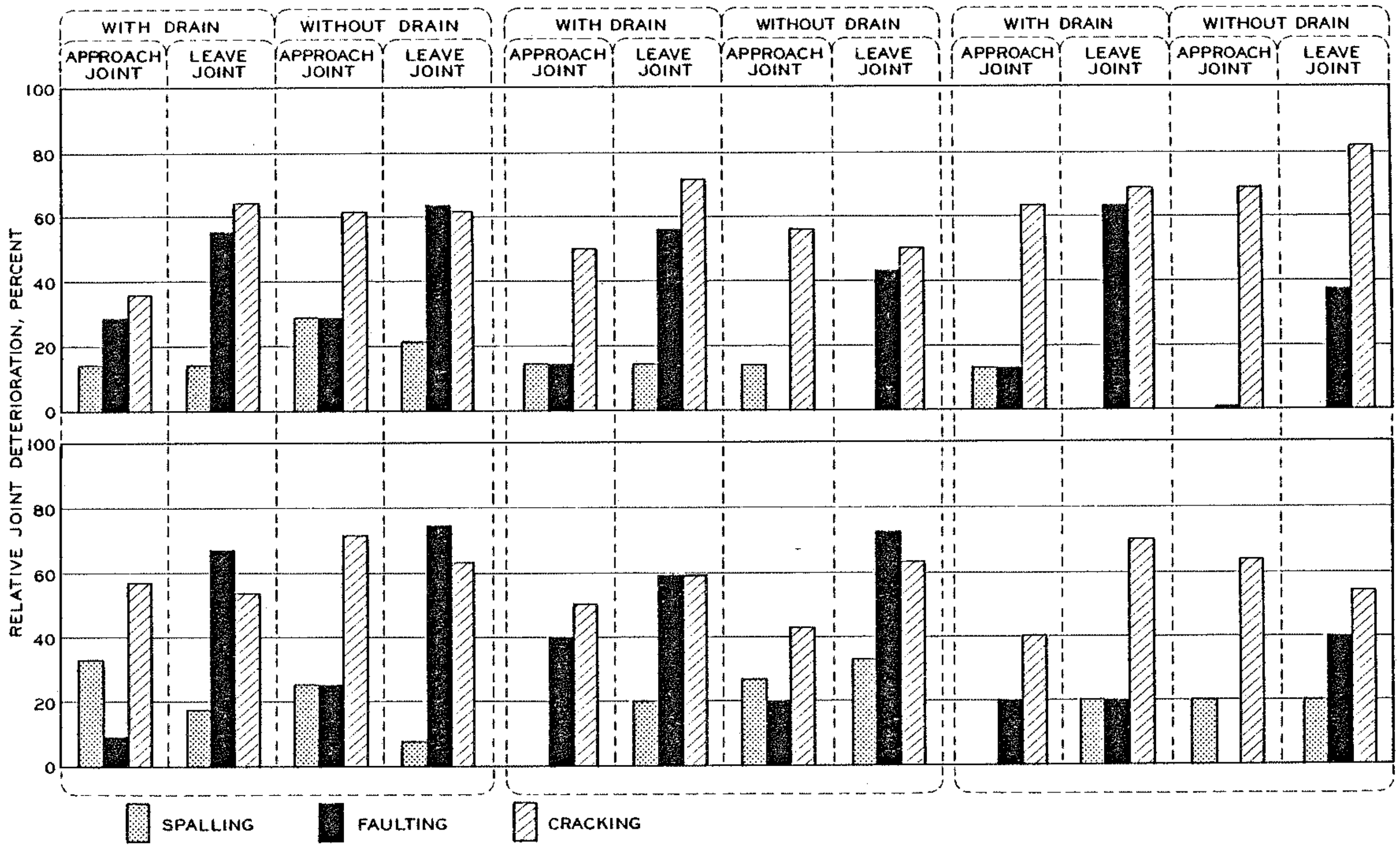


Figure 13. Relative joint deterioration at 120 instrumented repairs based on visual inspection.

After five years of repaired pavement service, the joint repairs have developed visible distress as follows:

Joint Spalling — Joint spalling is the disintegration of the slab edges within 2 ft along the joint groove. It may result from one or more factors such as D-cracking in the concrete, infiltration of incompressibles, improper joint design and fillers, incompressibles in the joint seal reservoir, improper joint forming practice, or water accumulation and freeze-thaw cycles in the joint.

Spalling, at least 4 in. away from the joint and 1 ft or more along the joint groove, was visually estimated and recorded in the January 1982 survey. Figure 13 shows the relative proportion, in percentages, of spalled joints for each of the six joint types being compared.

The spalling data from the 120 instrumented repairs collected visually in the 1982 joint survey are summarized as follows:

1) The presence (WD) or absence (ND) of shoulder drains at repairs did not show any significant effect on the proportions of joint spalling among the 24 grouped joint repairs evaluated. The observed difference in proportions of spalling was merely attributed to chance or random variations at the 99 percent level.

2) Joint spalling was found in seven out of the 54 expansion repair joints (approximately 13 percent), and 13 out of the 66 contraction repair joints (approximately 20 percent). The observed difference between these two proportions would be expected by chance at the 95 percent level and therefore not statistically significant.

Transverse Cracking — Transverse cracking is a surface break approximately at right angles to the pavement centerline. It occurs when tensile stresses in the concrete slab exceed the concrete strength. Thus, loss of support under the slab, traffic loading, restrained shrinkage, warping or curling stresses, and restrained volume changes due to friction, moisture and temperature differentials are factors that can cause transverse cracking. However, in the case of cast-in-place repairs, traffic loading early in the life of the concrete, prior to total strength attainment, is a significant factor.

Transverse cracks at least 1/8 in. wide and located within 3 ft of either side of joints at repairs were considered as joint related, counted and recorded in the January 1982 survey.

Figure 13 shows the relative proportion, in percentage, of cracked repairs among the six different joint repair designs, with and without shoulder drains, at the 95 percent level.

The results of the data collected into the 1982 visual joint survey are summarized as follows:

1) There was no significant difference in the proportions of cracked repairs among the six different joint repair designs, with and without shoulder drains, at the 95 percent level.

2) Cracked repairs were noted in 34 out of the 54 expansion repair joints (63 percent), and 37 out of the 66 contraction repair joints (56 percent). This difference in crack proportions was far from significant at the 95 percent level.

Joint Faulting — In addition to joint faulting determined from the measured vertical movements, faulting across the approach and leave joints at the instrumented repairs were also visually inspected on a joint-by-joint basis and estimated between 1/4 and 1 in. in depth. Figure 13 shows the relative proportion, in percent, of joint faulting visually estimated from the 120 locations. The results of the 1982 visual faulting survey were similar to those found from the measured vertical movement data with one exception; there was no statistically significant difference in frequency of visually discernible faulting between contraction and expansion joints.

Sealer Damage — Joint sealer damage occurs when the sealer loses bond, is extended beyond its capabilities, extruded or extracted, and therefore becomes incapable of preventing infiltration of water, deicing solutions, and incompressible solids into the joint. Typical examples of joint sealer damage are: joint filler extrusion and stripping, hard and brittle sealer (causes cracking when elongated), lack of adhesion to the joint edges, lack of sufficient sealant in the joint, incompatible joint material, improper expansion filler size or application. Since most poured sealers rarely exceeded three years of maintenance-free life in 99-ft slab lengths, joints would have to have been resealed periodically to ensure longer service life of the seals in the original jointed pavement. Seals applied to the repairs were designed more conservatively and contained improved materials.

To determine whether neoprene seals showed better physical appearance in contraction joint T_4 than hot-poured seals placed in contraction joint T_5, joint sealer materials were visually inspected on a joint-by-joint basis and sealer damage estimated and recorded in the January 1982 joint repair survey. In general, the seal damage data may be summarized as follows:

1) All 25 instrumented contraction repair joints (T_4) with preformed neoprene filler showed 100 percent better performance than the 20 instrumented contraction repair joints (T_5) with hot-poured sealer. On the other hand, all 50 instrumented contraction and expansion repair joints with the cold and hot-poured seal showed various types of sealer failure such as loss of seal, adhesion or cohesion failures without statistically indicating better performance of one poured sealer type over the other.

2) Apparently, the presence or absence of shoulder drains at joint repairs showed no distinctive effect on sealer damage among the 100 instrumented, seal-treated repairs evaluated.

Conclusions

In this limited, experimental concrete patching project, an attempt was made to evaluate the relative performance of six different types of joint repairs in a badly distressed, 19-year old rigid pavement. Relative performance was estimated with respect to horizontal and vertical (faulting) joint movements and joint deterioration such as spalling, surface cracking, and joint sealer damage. The following conclusions can be drawn from this experiment with field data collected from the 120 instrumented repairs.

1) French drains adjacent to repair slabs showed no benefits.

2) Joint faulting occurred at all repairs, regardless of the type of joint detail.

3) About 60 percent of the repair slabs or the adjacent 3 ft of pavement on either side suffer cracking before reaching five years of age.

4) No significant association between pavement growth and joint seal performance at repairs was statistically established.

5) Overall, contraction joints (T_1, T_4, T_5) under study showed progressive changes in width (opening and closing) that might eventually reach a permanent average joint opening between 0.06 and 0.12 in. (Fig. 6).

6) Neoprene seals performed significantly better than cold-poured seals in expansion joints. However, the initial cost was high and some failed by coming out of the joint. In general, they do not seem to be worth the extra cost for use in repair of old pavements where poured sealants were used in the original pavement.

7) Due to the load deformation characteristics of the expansion filler material the progressive closing rate of the T_{2-2}" expansion joint was higher than the other two expansion joints, where only 1 in. of filler was used. Closing rate for the 2-in. joint averaged 0.13 in./year for T_{2-2}" against 0.08 in./year for T_{2-1}" and T_3 (Figs. 8 and 9). Expansion joint repairs were randomly located throughout the experimental project.

8) Joint faulting was significantly greater for leave joints (L_j) than that for approach joints (A_j) at the 99 percent level of confidence. Furthermore, at the leave joints (L_j), the vertical differential trend continued increasing at the average rate of 0.03 in./year.

9) Faulted joints were instrumentally recorded at significantly greater numbers of locations for contraction joints than for expansion joints.

10) Average vertical differentials at instrumented repairs ranged between 0.01 and 0.18 in. without showing any significant difference in relative severity or depth of joint faulting at the 95 percent level between contraction and expansion joints.

11) The 1982 visual joint repair survey of the 120 instrumented joint repairs disclosed the following:

a) The leave joints showed a significantly greater proportion of faulted joints than did the approach joints at repairs, well beyond the 99 percent confidence level.

b) There was no statistically significant difference in the occurrence of visually discernible faulting between contraction and expansion joints.

c) With respect to relative severity or depth of joint faulting between contraction and expansion joints at repairs, the results did not show any significant difference at the 95 percent level.

d) There was no significant difference in joint spalling between expansion and contraction joints.

e) There was no significant difference in repair slab cracking between repairs with expansion joints and those with contraction joints.

f) All 25 instrumented contraction repair joints (T_4) with preformed neoprene filler showed 100 percent better performance than the 20 instrumented contraction repair joints (T_5) with hot-poured sealer. On the other hand, all 50 instrumented contraction and expansion repair joints with the cold and hot-poured seal showed various types of sealer failure such as loss of seal, adhesion or cohesion failures without statistically indicating better performance of one poured sealer type over the other.

g) Apparently, the presence or absence of shoulder drains at joint repairs showed no distinctive effect on sealer damage among the 100 instrumented, seal-treated repairs evaluated.

Recommendations

1) Repairs without load transfer should not be used for locations having significant volumes of commercial traffic (more than about 150 trucks per day).

2) French drains of the type used on this project should not be included in future projects.

3) Neoprene seals should not be used in the repair of older pavements having baseplates and poured sealants in the original installation.

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APPENDIX A

PAVEMENT PATCHING INSTRUMENTATION

Station	Joint Type (T)*	Patch Size	Patching Area, sq yd
Construction Project 25131 C5			
Southbound			
122+70	4	6 x 24 WD	16
126+70	2-1"	(6 x 12) + (8 x 12)	19
129+70	2-1"	(6 x 12) + (12 x 12) WD	24
148+40	1	8 x 24 WD	21
149+40	3	6 x 24	16
153+25	3	8 x 24 WD	21
185+60	2-1"	6 x 24 WD	16
191+95	2-2"	6 x 24	16
192+95	5	6 x 12 WD	8
193+95	1	6 x 24 WD	16
197+90	4	(8 x 12) + (6 x 12) WD	19
201+85	5	6 x 24 WD	16
202+85	4	6 x 24	16
203+85	1	6 x 24 WD	16
210+80	3	6 x 24	16
224+65	1	6 x 24	16
			272
Construction Project 25131 C3			
Southbound			
1157+75	2-1"	6 x 24	16
1152+80	2-1"	8 x 24 WD	21
1150+80	4	6 x 24 WD	16
1146+85	3	(6 x 12) + (9 x 12)	20
1144+85	1	6 x 24 WD	16
1140+90	3	6 x 24 WD	16
1131+00	4	6 x 24 WD	16
1128+10	1	6 x 24 WD	16
1123+05	5	6 x 24 WD	16
1121+10	4	6 x 24 WD	16
1120+10	2-1"	(8 x 12) + (10 x 12) WD	24
1118+10	4	6 x 24 WD	16
1117+15	1	6 x 24 WD	16
1111+20	5	6 x 24	16
1110+20	1	6 x 24	16
1108+20	4	6 x 24	16
1106+20	3	6 x 48	32
1101+25	5	6 x 36	24
1096+30	4	6 x 12	8
1095+30	1	6 x 24	16
1086+40	2-2"	6 x 36	24
1078+45	2-2"	6 x 36 WD median shoulder	24
1068+55	5	6 x 36	24
1067+55	4	6 x 12	8
1064+55	1	6 x 12	8
1058+60	4	6 x 36 WD	24
1056+65	5	6 x 24	16
1053+65	1	6 x 24	16
1046+75	3	6 x 36 WD	24
1033+90	4	6 x 24	16
1032+90	5	(6 x 12) + (6 x 12) WD	16
1030+95	1	6 x 24	16
1029+00	5	6 x 12	8
1028+00	2-2"	6 x 36	24
969+30	2-2"	6 x 36	24
966+30	3	(6 x 12) + (6 x 12) + (8 x 12) WD	27
958+25	2-2"	6 x 36 WD	24
			2260
Const. Project 25131 C1			
Southbound			
903+05	2-2"	6 x 36	24
890+55	2-2"	6 x 36 WD	24
879+70	5	6 x 24	16
877+70	1	6 x 24	16
871+75	5	6 x 12	8
862+85	4	6 x 24	16
855+90	1	6 x 12	8
851+95	2-2"	(6 x 6) + (6 x 12) + (8 x 12) + (11 x 12)	37
846+00	2-2"	6 x 36 WD	24
			173

Station	Joint Type (T)*	Patch Size	Patching Area, sq yd
Construction Project 25131 C1			
Northbound			
835+10	1	6 x 36 WD median shoulder	24
850+90	5	6 x 12	8
853+85	2-2"	(7 x 12) + (9 x 12) + (16 x 12) WD	43
869+75	3	6 x 36 WD	24
889+75	3	6 x 24	16
893+55	2-1"	6 x 36 WD	24
895+55	4	(8 x 12) + (10 x 12)	24
897+50	5	6 x 12	8
905+40	1	6 x 24	16
913+35	2-1"	6 x 36	24
921+25	1	6 x 24	16
922+25	4	6 x 24	16
923+25	5	6 x 24	16
927+20	1	6 x 24	16
932+15	3	6 x 36 WD	24
933+15	4	6 x 24	16
934+15	5	(6 x 12) + (6 x 12) WD	16
935+15	1	6 x 36 WD	24
940+05	3	6 x 36	24
			379
Construction Project 25131 C3			
Northbound			
952+60	5	6 x 12	8
960+50	1	6 x 12	8
973+35	2-2"	(6 x 12) + (8 x 24) WD median shoulder	29
982+25	4	(6 x 12) + (6 x 12) WD	16
984+25	5	6 x 24	16
997+10	2-2"	(6 x 24) + (8 x 12)	27
1002+05	4	7 x 24	19
1020+20	3	6 x 36 WD	24
1023+20	3	9 x 36	36
1028+10	2-1"	6 x 36 WD median shoulder	24
1037+95	3	(8 x 12) + (6 x 24) WD median shoulder	27
1042+95	4	6 x 12	8
1050+90	5	8 x 24	21
1052+85	1	6 x 24	16
1054+85	4	6 x 24	16
1064+75	3	6 x 36	24
1068+70	2-1"	8 x 36	32
1075+65	4	6 x 12	8
1078+60	5	6 x 12	8
1081+60	4	6 x 12	8
1086+55	3	6 x 36 WD	24
1090+55	3	(6 x 12) + (8 x 12) + (6 x 12)	27
1094+50	4	6 x 24	16
1096+50	5	8 x 24	21
1131+96	2-2"	6 x 24 WD median shoulder	16
1137+90	2-1"	6 x 24	16
1149+70	3	7 x 24 WD	19
1153+65	3	7 x 24	19
1164+50	4	6 x 24 WD	16
			549
Construction Project 25131 C5			
Northbound			
227+30	2-1"	6 x 24	16
215+90	3	8 x 24 WD	21
203+90	3	10 x 24	27
199+00	2-1"	6 x 24 WD	16
189+30	4	8 x 24 WD	21
167+40	2-2"	6 x 24	16
142+15	2-2"	6 x 24 WD	16
126+85	2-1"	6 x 24	16
123+10	3	24 x 24 WD	64
119+00	3	6 x 24	16
			229

* Type 1 - Concrete plug, no seal

Type 2 - Cold-poured seal, expansion joint with 1 in. (Type 2-1") or 2 in. fiber joint filler (Type 2-2")

Type 3 - Preformed neoprene seal, 1-5/8 in. seal in 1-3/8 in. ± 1/16 in. groove 2-1/2 in. deep, 1 in. expansion joint with 1 in. fiber joint filler.

Type 4 - Preformed neoprene seal, 1-1/4 in. seal in 1/2 in. ± 1/16 in. groove 2-1/2 in. deep.

Type 5 - Hot-poured Super Seal 444, 1 x 1-1/2 in. groove, nominal 1 x 1 in. seal.

APPENDIX B

MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION FOR CONCRETE PAVEMENT PATCHING

a. Description.-This specification covers the mixing, placing, and curing of a 9.0-sack fast-setting concrete to be used for cast-in-place repairs of pavements which will be opened to traffic when the concrete has attained a flexural strength of 300 psi.

This work shall be performed in accordance with the 1973 Standard Specifications unless otherwise provided herein.

b. Materials.-The materials shall meet the requirements specified in the designated Sections of the 1973 Standard Specifications, except as otherwise provided herein.

Base Course Aggregate, 22A, 22B, 24A	8.02
Cement, Type 1A, Type 1*	8.01
Coarse Aggregate 6A	8.02
Fine Aggregate 2NS	8.02
Steel Reinforcement	8.05
Water	8.11
Joint Materials	8.16
Admixtures and Curing Materials	8.24

* Type 1A cement shall be used if available.

The joint materials required will be fiber joint fillers, cold applied concrete joint sealers, preformed neoprene seal, or Hot Poured Super Seal 444.

c. Temperature Limitations.-Concrete shall not be placed on a frozen subgrade nor when the air temperature falls below 25F.

d. Pavement Removal.-The size of the area to be removed shall be as specified on the plans, in the proposal, or as directed by the Engineer. The sawing operations shall not precede the removal operations by more than 2 weeks, unless otherwise permitted by the Engineer. Full depth saw cuts shall be made with a diamond blade in accordance with the sawing diagram. Concrete between narrowly spaced saw cuts shall be removed with air hammers and hand tools. Lifting devices shall be installed and the slab lifted out without disturbing the aggregate base. One such lifting device which may be used is detailed on the attached drawing. Other methods of removing the pavement which will not disturb the base may be used if approved by the Engineer.

The area shall be cleaned out with hand tools.

A low base condition which existed prior to removal of the concrete shall be corrected by adding additional base course aggregate and thoroughly compacting to proper elevation.

The removal of the distressed concrete, the placement and compaction of any subbase required, and the form setting shall be completed prior to the arrival of the concrete. The placement and compaction of this subbase material shall be accomplished in accordance with the requirements specified under Subsection 3.01.07-b, if directed by the Engineer.

Sawing operations may not be conducted during or under the threat of freezing temperatures, when there is a possibility of the water freezing and presenting a hazard to adjacent traffic.

e. Forming Patch.-Forms shall be oiled prior to concrete placement.

1. First Pour.-The first pour of a 2-lane roadway repair shall be formed in accordance with the requirements shown on the plans for the type of repair involved.

The fiber filler, when required for the joint, shall be placed against the existing pavement at each end of the patch.

Where the first pour is longer than the second pour, fiber filler shall be placed in the longitudinal joint against portions of the adjacent lane which will remain in place.

Nominal 1-inch or 2-inch form lumber, or equivalent, shall be placed in the longitudinal joint against portions of the adjacent lane which will be removed.

Nominal 2-inch form lumber, or equivalent, shall be used for forming the pavement edge adjacent to the shoulder.

2. Second Pour.-The center form shall be removed; nominal 2-inch form lumber, or equivalent, placed at the shoulder edge; and fiber filler placed at each end of the patch when required.

Where the second pour is longer than the first pour, the fiber filler shall be placed in the longitudinal joint against portions of the original slabs which were left in place.

f. Concrete Proportioning.-The concrete shall contain 6.5 ± 1.5 percent entrained air and shall be proportioned as follows:

Material	Proportions, lb/cu yd of Mix
Cement	846
Water* (including moisture in aggregate)	315 (approx.)
Fine Aggregate, dry weight**	1017
Coarse Aggregate, dry weight**	1656
Calcium Chloride*	Table 3.06-1

* Calcium chloride shall be added at the job site for all patches, except those designated by the Engineer to be closed to traffic overnight.

  For ready-mixed concrete, the initial water shall be adjusted to result in a slump of 2 to 4 inches immediately prior to adding the flake chloride.

  For continuous-mixed concrete, the chloride shall be added in solution form at the time of mixing and the quantity of water in the solution shall be considered in determining the amount of water to be used in the mixture to obtain a concrete consistency of 2 to 4 inches.

** The aggregate weights are based on a specific gravity of 2.65 and will be adjusted by the Engineer if the materials used differ from this value.

Table 3.06-1 - Quantities of Chloride to be Added According to Temperature and Type of Chloride Used

Quantity of Calcium Chloride to be Used		Ambient Temperature		
		Below 45 F	45 F to 65 F	Above 65 F
Ready-Mixed Concrete, lb/cu yd		36	27	18
Continuous-Mixed Concrete	Job-Mixed Solution, qt/cu yd*	36	27	18
	Premixed Solution, gal/cu yd**	7.2	5.4	3.6

* Job-mixed solutions shall contain 1.0 lb/qt of Type 1 calcium chloride or 0.8 lb/qt of Type 2 calcium chloride.

** Premixed solutions shall meet the requirements of Subsection 8.24.02 of the 1973 Standard Specifications.

g. Mixing.

1. General.-When the temperature of the air is less than 45 F, the concrete temperature shall be at least 60 F.

The initial set of a mix containing the prescribed amount of calcium chloride and having a slump of 2 to 4 inches before addition of the calcium chloride, will occur approximately 15 to 20 minutes after addition of the calcium chloride.

2. Ready-Mixed Concrete.-Ready-mixed concrete shall be supplied to the job site in a completely mixed condition except for the chloride additive. The concrete shall have a slump of 2 to 4 inches. If necessary, water may be added to bring the consistency within the specified range. Type 1 calcium chloride shall then be added to the concrete mixture at the job site. The chloride shall be added in the amounts indicated in Table 3.06-1 in accordance with the ambient temperature. The chloride shall be free of lumps. Flake chloride on the inside of the mixer opening and fins may be rinsed off with water; a gallon should be sufficient but in any case, not more than 2 gallons will be permitted. After addition of the chloride, the concrete shall be mixed in the truck mixer for an additional 20 revolutions at mixing speed before discharging the concrete.

3. Continuous-Mixed Concrete.-Concrete produced by volumetric batching and continuous mixing in accordance with ASTM C 685 may be furnished, provided that a satisfactory product, as determined by the Engineer, is obtained. The equipment shall have sufficient capacity to dispense the quantity of calcium chloride admixture required for this work and insure completed patches within the short setting time.

h. Placement of Concrete.-The concrete shall be placed on the same day that the old pavement is removed.

Pavement reinforcement shall be placed in all patches having a length equal to or longer than 10 feet. Pavement reinforcement shall be supported during concrete placement by the use of bar chairs or other means approved by the Engineer.

Each repair shall be poured in one continuous full-depth operation. The concrete shall be consolidated in place by use of an immersion type vibrator and the surface shall be finished by screeding, floating, and brooming. The placement operations shall be scheduled in such manner that each repair is completed within 20 minutes after addition of the calcium chloride.

Test beams shall be cast as directed by the Engineer.

When tests indicate that a modulus of rupture of 300 psi has been attained, the Contractor will be permitted to open the concrete pavement patch to traffic.

If tests indicate that a modulus of rupture of 300 psi cannot be attained under the prescribed temperature and calcium chloride addition rate, adjustment in the amount of calcium chloride added to each cubic yard shall be made to attain the required strength for the next day's repairs within the allowed lane closure time.

i. Curing.-Concrete curing compound shall be applied as soon as the concrete surface has set sufficiently to apply the curing agent without damage.

When the temperature is below 65 F, insulation blankets having a minimum thickness of 2 inches shall be placed over the new concrete as soon as the curing compound has dried sufficiently to allow the blanket to be placed without damage to the curing membrane. Edges and seams in the blanket shall be secured to prevent penetration of wind. Test beams shall be cured the same as the new patch. Curing blankets may be removed when the concrete has attained a flexural strength of 300 psi.

j. Opening to Traffic.-The patches may be opened to traffic when the new concrete has attained a flexural strength of 300 psi, usually within 4 to 7 hours after placement.

k. Joint Sealant "Super Seal 444".

1. Where called for, the joint shall be sealed with hot-poured elastomeric type joint sealant "Super Seal 444" as manufactured by Superior Products Company, Inc. 822-47th Avenue, Oakland, California, 94601. The joint sealant shall not be exposed to temperatures higher than 100 F in either open or closed storage.

2. The equipment for heating the Super Seal 444 material shall be a kettle or melter constructed as a double boiler, with the space between the inner and outer shells filled with oil or other heat transfer medium. Positive temperature control, mechanical agitation, and recirculating pumps shall be provided.

3. The joints to be filled with Super Seal 444 shall be prepared and sealed in accordance with the following requirements:

The material shall be heated in a kettle or melter meeting the requirements as specified above. Direct heating shall not be used. The material shall not be heated to a higher temperature or for a longer time than recommended by the manufacturer.

Pavement joints shall be dry and free of dust and foreign material. The sidewalls of the joint space to be sealed shall be sandblasted, blown clean with high pressure air, and sealed by use of the melter-applicator described above.

A bond breaker or back-up material shall be placed in the bottom of the joint groove to control the depth of sealant. Cotton jute upholstery cord or other material as recommended by the manufacturer and approved by the Engineer shall be used. The diameter shall be sufficient to assure that it remains securely in place to prevent sagging or floating when the sealant is poured.

Joints shall be filled in a neat workmanlike manner to within 1/8 inch to 1/4 inch below the pavement surface.

l. Method of Measurement.-Concrete Pavement Patching Type 1, Type 2, Type 3, Type 4, and Type 5 will be measured by area in square yards. Longitudinal measurements for area will be made along the actual surface of the roadway. Transverse measurement shall be the dimensions shown on the plans or by authorization.

Tolerance in Pavement Thickness.-Before final acceptance of the pavement patches, the Engineer may direct that the thickness of the patches be determined by coring units of pavement as specified under Concrete Pavement, 4.14.27.

m. Basis of Payment.-The completed work as measured for CONCRETE PAVEMENT PATCHING TYPE 1, TYPE 2, TYPE 3, TYPE 4, AND TYPE 5, will be paid for at the contract unit prices for the following contract items (pay items), except that pavement patches which have been cored and found to be deficient in depth will be paid for at an adjusted unit price as provided under Concrete Pavement, 4.14.

Pay Item	Pay Unit
Concrete Pavement Patching Type 1	sq yd
Concrete Pavement Patching Type 2	sq yd
Concrete Pavement Patching Type 3	sq yd
Concrete Pavement Patching Type 4	sq yd
Concrete Pavement Patching Type 5	sq yd

Payment for Concrete Pavement Patching Types 1, 2, 3, 4, or 5 includes payment for furnishing and placing steel reinforcement; furnishing, placing, finishing, and curing the concrete patch, furnishing and placing joint materials; any work of part-width construction; and any work of final trim and cleanup.

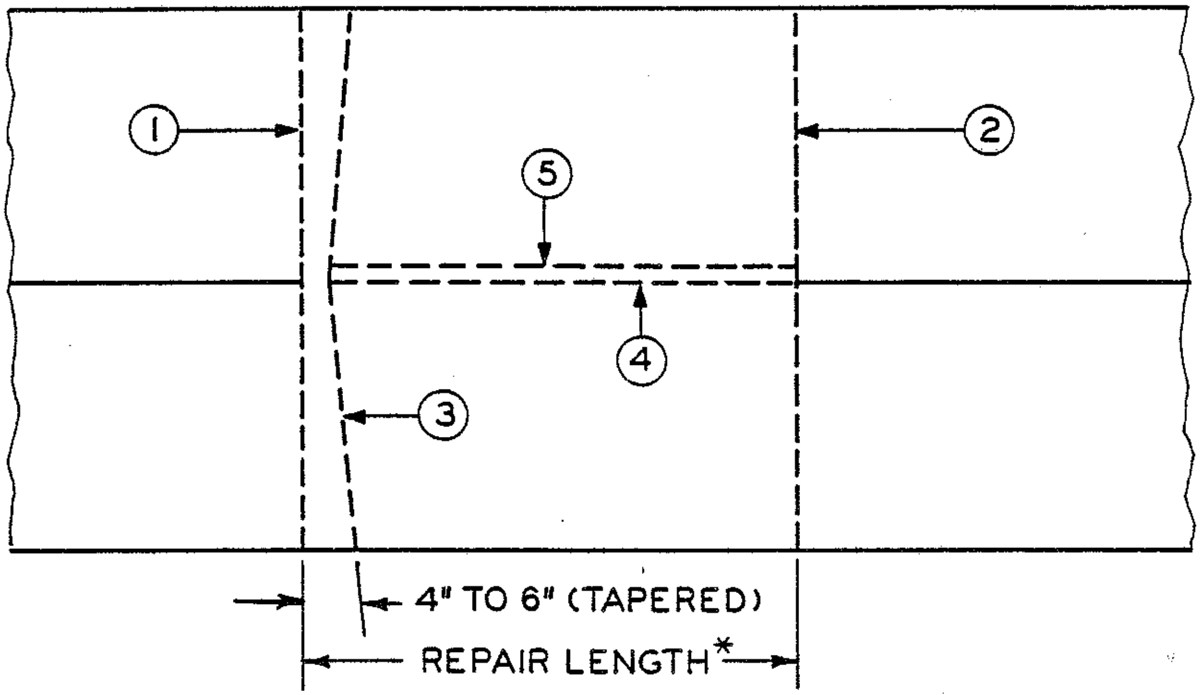
Payment for removing old pavement (Patching) will be paid for as specified under Section 2.07 of the 1973 Standard Specifications.

Payment for additional aggregate required for correction of low base conditions which existed prior to pavement removal will be paid for as Aggregate - Base Patching as specified under Section 3.03 of the 1973 Standard Specifications.

Calcium chloride used for base stabilization or as a concrete admixture will not be paid for separately.

SAWING DIAGRAM

All Sawcuts To Be Full-Depth



* Repair length as specified in the log of work or as directed by the Engineer.

(1) (2) These sawcuts shall be perpendicular to the edge of the roadway. If the repair is on a curve the cuts shall be perpendicular to a straight line extended between the limits of the repair at the edge of the roadway.

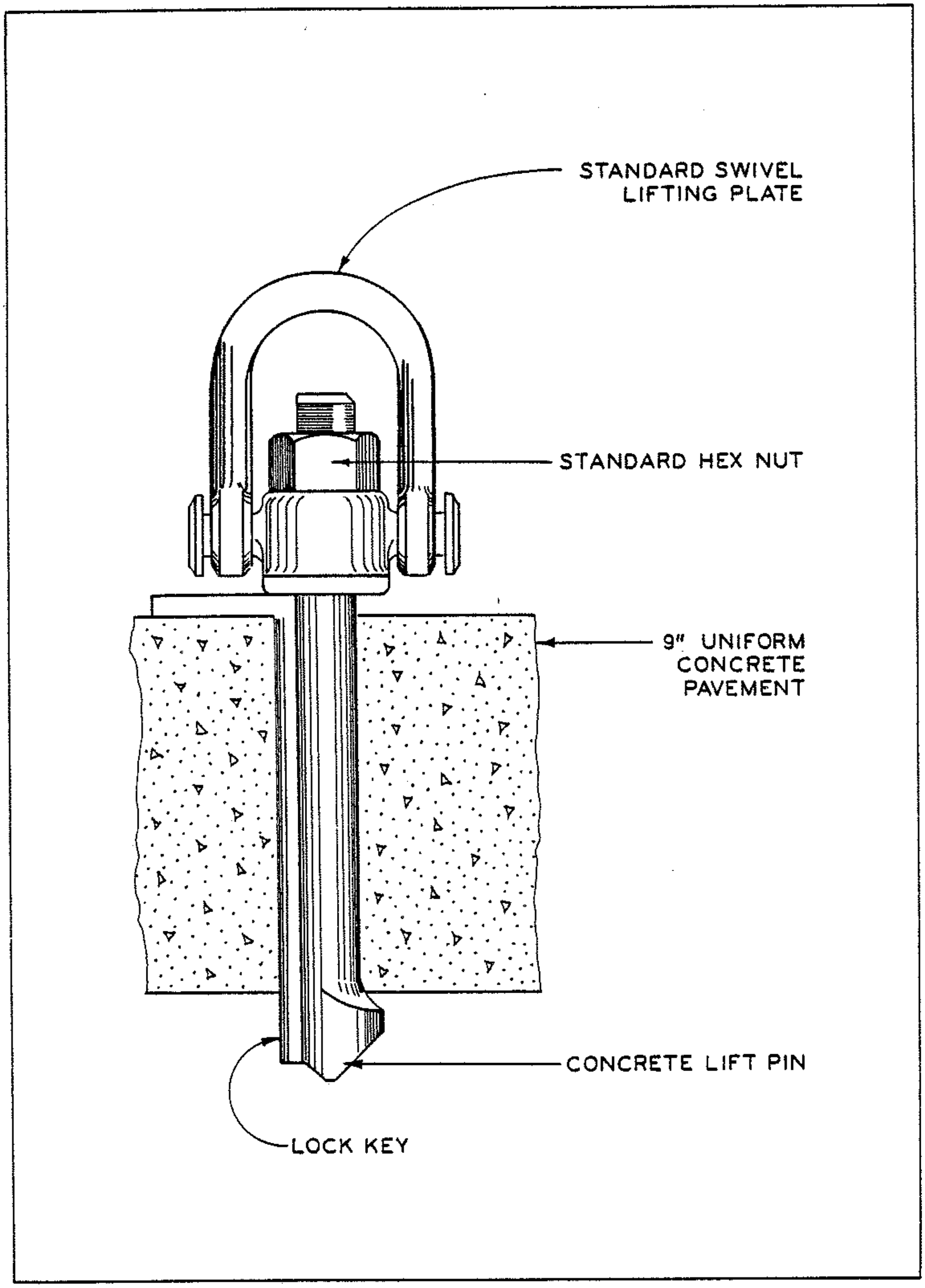
(3) This cut is made to facilitate opening a trench across the slab to relieve compression in the pavement prior to lifting out the failed areas.

(4) This cut is made between lanes, between a lane and a curb, and between a lane and a ramp.

(5) This cut is made for the reasons given in 3 except for facilitating pressure relief in the transverse direction. The cut can be omitted if there are no adjacent lanes, curbs or ramps.

Additional sawcuts may be made inside the repair limits at the contractor's option.

The specified distance between sawcuts (1) and (2) shall be held within a tolerance of -0 + 1/2 in. in 24 ft.


STANDARD SWIVEL LIFTING PLATE
STANDARD HEX NUT
9" UNIFORM CONCRETE PAVEMENT
CONCRETE LIFT PIN
LOCK KEY

APPENDIX C

TABULATION OF BIDS

I 75 Joint Repair, Genesee County

Item of Work	Code	Quantity	Unit	Engineer's Estimate		Sargent Contracting Company Saginaw, Michigan - 262		Kelcris Corporation Farmington Twp., Michigan - 323		John G. Yerington Co., et al Benton Harbor, Michigan - 561	
						Unit Price	Amount	Unit Price	Amount	Unit Price	Amount
09373A	*	*	*								
Mjt 25131	*	*	*								
Remove old pavement (patching)	2070017	5647	syd	22.00	124,234.00	17.00	95,999.00	20.25	114,351.75	25.00	141,175.00
Concrete Pavement Patching Type I	3067000	973	syd	25.00	24,325.00	20.00	19,460.00	19.70	19,168.10	19.00	18,487.00
Concrete Pavement Patching Type II	3067001	2275	syd	26.50	60,287.50	23.00	52,325.00	26.15	59,491.25	22.00	50,050.00
Concrete Pavement Patching Type III	3067002	580	syd	32.00	18,560.00	31.00	17,980.00	36.25	21,025.00	30.00	17,400.00
Concrete Pavement Patching Type IV	3067003	955	syd	30.00	28,650.00	24.00	22,920.00	28.60	27,313.00	24.00	22,920.00
Concrete Pavement Patching Type V	3067004	864	syd	27.50	23,760.00	21.00	18,144.00	24.80	21,427.20	20.00	17,280.00
Shoulder drain	6147000	124	ea	30.00	3,720.00	80.00	9,920.00	80.00	9,920.00	75.00	9,300.00
Lighted arrow, Type A - furnished	6310011	2	ea	750.00	1,500.00	2,500.00	5,000.00	1,000.00	2,000.00	500.00	1,000.00
Lighted arrow, Type A - operated	6310012	2	ea	500.00	1,000.00	750.00	1,500.00	250.00	500.00	750.00	1,500.00
Type II barricade - lighted	6310018	146	ea	40.00	5,840.00	20.00	2,920.00	1.00	146.00	45.00	6,570.00
Sign, Type IIB temporary	6310036	132	sft	7.50	990.00	10.00	1,320.00	15.00	1,980.00	4.00	528.00
Mobilization	6230001	1	ls	1,000.00	1,000.00	10,000.00	10,000.00	1,000.00	1,000.00	2,000.00	2,000.00
Minor traffic devices	6310054	1	ls	3,000.00	3,000.00	100.00	100.00	9,600.00	9,600.00	4,000.00	4,000.00
				TOTAL	$296,866.50	TOTAL	$257,588.00	TOTAL	$287,922.30	TOTAL	$292,210.00