MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

THE MUSKEGON EXPERIMENTAL PROJECT

AFTER SEVEN YEARS IN SERVICE

E. A. Finney

Construction Project M-61-27, C5

Research Projects 36 B-2, 7, 8 and 9
38 F-5
36 G-4

Research Laboratory
Testing and Research Division
Report No. 78
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AFTER SEVEN YEARS IN SERVICE

During the summer of 1938, the Department constructed 1.387 miles of experimental concrete pavement on M-126 in Muskegon Heights, from Peck Street southeast to Getty Avenue. The construction project is M-61-27, C5 and will be referred to as the Muskegon Experimental Project. The location of the project is shown in Figure 1.

Embodied in the construction of the project are several experimental features for the purpose of determining methods for eliminating scale and also to evaluate current practices concerning the spacing and construction of transverse joints. In addition, the concrete was vibrated during placement to obtain more information on this type of pavement construction. The work was divided into several separate investigations which are defined below:

- Project 36 B-2 Vibrated Concrete Pavement
- Project 38 B-7 Curing of Concrete Pavement
- Project 38 B-8 Use of Pozzolith Admixture and Portland Natural Cement Blend in Concrete Pavement
- Project 38 B-9 Final Finishing of Concrete Pavement by Brooming
- Project 38 F-5 Investigating of Dowel Bar Load Transfer Devices in Concrete Pavements
- Project 36 G-4 Investigation of Expansion Joint Fillers

During the Construction of the Muskegon Project observations were made as the work progressed and at the completion of the project several

MUSKEGON EXPERIMENTAL PROJECT

STATE PROJECT NO. 61-27

City of Muskegon Heights

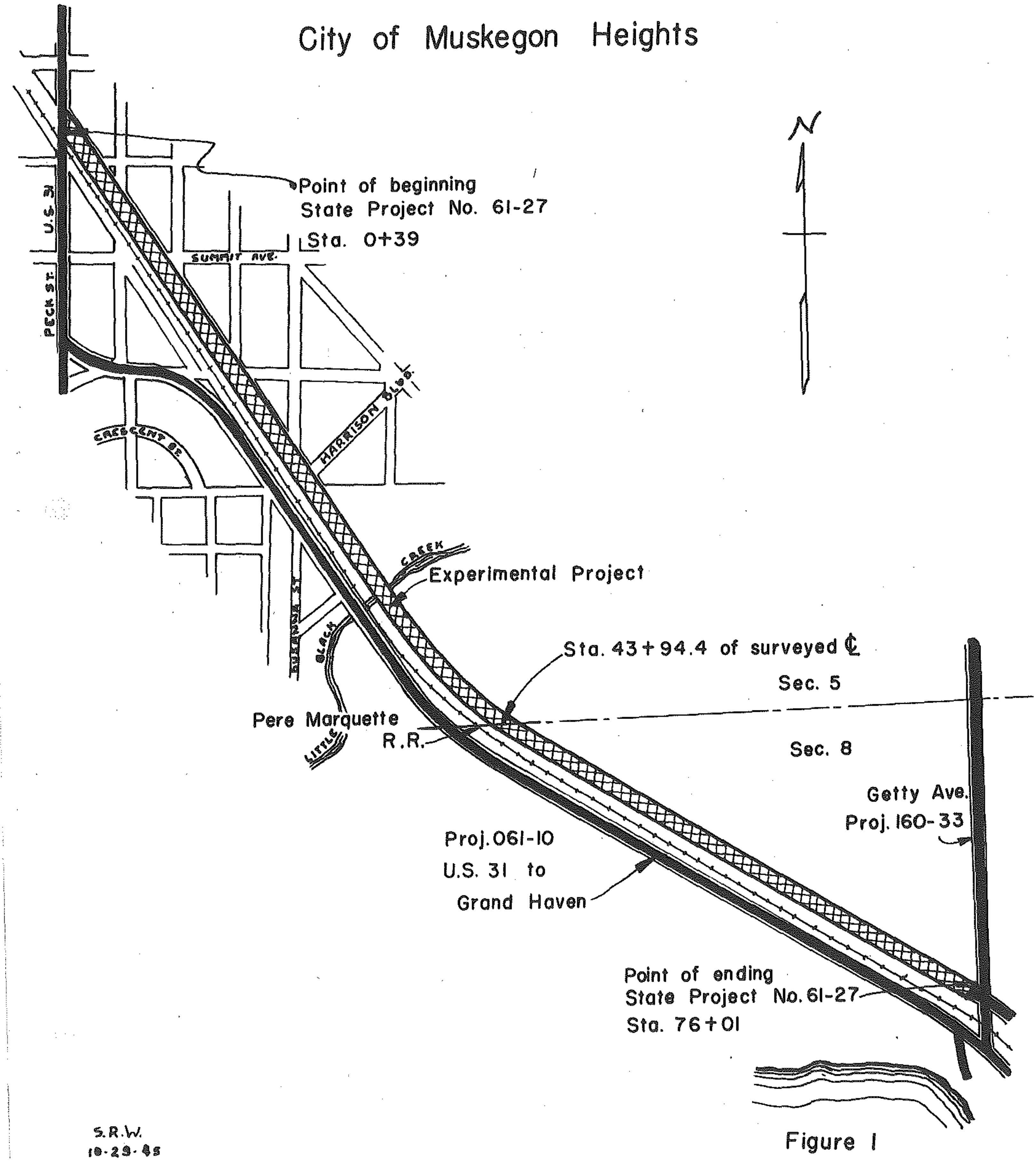

Figure 1

reports were prepared by Homer Cash (1) (2) (3) (4) (5) who was in charge of the experimental work on the project.

On October 4, 1945, a condition survey was made of the Muskegon Experimental Project with the view of correlating the physical condition of the pavement with the factors under study to determine if any developments have occurred during the interim which would be of value to the Department in setting up requirements for future construction. This report has been prepared with that purpose in mind. It will include a brief summary of original construction information of interest to the reader and will explain in detail the happenings on the project with respect to the principal features under investigation.

CONSTRUCTION INFORMATION

The construction details of the Michigan Experimental Project are scattered throughout the routine construction records and in the interim reports by Mr. Cash. Therefore, it was believed desirable to include at this point a brief summary of the important construction details in order that the reader would have a better understanding of the nature of the work in relation to the subsequent behavior of the project. A summary of pertinent construction information will be found in Table I.

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(1) Chronological Diary on Construction and Experimental Work on Project M-61-27, C5, Homer Cash, Sept. 30, 1938, Departmental Report.

(2) Curing Concrete Pavement by Application of Asphalt Emulsion Immediately after Finishing, Homer Cash, October 14, 1938, Departmental Report.

(3) Final Finishing of Concrete Pavement by Brooming, Homer Cash, October 19, 1938, Departmental Report.

(4) The Use of Portland Natural Cement Blends and Pozzolith Admixture in Concrete Pavements, Homer Cash, October 28, 1938, Departmental Report.

(5) Vibrated Concrete Pavement, Homer Cash, November 1939, Departmental Report.

TABLE I, SUMMARY OF CONSTRUCTION INFORMATION

General Information:

Contractor	Amos Baker
Contract Let	July 25, 1938
Work Began	July 25, 1938
Completion Date	Sept. 15, 1938
Contract Price	$42,736.28
Project Engineer	W. O. Theeringer

Construction Data:

Length	1.387miles
Width	20 feet
Cross Section	9-7-9
Reinforcement	None
Expansion Joint Spacing	120 feet
Load Transfer at Expansion Joints	None on major portion of project 3/4" x 15" Dowels where used
Plane of Weakness Joint Spacing	20 foot and 30 foot
Load Transfer at Plane of Weakness Joints	3/4" x 15" dowels
Vibrating Equipment	20 foot Internal type vibrating tube furnished by Jackson Vibrating Equipment Co. Ludington, Mich.
Curing	Asphalt Emulsion, AE-1 and Cotton Mats
Finishing	Brooming
Subgrade	Lake Michigan Dune Sand

Materials:

Cement	Huron Cement from Muskegon Storage
Aggregates, fine	Grand Rapids Gravel Co., Plant 4.
Aggregates, coarse	Grand Rapids Gravel Co., Plant 4.
Natural Cement	Luxment, Utica, Illinois
Pozzolith	Master Builders Co., Cleveland, Ohio

Concrete Mix Design:

Cement Content	5.5 sacks per cubic yard
b/bo ratio	0.80
Relative Water Content	1.20
Natural Cement Blend	5 sacks Portland Cement and 1 sack Natural Cement per cubic yard
Pozzolith Admixture	2 lbs. of Pozzolith per sack of cement

VIBRATED CONCRETE PAVEMENT

The experimental work in connection with the vibratory placement of the concrete pavement was carried on in conjunction with several other projects on which the concrete had been vibrated. The principal objectives of the vibration study on the Muskegon project were (1) to determine whether a standard finishing machine would have enough power and traction to push the vibrating unit and properly finish a two-lane pavement and (2) to observe if the plane of weakness center joint could be properly installed in vibrated concrete with the standard equipment then in use.

A complete account of the vibration investigation associated with the Muskegon Experimental Project may be found in a report entitled "Vibrated Concrete Pavement" by H. C. Cash, dated November, 1939, to which the reader is referred for a description of this phase of the work.

SCALE PREVENTION STUDY

In the attempt to eliminate scaling from concrete pavements several construction features were considered in the Muskegon project. These features are described below:

1. The application of a bituminous membrane material to the surface for the purpose of curing and at the same time seal the surface against penetration of chloride salt solutions which influence scaling.
2. The use of proprietary admixtures such as Pozzolith to produce a more durable concrete pavement.

3. The blending of natural cement with portland cement to reduce surface laitance and consequently scaling.

4. By brooming the surface to remove the excess mortar and laitance coat which forms on the surface of the pavement due to manipulation of the fresh concrete.

The results from the recent condition survey of the Muskegon project, as shown in Figures 2 and 3, as well as the results from other subsequent experiment work conducted by the Department and embodying the same features, clearly indicate that none of the methods outlined above will prevent scaling of concrete pavements.

In Figures 2 and 3, it may be observed that considerable scaling has occurred on both lanes between Stations 0+00 and 19+00, and from 31+00 to 36+50; on the east lane only between Stations 51+00 and 54+00 and from 66+00 to 68+00; and again over both lanes from Station 71+00 to the end of the project at Getty Avenue. The worst scaling has occurred between Peck Street and Leahy Avenue, Stations 0+00 to 19+00. This is probably due to the fact that frequent and heavy chloride-sand applications are necessary because of the many intersections in that particular area. The same condition prevails at the Getty Avenue end of the project. Scaling in the other areas was observed to be sporadic and of no serious consequence at the present time. No scaling was noted on the area containing Pozzolith, but that test section is so short that it is of no value in establishing a criterion in this respect and, therefore, must be discounted. The use of bituminous membranes, as well as the brooming process did not prevent scaling of concrete pavement surfaces. Views illustrating character of scaling are shown in Figure 4.

VIBRATED CONCRETE POURS 61-27

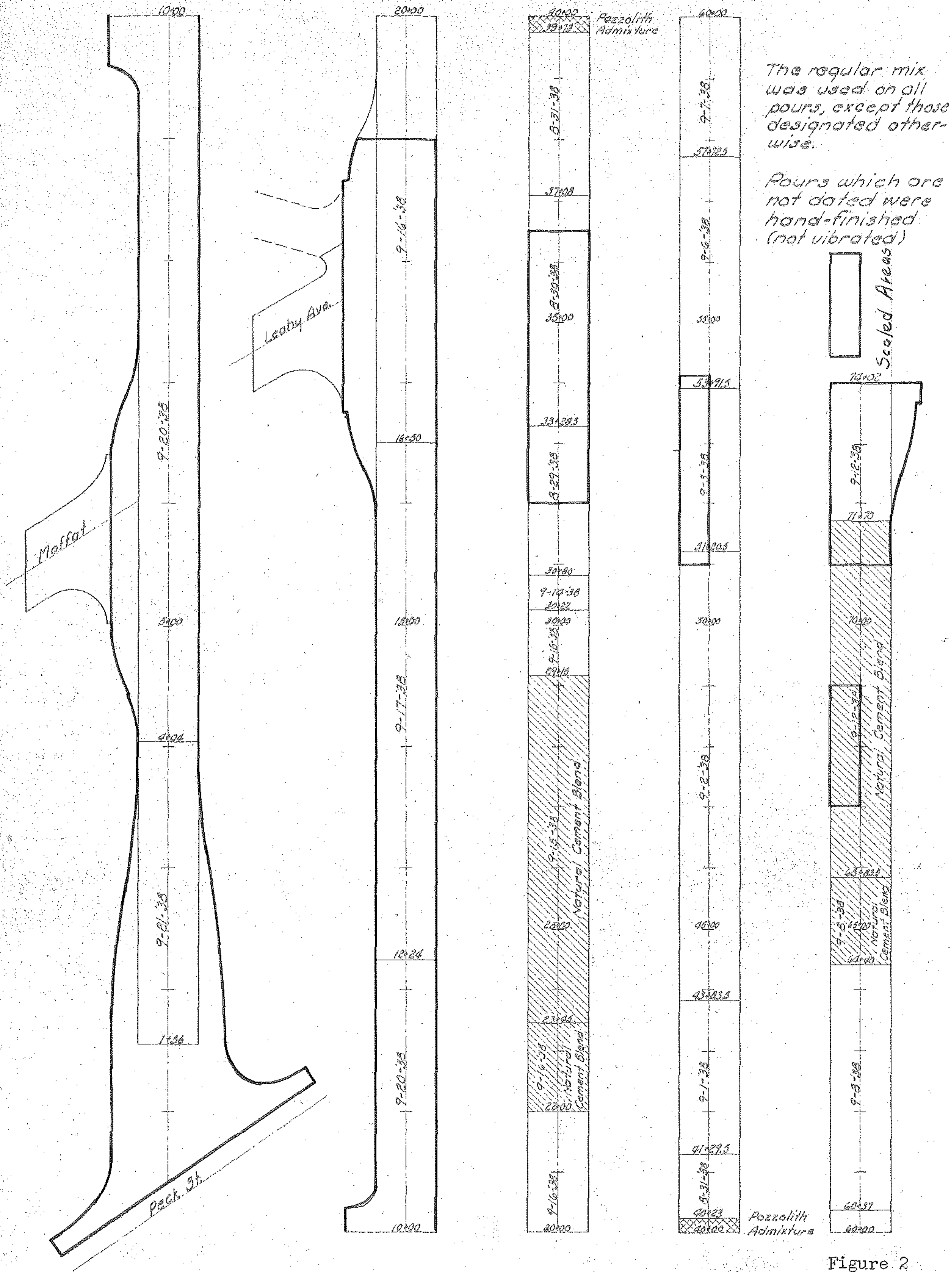


Figure 2

METHODS OF CURING AND FINAL FINISHING 61-27

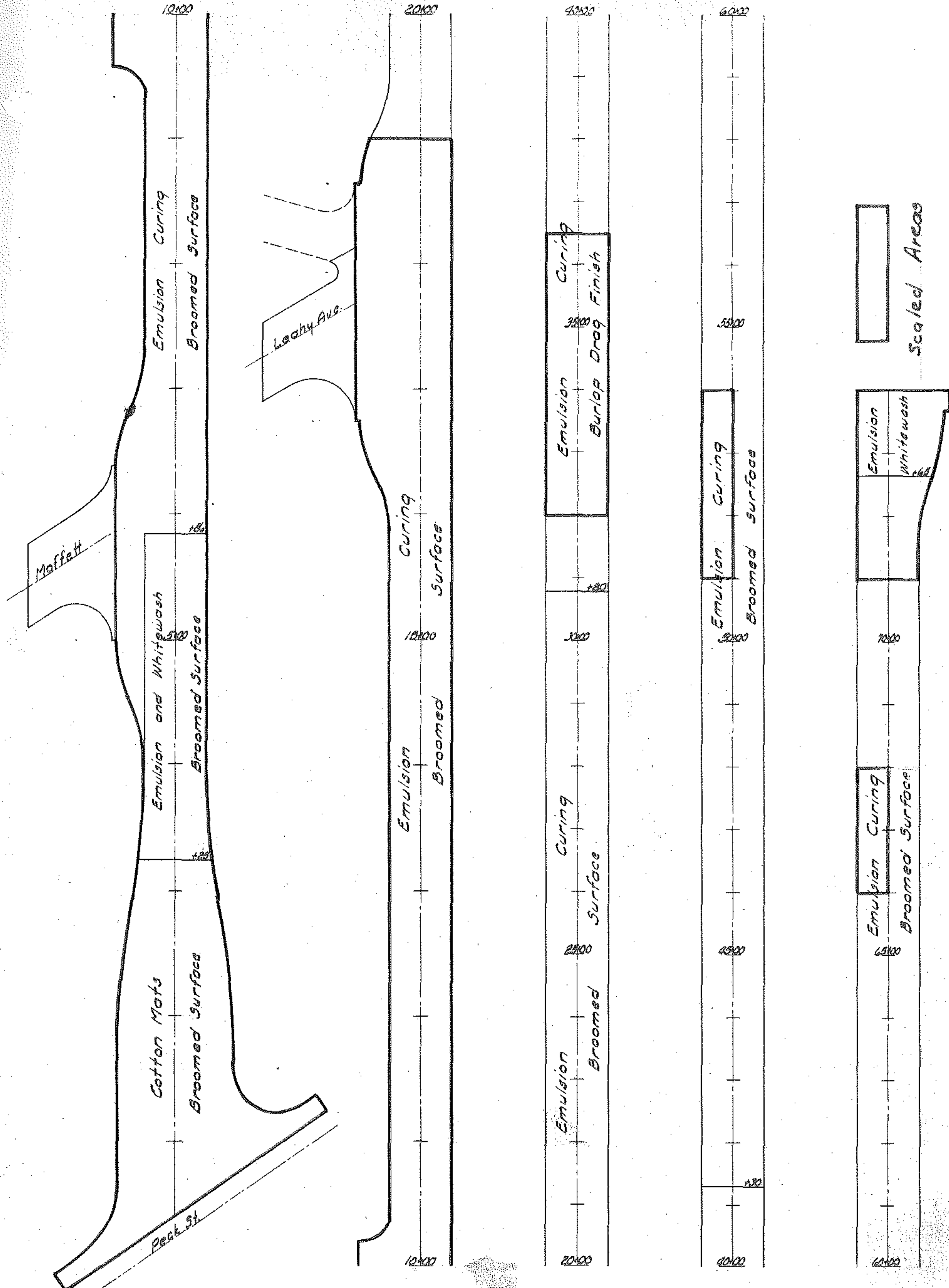
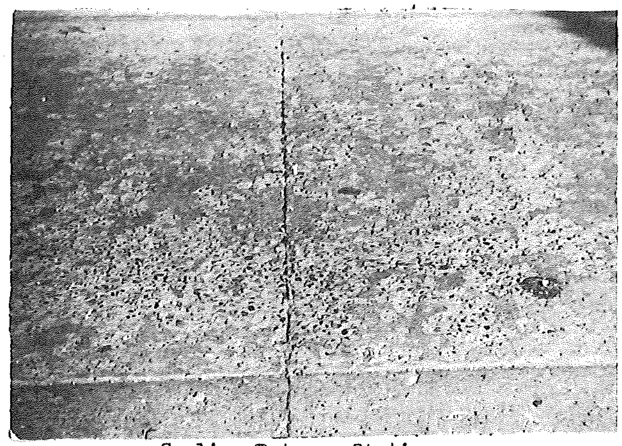


Figure 3

Scaling Between Stations
0+00 to 19+00



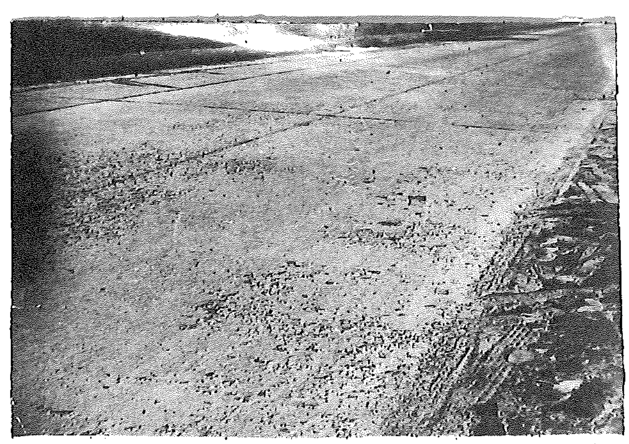
Scaling Between Stations
0+00 to 19+00

TYPICAL SCALING

ON

MUSKEGON PROJECT

Typical Edge Scaling Stations
51+00 to 54+00 and 66+00 to 68+00



Typical Scaling at Getty Avenue

Figure 4

TRANSVERSE JOINT INVESTIGATION

The structural features included in the transverse joint investigation are:

1. The spacing of plane of weakness joints at 20 and 30 foot intervals for comparative study in slab behavior.
2. The installation of coated and uncoated 3/4" x 15" dowel bars at plane of weakness joints to determine the practicability of such treatment.
3. The omission of load transfer devices at expansion joints to determine the necessity of such devices on sandy subgrades.
4. The installation of three special asphalt-latex poured type expansion joints to determine their practicability in comparison with other methods of expansion joint construction.
5. The installation of three expansion joints with wood fillers for comparative study with other types of expansion joint filler material.
6. The sealing of several expansion joints with asphalt-latex joint sealing compound to determine the merits of this type of compound as a joint seal in comparison with materials in current use, and to study ways and means of installing the compound in joints satisfactory to the contractor.

The locations of the joint features described on the preceding page have been presented in Figure 5 with respect to their relative position with one another and to the project as a whole. The various features will be discussed in the order given.

Spacing of Plane of Weakness Joints

With reference to the 20 and 30 foot plane of weakness joint spacings as illustrated in Figure 5, there are a total of 155 individual slabs 30 feet long and a total of 126 slabs, 20 feet in length. The recent survey revealed that, of the total of 155 slabs 30 feet in length, 13 slabs or 8.4 percent contained full transverse cracks and 4 slabs had one-half transverse cracks. Whereas in the case of the 20 foot slabs, 126 in number, 2 or 1.6 percent had full transverse cracks and only 3 slabs had one-half transverse cracks.

Painted and Unpainted Dowels

During the condition survey each plane of weakness joint was carefully examined to determine whether or not the joint had been functioning in a normal manner; that is, opening and closing with temperature variations. In addition, the expansion joints were also observed especially for faulting since they were constructed without dowels. The present status of the joints has been noted by letters in Figure 5. As a help in studying the data, Table II has been prepared.

TRANSVERSE JOINTS 61-27

Figure 5

TABLE II. COMPARISON OF PLANE OF WEAKNESS JOINTS WITH PAINTED AND UNPAINTED DOWELS

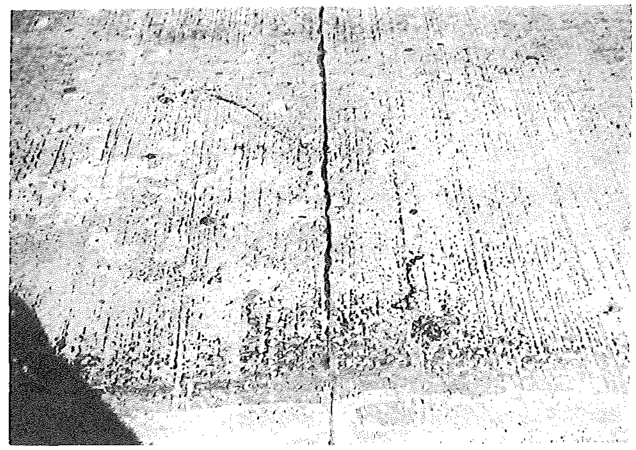
Condition of Dowels	Total Joints	CONDITION OF JOINTS					
		Open		Closed		Faulted	
		No.	Percent	No.	Percent	No.	Percent
Coated with AE-1 Bituminous Emulsion	77	61	79	16	21	2	2.6
Coated with Grease	7	5	71	2	29	0	0
Uncoated	115	41	36	74	64	3	2.6

Since no method for determining the true joint width movement was provided on the project for this study, the data in Table II is based on what would be apparent to the eye and, therefore, must be considered in that light. However, it was readily discernible that many of the joints were locked because, in a great many cases where the dowels in the joints midway between the expansion joints were coated with grease or asphalt, there appeared unusually wide openings, as much as 1/2 inch and even 3/4 inches in certain instances. See Figure 6. On the other hand, joints with uncoated dowels, especially those located adjacent to the expansion joints, have apparently not been opening and closing in a normal manner. Obviously many of the plane of weakness joints which seem to be locked are operating in a manner similar to that of dummy joints in which the mesh is continuous through the joints, as in the case of current construction practice.

The locking of the joints may be caused, in some cases, by the misalignment of the dowel bars during the pouring operation.

The method for holding the dowel bars in alignment is shown in Figure 8. It may readily be seen in Figure 8 that the method employed on

Typical Condition of Closed Transverse Plane of Weakness Joints. Station 14+92. Dowels Uncoated.



Typical Condition of Open Transverse Plane of Weakness Joints, Opening 3/4 inch. Station 31+08. Dowels Greased.

Open Transverse Plane of Weakness Joint at Station 55+12, Opening 3/4 inch. Dowels Coated with AE-1 Bituminous Emulsion.

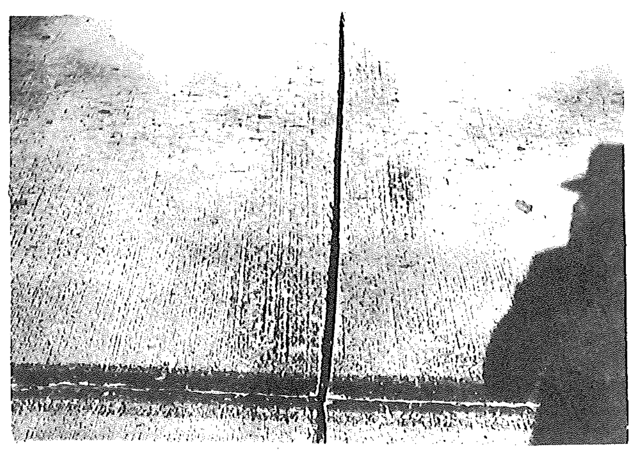


Figure 6

this project did not provide enough rigidity to insure positive alignment of the dowels.

Expansion Joints Without Load Transfer Devices

With the exception of 4 expansion joints between Stations 31+00 and 36+00, and 3 between Stations 68+00 and 71+00, all of the expansion joints on the project were constructed without load transfer devices. The present status of the joints with respect to faulting is given in Table III.

TABLE III. EXPANSION JOINTS WITH AND WITHOUT LOAD TRANSFER

		Condition			
		Normal		Faulting	
Factor	Total No.	No.	Percent	No.	Percent
No dowels	43	24	56	19	44
Dowels	4	3	75	1	25

The faulting of the joints amounted to as much as 1/2 to 1 inch at the outside corners. Most of the faulting occurred in the west lane carrying southbound traffic out of Muskegon. Corner cracks which might be expected to develop from this type of faulting were not observed during this survey.

Poured Type Expansion Joints

Three asphalt-latex poured type expansion joints developed by the Department were installed at stations 68+80, 69+80 and 71+00. An asphalt-latex joint sealing compound also developed by the Department was used to seal the joints.

Since this particular type of expansion joint construction has not been described in previous reports on the Muskegon test project, a few of its essential details have been presented in Figure 7. In Figure 8, there are several views showing how the joint was installed in the pavement.

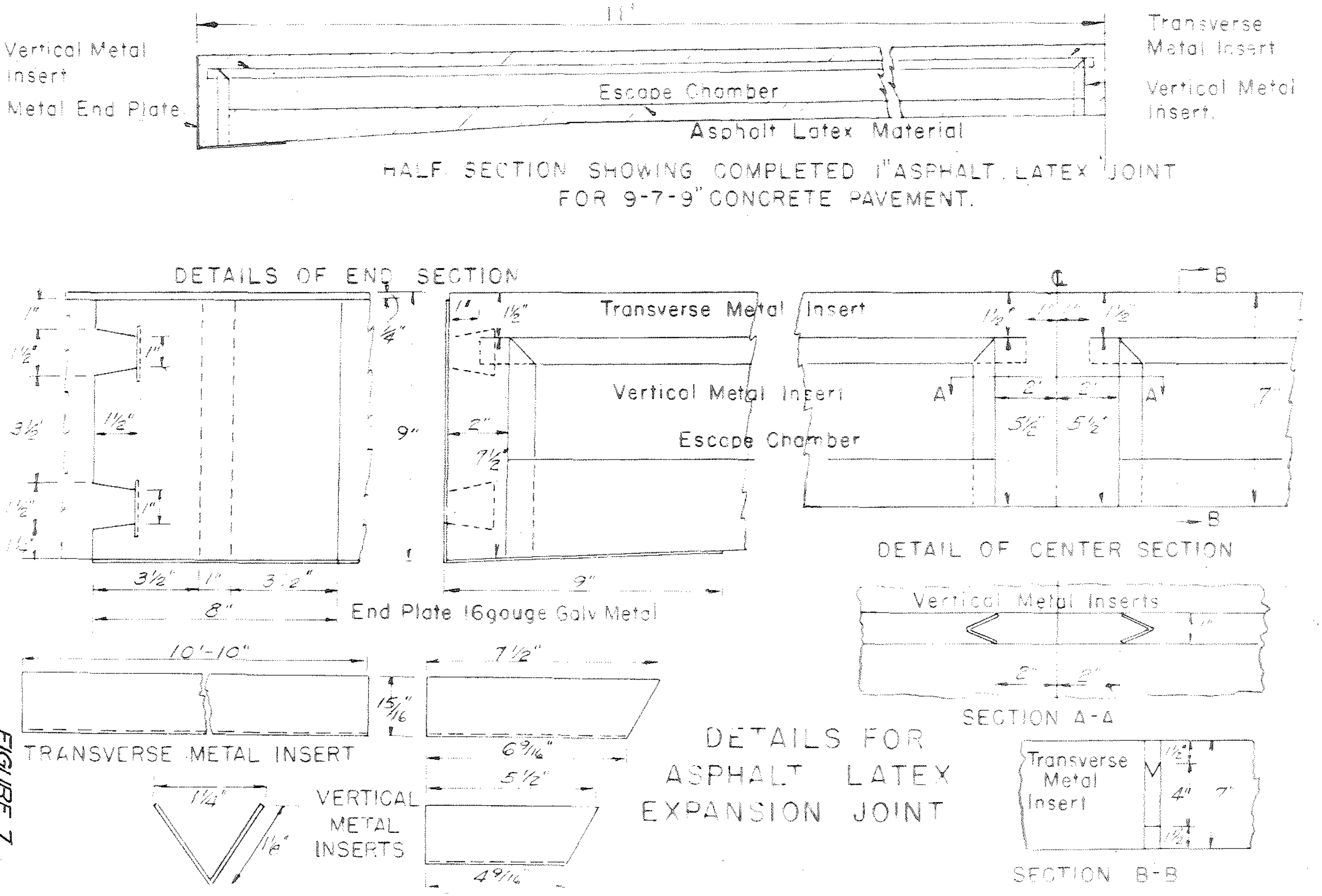
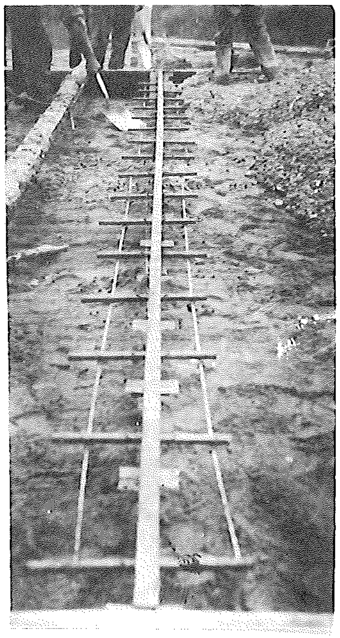
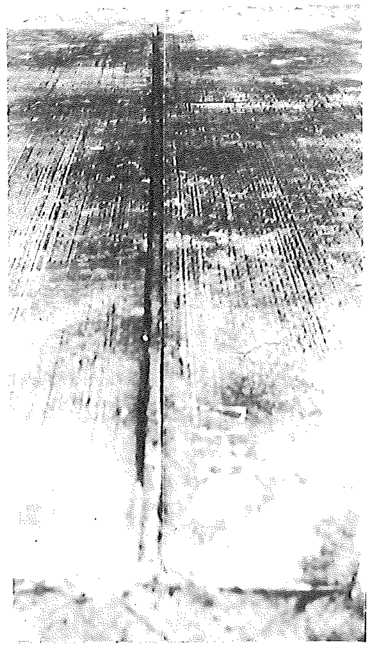

11'
Vertical Metal Insert
Metal End Plate
Escape Chamber
Asphalt Latex Material
Transverse Metal Insert
Vertical Metal Insert.
HALF SECTION SHOWING COMPLETED 1" ASPHALT LATEX JOINT FOR 9-7-9" CONCRETE PAVEMENT.
DETAILS OF END SECTION
Transverse Metal Insert
Vertical Metal Insert
Escape Chamber
End Plate 16gauge Galv Metal
DETAIL OF CENTER SECTION
Vertical Metal Inserts
SECTION A-A
TRANSVERSE METAL INSERT
VERTICAL METAL INSERTS
DETAILS FOR ASPHALT LATEX EXPANSION JOINT
Transverse Metal Insert
SECTION B-B

FIGURE 7

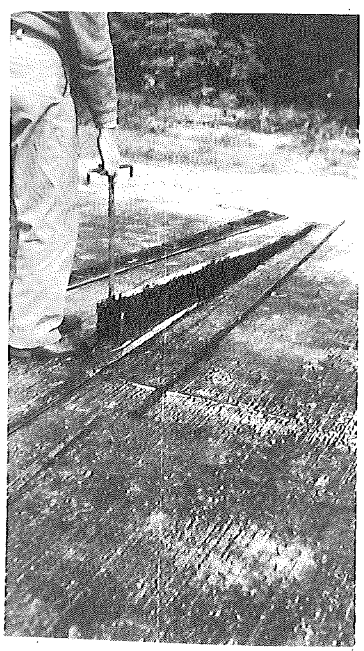


Installation of Joint Assembly Prior to Placing Concrete



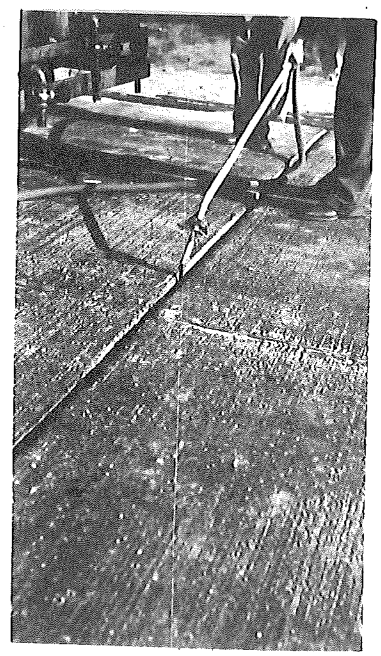
View of Finished Joint Prior to Pulling Tee Irons

Pulling Tee Irons Prior to Removing Collapsible Joint Forms.



Removing Collapsible Forms in Sections

Pouring Asphalt Latex Joint Sealing Compound into Open Joint.



CONSTRUCTION OF SPECIAL ASPHALT-LATEX EXPANSION JOINT

Figure 8

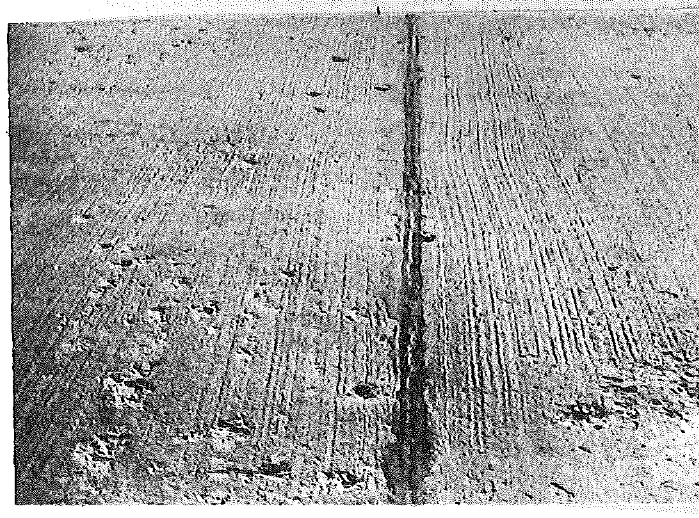
The survey revealed that the expansion joints at Stations 68+80 and 69+80 have been functioning in a normal manner. The present condition of the two joints is illustrated in Figure 9. A blow up has occurred at the third special joint located at Station 71+00. The slab edges at the joint have heaved approximately two inches causing the slabs to crack several feet back from the joint. The present condition of the joint is shown in Figure 9.

Wood Filler Material

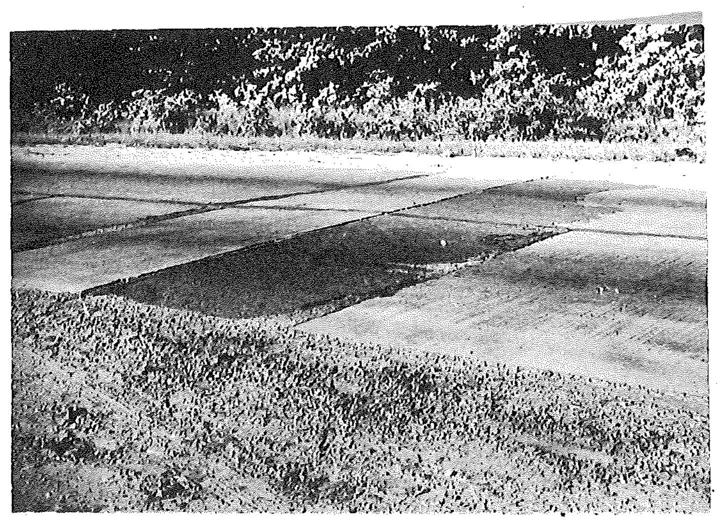
At Stations 67+70, 72+21 and 73+10, white pine boards specially prepared were installed in the expansion joints as a substitute for the common bituminous fiber board type of filler. The boards were cut in sections 10 feet long and installed with the grain horizontally. The physical condition of the joints at the present time are illustrated in Figure 10. Certain sections of the wood board in joints at Stations 67+70 and 72+21 have been displaced by traffic. This condition would not occur if the grain of the wood ran vertically. With the exception of this one incident both joints are apparently in good condition. The joints should be sealed, however.

Asphalt-Latex Joint Seal

The asphalt-latex joint seal compound used in the three poured type expansion joints was still in place at the time of condition survey and the material possessed a considerable amount of plasticity and adhesion. The condition of the material may be observed in Figure 9. The material had a brownish granular appearance, the typical effect of weathering. The asphalt-latex material and method of application have been considerably improved since this experiment. It has not been necessary to service these joints during their seven years in service.

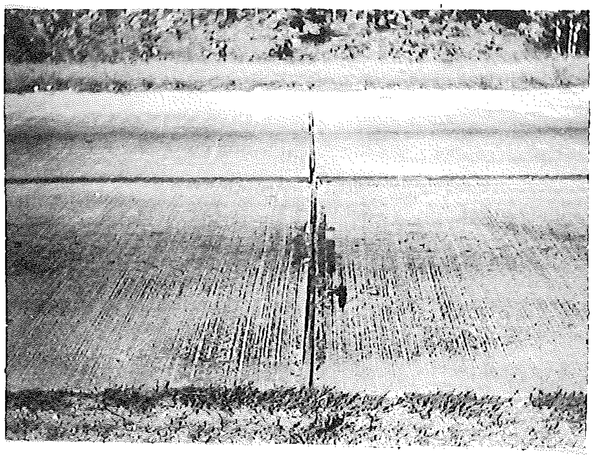


Typical Condition of Special Asphalt Latex Expansion Joints at Station 68+80. Age 7 years.

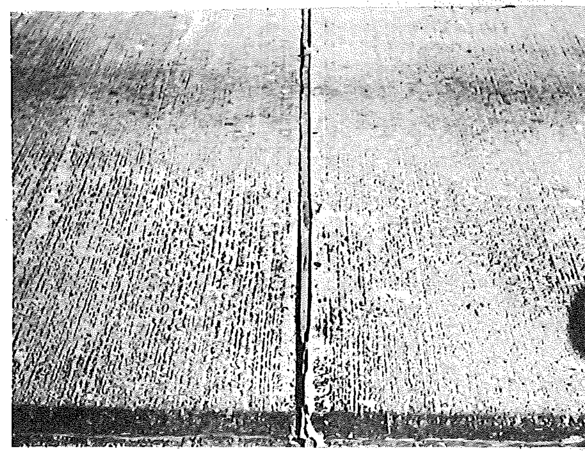


Blowup Has Occurred at Third Special Asphalt Latex Expansion Joint at Station 71+00.

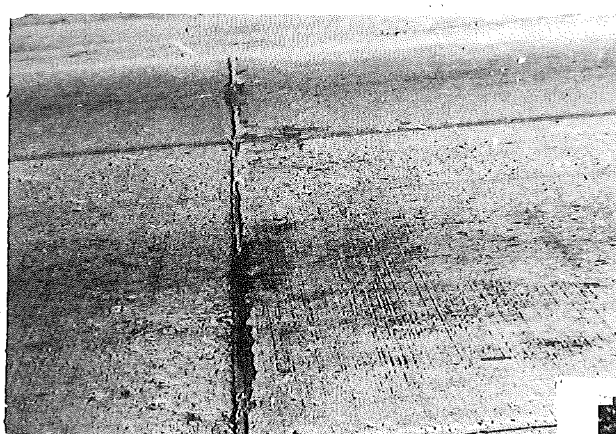
Figure 9



Condition of Expansion Joint with Wood Filler at Station 67+70



Close View of Joint at 67+70 Showing Failure of Wood Installed with Grain Horizontal.



View of Expansion Joint with Wood Filler at Station 73+10

View of Expansion Joint with Wood Filler at Station 72+21

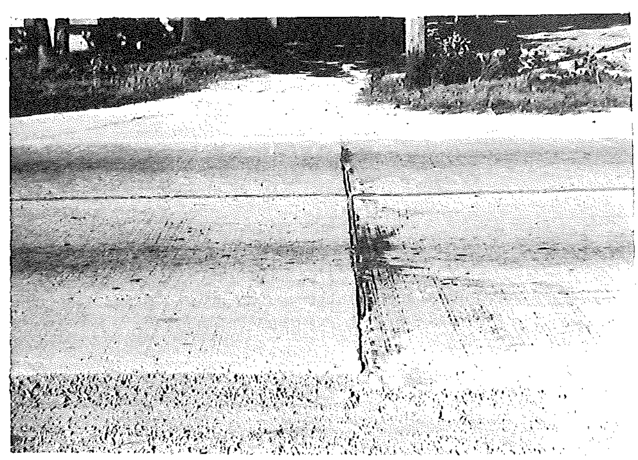


Figure 10

REVIEW OF OBSERVATIONS

1. The results from the Muskegon project further substantiate the fact that such treatments as brooming, applying bituminous membranes and using natural cement blends without air-entraining agents are not successful in preventing scale on concrete pavements.
2. The greatest amount of transverse cracking occurred in the 30 foot slabs. This is to be expected since maximum warping stresses are known to develop in slabs of approximately this length.
3. Results in connection with the load transfer study indicate that dowel bars, if not properly coated or aligned, will tend to lock the abutting slabs at the joint thus causing the joint width movement to be much greater at some joints than at others instead of being properly distributed equally among all the joints as intended for this type of construction. Dowel bars must be adequately coated with a suitable material and properly aligned when installed to insure normal functioning of each joint.
4. Faulting had occurred at 44 percent of the undoweled expansion joints. Pavements constructed on well-drained sandy subgrades are not immune to faulting and, consequently, adequate load transfer and subgrade support must be provided under such conditions.

5. Wood filler material in order to give satisfactory service should be placed in the joint with the grain vertical. This is now recognized as the proper procedure for wood filler material.

6. The asphaltic-oil latex joint seal still possessed remarkable life and tenacity after seven years. These results further substantiate the fact that asphalt-rubber joint seal compounds are the best materials which have been developed for this purpose up to the present time.