94

MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

RESEALING OF OLD EXPANSION JOINTS WITH BITUMINOUS-RUBBER COMPOUND IN RELATION TO HIGHWAY MAINTENANCE

LAST COPY
DO NOT REMOVE FROM LIBRARY

by

Bryant W. Pocock

and

William Martin

Research Project 36 G-4 (3) F

in conjunction with

Research Project 36 G-4 (6)

Research Laboratory
Testing and Research Division
Report F-94
March 14, 1947

CODE

Material	Brand	Manufacturer
A	Careylastic	Philip Carey Manufacturing Co. Lockland Cincinnati, Ohio
B	(Paraplastic (Kapco *	Servicised Products Company 6051 W. 65th Street Chicago, Illinois
C	Sealz	Dispersions Process Inc. Rockefeller Center New York, N. Y.
D **	Flintseal	The Flintkote Company 30 Rockefeller Plaza New York, N. Y.

* Vendor - Keystone Asphalt Products Co.
Chicago, Illinois

** Used in laboratory tests only for comparative study.

FOREWORD

This report describes the work and subsequent results of an experimental field project conducted jointly by the Research Laboratory of the Testing and Research Division and the Maintenance Division. The project is concerned with the cleaning and resealing of expansion joints in old concrete pavements as a future maintenance consideration.

The work of cleaning and resealing the joints was performed by a maintenance crew out of the Kalamazoo District under the direction of Harvey Sibbald. The laboratory work performed in conjunction with the field project as well as the experimental field work were under the general direction of the authors.

TABLE OF CONTENTS

RESEALING OF OLD EXPANSION JOINTS WITH BITUMINOUS-RUBBER COMPOUNDS IN RELATION TO HIGHWAY MAINTENANCE

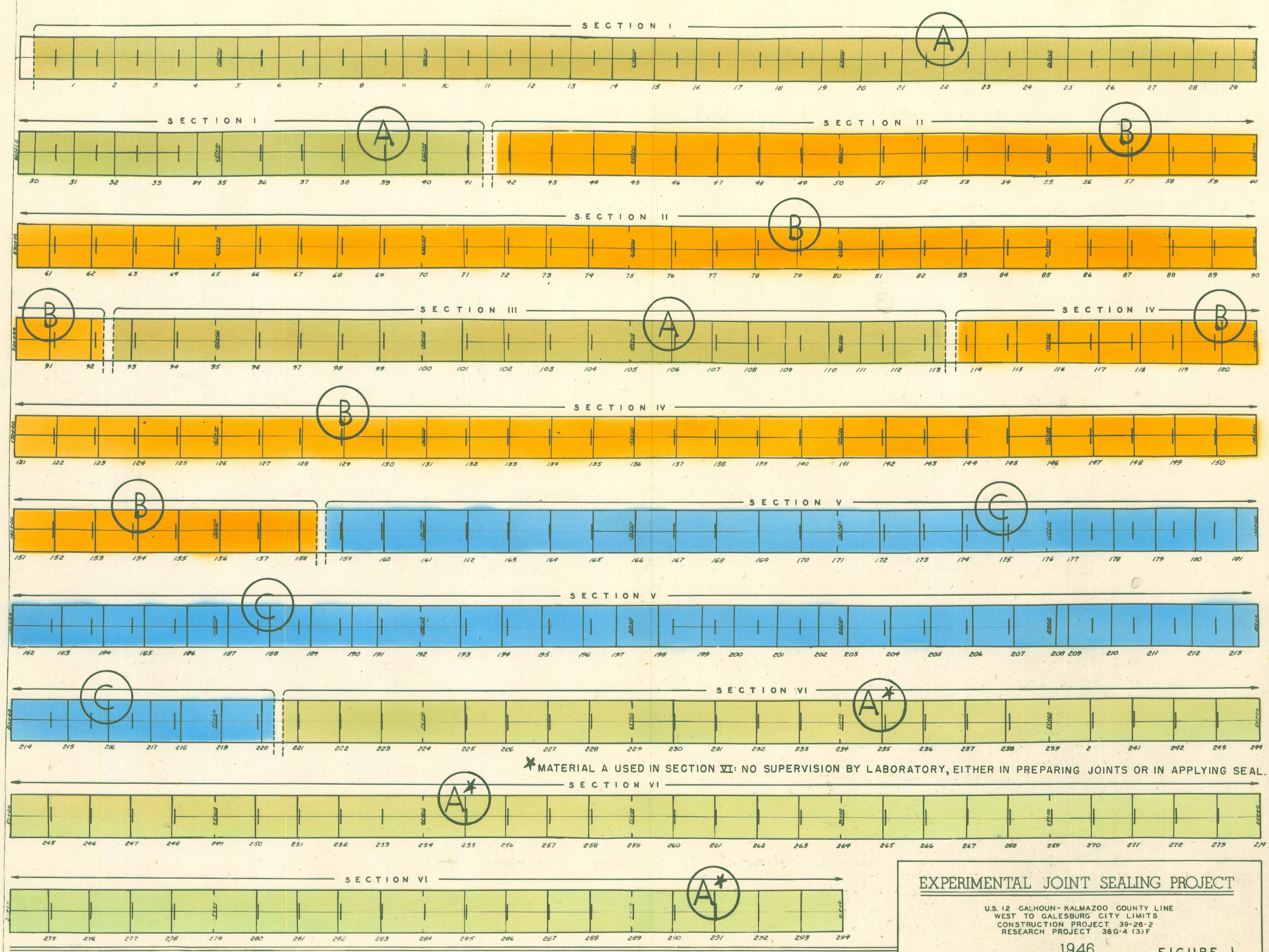
INTRODUCTION

As a corollary to the Department's current investigation of hot-poured bituminous-rubber joint-sealing compounds, research project 36 G-4 (6), a study was initiated in 1945 to determine the feasibility of using these compounds for resealing joints in old concrete pavements under normal maintenance conditions. A preliminary experimental project, 36 G-4 (3)E, was established in November of that year on US 16 west of Lansing. This work included the plowing out of the old joint seal material to a minimum depth of 1-1/2 inches and resealing with new material of the bituminous-rubber type. A report covering this project was presented in May, 1946.

On the basis of the results from this study it was decided to carry on the investigation on a much larger scope in order to realize more conclusive information concerning equipment, handling and costs; also to evaluate the relative performance of the various types of commercial seals when this work is done under regular maintenance procedure.

This new experimental field project, 36 G-4 (3)F, was established July, 1946 on US 12, construction project 39-26,C2, west of Battle Creek, starting at the Calhoun-Kalamazoo County line and going west to Galesburg.

The research project (see map, Figure 1) was set up to include 294 expansion joints. These were divided into 6 groups, or sections, according to materials used. The old joint seal was plowed out and the joints resealed in accordance with the following schedule. The three types of commercial compounds included in the study are designated as materials A, B and C.



EXPERIMENTAL JOINT SEALING PROJECT

U.S. 12 CALHOUN - KALAMAZOO COUNTY LINE
WEST TO GALESBURG CITY LIMITS
CONSTRUCTION PROJECT 39-26-2
RESEARCH PROJECT 36G-4 (3)F

1946

FIGURE I.

Section	Station		No. of Joints in Section	Material	Date of Resealing
	From	To			
I	288+63	248+98	40	A	7-22-46
II	247+98	198+10	51	B	7-23-46
III	197+10	177+80	21	A	7-24-46
IV	176+80	136+98	46	B	7-24-46
V	131+98	73+90	62	C	7-25-46
VI	73+06	0+00	74	A	October, 1946

All work was carried out by a Department maintenance crew supplied by the maintenance unit at Kalamazoo. Regular maintenance equipment was used for cleaning the joints, including plow, Figure 2, and air compressor. Additional equipment included special steel plate and spade for slicing material into thin slabs preparatory to melting, Figure 3. A new Littleford melting kettle of the direct heating type and 75 gallon capacity, as shown in Figures 4 and 5, was used for melting all seals included in the study. Operations in sections I through V were carried out under supervision by members of the Research Laboratory staff. All sealing compounds were tested prior to use and found to fulfill the requirements of Federal Specification SS-F-336.

The expansion joints were plowed out to a depth of approximately 1 inch minimum, and all loose material was blown out of the joints by compressed air. Various methods were tried of removing all traces of the old joint seal material from the joint faces; no method tried, however, proved satisfactory. A rotating wire brush, for example, was found to smear rather than cut through and remove the thin layer of old seal material (SOA). Eventually it was decided to clean the joints as well as possible by manual operations, assuming this to be typical of the best that could be expected under normal conditions with available equipment and technique, then to investigate the condition of the seals at a later date. Subsequent evaluation would then indicate whether

Figure 2. Plow used for cleaning out old joint seal in preparation for resealing of expansion joints.

Figure 3. Hot steel spade being used to cut seal into thin slices preparatory to melting. Note steel plate for preventing contamination of seal.

or not it would be necessary to remove the last traces of old seal in future work of this nature.

As shown in Figures 4 and 5, a dial type thermometer was installed on the melting kettle, with its bulb located at a representative spot within the melted material. Although some difficulty was experienced at first in keeping the temperature of the material within the manufacturers' recommended melting temperature ranges, this difficulty was shortly overcome. With the possible exception of a few isolated instances of short duration, all seals used in sections I through V were melted and poured within recommended limits of temperature (between 400 and 435 degrees F.) Figures 6 and 7 show pictures of general sealing operations.

The joints in section VI were sealed at a later date, the following October. Work in this section was not supervised by the research laboratory personnel. A stirring device, Figure 5, which had been added to the kettle in the meantime, was used during the melting of material for these joints.

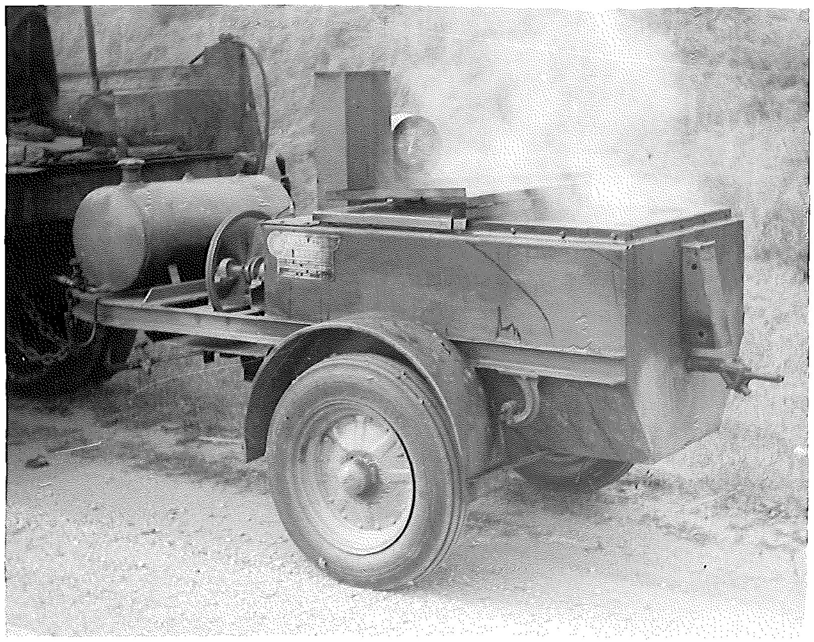


Figure 4. Littleford melting kettle used for melting seal. Note specially-installed dial type thermometer.

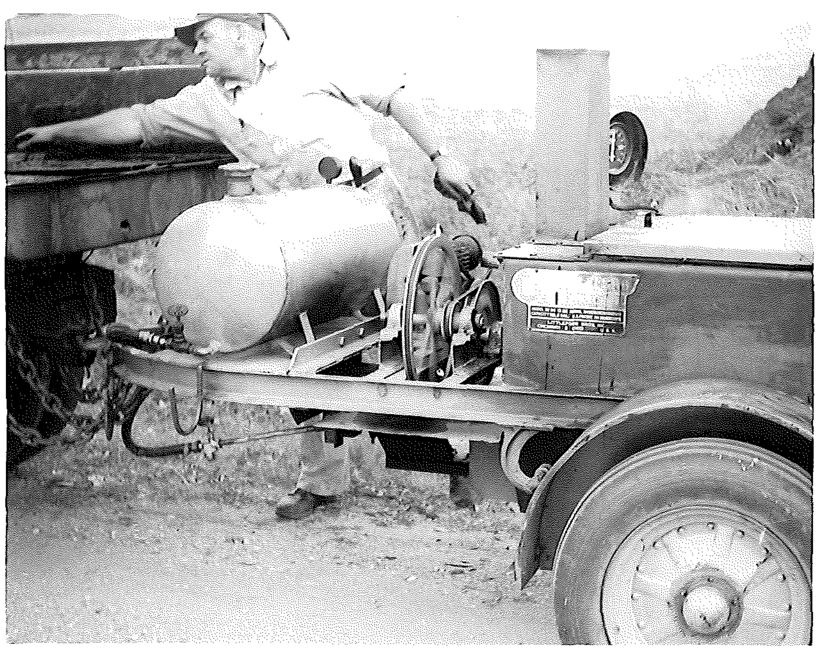


Figure 5. View of melting kettle showing power supply (gasoline motor plus suitable reductions) for driving screw type horizontal agitator about 60 R.P.M.

Figure 6. General view of sealing operations.

Figure 7. Close-up view of pouring operations.

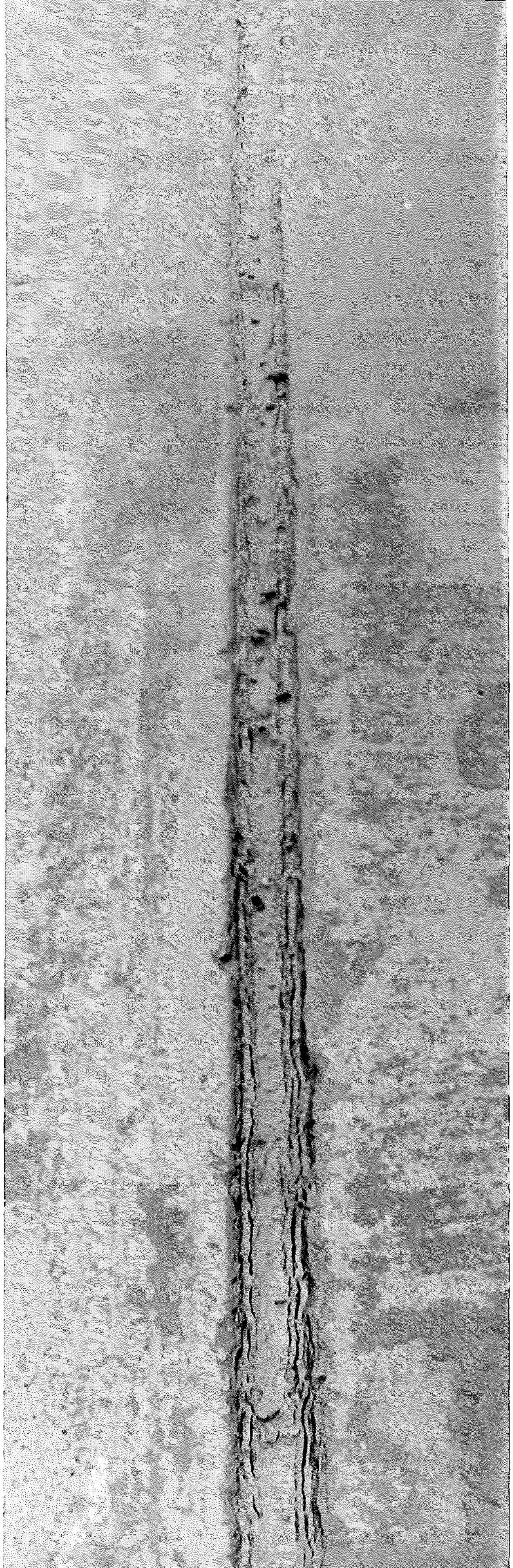
FIRST CONDITION SURVEY

A complete inspection of the condition of all joints in all sections was made during a survey conducted on February 17, 1947, in the midst of a spell of cold weather. Of considerable interest was the fact that out of 294 joints included in the experiment, only 12 showed no failure of any kind.

Examination disclosed that failure of the joint seals was largely a failure in adhesion. Only 29 joints showed internal breaks characteristic of failure in cohesion, and these breaks were only a few inches in length. A sufficient number of adhesion failures was examined closely to demonstrate that break in bond occurred somewhere between the new seal and part of the old seal which had been left on the joint faces. In no case did failure occur because the new seal had pulled away from bare concrete.

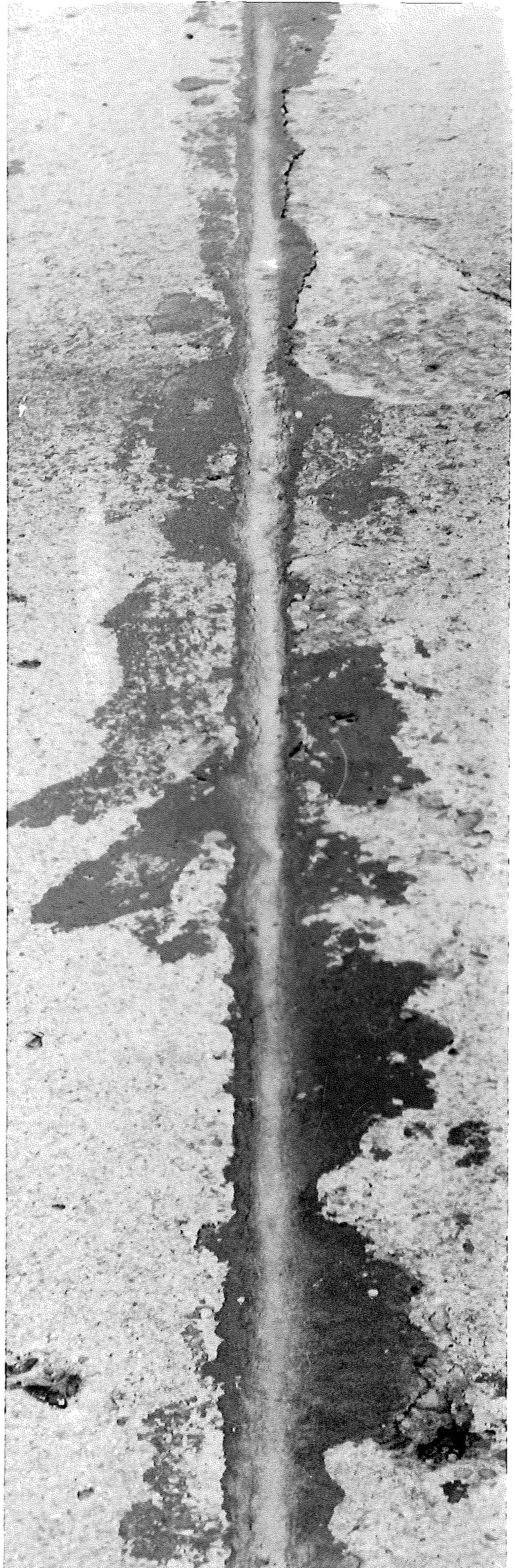
Differences Among Materials

Several interesting facts were brought to light as a result of this survey. For one thing, there were differences among materials. Figure 8, left, taken at Station 288+63, shows the wrinkled surface texture characteristic of all joints in this study which were sealed with material A. This wrinkled condition is quite different from the smooth surface of joints sealed with material C, as shown in the same figure, right, taken at Station 130+98. The surface of joints sealed with B is illustrated in Figures 9 and 10, right, taken at Stations 224+12 and 160+90, respectively. Material B, while wrinkled slightly, is much less so than is true of material A. Also, there appeared to be a greater tendency for stones to become embedded in A than in the other materials (see Figure 9, left, taken at Station 265+62).



Material A, Station 288+63
No failure.

2332



Material C, Station 130+98
No failure.

2340

Figure 8

Figure 8 shows two of the very few joints having no failure in either adhesion or cohesion. The one on the left is material A, that on the right is material C. Figure 11 shows in the case of two different joints one of the most interesting facts brought out by the survey of February 17. These joints are located at Stations 285+61 and 268+62, respectively. They both show that failure in adhesion has occurred mostly along the far side of the joint with respect to the direction of traffic. Figure 9, right, at Station 224+12, shows an exception to this rule, where the seal has pulled away from alternate sides all along the joint. (All photographs were taken looking south.) Another exception is seen in Figure 10, of joints at Stations 177+80 and 160+90. This view shows two pronounced failures in cohesion. The seal on the left of this figure is material A, that on the right is material B.

Failures in Adhesion

Reference to the chart, Figure 12, discloses that the various materials had the following total linear percentages of failure in adhesion on both sides of the joints, based on 40 feet of joint face for each joint:

Material C, 62 joints	9.38%
Material A, 61 joints	19.24%
Material B, 97 joints	21.46%
Material A*,74 joints	39.14%

* This comprised the group in section VI, which was not prepared or sealed under supervision by research laboratory personnel. (This means that, in the case of material C, for example, $62 \times 40 \times \frac{9.38}{100}$ gives 232.6 linear feet of adhesion failure out of a total of 2,480 feet of total joint face for all of the joints sealed with "C", considering both sides of the joints.)

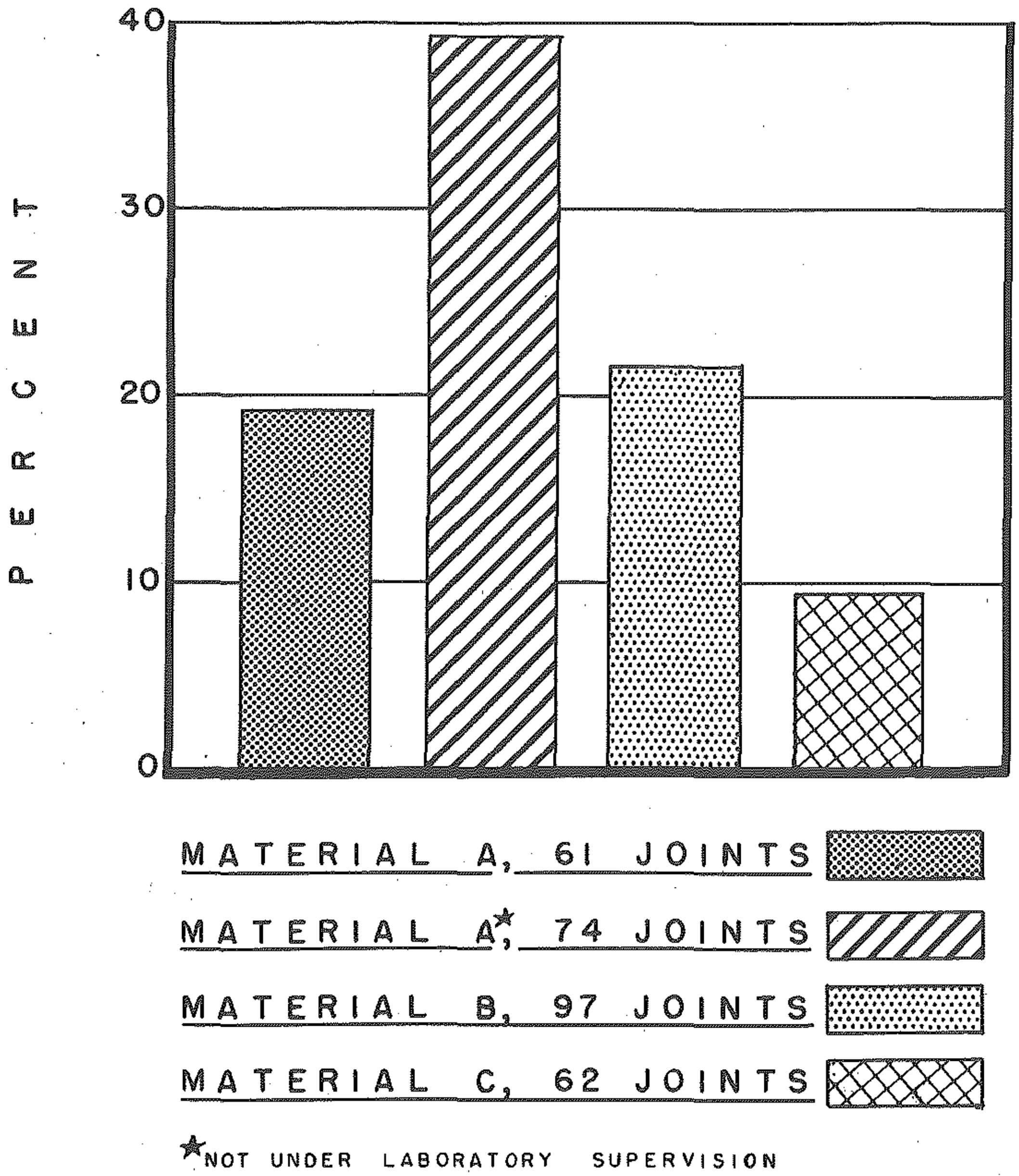
Material A, Station 177+80
Failures in cohesion.

2339

Material B, Station 160+90
Failures in cohesion.

2339a

Figure 10



COMPARISON *of* ADHESION FAILURE *in* PERCENT *of* TOTAL LINEAR JOINT FACE

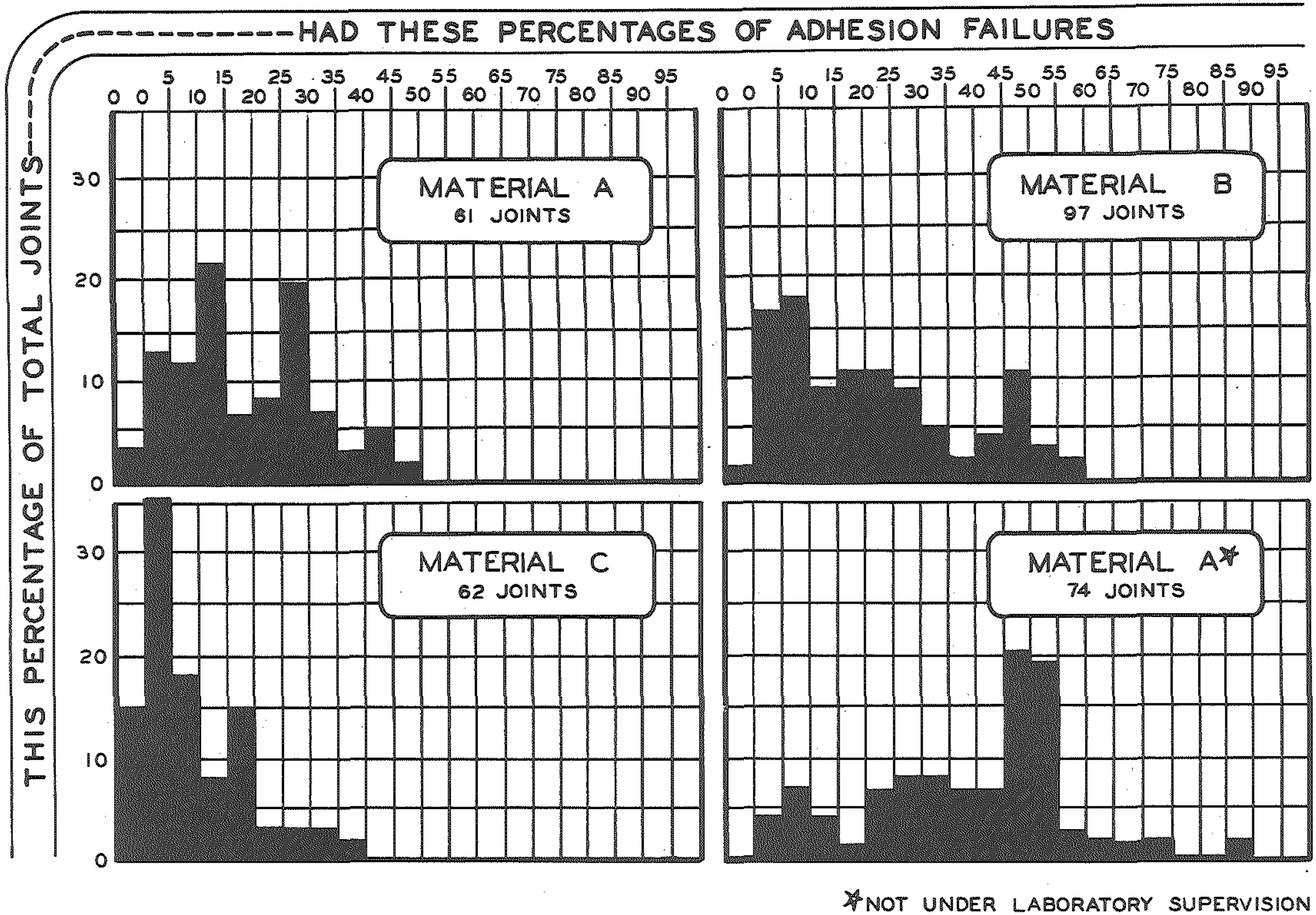
FIGURE XII

The chart in Figure 13 shows the frequency with which joints exhibited varying percentages of failure in adhesion. The ordinates are the numbers of joints within the failure brackets expressed as percentages of the total number of joints for each seal. Along the abscissae are plotted the failure brackets expressed as percentages of the total linear feet of joint face (40 feet). Here again, significant differences are seen among materials, material C showing up by far the best.

Effect of Direction of Traffic Flow

If the failures in adhesion are expressed as percentages of lane width and separated into east and west sides of the joint, as in Table I, significant differences again become apparent. In the north lane, for example, over twice as many failures occur on the far side of the joint with respect to the direction of traffic as occur on the near side. In the south lane the ratio is over 3 to 1. These figures are for the entire project of 294 joints. They are broken down in the table into comparable figures for each of the 6 sections and for each kind of material. No attempt is made to account for the reversal of trend in the case of material C in the south lane, or of material B in the north lane of section IV, but the high ratios of material A in sections I and VI are too outstanding to be ignored.

Whether these unsymmetrical failures in adhesion were caused by wheel traction or whether they are a result of sudden impact by heavy traffic approaching the near end of each successive slab is a question difficult to answer. Probably both factors contributed. In the absence of load transfer, considerable deflection of the slab ends due to impact must be expected, as is true also in cases where load transfer is not efficient. This is dynamic deflection, which under certain circumstances might approach twice the amount



COMPARISON *of* ADHESION FAILURE *in* RELATION *to* FREQUENCY DISTRIBUTION *of* EACH MATERIAL

FIGURE XIII

TABLE I

FAILURES IN ADHESION GROUPED BY SECTIONS AND BY MATERIALS

Section	Material	No. of Joints	Linear Failure in Adhesion in Average Percent of Lane — North Lane — East Face of Joint	North Lane — West Face of Joint	South Lane — East Face of Joint	South Lane — West Face of Joint
I	A	40	9.38	13.00	52.13	4.00
II	B	51	17.18	17.29	49.02	11.57
III	A	21	3.90	19.52	29.29	19.76
IV	B	46	16.65	9.63	21.65	24.37
V	C	62	1.90	2.94	4.42	11.65
VI	A*	74	17.07	64.03	65.76	10.03
I, III	A	61	7.49	15.24	44.27	9.43
II, IV	B	97	16.93	13.66	36.04	17.64
V	C	62	1.90	2.94	4.42	11.65
VI	A*	74	17.07	64.03	65.76	10.03
I - V	A,B,C	220	10.08	11.08	29.41	13.68
VI	A*	74	17.07	64.03	65.76	10.03
I - VI	All	294	11.84	24.41	38.56	12.76

* Material A used in Section VI: no supervision by Laboratory, either in preparing joints or in applying seal.

of static deflection, and will be vibratory in character. As a result of such deflections, it would not be difficult to predict wholesale shearing action of considerable magnitude along joint faces.

In view of these factors it is logical to conclude that shearing action would account for these failures in adhesion of joint-sealing compounds to the joint faces in cold weather. Differences in adhesion failure among brands of compounds could then be explained on the basis of differences in their physical properties when cold. Shearing action alone, however, would not account fully for the pronounced effect of direction of traffic, as the shearing action should be nearly as great on the near side of the joint as on the far side. Wheel traction could be expected to push seal away from the far side of the joint, especially when bond has been initially damaged by shearing action. The greater extent and frequency of failures in the south lane might be accounted for by a local traffic condition resulting in heavier traffic, and more of it, going east than west. The Traffic Division has no data on this.

The above would seem to indicate the possibility that perfect results may not be obtained even when old joint seal is entirely cleaned out, in cases where load transfer is absent or not efficient. Differences among sealing materials with respect to their susceptibility to dynamic shear resulting from impact when cold would seem to be highly important.

Failures in Cohesion

Failures in cohesion were relatively few in number and extent compared with failures in adhesion, as shown in Table II. Typical of the worst such failures are those illustrated in Figure 10. The total linear footage of cohesion fracture for 294 joints amounted to 0.041 percent, or 2.43 feet

TABLE II

FAILURES IN COHESION GROUPED BY SECTIONS AND BY MATERIALS

Section	Material	No. of Joints	Percentage of Failure in Cohesion — North Lane: Percent of Joints in Section Showing Cohesion Failure	North Lane: Linear Percent of Cohesion Failure, Percent of Lane	South Lane: Percent of Joints in Section Showing Cohesion Failure	South Lane: Linear Percent of Cohesion Failure, Percent of Lane
I	A	40	0	0	0	0
II	B	51	0	0	0	0
III	A	21	0	0	4.76	0.95
IV	B	46	10.88	0.22	6.53	0.26
V	C	62	1.61	0.24	0	0
VI	A*	74	18.90	2.03	10.81	0.49
I, III	A	61	0	0	1.64	0.33
II, IV	B	97	5.16	0.10	3.09	0.13
V	C	62	1.61	0.24	0	0
VI	A*	74	18.90	2.03	10.81	0.49
I - V	A,B,C	220	2.73	0.11	1.82	0.15
VI	A*	74	18.90	2.03	10.81	0.49
I - VI	All	294	6.80	0.060	4.08	0.023

* Material A used in Section VI: no supervision by Laboratory, either in preparing joints or in applying seal.

out of a total of 5,880 linear feet of joint seal of all kinds. For all practical purposes this is insignificant, except that differences among materials were again noted (see Table II).

The Importance of Rigid Control

It is firmly believed that the considerably larger extent and degree of failures in section VI can be attributed to the fact that none of the work in this section was supervised directly by the laboratory. If anything, failures should have been fewer and less extensive in this section, due to better control of melting conditions through the use of a slow speed (approximately 60 R.P.M.), positive acting, screw-type mechanical agitator which was added to the Littleford melting kettle after the joints in the first 5 sections were sealed. Everything else was the same, except for the matter of supervision. This is significant in that it demonstrates the necessity for rigid control of joint-sealing operations.

FACTORS RESPONSIBLE FOR THE FAILURES

In view of the facts set forth above, the question now arises, what factors were ultimately responsible for the failures observed in the survey of February 17? Was it the materials themselves which failed, or was failure due to other causes?

Examination of the Materials

In order to settle the question of the materials themselves, samples of each seal material were removed from joints at the following stations and subjected to flow and bond tests in the laboratory:

Material	Section	Joint No.	Station
A	I	9	280+62
B	II	55	235+12
C	V	214	79+60

Results of the laboratory tests were as follow :

Material	Flow		Bond	
	Spec.	Sample	Spec.	Sample
A	0.5 cm. max.	6.9 cm.	5+ cycles	Passed 5 cycles
B	0.5 cm. max.	1.9 cm.	5+ cycles	Passed 5 cycles
C	0.5 cm. max.	1.7 cm.	5+ cycles	Passed 5 cycles

All existing specifications require hot-poured bituminous-rubber sealing compounds to exhibit flow results under 0.5 cm. The materials used in this project actually did have flows under this amount prior to use. Research conducted in the laboratory, however, has proved conclusively that the flow test is extremely critical, that materials kept well within their manufacturers' recommended melting temperatures for as little as 2 hours show as much as 13 times the maximum flow permitted by specifications. The full effect of this has not been explored completely, but it is probable that such increases are indicative of the earliest stage of what would result in breakdown of the materials if heating were prolonged or intensified greatly.

In view of the above, the increases in flow shown by the 3 reclaimed specimens is not surprising, and its significance should not be considered unduly alarming. Particularly is this true when it is remembered that these samples were melted a second time in the laboratory in order to prepare specimens for tests. There is little doubt that samples taken from seals with excellent service records in the field would show excessive flow if returned to the laboratory for investigation.

The True Factors Responsible

The fact that all the materials were able to pass repeated cycles of extension at 0 degrees F. in the laboratory after months of service in the field, and after remelting, is of great significance. This indicates rather conclusively that failure in adhesion must have been due to failure in bonding securely with the traces of old asphalt left on the joint faces. This interpretation is corroborated by the excellent bonding of like materials with the joint faces of new concrete in cold weather, which has been observed in the numerous instances where the same compounds have been used for sealing joints in new construction. Among such instances may be mentioned the Michigan Test Road, in which a number of joints sealed in 1941 with material of this general type are in excellent condition today. Many of these joints may be assumed to have opened even more than those on US 12.

It would seem that the differences noted in this study among the various brands of compounds with respect to adhesion may be explained on the basis of differences in the degree to which they adhere to and penetrate asphalt. A laboratory investigation of such differences is now under way. Results so far attained from this study are presented below.

Laboratory Investigation of Effects of Asphalt on Bond

A series of standard bond test mortar blocks was prepared in the usual way. Opposing surfaces were coated with a stain of SOA asphalt, about 400 square feet per gallon coverage. Bond test specimens were prepared by pouring fresh sealing material into these molds between asphalt-stained surfaces. Bond tests were then run at 0 degrees F. Results of the bond tests are shown in Table III.

TABLE III

BOND TESTS USING SOA - STAINED BLOCKS

		Percent Failure in Adhesion				
		Cycle				
Material	Specimen	1	2	3	4	5
A	1	100	-	-	-	-
	2	100	-	-	-	-
B	1	5	20	30	40	50
	2	5	30	50	75	80
C	1	0	0	2	10	35
	2	0	0	10	90	100
D	1	0	0	0	0	0
	2	0	0	0	0	0

The results in Table III show that material A failed completely in adhesion during the first cycle as illustrated in Figure 14. It may be observed in Figure 14 that approximately 50 percent of the asphalt stain was pulled from the block. Materials B and C showed progressively increasing failure in adhesion during the 5 cycles, material B starting with the first cycle and material C the third. Typical failures of these materials are shown in Figures 15 and 16. Material D showed no failure in five cycles (see Figure 17). This particular material was submitted to the laboratory for examination and has not, to our knowledge, been used on any Highway work in Michigan. Material D, likewise, passes Federal Specification requirement SS-F-336.

Laboratory investigation, therefore, substantiates the view, as set forth above from data derived from field sources, that differences exist among materials in the degree to which they adhere to concrete joint faces previously coated with asphalt.

The theory of the mechanism of failure in bond between the old seal and the new seal can be extended by considering the thin layer of old seal to be of finite thickness. If it were thick enough, it is conceivable that such failures as were noted were actually failures in cohesion on the part of the old seal - that a break occurred at some point, or along some plane, in the interior of the old asphalt film. All films have thickness, and a thick film can conceivably crack apart into two thinner films, one adhering to the concrete and one to the sealing compound. In connection with the resealing of joints in old concrete pavements with bituminous-rubber compounds, this conception lends emphasis to the importance of either complete removal of all traces of existing asphalt by mechanical means or the application of a surface treatment such as a prime coat.

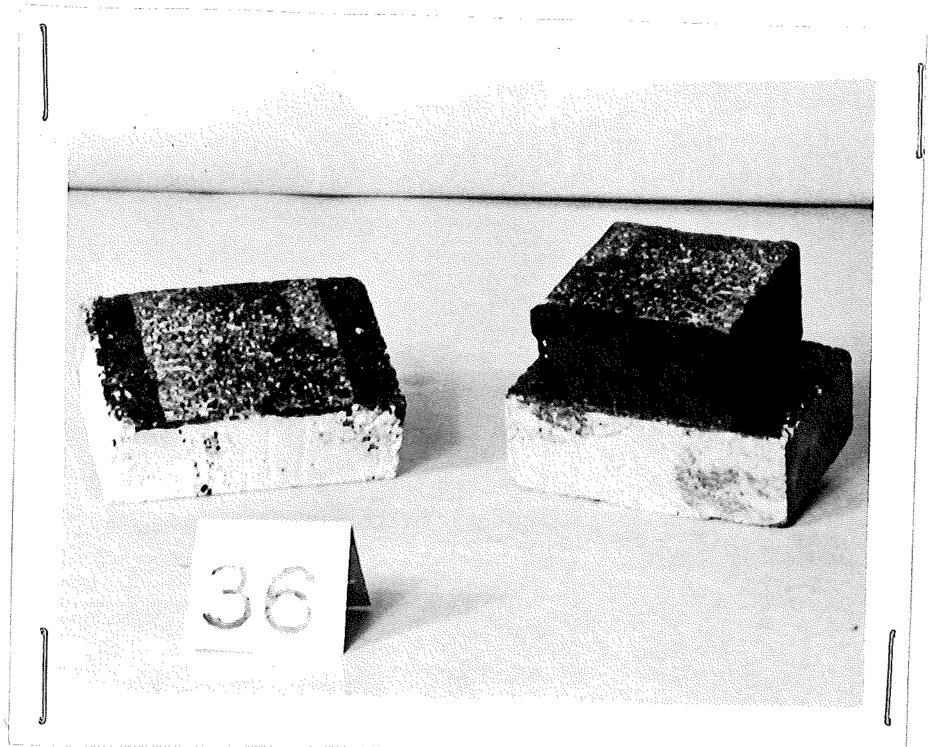


Figure 14. Bond specimen material A, block stained with asphalt. Failed 100% during first cycle of extension at 0 degrees F. Note approximately half thickness of asphalt stain pulled off block.

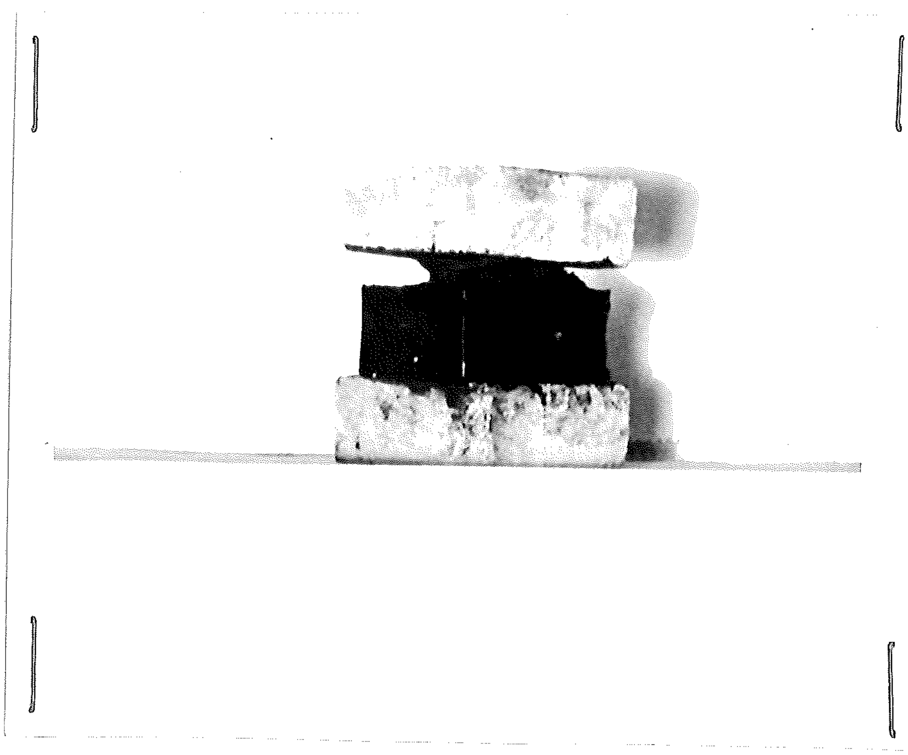


Figure 15. Bond specimen, material B, block stained with asphalt. Shows approximately 80% failure after 5 cycles of extension at 0 degrees F.

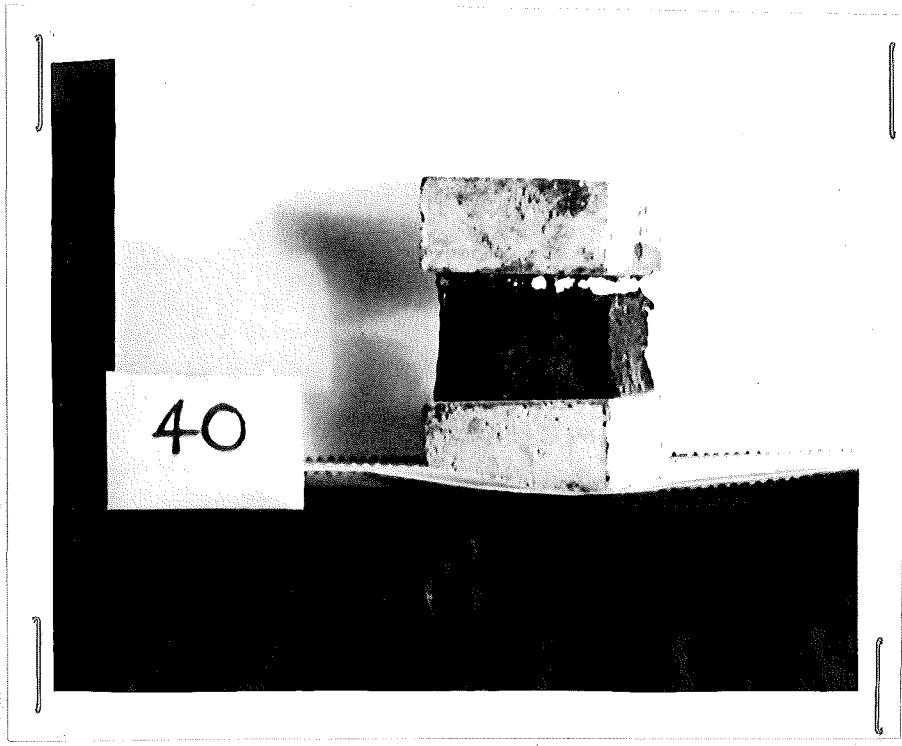


Figure 16. Material C during bond test at 0 degrees F. using asphalt-stained blocks. Shows 90% failure in adhesion after fourth cycle.

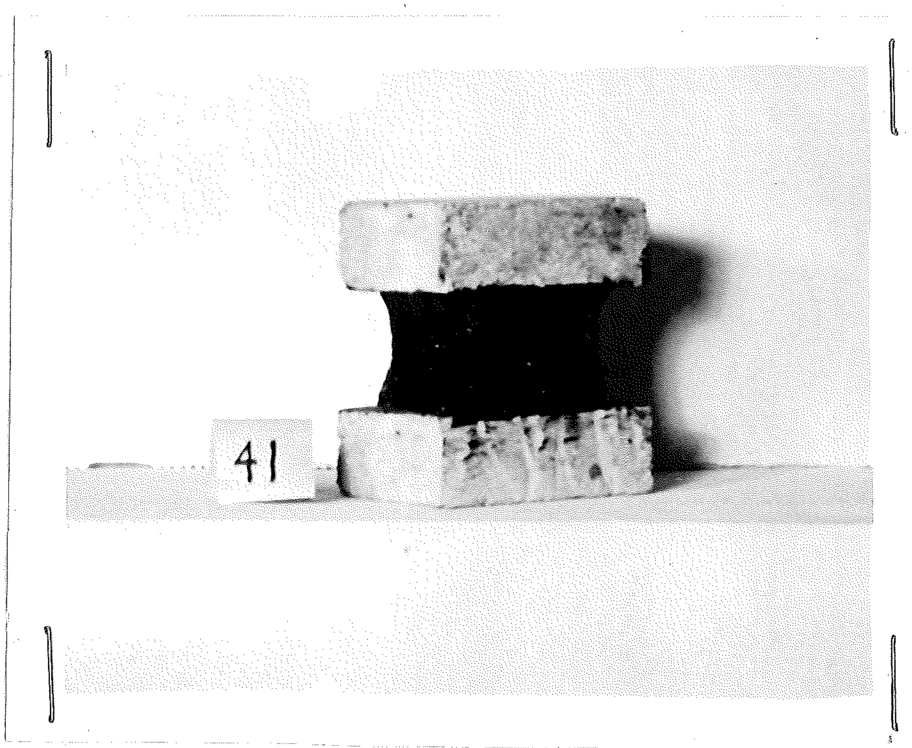


Figure 17. Material D showing condition at conclusion of bond test at 0 degrees F. using asphalt-stained blocks. Material passed 5 cycles of extension with no failure.

The Effect of Priming

It is theoretically sound to assume that a priming material consisting essentially of a solvent such as gasoline would serve a useful function. It would penetrate the old seal, thinning it out and "wetting" it, and it would render the freshly exposed face of the old asphalt material tacky. If in particular a small quantity of new seal were dissolved in the gasoline, this should result in a firm bond between the old and new seals, at the same time affording a progressive, penetrating solvent action tending to facilitate a growing mutual solution of the two materials in each other. This in turn should effectively increase the ductility or elasticity of the asphalt film at low temperatures without materially detracting from that of the bituminous-rubber compound. Laboratory studies on this subject are now in progress.

A survey conducted February 26, 1947, of the condition of expansion joints sealed in October and November, 1945, on US 16 west of Lansing, construction project 19-32,C1, lends some support to the value of priming. Of 15 joints (Research Project 36 G-4 (3)E), 5 were sealed with material B and 4 with material A. In each case the south lane of joints was left unprimed, but those in the north lane were primed over traces of old material not removed, with naphtha containing dissolved quantities of the seal to be used. The February 26 survey showed no failures of any kind in the joints sealed with material B. Moderate failure in adhesion noted in 3 out of the 4 joints sealed with material A was sufficiently more extensive in the south lane than in the north lane to demonstrate that priming probably assisted in the formation of good bond. Here again, failure in adhesion was more pronounced on the far side of the joints with respect to the direction of traffic flow.

CONCLUSIONS

The evidence obtained from this investigation warrants the following conclusions:

1. Failure in adhesion of the various materials was apparently due to a joint condition at the time of pouring and not to any inherent fault of the materials themselves either from a manufacturing standpoint or from the effects of handling in the field.

2. It is evident, however, that some differences exist among brands of sealing materials with respect to service performance under similar conditions due to inherent physico-chemical properties of the materials themselves.

3. It is also evident that when old joints are to be resealed with bituminous-rubber compounds all the joint surfaces must be completely cleaned of all traces of old joint seal material. In lieu of this a suitable surface treatment must be provided which will insure permanent bond.

4. It is obvious that the present specifications may need to be fortified by additional tests. Such tests may include impact resistance at low temperature and accelerated weathering.

5. The investigation brings out the importance of rigid control of various phases of this type of work and the use of properly designed equipment for melting and pouring the materials.

6. Although these materials have been designed primarily to withstand the slow movement of pavement slabs resulting from volume changes, they must also withstand sudden vertical and horizontal stresses induced by traffic under varying temperature conditions.