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A FIVE-YEAR EVALUATION OF PREVENTIVE MAINTENANCE CONCEPTS ON JOINTED CONCRETE PAVEMENT (I 75 AND I 696 IN OAKLAND COUNTY)

MICHIGAN DEPARTMENT OF TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

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A five-year evaluation of preventive maintenance concepts on jointed concrete pavement : (I 75 and I 696

A FIVE-YEAR EVALUATION OF PREVENTIVE MAINTENANCE CONCEPTS ON JOINTED CONCRETE PAVEMENT (I 75 AND I 696 IN OAKLAND COUNTY)

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Research Laboratory Section
Testing and Research Division
Research Projects 71 F-122
and 74 F-140
Research Report No. R-1185

Lansing, February 1982

Summary

Experimental jointed concrete pavement preventive maintenance procedures were used on 270 lane miles of I 75 and I 696 during the summer of 1975. These procedures included an objective rating of the condition of the joints, selection of the worst joints for replacement, and the use of pressure relief joints (PRJs) at structures and at least every 850 ft in pavement sections where repairs were not made. Pressure relief was incorporated at repairs as well, by using joint filler alongside the patch.

Results of an earlier experiment showing 10-year experience with PRJs, have been included because of the relevance to the subject at hand.

The expressed intent was to limit or eliminate emergency repairs or extensive contract repairs for a period of at least five years.

The condition of the pavement was recorded periodically, using a pavement survey rating system explained in the Appendix, to determine the effectiveness of the procedures used.

It was determined that the conditions of the projects varied widely with some requiring extensive repairs at present, but that in general the intended five-year interval without emergency or extensive additional repairs, was attained.

Differences in performance under the given traffic situation appear to be related to type of coarse aggregate used in the mix.

Conclusions

1) Pressure relief joints are effective in delaying joint blow-ups in the 99-ft slab reinforced pavements with base plates and poured joint sealants. They are specifically not recommended for neoprene sealed pavements.

2) Preventive maintenance concepts including joint selection based on objective ratings, selective joint replacement, and pressure relief (either using PRJs or expansion filler at repairs), such as used in 1975 on 270 lane miles of I 75 and I 696, have accomplished the intended goal of delaying emergency-type repairs for five or more years. Again, the type of pavement is emphasized as in (1) above.

3) Some of the projects included in the evaluation are in need of extensive additional repairs at the present time.

4) All of the projects evaluated on I 75 and I 696 required numerous repairs before their 20-year design lives were attained.

5) The major causes of the pavement problems encountered are heavy traffic and D-crack susceptible aggregates, coupled with the long-slab, base plated, poured-seal design. Under existing traffic and design, coarse aggregate is the significant variable.

6) Considerable improvements in performance can be attained by using high quality coarse aggregates.

7) Approximately 20 to 25 percent of the old-type PRJs (with ethafoam) now have lost their filler. Pressure relief joints with fillers lost, do not close further due to incompressibles entering, or maintenance-applied bituminous material, and therefore, are no longer effective for their intended purpose.

8) There is no evidence that the addition of pressure relief has had any adverse effect on the pavements. (Note again the cautions under (1) above.)

Recommendations

1) Continue to use preventive maintenance with pressure relief on the old 99-ft slab pavements with base plates and poured joint sealants. Installations should be preceded by a comprehensive survey of the existing pavement and previous repairs.

2) Increase the use of dolomite and certain limestones known to be resistant to D-cracking, in new construction; use dolomite especially on those projects requiring long-term performance under heavy traffic.

3) Reduce the maximum size of the coarse aggregate used (to 3/4 in.) if they are not of the above mentioned premium types.

4) Continue priority research in identification of deleterious aggregates and methods of improvement.

5) Apply the smaller (3/4 in. or less) maximum size of coarse aggregates in all recycling of pavements that show signs of D-cracking.

Background Information

During the late 1960's and early 70's, Michigan experienced problems with joint failures and blow-ups on many miles of portland cement concrete (PCC) pavements. This was caused by deterioration of the joint faces and infiltration of incompressible materials that caused high pressures on the deteriorated joints when spring moisture and higher temperatures caused the slabs to expand. Numerous blow-ups caused traffic problems, and emergency repairs became quite expensive.

Based on the results of earlier experimental work, recommendations were made in 1971, concerning preventive maintenance of pavements to remove and replace the worst joints while providing some additional expansion space to relieve the compressive stress applied to the remaining joints. It appeared at that time that such treatment had a reasonable probability of eliminating or greatly reducing emergency repairs for a period of several years, although regular patrol patching still would be required.

During approval of the first major preventive maintenance projects on I 75 and I 696, G. J. McCarthy, Deputy Director for Highways, instructed the Research Laboratory to monitor the installation and performance of the repairs, to determine whether the intended goals were met.

It was intended to repair and apply pressure relief in such a way as to achieve five years of additional service life without emergency repairs or major additional contract repairs. More than five years now have passed since the initial installations on I 75 and I 696. This report is to cover the evaluation of those installations and to terminate the subject research project.

Location

The evaluation covered pavements on 11 construction projects on 43 miles of I 75, from Sprague Ave (just north of I 696) north to the Oakland-Genesee County line; and two construction projects on eight miles of I 696 between I 96 and Telegraph Rd (US 24) (Fig. 1). In total, this includes 270 lane miles of jointed PCC pavement, all of which is the older design with 99-ft slab lengths, base plates, and poured joint sealants. All of the projects were paved in 1962 or 1963, according to the records.

Joint Condition Survey Rating System

A pavement rating system that had been developed for previous research projects was modified and used to evaluate the condition of the pave-

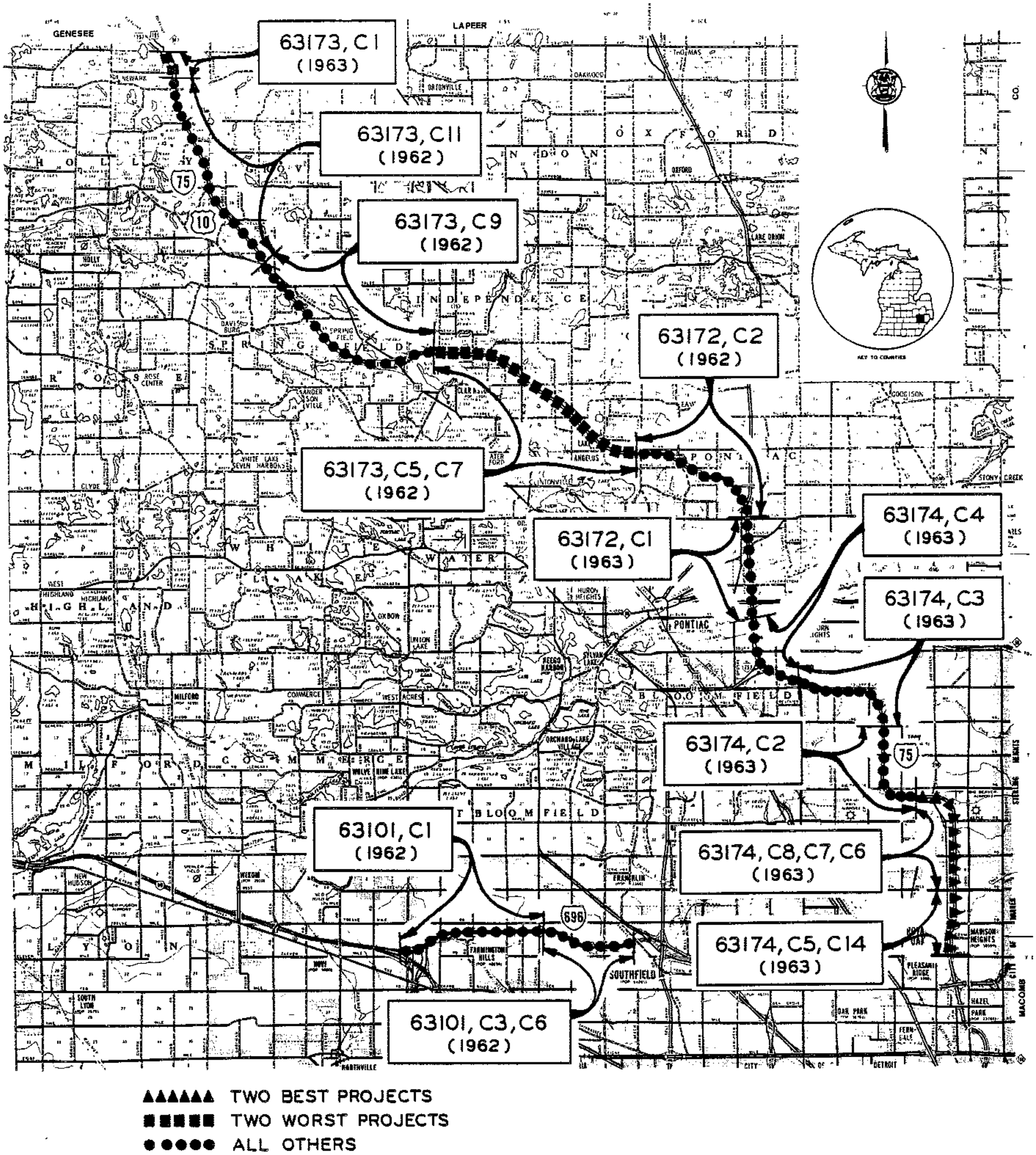


Figure 1. Location of the construction contracts included in the initial preventive maintenance contracts of 1975.

ments before and after repair. This type of system had been shown previously to be related to probability of joint failure. The system rates each joint (or deteriorated crack) by the number of feet along the joint that is spalled to a width of more than 4-in., or is within a corner break. (An explanation of the method is given in the Appendix.) This gives each lane joint a value in lineal feet of deterioration from 0 to 12, depending on the severity at that particular location. Once the initial rating was completed, it was used in the selection of which joints were to be removed, and where to place pressure relief joints (PRJs) in longer stretches of pavement where no repairs were required. In general, 6-ft or more of lane joint deterioration was considered to warrant a lane patch. This warrant figure can be adjusted upward or downward depending upon available funds, but such a rating should be made in order to select the joints for replacement based on an objective system that has been shown to be related to the structural condition of the joint.

Subsequent condition surveys recorded the location, condition, and amount of closure on PRJs; joint repairs were recorded as to estimated size, type of seal, and type of repair (precast, PC; cast-in-place, CIP; or bituminous, bit). Mid-slab cracks were noted in later surveys if they were 'working' and/or showed at least 1 ft of spall. Additional details are given in the "selection procedure for joints at repairs for preventive maintenance projects," in the Appendix. This procedure was initiated on earlier research projects, and was modified for use on this particular project. It was found to be a useful tool for use in selecting the types and locations for the various treatments for the pavement, and in conjunction with the rating system gives a reasonable procedure for use in design of pavement repair projects.

Pressure Relief

An experimental PRJ installation with variable spacing had been made on US 23 in 1971. Results of that work were used to establish the maximum distance between pressure relief joints for the preventive maintenance projects. The maximum interval for pressure relief (either along with a repair or in a PRJ if no repairs were needed), was established as 850 ft. This interval seems to have been reasonable for the range of pavement condition encountered in the preventive maintenance projects.

Figure 2 shows the data from the experimental installation on US 23, indicating the rate at which the pavement utilizes the additional expansion space provided. It was noted from this project that mid-slab fractures tend to open and collect incompressibles quite rapidly, since the load transfer dowels at joints make it easier to pull open a crack than to open a joint.

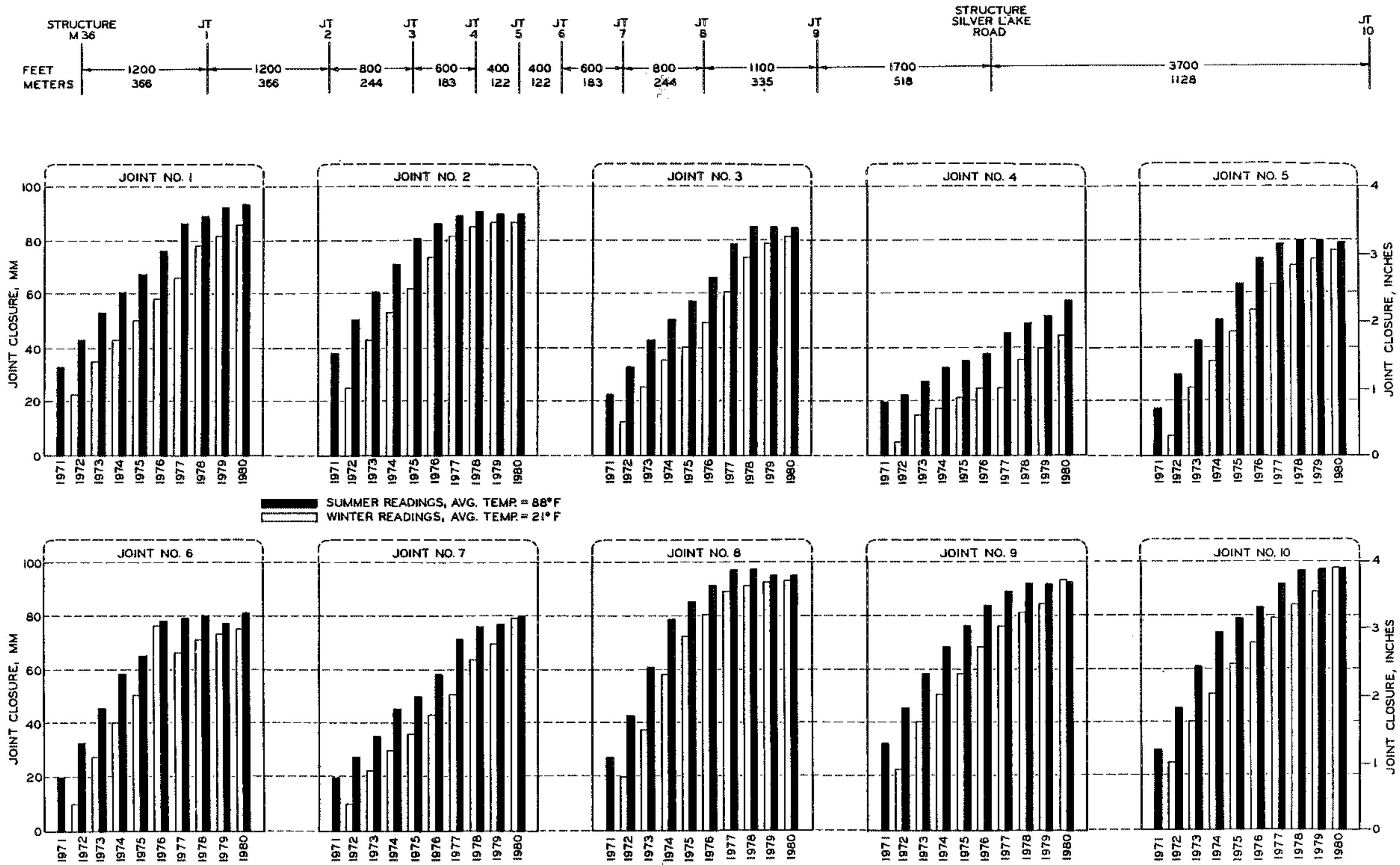


Figure 2. Location of pressure relief joints and total closure (US 23).

However, most adjacent joints do tend to open more and more as time goes on. Once open, the cracks and joints collect incompressible materials that prevent them from reclosing, thereby using up the extra space that has been provided, and forcing the PRJ (or expansion space at a repair) ever more tightly closed until all available compression space has been utilized. The foam filler in the PRJ allows the joint to open during cooler weather without allowing incompressible material to enter, so that the PRJ can close again the next summer. Similarly, the seal in an expansion joint at a repair helps to eliminate incompressibles for the same purpose.

The slow readjustment that takes place in a pressure relieved pavement, allows the relief of compressive forces that otherwise would result in the crushing of deteriorated joints. The preventive maintenance concept of removing the worst joints along with pressure relief, allows the pavement to function a few more years without disruptive emergency type joint failures. The figure shows that most of the space provided by the PRJs on US 23 was used up during the first six or seven years. However, the more closely spaced joints have been effective in eliminating blow-ups from the area during the approximately 10-year period that they have been in service. An adjacent control section without pressure relief continued to deteriorate as usual.

During the construction of the preventive maintenance repairs, 16 PRJs on I 75 and 10 on I 696 were instrumented so that measurements could be made on the rate of closure. Spacing between pressure relief locations was 850 ft maximum, with some of the relief provided at repairs. Figure 3 shows the amount of closure that has occurred on the instrumented PRJs. Note that the closure rates are somewhat similar to those shown in the previous figure for US 23; and that none of the instrumented joints had been closed to the maximum amount in the five-year period.

Problems with loss of ethafoam filler from PRJs has been reported previously. The figure shows the effect of such loss in some joints. All measurements were made on reference points installed at the outside edge of the traffic lane. Once the filler is lost from the PRJ, closure stops, and the joint is no longer effective because of incompressible materials entering the joint. In instances where the filler was lost only from one lane, the other may continue to close only by shearing off the old lane ties between the lanes. It would seem worthwhile to clean joints and replace lost fillers, either by maintenance forces, or as a part of later repair contracts.

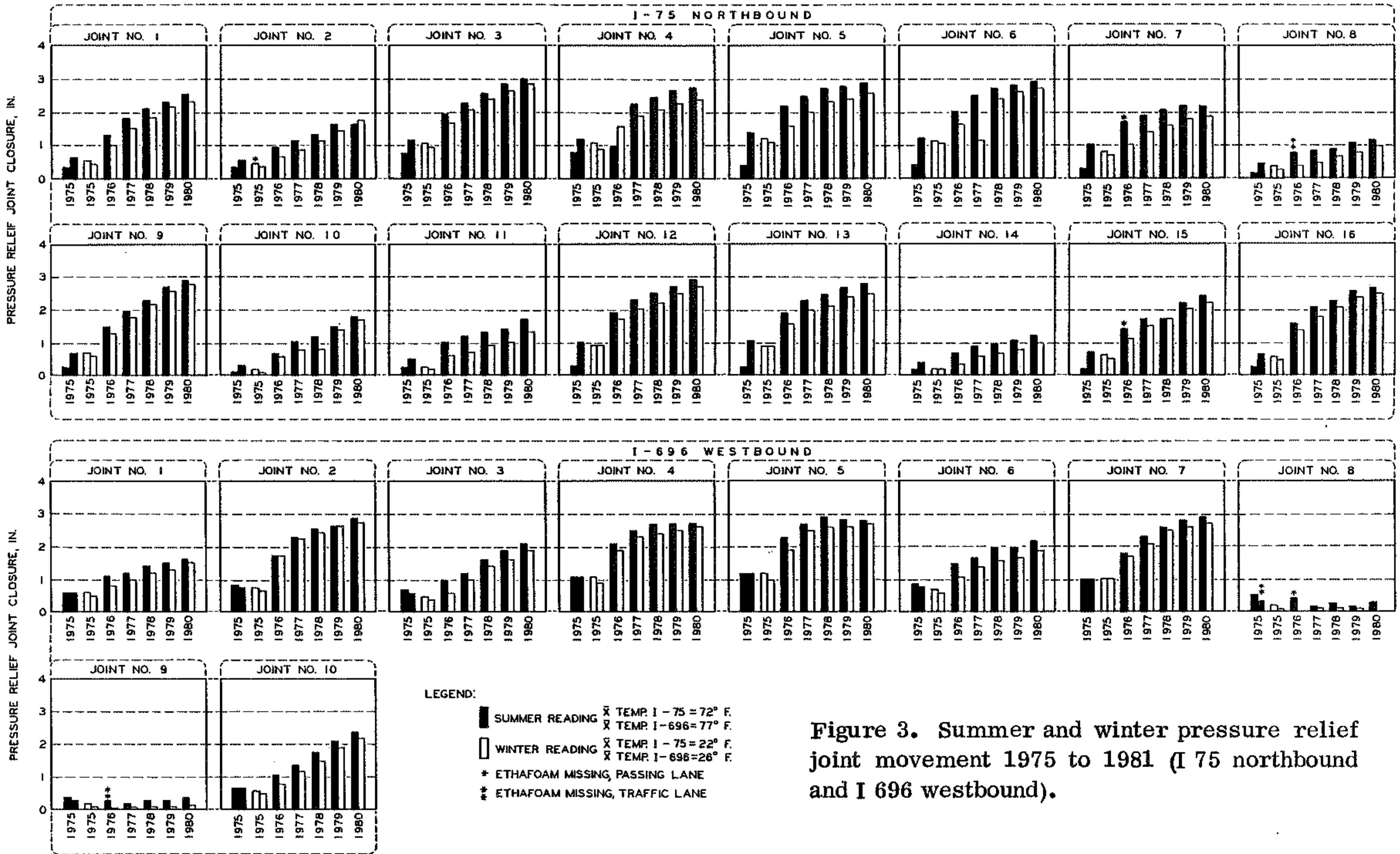


Figure 3. Summer and winter pressure relief joint movement 1975 to 1981 (I 75 northbound and I 696 westbound).

Additional reference points were placed on 'working' cracks and joints adjacent to the instrumented PRJs on I 75 and I 696. Results of measurements for these locations are shown in Figure 4. Several inferences can be drawn from these data. In most cases, the openings of the immediately adjacent joints and cracks do not add up to the amount of closure at the PRJ, so rearrangement of the slabs is taking place over a broader area of pavement, as desired. Cracks open preferentially to joints as expected, but in most cases the joints do open to some extent as well. If cracks are not present, joints open fairly uniformly. Although quite limited in extent, the data seem to indicate a general distribution of the pressure relief among several different portions of the pavement, which is as expected and intended.

Pavement Condition and Deterioration

Pavement condition survey data were collected before and after construction of the repairs, and annually from 1977 through 1979, with a more limited survey in 1980. Additional information which could relate to pavement performance, has been assembled for each project. These variables include construction dates, paving contractor, and sources of cement and coarse aggregates. Data for the 11 projects on I 75 and two projects on I 696 are shown in Table 1. These are the first such data for Michigan pavements, covering repeated numerical ratings of large segments of major roadways. The data show the relatively large variation in performance that exists for similar segments of the highway.

From the data shown in the table, computations of the average amount of deterioration per lane joint were made. These figures give a good idea of the general condition of the roadway, and plots of these values for repeated periodic evaluations of the projects show the rate at which the general condition of the roadway is changing. This type of information provides specific insight into the future needs for repair of the project. Plots of the average lane joint deterioration for the projects on I 75 and I 696 are shown in Figure 5. The number in the square box gives the average number of joint repairs per lane mile that existed before the preventive maintenance work was begun. The numbers inside circles show the average additional repairs that were added per lane mile in 1975, a part of the preventive maintenance projects, and also in a few cases, subsequent joint replacements that were made at later dates. Please note that the 1975 projects included at least 4 in. of expansion space every 850 ft, either alongside the repair slabs, or in separate PRJs when repairs were not needed in the vicinity. The information being plotted in this figure is the condition of the average joint on the project, which is a general measure of the quality of the joints. Since we are dealing with pavements having only early stages

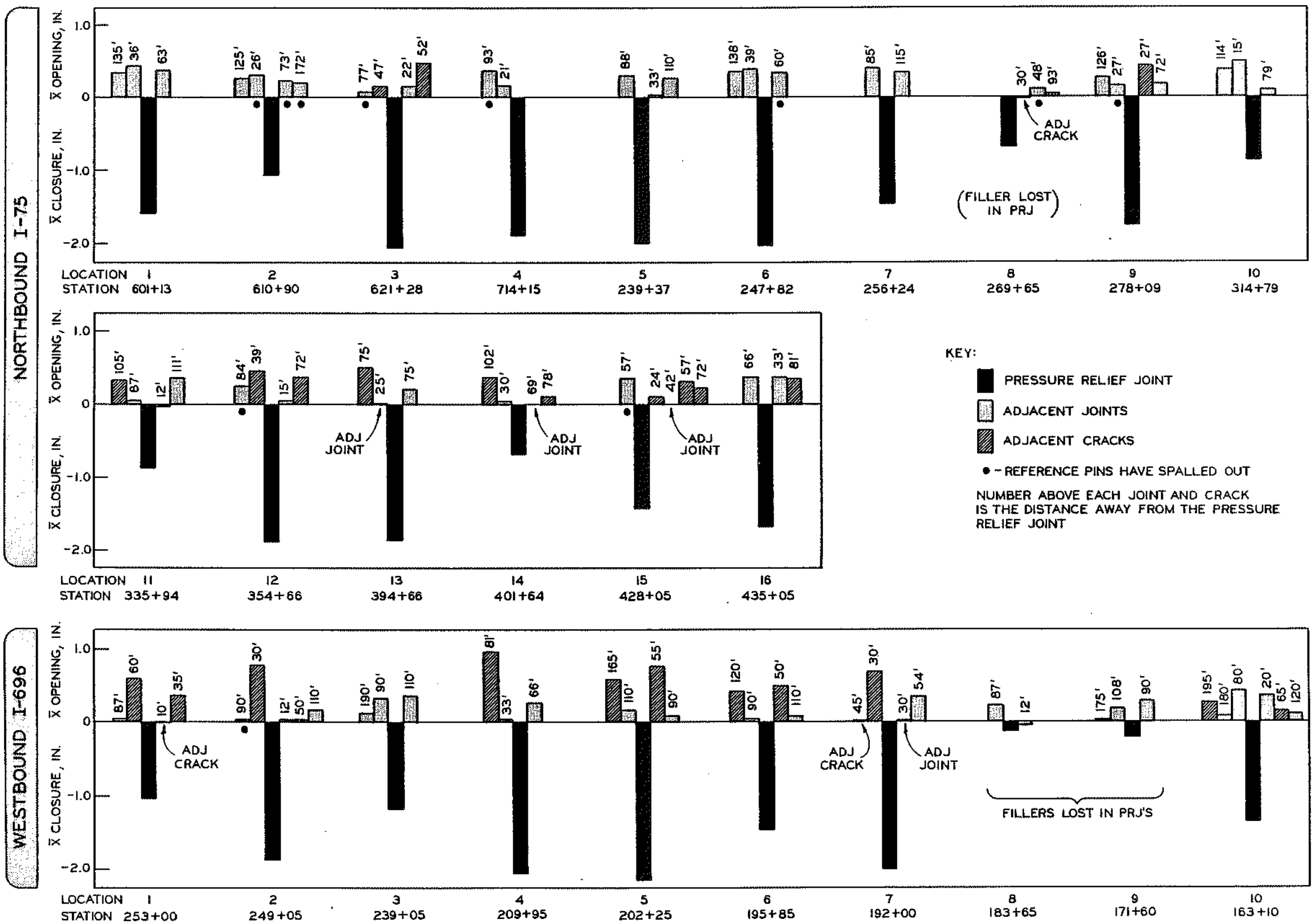


Figure 4. Average PRJ and adjacent joint and crack movement from 1975 to 1981.

TABLE 1
PAVEMENT CONDITION DATA
(I 75, Oakland-Genesee County Line to Sprague Avenue, North and Southbound 42.98 Miles and I 696, I 96 to Telegraph Rd (US 24) 7.9 Miles)

Project No.	Paving Contractor (year constructed)	Concrete Aggregate Source	Total Lane Miles	Survey Year	Unrepaired Lane Joints	Total Deterioration, lin ft	Average Deterioration/ Lane Mile, lin ft	Number of Existing Joint Repairs: Total	Number of Existing Joint Repairs: Avg/ Lane Mile	Total PRJ	PRJ Missing Filler
I 75	Cooke Con-	American Agg.	3.66	1974	---	218	60	8	2.18	1	--
63173,	struction Co.	Pit #63-4		After Repair	---	---	---	0	--	+30	--
C1	(1963)			1977	183	348	95	8	2.18	31	--
				1978	---	453	124	8	2.18	31	19
				1979	---	718	196	8	2.18	31	23
I 75	Hertel-Deyo Co.	Groveland Gravel	39.05	1974	1,954	2,713	70	110	2.82	9	--
63173,	C. E. Utterback	Pit #63-54		After Repair	---	1,941	50	+77	1.97	+232	--
C11	(1962)			1977	1,877	2,471	63	187	4.79	241	12
				1978	1,877	3,583	92	187	4.79	241	13
				1979	1,877	5,195	133	187	4.79	241	21
I 75	Sargent Con-	American Agg.	36.80	1974	1,881	3,117	85	108	2.93	1	N/A
63173,	struction Co.	Pit #63-4		After Repair	---	2,385	65	+75	2.04	+240	--
C9	(1962)	Groveland Gravel									
		Pit #63-54		1977	1,806	3,038	83	183	4.97	241	12
				1978	1,806	4,146	112	183	4.97	241	13
				1979	1,806	5,550	151	183	4.97	241	21
I 75	Denton Con-	American Agg.	32.58	1974	1,722	2,900	89	78	2.39	0	--
63173,	struction Co.	Pit #63-4		After Repair	---	2,605	80	+38	1.17	+190	--
C5, C7	(1962)			1977	1,684	3,780	116	116	3.56	190	10
				1978	1,684	5,376	165	116	3.56	190	18
				1979	1,684	8,233	253	116	3.56	190	18
I 75	Denton Con-	American Agg.	19.32	1974	1,056	532	27	18	0.93	0	--
63172,	struction Co.	Pit #63-4		After Repair	---	476	25	+9	0.47	+125	--
C2	(1962)			1977	1,047	750	39	27	1.40	125	9
				1978	1,047	1,165	60	27	1.40	125	12
				1979	1,047	1,737	90	27	1.40	125	14
I 75	Pierson Con-	American Agg.	12.00	1974	632	289	24	6	0.50	0	--
63172,	struction Co.	Pit #63-4		After Repair	---	265	22	+2	0.17	+88	--
C1	(1963)			1977	630	433	36	8	0.67	88	14
				After Repair	---	361	30	+9*	0.75	0	--
				1978	621	555	46	17	1.42	88	14
				1979	621	745	62	17	1.42	88	16
I 75	Sargent Con-	American Agg.	13.77	1974	722	748	54	9	0.65	0	--
63174,	struction Co.	Pit #63-4		After Repair	---	576	42	+33	2.40	+79	--
C4	(1963)			1977	689	650	47	42	3.05	79	18
				After Repair	---	420	31	+16*	1.16	0	--
				1978	673	584	42	58	4.21	79	18
				1979	673	797	58	58	4.21	79	19
I 75	Sargent Con-	American Agg.	19.70	1974	1,114	1,302	66	11	0.56	0	--
63174,	struction Co.	Pit #63-4		After Repair	---	872	44	+44	2.23	+133	--
C3	(1963)			1977	1,070	1,168	59	55	2.79	133	21
				1978	1,070	1,417	72	55	2.79	133	22
				1979	1,070	1,888	96	55	2.79	133	23

* These CIP repairs have no seal, just fiber filler.

TABLE 1 (Cont.)
PAVEMENT CONDITION DATA
(I 75, Oakland-Genesee County Line to Sprague Avenue, North and Southbound 42.98 Miles and I 696, I 96 to Telegraph Rd (US 24) 7.9 Miles)

Project No.	Paving Contractor (year constructed)	Concrete Aggregate Source	Total Lane Miles	Survey Year	Unrepaired Lane Joints	Total Deterioration, lin ft	Average Deterioration/ Lane Mile, lin ft	Number of Existing Joint Repairs: Total	Number of Existing Joint Repairs: Avg/ Lane Mile	Total PRJ	PRJ Missing Filler
I 75 63174, C2	Cooke Construction Co. (1963)	American Agg. Pit #63-4	17.52	1974	978	521	30	18	1.03	0	--
				After Repair	---	432	25	+14	0.80	+132	--
				1977	964	522	33	32	1.83	132	20
				1978	964	728	42	32	1.83	132	21
				1979	964	1,013	58	32	1.83	132	23
I 75 63174, C8, C7, C6	Denton Construction Co. (1963)	American Agg. Pit #63-4	18.54	1974	1,064	289	16	1	0.05	0	--
				After Repair	---	253	14	+3	0.16	+164	--
				1977	1,061	466	25	4	0.21	164	24
				1978	1,061	596	32	4	0.21	164	32
				1979	1,061	952	51	4	0.21	164	34
I 75 63174, C5, C14	Cooke Construction Co. (1963)	American Agg. Pit #63-4	14.40	1974	801	288	20	0	0.00	6	--
				After Repair	---	244	17	+6	0.42	+117	--
				1977	795	422	29	6	0.42	123	19
				1978	795	526	37	6	0.42	123	21
				1979	795	716	50	6	0.42	123	22
I 696 63101 C1	Sargent Construction Co. (1962)	American Agg. Pit #63-4 Oxford	29.30	1974	1,233	1,567	53	26	0.89	0	--
				After Repair	1,143	1,264	43	+94	3.21	118	--
				1977	1,143	1,533	52	120	4.10	118	18
				1978	1,143	1,692	58	120	4.10	118	25
				1979	1,143	1,879	64	120	4.10	118	25
I 696 63101, C3, C6	Western and Sargent Construction Co. (1962)	American Agg. Pit #47-3 Green Oaks	13.30	1974	675	479	36	5	0.38	0	--
				After Repair	664	429	32	+11	0.82	67	--
				1977	664	798	60	16	1.20	67	12
				1978	664	876	66	16	1.20	67	12
				1979	664	1,113	84	16	1.20	67	13

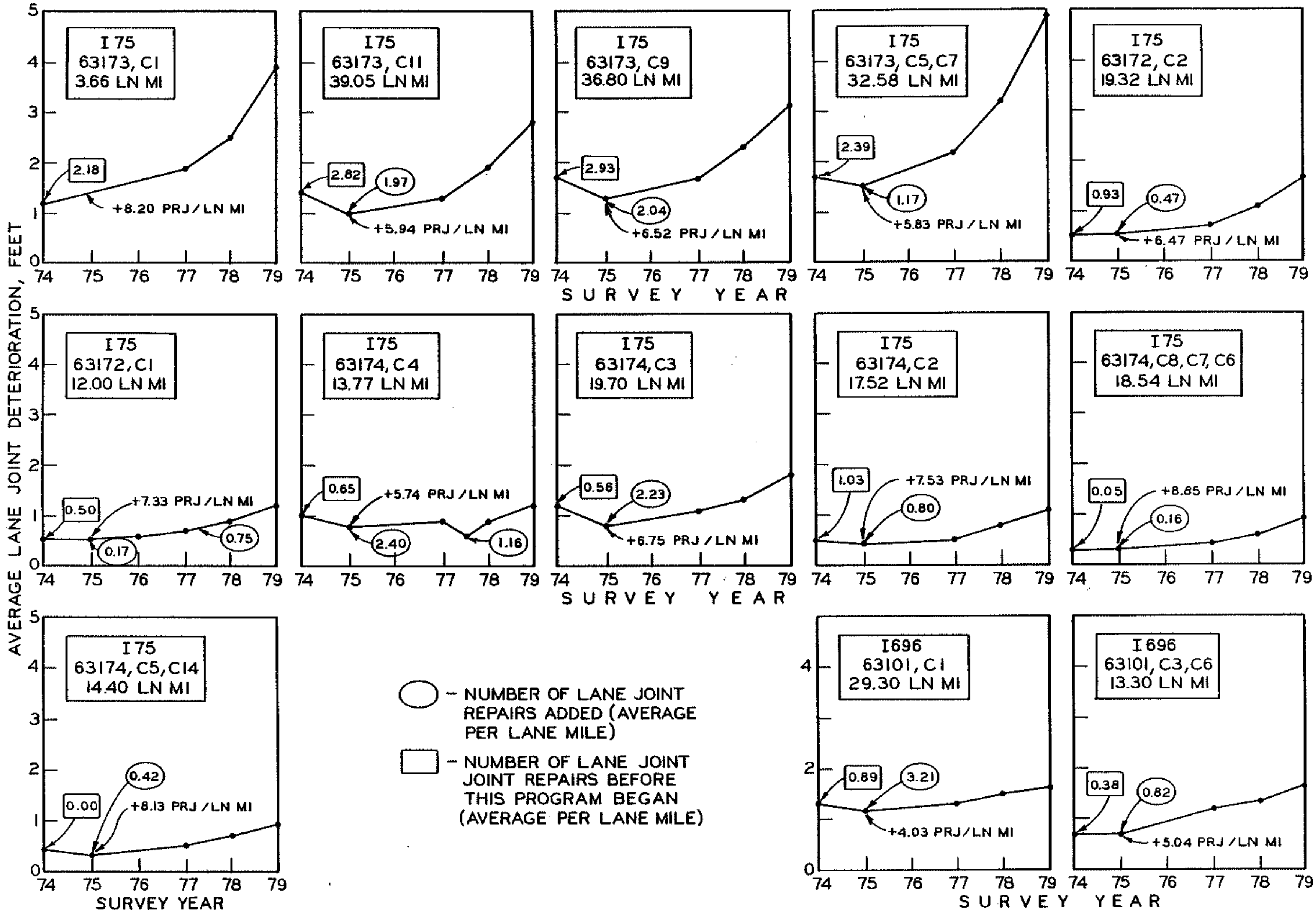


Figure 5. Average lane joint deterioration before and after joint repairs.

TABLE 2

FIVE YEAR DATA FOR FOUR PREVENTIVE MAINTENANCE CONTRACTS SHOWING BEST AND WORST PERFORMANCE OF THE 13 PROJECTS RATED

		Survey Date	Unrepaired Lane Joints	Total Deteri-oration, lin ft	Average Deteri-oration/ Unrepaired Lane Joint, lin ft	Average Deteri-oration/ Lane Mile, lin ft	Annual Average Lane Mile Deteri-oration Increase, percent	Total Joint Repair	Mid-Slab Crack Repairs	PRJ Repairs	Total PRJ	PRJ Missing Filler
Least Deterioration	Project 63174, C5, C14 14.4 Lane Miles	1974	801	288	0.40	20	--	0	--	-	6	--
		After 6 joint repairs and 117 PRJs	795	244	0.30	17	--	6	--	-	123	--
		1977	795	422	0.50	29	35	6	--	-	123	19
		1978	795	526	0.70	37	28	6	--	-	123	21
		1979	795	716	0.90	50	35	6	--	-	123	22
		After 91 joint repairs and 182 other repairs	704	447	0.60	31	--	97	175	7	116	--
		1980	704	809	1.20	56	80	97	175	7	116	24
	Project 63173, C8, C7, C6 18.5 Lane Miles	1974	1,064	289	0.30	16	--	1	--	-	0	--
		After 3 joint repairs and 164 PRJs	1,061	253	0.20	14	--	4	--	-	164	--
		1977	1,061	466	0.40	25	22	4	--	-	164	24
		1978	1,061	596	0.60	32	28	4	--	-	164	32
		1979	1,061	952	0.90	51	59	4	--	-	164	34
		After 102 joint repairs and 21 other repairs	959	645	0.70	35	--	106	20	1	163	--
		1980	959	1,161	1.20	63	80	106	20	1	163	33
Most Deterioration	Project 63173, C1 3.7 Lane Miles	1974	183	218	1.20	60	--	9	--	-	1	--
		After 30 PRJs	183	218	--	--	--	9	--	-	31	--
		1977	183	348	1.90	95	29	9	--	-	31	--
		1978	183	453	2.50	124	31	9	--	-	31	19
		1979	183	718	3.90	196	58	9	--	-	31	23
		1980	183	1,081	5.90	295	51	9	--	-	31	26
	Project 63173, C5, C7 32.6 Lane Miles	1974	1,722	2,900	1.70	89	--	78	--	-	0	--
		After 38 joint repairs and 190 PRJs	1,684	2,606	1.50	80	--	116	--	-	190	--
		1977	1,684	3,780	2.20	116	23	116	--	-	190	10
		1978	1,684	5,376	3.20	165	42	116	--	-	190	18
		1979	1,684	8,233	4.90	253	53	116	--	-	190	18
		After 29 joint repairs	1,655	7,896	4.80	242	--	145	--	-	190	--
		1980	1,655	10,053	6.10	308	27	145	--	-	190	22

of deterioration at the time of preventive maintenance work, the joints are the weakest links in the system, thus making this particular information a good indicator of the general condition of the pavement as a whole. (In older pavements where centerline deterioration and mid-slab crack spalling have occurred, joint ratings must be supplemented to give a more meaningful statistic for general condition. Some of the poorer projects included in this study are approaching this latter condition at the present time.)

In Figure 5, average lane joint deterioration is being plotted, so an increase or rise in the curve represents increased deterioration or poorer condition; a rating of 4 ft on the vertical scale means that the average joint would have a total of 4 ft of spall (exceeding 4 in. width) and/or corner breaks. A glance at the curves shows that four of the 13 projects appear to be deteriorating at a rate that is considerably faster than the others. A check of the square boxes also indicates that all four had considerably more joint repair done prior to the preventive maintenance contract. These are both indications of relatively poor performance. The other nine projects have plots that show more comparable relative performance one to another, although two are noticeably better than the others. Those two are on I 75, 63174 C8, C7, C6 and 63174 C5, C14. In contrast the two worst are I 75, 63173 C1 and 63173 C5, C7.

Since there are budget limitations and personnel shortages, it was decided during the last year to concentrate on these four projects, rather than making ratings on all of the projects. Compilations of the data for the total five-year period for these four projects are shown in Table 2, and the associated average unrepaired lane joint deterioration plots are shown in Figure 6. It seems somewhat ironic that nearly 400 repairs were placed on 33 miles of the two best projects during the past year, while only 29 were placed on 36 miles of the worst projects. It is also interesting to note that the average joint on the two worst projects now has reached the level '6 ft' of deterioration that was used as the criterion for selection of the isolated joints that were repaired at the beginning of the preventive maintenance work. The average amount of deterioration still is climbing steeply as well. It is obvious that these projects are in need of extensive work in the near future, at nearly every joint and undoubtedly at many mid-slab cracks as well.

Figure 7 shows the same type of information in a slightly different format, for a best and a worst project. It shows that although the best project has 90 percent of the lane joints with less than 3 ft of deterioration, only about 28 percent of the joints in the worst project are in this category. Conversely, if we sum the two right hand bars of the graph, the worst project has 40 percent of the joints with more than 6 ft of deterioration, while

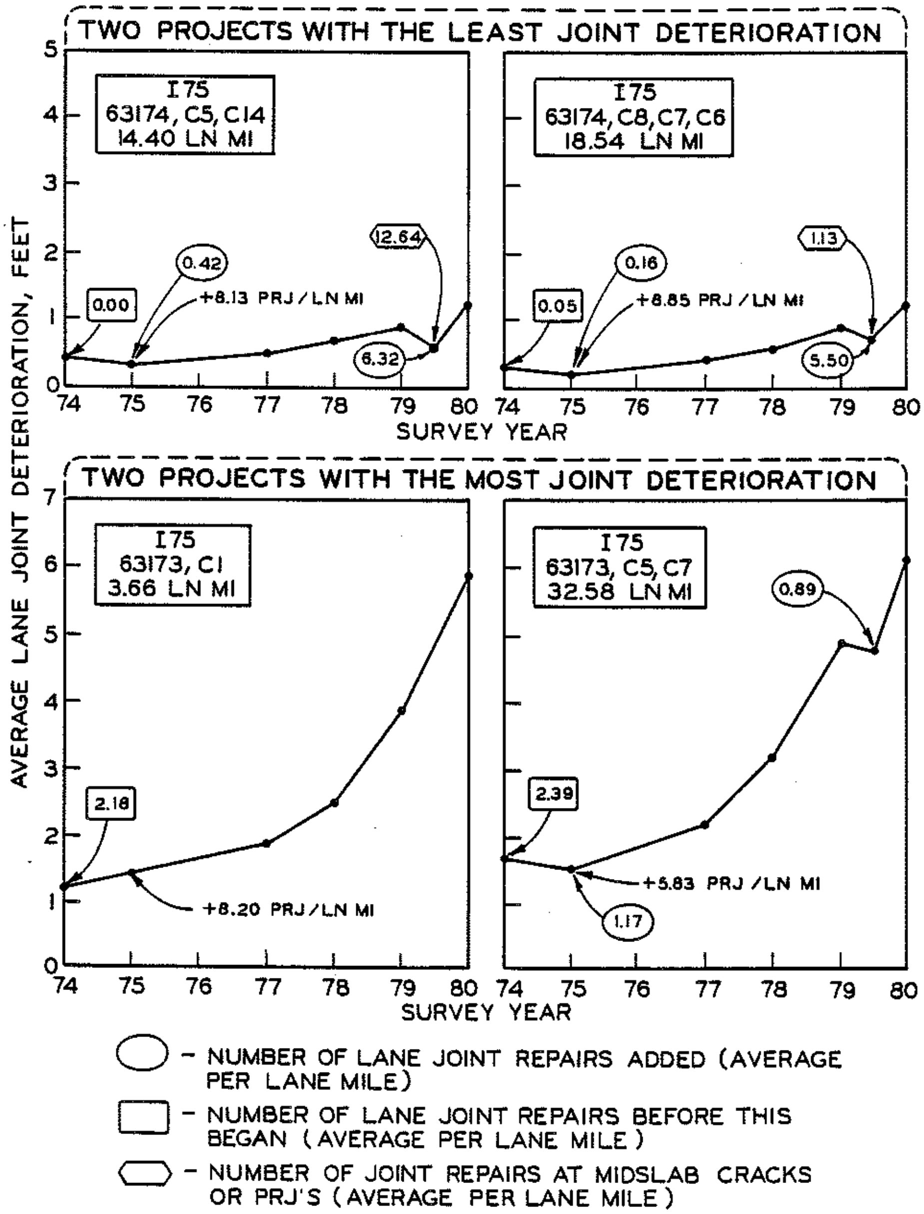
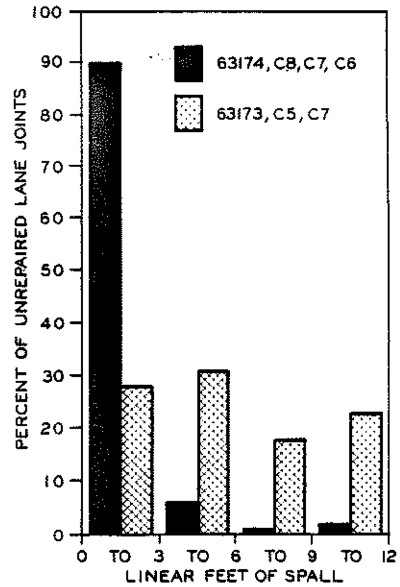


Figure 6. Average unrepaired lane joint deterioration for four preventive maintenance projects showing best and worst performance of the 13 projects evaluated.

Figure 7. Condition of unrepaired lane joints on two contrasting projects on I 75 (1979 data).



the best project has only 5 percent of the joints in this poor condition at the time of the survey. Again, it is obvious that the one project can continue to serve with only isolated repairs, while the other will require a considerable expenditure for both patrol patching and contract repair.

Causes of Deterioration

Once the deterioration had been documented, and the variations in performance noted, a search for the cause of the poorer performance was made. Records for the various projects were reviewed to determine the variables of the concrete pavement. Source of cement was eliminated, since problems with cement would have been likely to become obvious at an earlier age; and one source was used for nearly all the projects, including all those near the top and bottom of the performance list. Two contractors paved the two best and two worst projects, but each had a best and a worst project. While it is true that construction variables can and do affect the performance of a rigid pavement, the type and extent of deterioration evaluated here seems to be related more strongly to other factors. Also, fine aggregate generally is not related to deterioration of the type encountered here.

Another look at Table 1 reveals that most of the aggregates for the projects in question came from one source, Pit No. 63-4, including those aggregates used for the two best and two worst projects. However, a field review of the pavements in question shows a type of deterioration that is generally related to coarse aggregate. Namely, it is the type usually called

D-cracking, and is related to the freeze-thaw resistance of the coarse aggregate, and the proportion of D-crack susceptible material present; coupled with the maximum size of the aggregate particles and the rate at which they become saturated in service. The telltale signs of this type of deterioration are present, at various stages of development, on all of the projects involved in this investigation. The main differences in the projects are related to the rate of development of the later more damaging stages of this phenomenon, rather than to differences in type of deterioration.

Examples and discussion of the progression of D-cracking have been presented previously in MDOT Research Reports R-1158 and R-1169, and therefore, will not be repeated here in detail. Briefly, it is a type of attack that results in crumbling of the concrete (usually beginning at the bottom of the slab where it cannot be seen). Its first evident surface stage is dark staining and microcracking, usually on either side of longitudinal and transverse joints or cracks. The second stage is fine cracking, usually initiating at the intersection of longitudinal and transverse joints, and spreading from there. This is followed by separation of the pieces along the cracks.

It appears that although there are inherent differences in pavements due to construction variables and localized environmental factors, the main variable involved in the performance of the contracts in question is one of durability of coarse aggregates. This seems to be true, regardless of the fact that most of the aggregates came from the same pit. It is not unusual to find variability in the quality of glacial deposits from different locations in a large pit. The aggregates from different pits that were used on a few of the projects evidently have quality about like the average from the main source. It should be noted also that although the performance of some of the projects is fairly good in comparison to the others evaluated, most have had fairly extensive repairs and are in need of considerably more attention long before the design life of 20 years has been attained. This has been true in general throughout the state, partly due to the base plates and ineffective seals in the old pavement joints. However, several pavements with high-grade coarse aggregates have performed well for many years in spite of the deleterious effects of the joints. Table 3 shows the results of a 1981 survey made on two sections of the US 27 freeway in Isabella County using the rating system shown in the Appendix. One section was built with dolomite in the 4A fraction of the coarse aggregate while the other had 4A from a local pit. The 10A and fine aggregate for the two sections all came from the same source and the pavements were built by the same contractor. Each section included 6.6 lane miles of mainline divided highway. The sections were adjacent to each other, end to end. The dolomitic pavement was built in 1960 and the other section in 1961. The amount of joint deterioration per lane mile is more than 35 times greater on the section built with 'gravel' 4A than on the one built with crushed dolomitic 4A aggregate. This shows that even pavements with design handicaps can survive 20 years in relatively good condition if adequate materials are used. Job-site evidence also shows clearly that there is less compressive stress in the dolomitic pavement.

TABLE 3
PAVEMENT CONDITION SURVEY RESULTS ON ADJACENT SECTIONS OF US 27, ISABELLA COUNTY

Project No.	Total Lane Miles	Aggregate[1]	Number of Unrepaired Lane Joints	Total Spall, lin ft	Average Spall/Lane Mile, lin ft	Total Lane Joint Repair	Total PRJ
37013, C8 [2]	6.6	gravel 4A aggregate	341	1,673	253	17	26
37013, C4	6.6	crushed dolomite in 4A fraction	358	43	7	0	36

[1] The 10A and fine aggregates were the same for both sections.
[2] Plus approximately 3,000 ft of 37013, C4.

Several other sections of pavement in the state show the same kinds of superior performance in projects where better grades of coarse aggregates happen to have been used. In fact, it is the only factor that consistently has shown significantly improved pavement performance in numerous investigations covering many years. The lower coefficient of thermal expansion for concrete made from limestone or dolomite has a decided positive effect on pavement performance, in addition to the improvement due to D-crack resistance. Less thermal expansion and contraction helps in the retention of joint seals and cuts down on the probability of infiltration of incompressibles into open joints.

Additional comparisons of projects showing better performance, with others that exhibit problems, are under way at this Laboratory and will be reported at a later date. This is the final report to be issued on Projects 74 F-140, "Maintenance Procedures to Prevent Blow-Up of Concrete Pavement Joints," and 71 F-122, "Experimental Pressure Relief Joints, US 23 North of M 36."

APPENDIX

SELECTION PROCEDURE FOR JOINTS AT REPAIRS, FOR PREVENTIVE MAINTENANCE PROJECTS

(Pavements With 99-ft Slabs, Base Plates and Poured Seals)

The following process was established to determine the specific locations for joint repairs within each project. The process assumes completion of a joint condition survey record showing structures, ramps, repairs, patches, joint condition category, etc. (see next pages). In order to be noted on the survey as distressed, a joint had to exhibit a spall at least 4 in. wide and 1 ft long. Distressed joints were then categorized by the number of feet of spall plus corner breaks, along the joint.

A set of plan sheets for the project was prepared, showing each joint. All lane joints having 6 or more feet of deterioration were selected for replacement. (This number can be adjusted up or down, depending upon available funds or policy decisions.)

Step No. 1. Record on the plan all existing, full-width pressure relief points, and full-width joints proposed for repair. Such relief points, for example, might be full-width bituminous patches or recent full-width joint or crack repairs where relief has been provided, but will not include expansion joints placed during original construction.

Step No. 2. Record all other proposed repairs (not full-width) of distressed joints or cracks.

Step No. 3. Locate pressure relief joints (PRJ's) or a full-width repair with relief space within 400 ft of structures, if this previously has not been done.

Step No. 4. Locate relief in ramps by replacement of the worst joint in the ramp within 400 ft of the gore. If all of the joints in the 400 ft are in good condition place a PRJ.

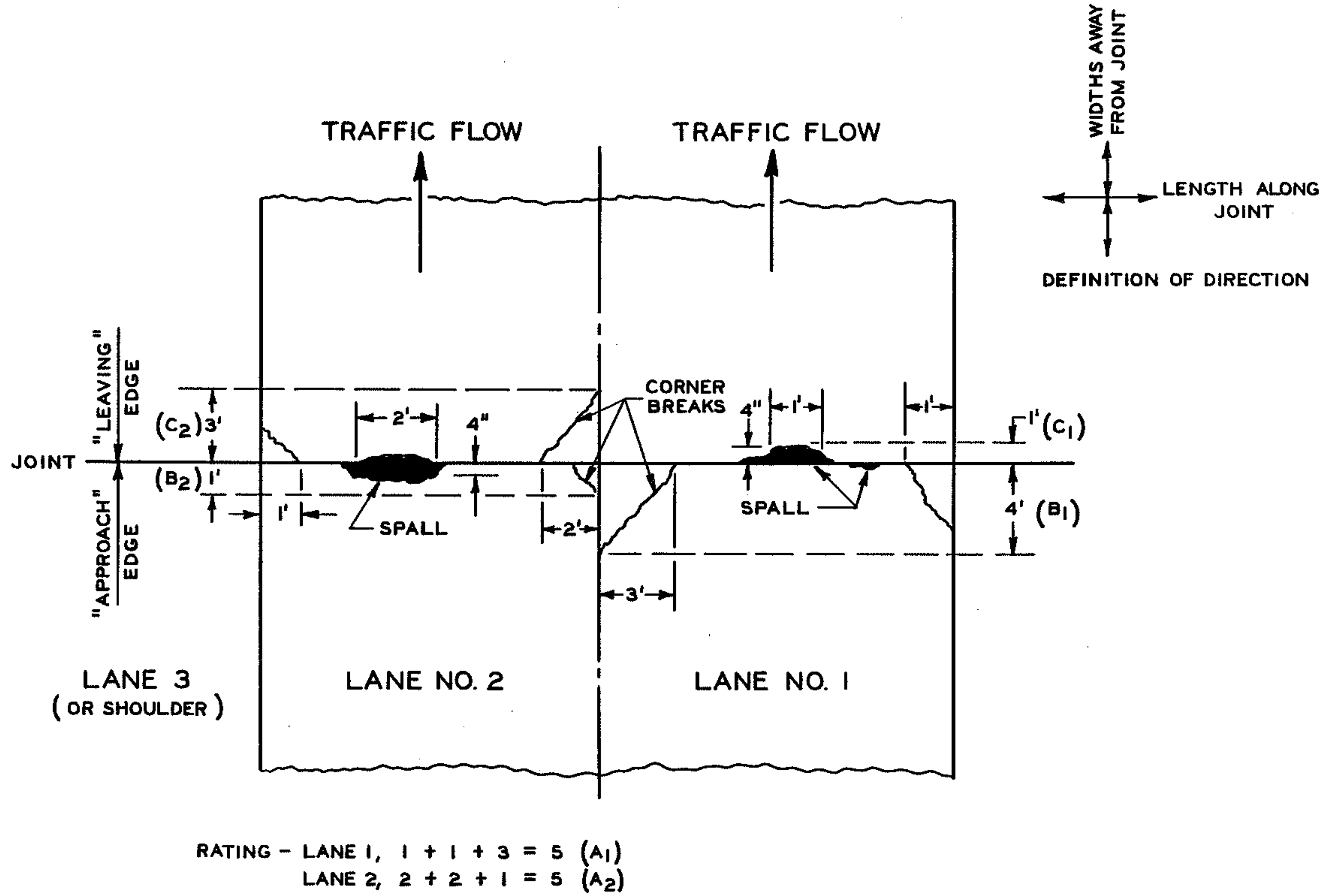
Step No. 5. Examine distances between all relief points established or determined in Steps 1 through 4, including those at joint repairs, structures, patches, etc. The spacings between these relief points will then be divided into approximately equivalent distances, not exceeding 850 ft by installing a full-width repair at the worst joint in the vicinity, or by placing PRJ's. Pavement lengths for consideration will begin and end at bridges or similar discontinuities, such as railroad crossings at grade.

The type of joint detail to be used at each side of each repair location (2-in. expansion, 1-in. expansion, or contraction), should be determined as follows:

> Select joint details so that at least 4 in. of expansion space are provided in any 850-ft length of pavement. Use only contraction joints at single-lane repairs, or at other repair locations in multi-lane pavement where expansion space is not provided full-width. (Note that taper sections, acceleration and deceleration lanes, attached concrete shoulders, curb, and gutter are included in the definition of "full-width.") In jobs with numerous full-width repairs, small amounts of expansion space placed close together are preferred to large amounts at isolated locations.

Step No. 6. Field GI of the project (by Design Division and District personnel) for the purpose of making any indicated changes or adjustments.

Step No. 7. Preparation of plans and specifications for the repair projects, showing the location of each repair or PRJ, and the type of joint required at each repair.



Example of deteriorated joint in two-lane one-way road.

PAVEMENT RATING SYSTEM
(MDOT Research Laboratory)

Selection of joints for removal and replacement can be done directly from the survey sheets once the rating is completed.

The system is based on previous experimental work which showed that the probability of blow-up or compressive failure at any joint, is related to the amount and type of observable defects at that joint. Therefore, the system requires that each joint on the project be evaluated, and the rating for each joint recorded. While this may sound complicated, in practice it is quite simple and can be done quickly, and has several distinct advantages.

1) It does not require highly skilled or experienced people to do the rating.

2) Once completed, it gives an objective, numerical value that is a measure of the condition of the project (amount of deterioration per lane mile), and can be used for comparison of projects throughout the State to determine which is in greatest need of repair. Condition ratings can be modified by factors related to traffic densities if desired, for purposes of allocating available funds to the areas of greater use.

3) The rating provides better justification for requests for maintenance funding. This will become more important as FHWA participation in repair contracts increases.

4) The selection of joints for removal can be done from the finished log. Each lane joint that has spall or corner break or black patch extending the full width of the lane is an obvious candidate for replacement. Recent preventive maintenance contracts have selected lane joints with 6 ft or more of deterioration, for replacement.

If funds are limited for a given job, joints can be selected from those with the greater rated deterioration, within the limits of funds available.

5) The finished log of joint ratings can be used directly in the Design Division for preparation of plans and contract documents, which then aid the Project Engineer during the construction phase. Also, the ratings can be updated to reflect repairs made, and used again in the future, to check on the rate of subsequent deterioration of the roadway.

Ratings are made and recorded by lane. For uniformity, Lane No. 1 is the right hand lane in the direction of travel.

Procedures for the rating system and a sample rating form are shown on the attached sheets. Please note that the type of joint used on previous repairs is important for the determination of whether additional pressure relief is required.

SURVEY PROCEDURE INSTRUCTIONS

1) The joint condition survey will be conducted by use of a vehicle equipped with a survey meter. Observations will be made from a vehicle driven on the outside shoulder in the same direction as traffic. Required safety precautions must be followed.

2) Record survey meter reading and point of beginning of project.

3) Record survey meter reading at each patch along with the following information:

a) Lane in which patch occurs (No. 1, No. 2, No. 3, etc.)
b) Type of patch (C - concrete, B - bituminous)
c) Size of patch (longitudinal length x transverse width)
d) Type of installation (S - sawed joint, NS - not sawed)
e) Presence of expansion material (E - ethafoam, P - hot or cold-poured bituminous seal over felt filler, C - construction joint no seal, CS - contraction joint with seal).

EXAMPLE: Two C-4 x 12 - S - E is a concrete patch in passing lane, 4 ft longitudinal by 12 ft transverse, with sawed joints and ethafoam expansion material.

4) Make a tally mark on the survey sheet, ("Good Joints" column), for each joint that has not yet developed spalling or corner breaks of 1 ft along the joint and 4 in. in width from the joint.

5) Record survey meter reading at each joint where the severity of spalling or corner break is 1 ft or more along the joint (accumulated length) and 4 in. or more in width from the joint.

a) Record accumulated length of spalling or corner break along the joint, in each lane.

b) Record the width of deterioration from the joint for both sides of joint. (Distance to a saw cut that would remove all deterioration.)

6) Record survey meter reading for all structures, ramp beginnings and endings, (state right or left side), county lines, city limits, etc., and at approximately 1,000-ft intervals on station marks. (This is required so that the same joints can be accurately located if selected for repair.)

7) Make a note if a condition exists where deterioration is not widespread along the joint, but is unusually severe and localized so as to form a hazard if not repaired.

8) Use additional sheets if pavement width is greater than two lanes (ramps, extra lanes, etc.).

9) Record survey meter reading at end of any slab that is mud-jacked or otherwise broken; and, therefore, unfit for placement of a pressure relief joint.

10) Record survey meter reading at any location where a wide crack exists in a slab. ("Wide" here means obviously open, approximately 3/16 in. or more, so that incompressible material can enter and add to pavement "growth.")

EXAMPLE OF A JOINT CONDITION SURVEY

JOINT CONDITION SURVEY

Route: I-96 E.B. KENT CO.

Date: 3-31-81

Personnel: JOHN DOE

Footometer Reading	Good Joints	Lane: 1 Rating	Lane: 1 Width Approach Edge	Lane: 1 Width Leaving Edge	Lane: 2 Rating	Lane: 2 Width Approach Edge	Lane: 2 Width Leaving Edge	Existing Patches Size and Type	Survey Reference Points
000									STA. 100+00
	~~||||~~								
600		5'(A1)	4'(B1)*	1'(C1)*	5'(A2)	1'(B2)	3'(C2)		
	///								
1002			EXAMPLE FROM SKETCH						STA. 110+00
1100								2-C-4X12-SE	
	//								
1320									WEST EDGE, BRIDGE OVER GRAND RIVER
1419									EAST EDGE
	////								
1823									POB ENTRANCE RAMP RIGHT SIDE
	///								
2125									℄ SMITH RD. OVER
	//								
2347									POE ENTRANCE RAMP
2420								1-B-3X12-NS	
	////								
2932									KENT-IONIA CO. LINE

* NOTE:

a) MINIMUM PATCH IS 6' BY LANE WIDTH, IF B+C EXCEEDS 6' THEN REQUIRED PATCH LENGTH IS B+C.

b) IF PATCHES IN ADJACENT LANES DON'T LINE UP, MAKE AT LEAST 2-FT OFFSET, OTHERWISE MAKE THEM LINE UP SO THAT SAW-CUT RUN-OUT IN OTHER LANE HAS LESS PROBABILITY OF CAUSING A LOSS OF THE CORNER OF THE REMAINING SLAB.

c) DO NOT PLACE PRJ IN SLABS THAT HAVE BEEN MUD JACKED, OR ARE BADLY FRACTURED. PRJ'S SHOULD BE A LEAST 10 FT FROM TRANSVERSE CRACKS OR JOINTS, IF POSSIBLE.