EVALUATION OF SAWED-SEALED LONGITUDINAL JOINTS BETWEEN BITUMINOUS SHOULDERS AND RIGID PAVEMENT AS A MEANS OF REDUCING LONGITUDINAL SHOULDER CRACKING

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EVALUATION OF SAWED-SEALED LONGITUDINAL JOINTS BETWEEN BITUMINOUS SHOULDERS AND RIGID PAVEMENT AS A MEANS OF REDUCING LONGITUDINAL SHOULDER CRACKING

The purpose of this study is to evaluate the effectiveness of a seal-treated joint (sawed-sealed and wheel cut-sealed) at the concrete pavement - shoulder interface, as a means of reducing longitudinal cracking of bituminous aggregate shoulders. This study is divided into two major phases: first, to construct, survey, and evaluate new shoulders placed in a manner that facilitates statistical analysis of survey results and, second, to survey and evaluate existing seal-treated and conventional bituminous shoulders.

To provide a means for comparing performance of seal-treated joints, a project was constructed in 1966 that included shoulders with several replicates of conventional and seal-treated interface joints. Test procedures, construction and results of preliminary surveys of this controlled project were presented in Research Report No. R-637R.[1] The recent data from this project are discussed in detail in this report. Additional information from new projects as well as further measurements on the projects listed in the above report are also discussed.

EVALUATION OF THE CONTROLLED PROJECT (Project 5)

Details of the experimental joint and class AA shoulder considered in this project are shown in Figures 1 and 2, respectively. The Project 5 test site consists of 3.3 miles of four-lane divided highway on US 127 northwest of Mason in Ingham County in Construction Project F 33035A, C6. The rigid pavement was poured between June 20 and September 19, 1966, and the bituminous shoulders were constructed between September 26 and October 15 of the same year. Moisture content values for 314 tests averaged 4.6 percent and varied from this average with a standard deviation of

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(1) The terms "experimental test area" or "controlled project" are used to denote a statistically designed experiment which, from beginning to end, is carefully conducted and supervised by Research Laboratory personnel.

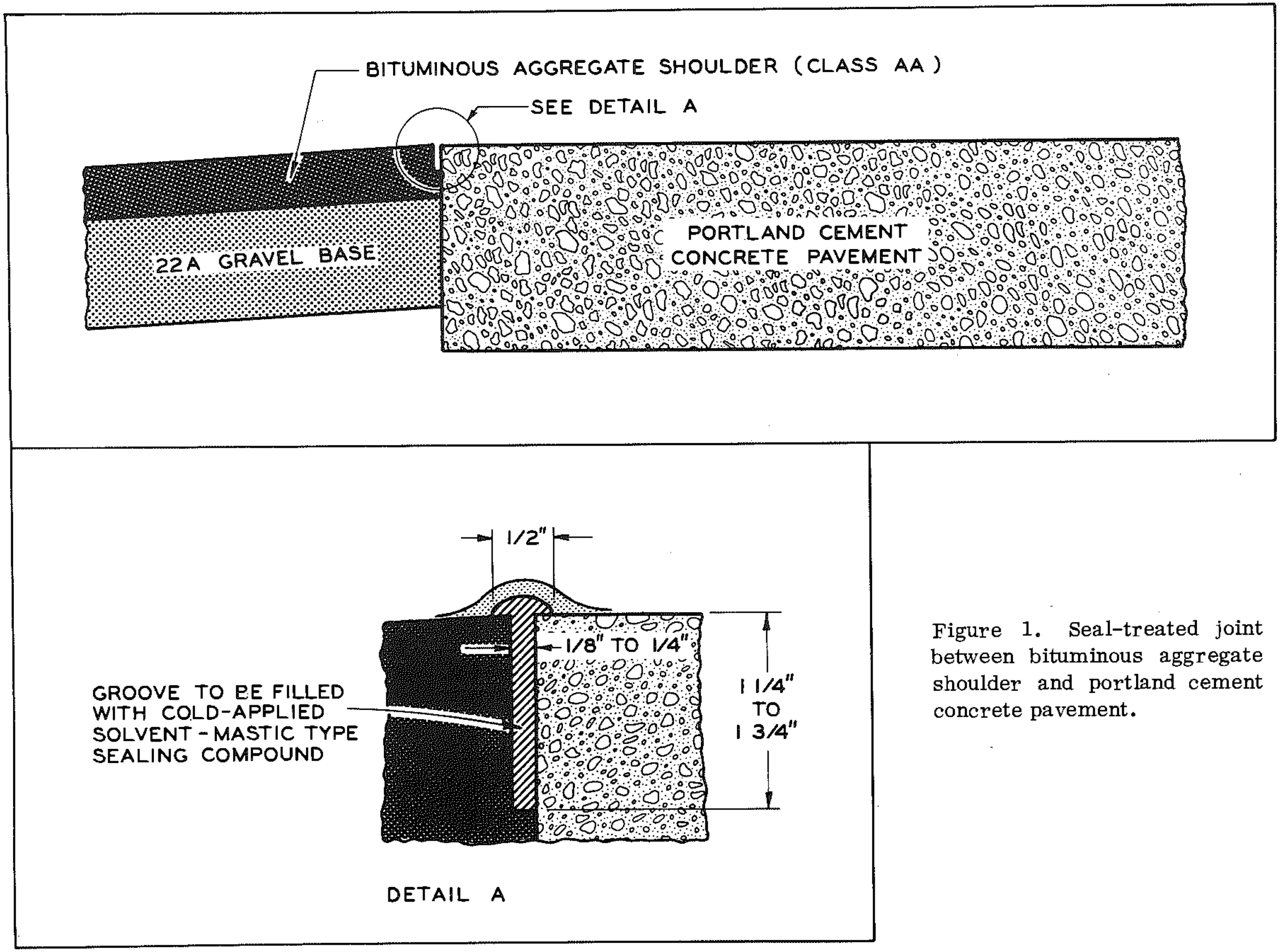


Figure 1. Seal-treated joint between bituminous aggregate shoulder and portland cement concrete pavement.

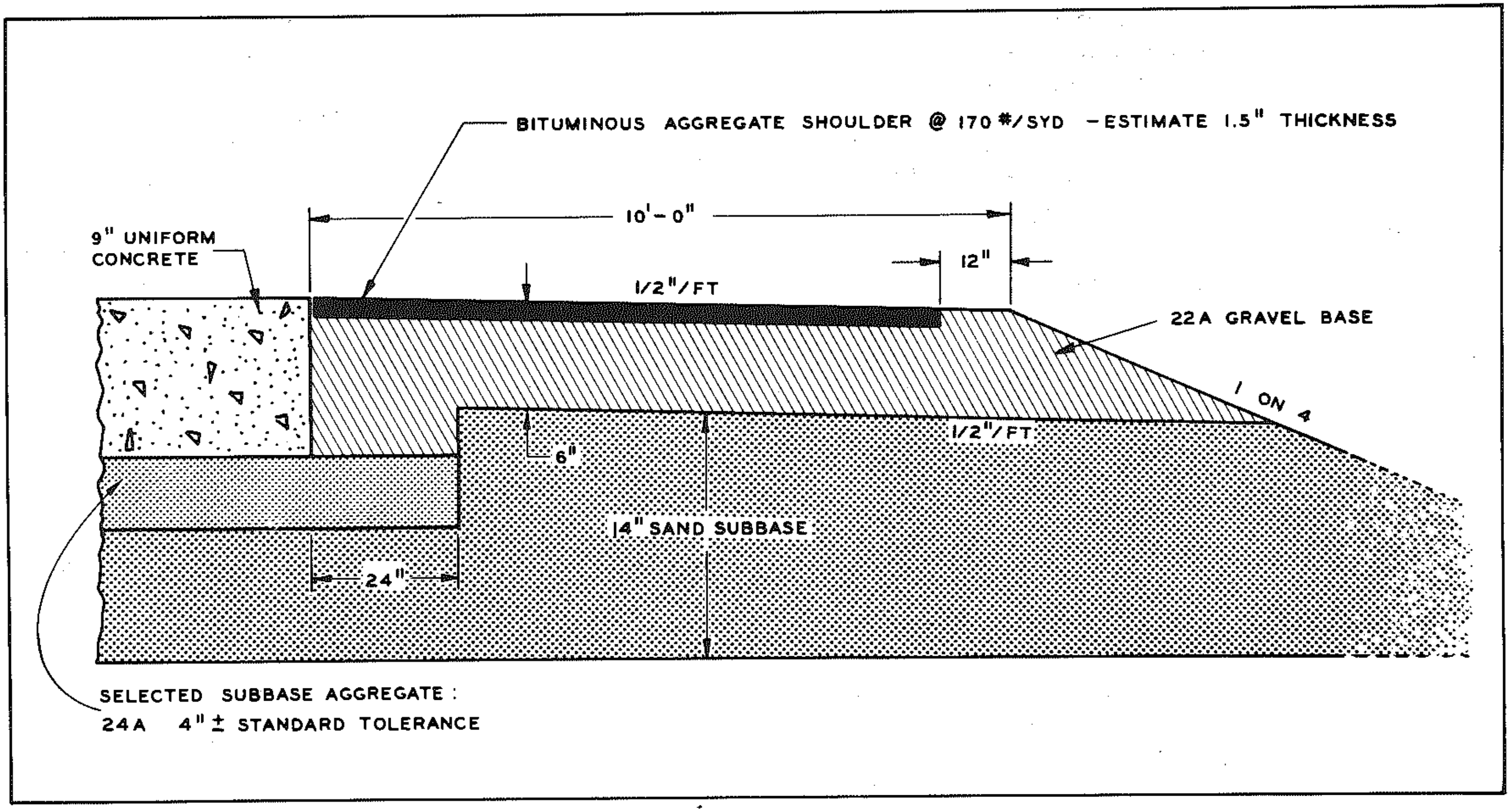
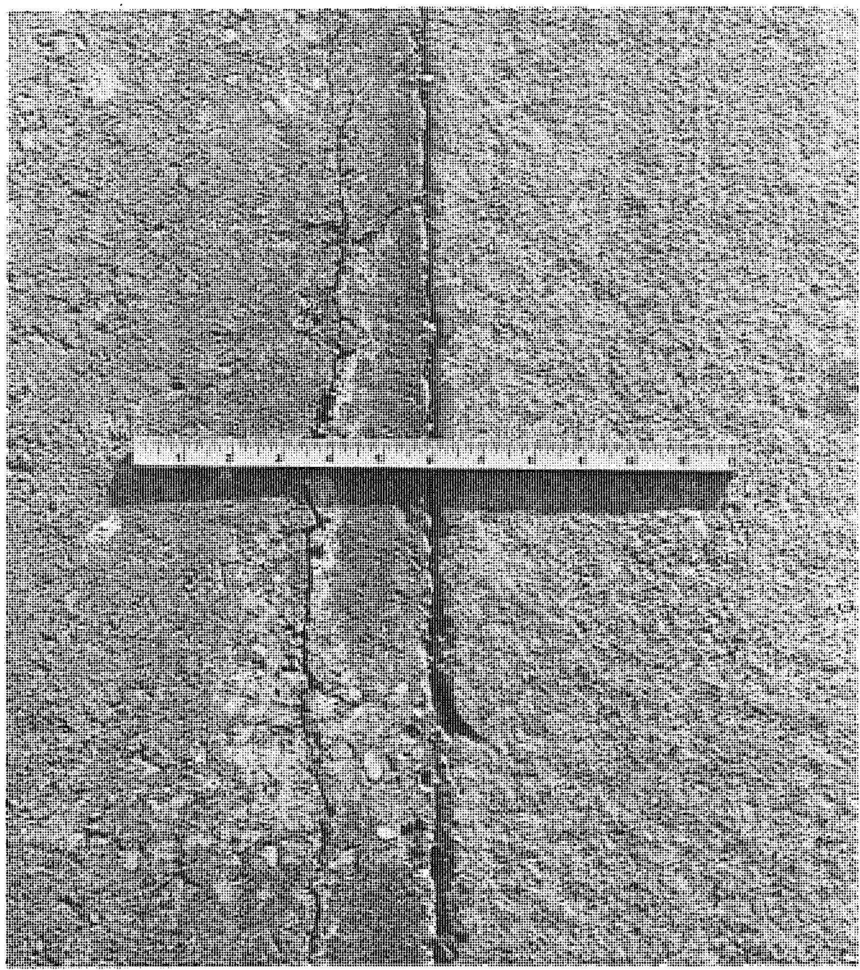
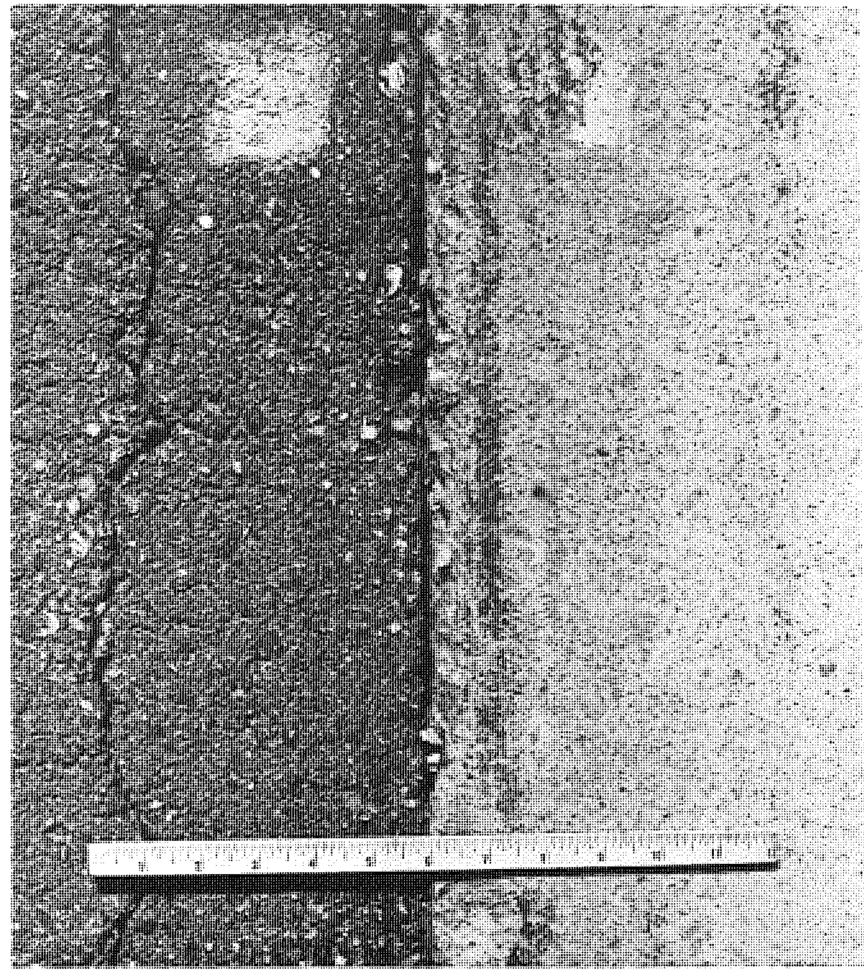


Figure 2. Typical cross-section of an outside (traffic lane) Class AA shoulder.



Station 516+30
Project 5 - SB Roadway
Age - 2 months
(December 1966)



Station 462+65
Project 5 - NB Roadway
Age - 1 year 5 months
(March 1968)

Figure 3. Typical longitudinal shoulder cracks 4 to 8 ft in length, located 3 to 9 in. from unsealed conventional longitudinal joints. Cracks were open less than 1/4 in.

± 0.9; compaction values for 314 tests averaged 101.3 percent and varied from the average with a standard deviation of ± 1.3 percent for the base material. Bituminous materials were proportioned by weight in batches containing 91-percent 20A gravel, 3-percent mineral filler, and 6-percent bitumen (200-250 penetration grade). Aggregate 22A base course gradation data and details concerning the bituminous mixing procedures are given in Tables 2 and 3 in Research Report No. R-637R.

Longitudinal joints were sawed in 12 selected test sections and filled with cold solvent-type mastic sealer as specified for concrete construction, per Standard Specification Section 7.16.03-d, 1965 edition (Section 7.16.08, 1967 Standard Specifications). Width and depth of the joints were measured at random locations in each sawed section and average joint width was 9/64 in. with a standard deviation of 2/64 in. from the average, and average depth was 1-1/4 in. with a standard deviation of 1/16 in. from the average (based on 60 random measurements). A self-propelled, water-cooled diamond blade saw cut the shoulders at an average rate of 1,300 lin ft per hour, four days after the shoulders had been placed. The groove was uniform and spall free after cutting. The joints were flushed with water, followed by a jet of compressed air. The sealer was applied under pressure and the treated joints were left uncovered after sealer application.

This experimental joint was used in an attempt to eliminate, or significantly reduce, longitudinal shoulder cracking, shown typically in Figure 3, which occurs in varying lengths, spacings, and widths.

To evaluate the effectiveness of the sawed-sealed joints in Project 5, the experimental test area shown in Figure 4 was constructed. Only outside (traffic lane) shoulders were considered in this study.

Outside shoulders of both roadways were divided into 24 test sections. Each section was 0.25 miles long and separated from adjacent sections by marks painted on the bituminous surface. Twelve replications were provided for both types of joint under study. Each replicate consisted of two adjacent test sections, one with a sawed-sealed joint and the other without a sawed-sealed joint (conventional construction). Immediately upon completion of construction, and periodically thereafter, test sections were inspected to note the condition of bituminous shoulders, joints, and sealing compound. These inspections included measurements of longitudinal cracking, lateral joint movement, vertical movement, sealer failure, and joint spalling. Photographs of shoulder conditions were taken periodically.

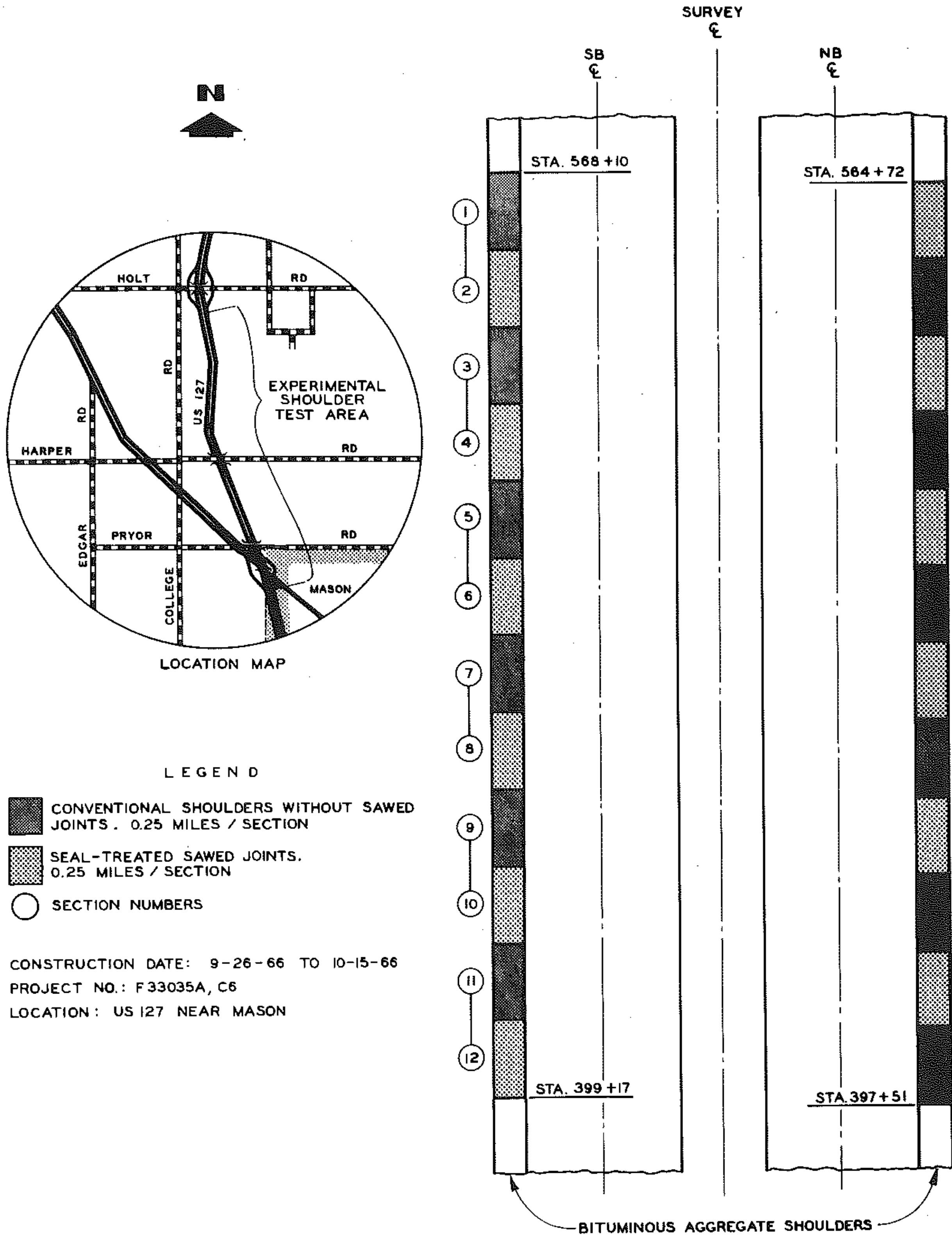


Figure 4. Schematic drawing showing 3 mi of experimental shoulders on four-lane divided highway. The outside shoulders of both roadways are divided into a total of 24 test sections paired for comparison (Project 5).

Longitudinal Cracking

Results of longitudinal cracking surveys made in April 1967 and June 1968 over Project 5 are shown in Table 1 and summarized in Figure 5.

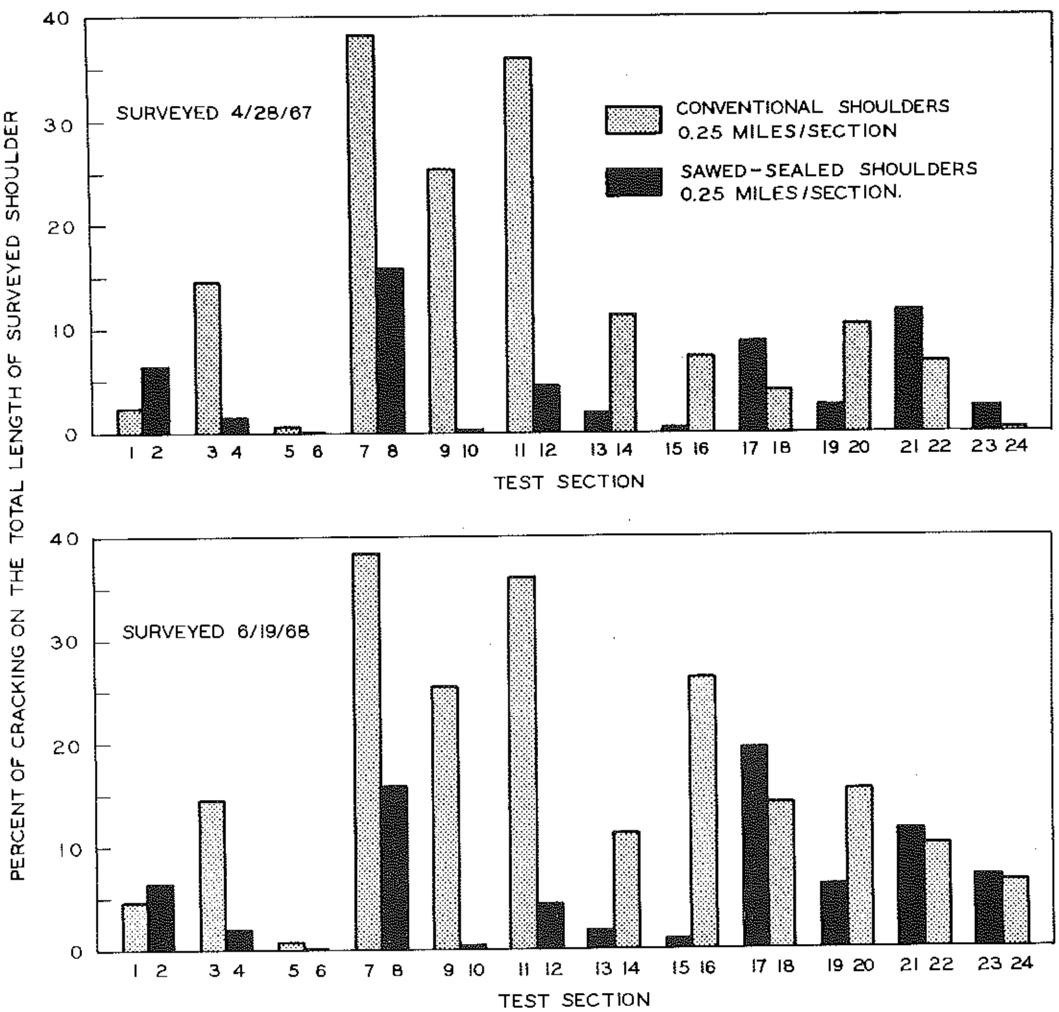


Figure 5. Crack formation in test project 5.

Since they were expected to be similar, except for the interface joint, adjacent sections were paired for interpretation of field data.

Progressive longitudinal cracking, after 20 months of shoulder service, varies markedly from section to section as shown in Figure 6. Longitudinal cracking increased sharply at an average annual rate of 6.6, 6.2, and 4.4 percent for conventional test sections 7, 11, and 9, respectively, and then

TABLE 1
SUMMARIES OF FIELD SURVEYS ON TEST PROJECT 5
(F33035A, C6, US 127 near Mason)

	Section Number	Station Number	Length of Shoulder, lin ft	Percent of Shoulder Length: Longitudinal Cracking (April 1967)	Percent of Shoulder Length: Longitudinal Cracking (June 1968)	Percent of Shoulder Length: Sealing Compound Failure (June 1968)	Percent of Shoulder Length: Pavement Spalling (June 1968)	Percent of total 1968 longitudinal cracking located within areas showing sealer failure or spalling.
Seal-Treated	2	541+57 to 554+90	1,333	6.5	6.5	20.4	1.4	50
	4	513+33 to 514+40 516+16 to 528+29	1,320	1.5	2.0	4.9	4.9	33
	6	487+22 to 500+29	1,307	0	0	2.6	7.6	0
	8	460+81 to 474+03	1,322	15.7	15.7	32.3	2.7	77
	10	434+38 to 447+61	1,323	0.2	0.2	16.4	5.4	0
	12	399+15 to 412+35	1,320	4.6	4.6	13.6	2.0	18
	13	554+90 to 563+52 564+35 to 564+72	899	1.9	1.9	36.8	8.0	33
	15	528+67 to 541+82	1,315	0.5	0.9	49.0	7.1	33
	17	500+33 to 513+32 515+17 to 515+49	1,331	8.8	19.6	73.8	0.4	38
	19	473+82 to 487+03	1,321	2.6	6.3	79.9	0.8	40
	21	447+41 to 460+62	1,321	11.7	11.7	79.2	1.8	50
	23	410+73 to 422+12 432+00 to 434+22	1,361	2.5	7.0	2.4	9.5	50
		TOTAL	15,473	Avg 4.8	Avg 6.5	Avg 34.2	Avg 4.2	
Conventional	1	554+90 to 563+54 564+44 to 568+99	1,319	2.2	4.7			
	3	528+29 to 541+57	1,328	14.6	14.6			
	5	500+29 to 513+33	1,304	0.6	0.8			
	7	474+03 to 487+22	1,319	38.3	38.3			
	9	447+61 to 460+81	1,320	25.5	25.5			
	11	412+35 to 423+92 433+75 to 434+38	1,220	36.1	36.1			
	14	541+82 to 554+90	1,308	11.4	11.4			
	16	515+49 to 528+67	1,318	7.4	26.3			
	18	487+03 to 500+33	1,330	4.1	14.2			
	20	460+62 to 473+82	1,320	10.5	15.5			
	22	434+22 to 447+41	1,319	6.9	10.2			
	24	397+45 to 410+73	1,328	0.5	6.6			
		TOTAL	15,733	Avg 13.0	Avg 16.9			

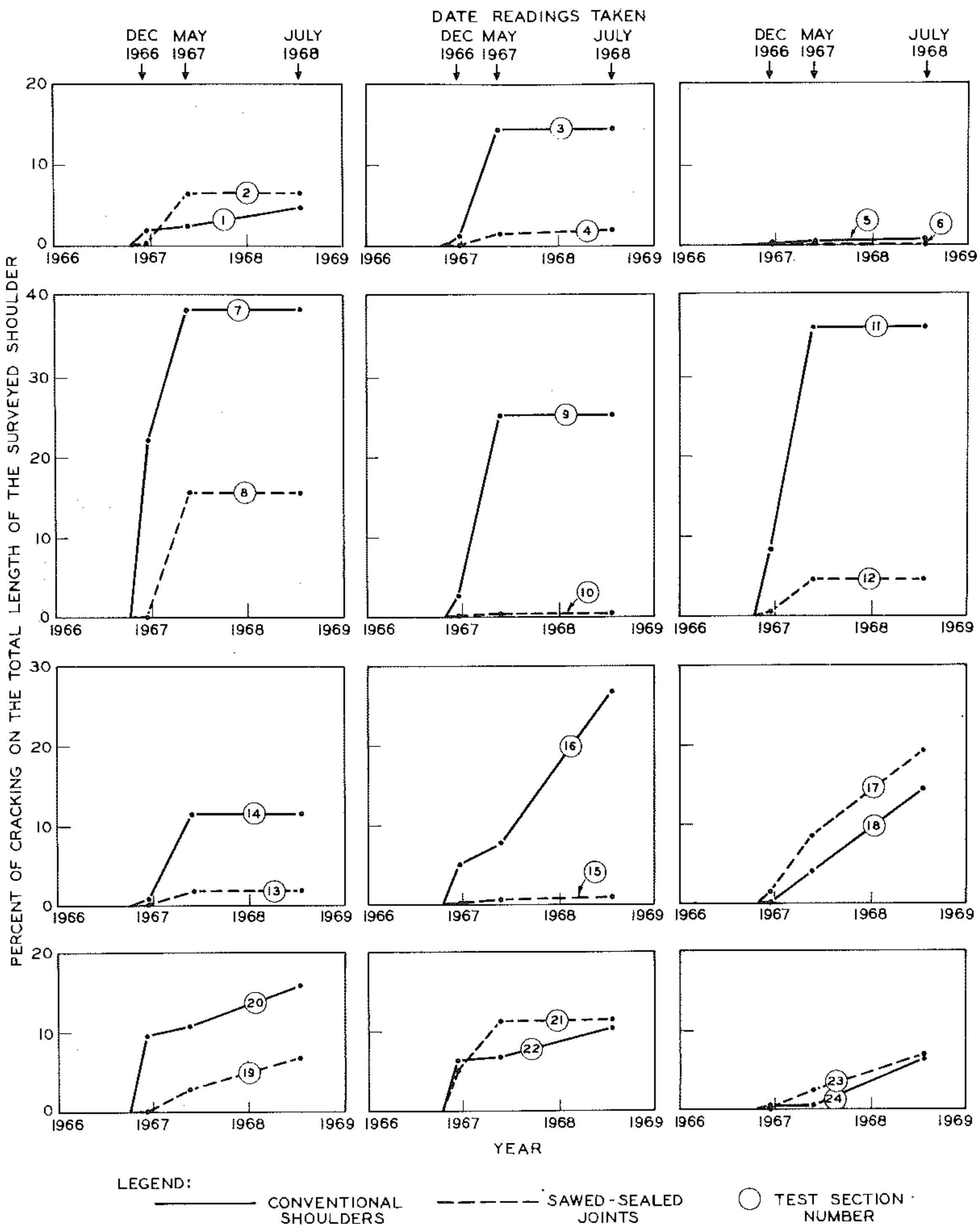


Figure 6. Crack formation progression, test project 5.

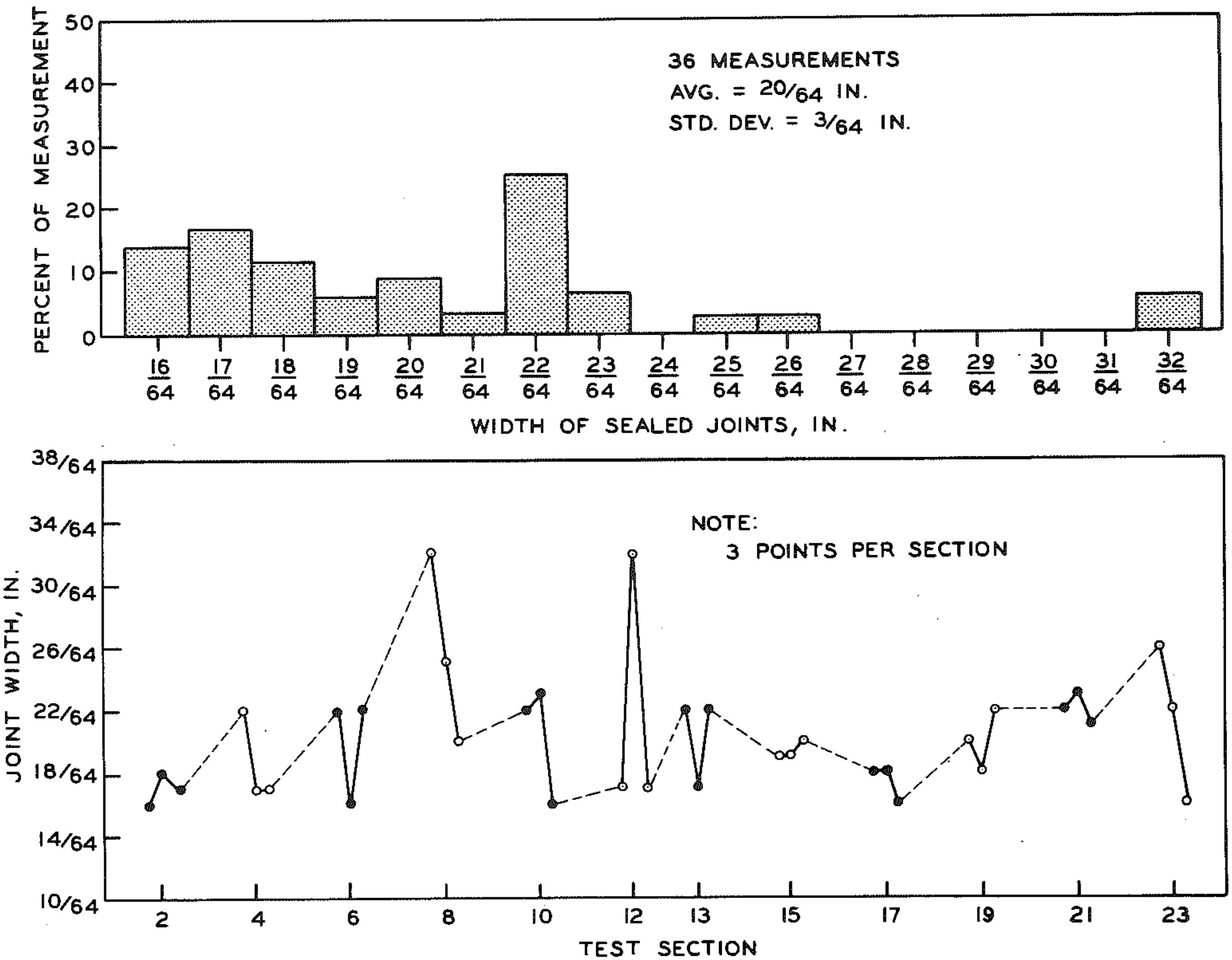


Figure 7. Lateral movement of sealed joint. March 1968 survey (test Project 5).

stabilized 13 months ago. Seven of the sealed test sections are currently showing better crack control than the conventional ones with which they are paired. For the other five pairs, the conventional shoulders show less cracking. Figure 6 shows that the typical curve of progressive longitudinal cracking consisted of two distinct periods. The first period is characterized by rapid crack development, especially during winter months, probably as a result of tensile stresses at the joint, settlement, or frost heave. The second period is characterized by a reduced rate of crack formation during warm weather, probably due to structural stability of the shoulders during this period.

For all test sections, the average (mean) shoulder length cracked was 16.9 percent for conventional shoulders and 6.5 percent for those that were seal treated.

Data from the twelve paired sections of project 5 indicate that statistically there is only a 5 percent probability of error if we accept the premise that the sawed-sealed joint is effective in reducing longitudinal cracking of shoulders constructed under similar controlled conditions. Future performance, however, might lead to altering that conclusion.

Lateral Movements

To evaluate the effects on the sealer of tensile stresses due to seasonal changes in temperature and humidity, lateral movements of the experimental joints of Project 5 were measured with a slide caliper at three random locations per test section. Results of these 36 random measurements recorded to the nearest 1/64 in. show a distribution with an average joint width of 20/64 in. and a standard deviation of $\pm$ 3/64 in. There has been a 122-percent stretch in the sealing material caused by lateral movement. This is about 2.5 times the 50-percent limit specified for sealing materials. A graphical record of the horizontal movement of the joints from test section 2 through 23 show two single measurements whose values are greater than three standard deviations from the average (Fig. 7). This could very likely be the result of joint spalling at those random locations.

To determine whether longitudinal cracking of the bituminous shoulders and lateral movement of the joints were related, results were plotted on a scatter diagram (Fig. 8). Although the correlation coefficient for the data is $r = 0.66$, which is statistically significant at the 0.05 level, the strength of this correlation depends mainly on the two single measurements falling outside the three standard deviations from the average width of 20/64 in. (Fig. 7). By neglecting these two "wild" points (a reasonable practice) located at the upper right corner of the scatter diagram, the two variables being compared give little or no indication of being associated.

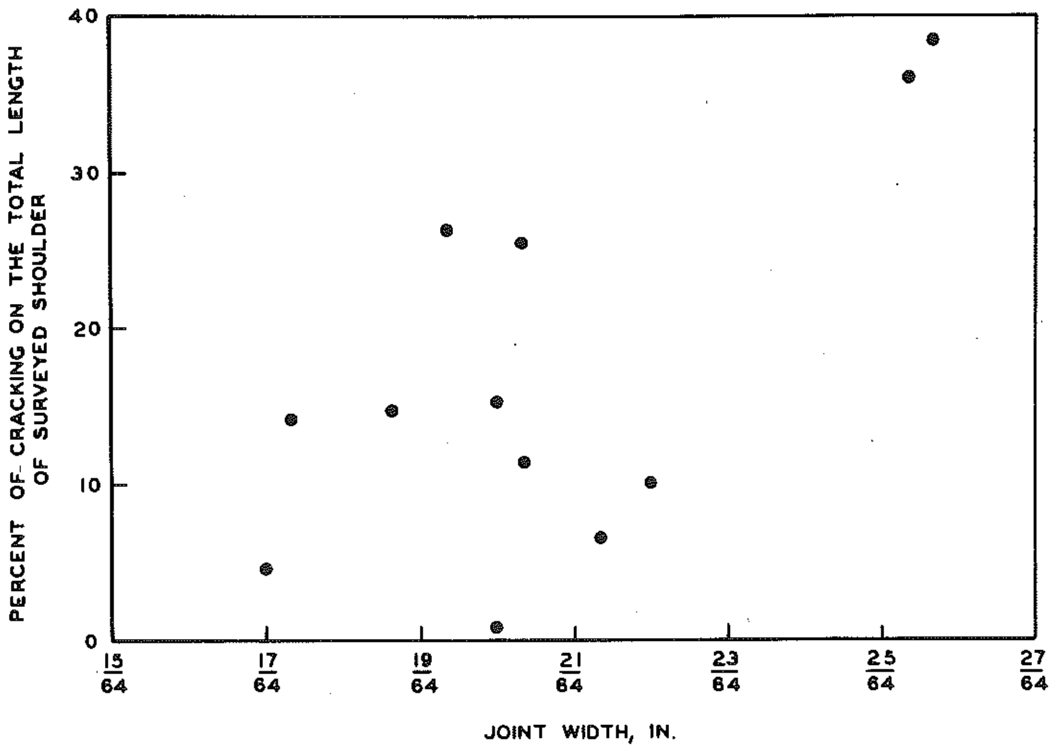


Figure 8. Scatter diagram of relationship between cracking and joint width, test Project 5.

Vertical Movement

Since it is possible that frost heave of bituminous shoulders has some effect on the formation of longitudinal cracks, elevations at Project 5 were obtained in February 1968 with a surveyor's level on both sides of the longitudinal joint between the concrete pavement and the bituminous shoulder. Elevations, recorded to the nearest 0.01 ft, were taken at three random locations in each test section. From these measurements, 72 elevation differentials were obtained showing that on the average the pavement was higher than the shoulder by 0.02 ft. Thus, since the initial elevation differential averaged -0.01 ft, it appears that a differential settlement of 0.01 ft was produced on the shoulders.

A graphical record of the elevation differentials from test sections 1 through 24 shows two extreme values, one falling more than three standard deviations below the average and another exactly on three standard deviations above the average (Fig. 9). These extreme values could be the result of frost action at those random locations.

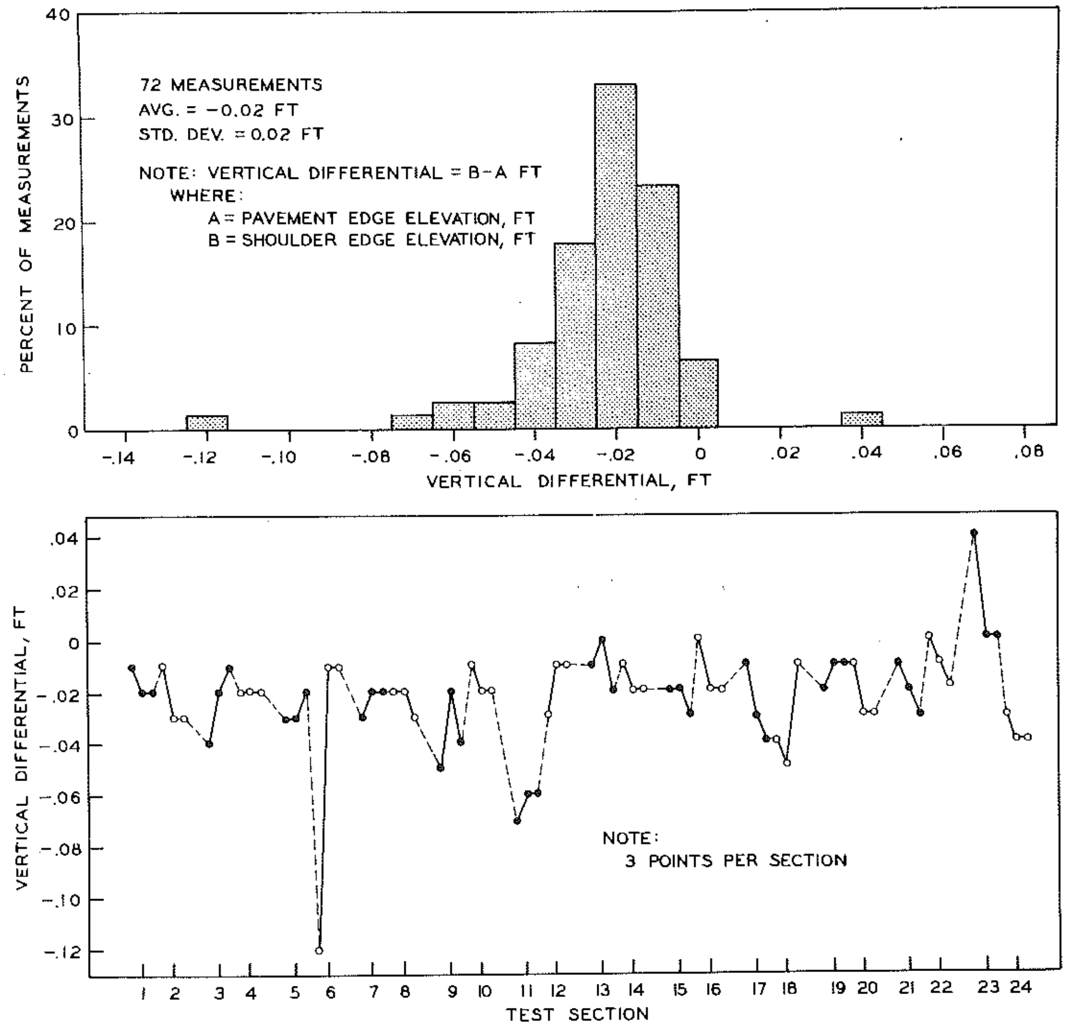


Figure 9. Vertical differential at joint between bituminous shoulder and pavement. February 1968 survey (test Project 5).

To determine whether longitudinal cracking of the shoulders was related in some manner to elevation differential, measurements were plotted on a scatter diagram (Fig. 10). The resulting points are so scattered that the two variables being compared give no indication of being associated.

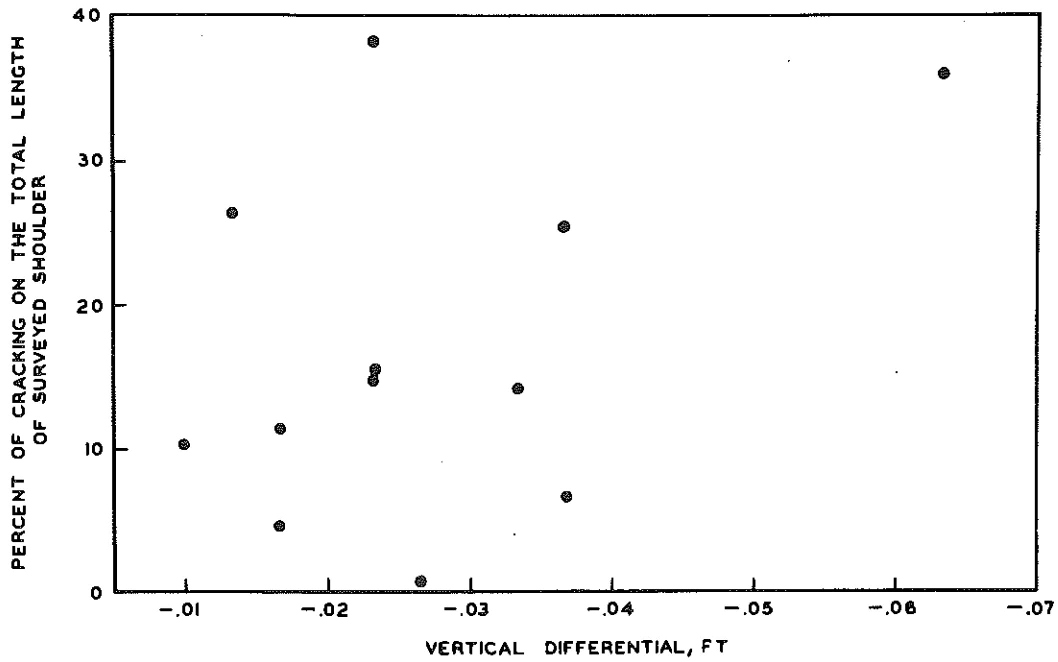


Figure 10. Scatter diagram of relationship between cracking and vertical differential, test Project 5.

Joint Failure

In Project 5, two types of interface joint failures were apparent: sealer failure caused by excessive tension in the sealing material, leaving opened joints wide enough for infiltration of water, sand, gravel, and salt (Fig. 11), and joint spalling caused by separation and removal of concrete at the pavement edge parallel to the experimental joint (Fig. 12).

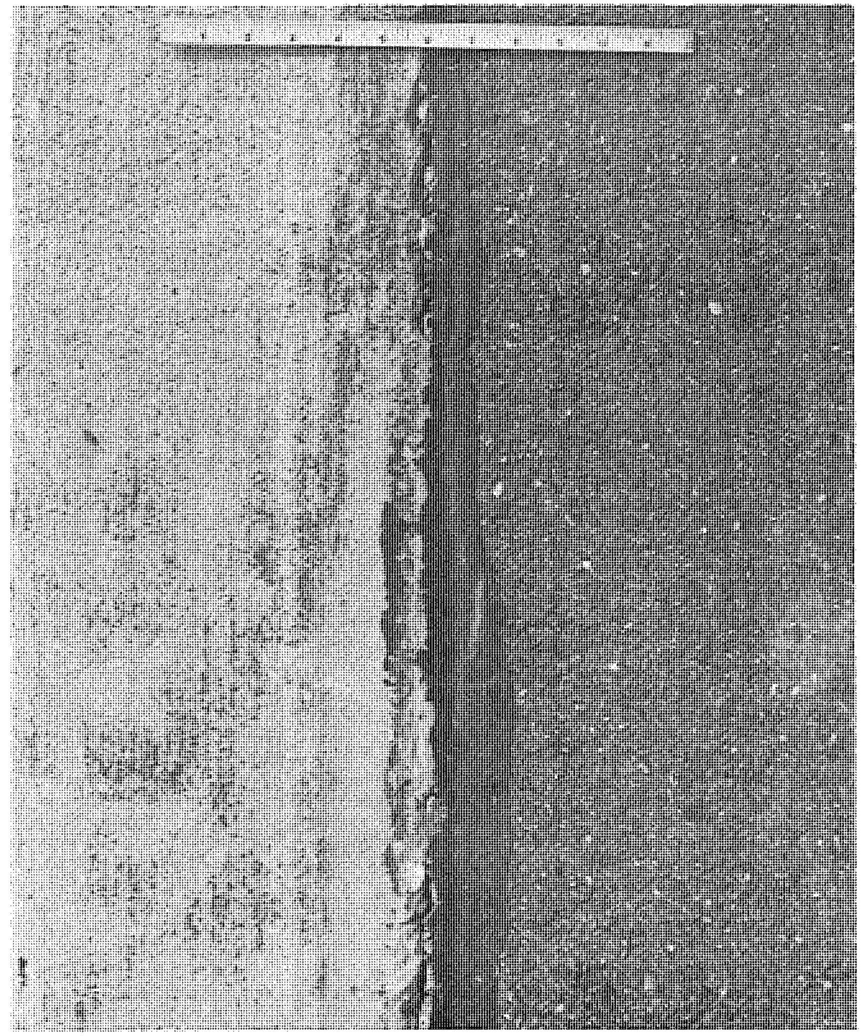
The extent of joint failure (in percent) of shoulder length surveyed in June 1968 is given in Table 1 and summarized in Figure 13. Here, the data display a percentage of sealer failure ranging from 2.4 to 79.9 percent and averaging 34.2 percent. However, there is no apparent correlation between this rising trend in percent of sealer failure and extent of longitudinal cracking over the same test sections. Similarly, when results of joint spalling and longitudinal cracking are compared, no relationship is obtained between the two sets of data.

Station 404+60
SB Roadway
Age - 1 year 5 months

Station 406+60
SB Roadway
Age - 1 year 5 months

Figure 11. Typical tension failure of sawed-sealed joints at two project 5 locations. Joints are open wide enough to allow infiltration of water, sand, gravel, salt, or other incompressible material. March 1968 survey.

Station 554+47
Project 5 - SB Roadway
Age - 1 year 8 months



Station 493+04
Project 5 - SB Roadway
Age - 1 year 8 months

Figure 12. Typical joint spalling (Project 5, June 1968).

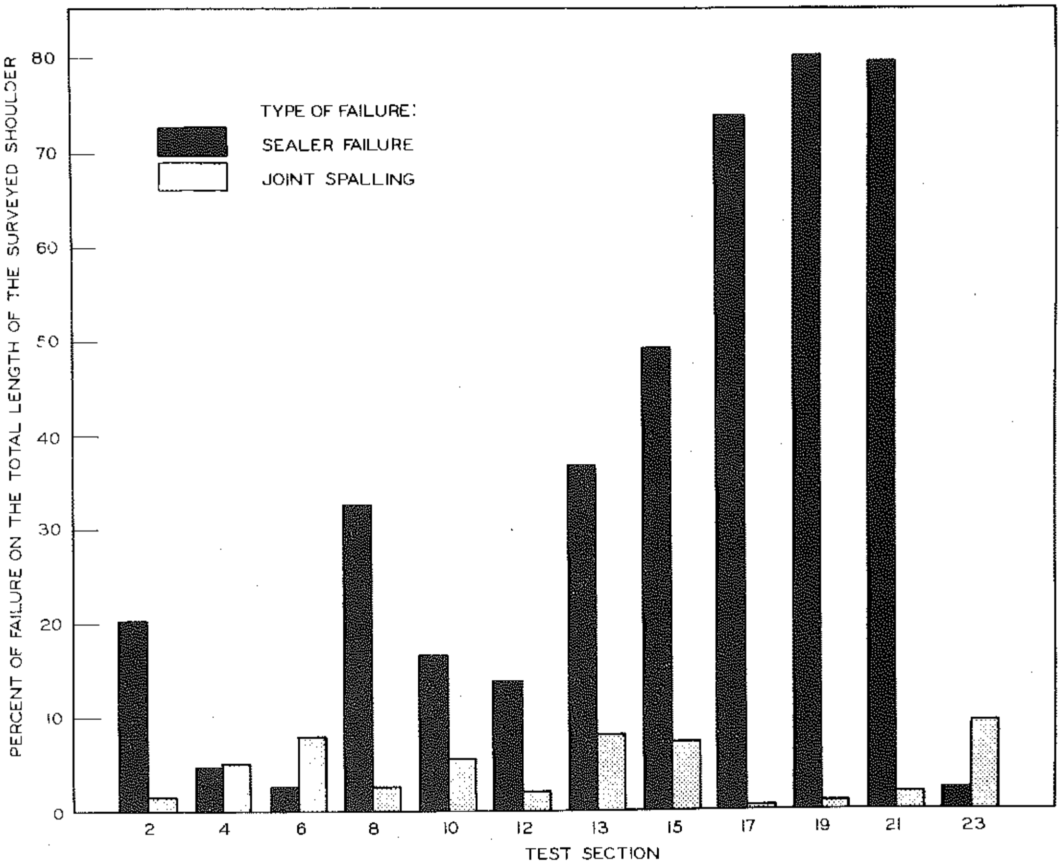


Figure 13. Sealer failure and joint spalling on test project 5.

RESULTS FROM OTHER PROJECTS

In addition to Project 5, investigations were made of 11 other construction projects with sawed-sealed shoulder interface joints which were not controlled experiments and thus provide only scant information. Table 2 and Figure 14 contain data obtained from recent field observations of four seal-treated joint projects (referred to as Projects 1 through 4) constructed prior to Project 5 and listed in the First Progress Report. Projects 1 through 3 incorporated lengths of conventional shoulder construction and comparison data are given in Table 2. Although the conventionally constructed shoulders showed cracking over a length proportionally less than the seal-treated area, no statistically sound conclusions can be drawn. A comparison between the two types of joints tested in these projects, sawed-sealed and wheel cut-sealed joints, shows no superiority of one over the other in controlling shoulder cracking. Among projects with sawed-sealed

TABLE 2

SUMMARY OF LONGITUDINAL CRACKING OF BITUMINOUS SHOULDERS, MAY 1968 SURVEY

Test Project	Construction Project and Construction Year	Project Location	Stationing	Traffic Direction	Joint Type	Shoulder Length, lin ft	Length of Cracked Shoulder	
							lin ft	percent
1	EBBF 56044, C16 (1962)	US 10 west of Sanford	1060+00 to 1192+35	WB	1/8- to 1/4-in. wide, sawed and sealed	13,235	958	7.2
				EB	conventional, without sawing	13,235	643	4.9
2	EBI 69013, C1 (1962)	I 75 north of Waters	2125+73 to 2256+00	NB	1/8- to 1/4-in. wide, sawed and sealed	13,027	1,895	14.5
				SB	conventional, without sawing	13,027	1,281	9.8
3	FI 34044C, C18 FI 19022C, C9 I 34044C, C19 I 19022C, C10 (1964)	I 96 east of M 100 to Portland	1348+00 to 1533+27.22 1533+27.22 Back 33+27.22 Ahead 33+27.22 to 83.00	EB	1/8-in. wide, sawed and sealed	42,162	5,167	12.3
					conventional, without sawing	4,973	35	.7
			1348+00 to 1533+27.22 1533+27.22 Back = 33+27.22 Ahead 33+27.22 to 319+35	WB	1/8-in. wide, wheel-cut and sealed	47,135	3,963	8.4
4	I 81062C, C14, C15 (1964)	I 94 from Ann Arbor to junction with US 23	934+90 to 936+00 79+00 to 458+38	EB	1/8-in. wide, wheel-cut and sealed	38,048	6,505	17.1
				WB	1/8-in. wide, wheel-cut and sealed	36,815	6,699	18.2
5	F 33035A, C6 (1966)	US 127 in Mason	568+10 to 399+17 SB and 397+51 to 564+72 NB	SB NB	1/8-in. wide, sawed and sealed	15,473*	806	6.5
				NB SB	conventional, without sawing and sealing	15,733*	2,471	16.9

* Bridges and ramps are not included.

joints, the percentage of length which showed cracking ranges from 1 to 35 percent, while among the other projects with wheel cut-sealed joints, from 2 to 41 percent.

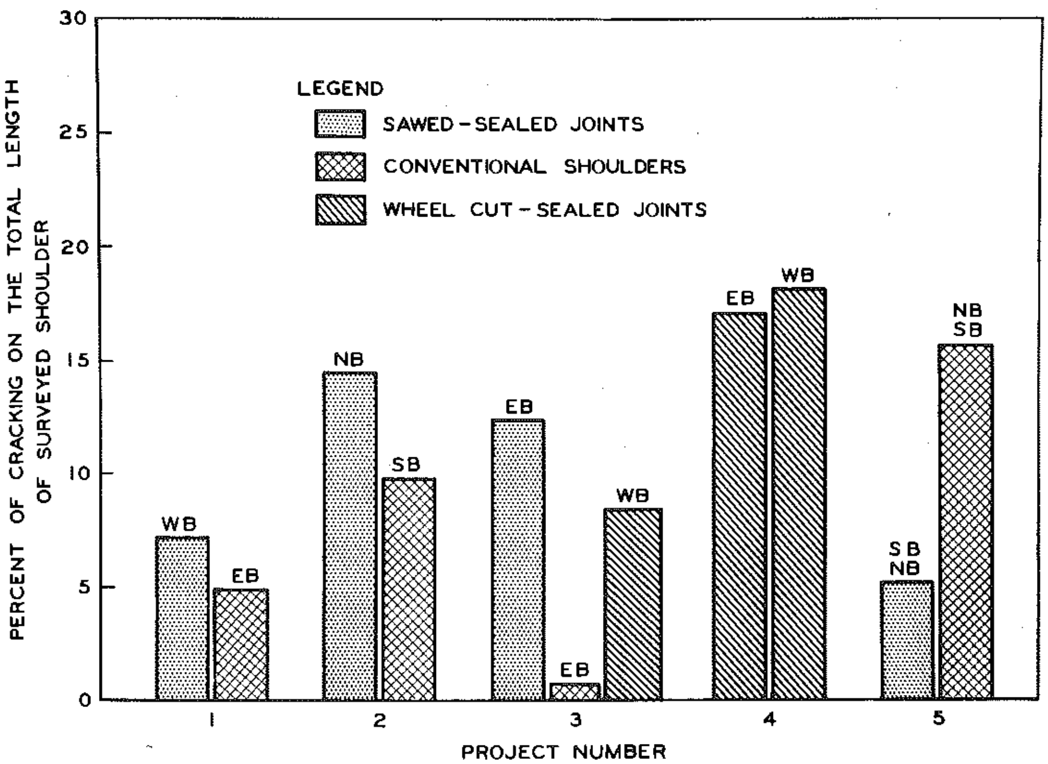


Figure 14. Longitudinal cracking of seal-treated and conventional (unsealed) shoulders. May 1968 survey.

Table 3 and Figure 15 present data from seven projects constructed after completion of Project 5 but prior to performance observations on it. These seven newer projects (referred to as Projects 6 through 12) were completed in 1967 on I 69 south of Marshall in Calhoun and Branch counties. On five of these projects, longitudinal joints between concrete pavement and outside bituminous shoulders were sawed and sealed (Projects 6, 8, 9, 10, and 12) and the other two were wheel-cut and sealed (Projects 7 and 11). Portions of the new projects were opened to traffic in September 1967.

Extensive longitudinal cracking of the shoulders was observed within a few months after construction. A very significant observation was made on Project 12; the southbound shoulder, opened to traffic, showed cracking over 30 percent of its length, while the northbound, not opened to traffic,

TABLE 3
SUMMARY OF LONGITUDINAL CRACKING OF BITUMINOUS SHOULDERS ON I 69 SOUTH OF MARSHALL (CALHOUN AND BRANCH COUNTIES), JUNE 1968 SURVEY

Test Project	Construction Project and Construction Year*	Stationing	Traffic Direction	Joint Type	Shoulder Length, lin ft	Length of Cracked Shoulder	
						lin ft	percent
6	12033A, C10 (1966)	47+00 to 217+00	SB	1/8-in. wide, sawed and sealed	15,217	222	1.5
			NB	1/8-in. wide, sawed and sealed	15,301	1,484	9.7
7	12033A, C9 (1966)	217+00 to 325+00	SB	1/8-in. wide, wheel-cut and sealed	10,766	185	1.7
			NB	1/8-in. wide, wheel-cut and sealed	10,755	1,368	12.7
8	12033B, C7, AC8 (1966)	325+00 to 590+00	SB	1/8-in. wide, sawed and sealed	24,446	2,888	11.8
			NB	1/8-in. wide, sawed and sealed	20,861	6,716	32.2
9	12033D, C5 (1966)	590+00 to 730+00	SB	1/8-in. wide, sawed and sealed	12,931	3,210	24.8
			NB	1/8-in. wide, sawed and sealed	12,984	4,509	34.7
10	12034A, C4 (1966)	730+00 to 850+00	SB	1/8-in. wide, sawed and sealed	11,320	2,915	25.7
			NB	1/8-in. wide, sawed and sealed	11,326	2,571	22.7
11	12034B, C1 (1966)	850+00 to 1215+00	SB	1/8-in. wide, wheel-cut and sealed	34,753	14,203	41.0
			NB	1/8-in. wide, wheel-cut and sealed	34,626	3,379	9.8
12	13073A, 65-1748 (1966)	1215+00 to 1375+00	SB	1/8-in. wide, sawed and sealed	13,960	4,280	30.1
			NB	1/8-in. wide, sawed and sealed	12,788	26	0.2

* Bridges and ramps are not included

had almost no cracking. During the first winter after construction, heaving of Project 6 through 12 shoulders exceeded 1/2 in. in some areas.

In summary, it seems that the type of longitudinal cracking under study is caused by frost heave followed by traffic loading. Further, since longitudinal cracking developed over 30 percent of the length of four of the projects, it can be concluded that seal-treated joints do not always prevent extensive cracking.

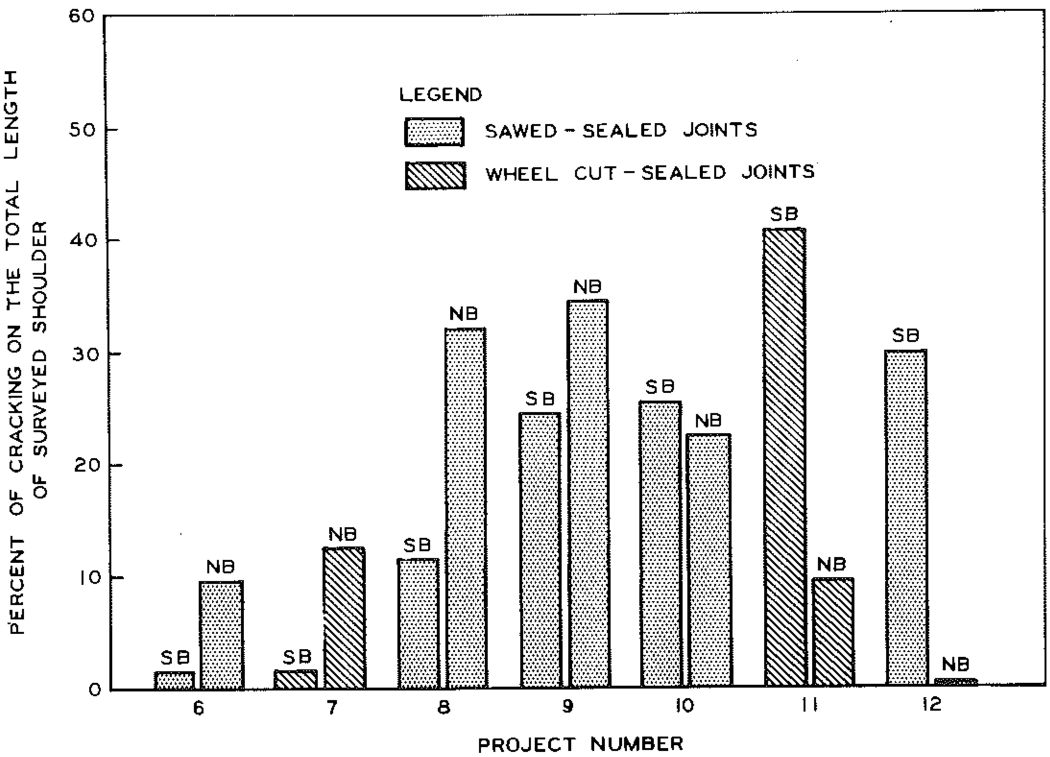


Figure 15. Longitudinal cracking of seal-treated shoulders, I 69 S of Marshall. June 1968 survey.

Progressive Crack Formation

Increase of longitudinal cracking with respect to age is shown in Figures 16 and 17. The graphs show the different rates at which longitudinal cracking increased after the projects were opened to traffic. However, for Projects 1 through 4, nothing can be said about early cracking since surveys were not made until two to three years after construction.

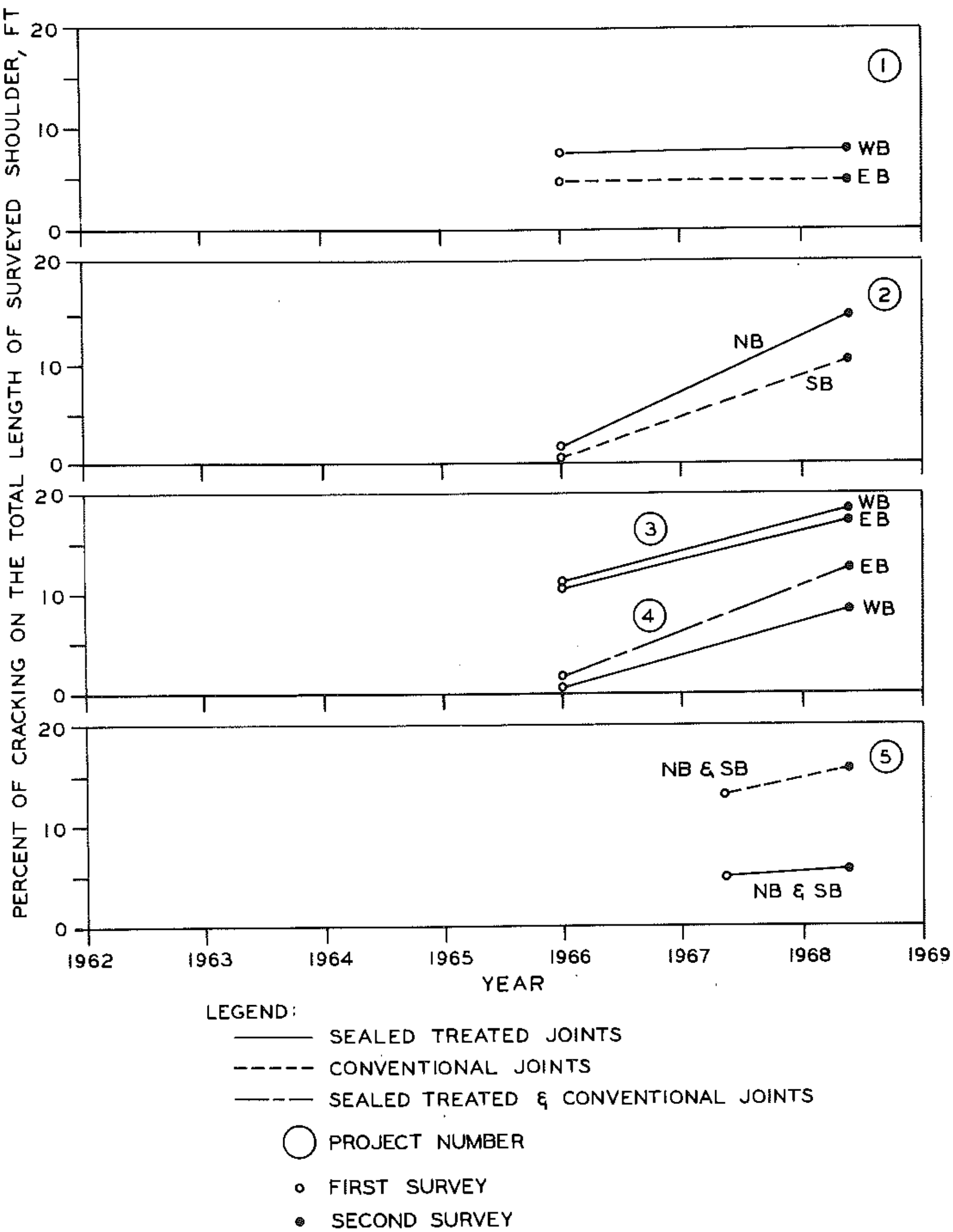


Figure 16. Relationship between longitudinal cracking and length of service in years.

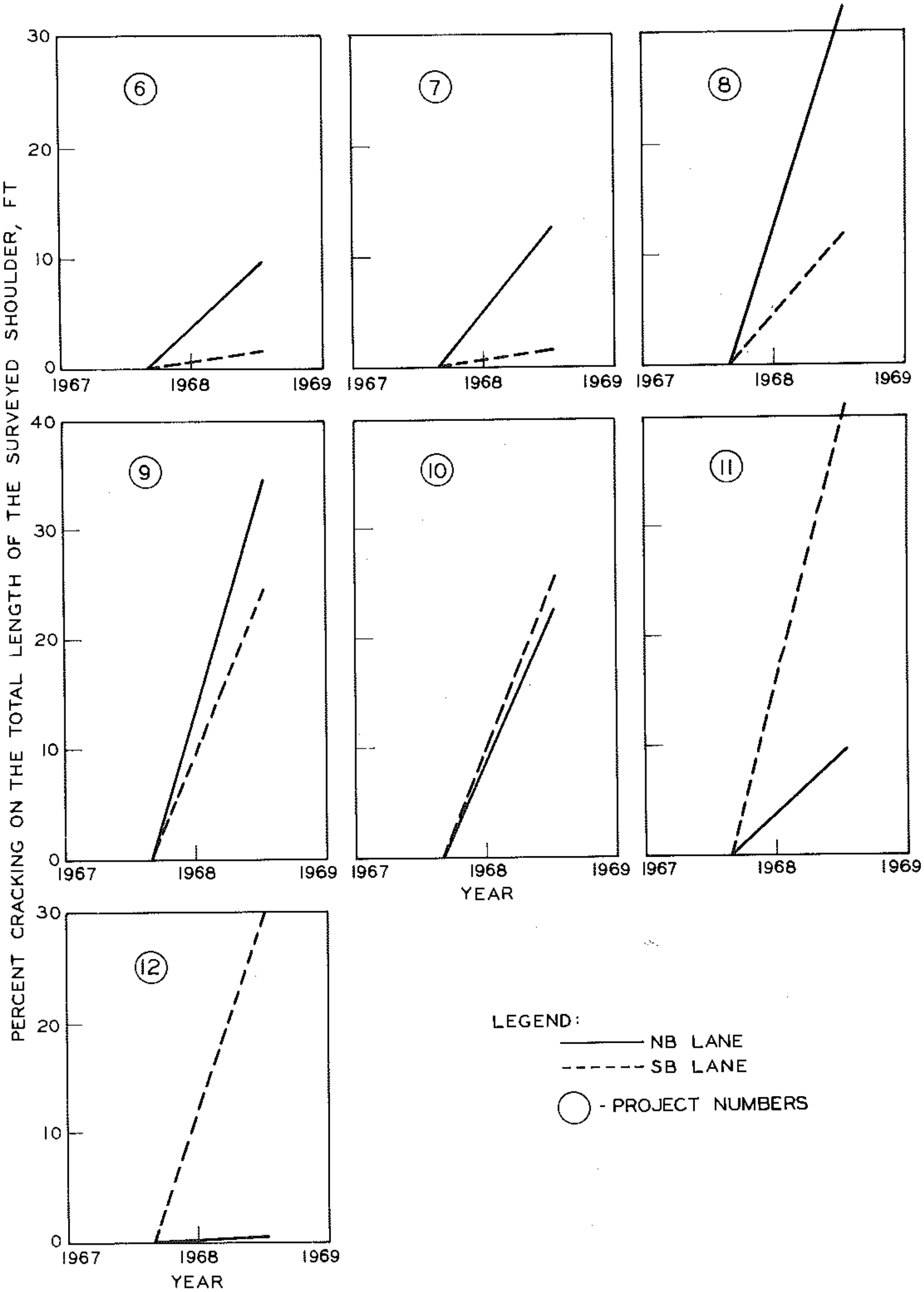


Figure 17. Relationship between longitudinal cracking and length of service in years.

In Project 1, after three years, longitudinal cracking was observed over about 6 percent of the total length and did not increase during the next two years. In Projects 2 and 3, after showing only moderate cracking during the first two or three years, cracking increased sharply at an average annual rate of 11 to 13 percent over the following two years. In Project 4, cracking has also increased during the two year survey period.

A review of progressive cracking shows that shoulders have cracked shortly after construction, probably because of water in the shoulder material when the bituminous wearing course was placed. Cracking in subsequent years probably resulted from water penetrating the wearing surface through cracks and through the interface joint where sealer had failed or was not placed.

CONCLUSIONS

1. Seal-treated interface joints do not completely prevent longitudinal shoulder cracking although, based upon 20 month observations of a controlled experiment, they do, at least temporarily, reduce the total quantity of cracking in this controlled project.

2. Longitudinal shoulder cracking can result from frost heave followed by traffic loading. Frost heave may occur a) almost immediately after construction as a result of water in the shoulder material when a wearing surface is applied or b) during years after construction as surface water enters the shoulder material through cracks or through an open interface joint. However, observation of shoulder cracking in bituminous shoulders in Florida, indicate that cracking can also occur in areas where there is no frost.

3. Although cutting and sealing should prevent the entrance of water into shoulder material through the interface joint; field observations indicate that the major length of joint sealer soon fails due to excessive tension or spalling, so very little protection is afforded. On Project 5, measurements showed joint movement to cause an average stretch of 122 percent in the sealing material. This is about 2.5 times the 50 percent limit specified for solvent-type mastic compound used in the Project.

RECOMMENDATIONS

Sawing or cutting and sealing of shoulder-pavement interfaces should be discontinued. Even though, in some cases, the seal-treated joint is effective in reducing shoulder cracking by a small percent, the effectiveness is soon lost because of joint sealer failure. Consequently, the additional cost of this operation is not justified.