MICHIGAN
STATE HIGHWAY DEPARTMENT
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State Highway Commissioner

LONGITUDINAL CRACKING ON PROJECT F 17-42, G2

by

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Research Project 47 F-16

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LONGITUDINAL CRACKING ON PROJECT F 17-42, C2

This is a report on an investigation requested by C. A. Faber, Road Engineer, to determine the cause of the unusual longitudinal cracking which is developing on Project F 17-42, C2, located in the Upper Peninsula on M-28 between Brimley Corners and U.S. 2.

A condition survey of the project was made in October, 1947 by the author, accompanied by William Martin of the Research Laboratory and David Stinchfield, District Soil Engineer. Subsequently, J. E. Bailey, Assistant Engineer of Materials, conducted a special survey on center joint performance and furnished valuable information concerning conditions under which the pavement foundation was constructed. In 1948, a second complete condition survey was made of the project by Harry Smith, Assistant District Soils Engineer, to determine if further longitudinal cracking had developed during the year and if so, to what extent. O. Stokstad and A. E. Hobbiebrunken have reviewed the survey data and have assisted in the interpretation of pavement performance in relation to prevailing soil and foundation conditions.

The facts brought out by the investigation indicate that the longitudinal cracking phenomenon is attributed, for the most part, to poor foundation conditions. The use of steel reinforcement and load transfer devices would have helped materially to control the cracking. An analysis of construction records reveals that the questionable foundation condition evidently developed during construction, the major portion of which was done in the late summer and fall of 1941, under exceedingly inclement weather. The reinforcement and load transfer devices were omitted as a war time measure to save steel. The character of construction practices

which generally prevailed during the war, no doubt are involved to a certain extent.

The report presents a brief history of the project, condition survey notes and pertinent facts concerning the general condition of pavement and foundation.

History of the Project

Project F 17-4B, 02 was constructed during the fall of 1941 and completed in the summer of 1942. Earthwork operations were started on May 15, 1941; paving started on August 28, 1941. In 1942, pavement operations started July 17 and the pouring of concrete was completed on July 28. The pavement is 7.9 miles in length, 22 feet wide, non-reinforced, 8-1/2 inches thick with expansion joints spaced at 120 feet and contraction joints at 20 feet. No load transfer devices were used. The materials used in construction of the concrete slabs were as follows: Peboksy cement, fine aggregate and coarse aggregate from the Bassett Pit in St. Ignace. The contractor was Wilbur Pierson of Saginaw.

Condition Survey

The first condition survey conducted in October 1947 revealed five different types of pavement failure. They include (1) longitudinal cracking parallel to the center joint, (2) spreading of slabs at center joint due to lack of tie bars, (3) uniform settling of pavement at center, (4) general transverse cracking over culverts, and (5) longitudinal cracking of pavement composing north leg of Wye at intersection with U.S. 2.

The location, extent and character of longitudinal and transverse cracking which existed at the time of the survey is represented graphically in Figure 1. The total length of longitudinal cracking at the time

of survey amounted to 1,281 linear feet. In all cases, the longitudinal cracking had the same general pattern, that is, breaking of the slabs parallel to the center joint at an average distance of 3 to 4 feet from it. Examples of typical longitudinal cracking are shown in Figures 2 and 3. Cracks have opened as much as 1/2 inch due to absence of reinforcement.

During construction, steel tie bars were not placed in the pavement between the end of the project at U.S. 2 and Station 328+00. In this section, the center joint has cracked and opened as much as 1/2 inch. Typical examples of this condition can be seen in Figures 4 and 5. At Station 325+00, an unusual situation has developed due to the lack of longitudinal tie bars. As shown in Figures 6 and 7, at the center joint, the slab has been displaced transversely as much as 1 inch.

At three locations on the project, it was observed that the pavement had settled at the center. Between stationing 330+00 and 328+00, 70+00 to 67+00 and 51+00 to the Naisha River bridge, the pavement crown was lower than the edge of the pavement as much as 1 3/4 inches in some instances.

General transverse cracking has taken place directly over the culverts. The worst example is at Station 258+60 as illustrated in Figure 8. Cracking in this case was obviously due to settlement of the high embankment which was 22 feet over the culvert.

The entire length of the north leg of the Y at the intersection of S-418 and U.S. 2 was erected in the center as shown in Figure 9. This section of pavement was constructed without a center joint which would have relieved transverse warping stresses. Since the pavement is 14 feet wide, longitudinal cracking can be expected under such circumstances.

Physical Conditions of Concrete

From visual observations, the concrete appears to be in excellent physical condition and of good quality. No spalling or scaling adjacent to the cracks or joints was noted. A summary of flexural strengths appear in Table I. These values are consistent with specification limits. Also, core strengths given in Table II are indicative of concrete of unquestionable quality.

Longitudinal Joint Condition

During the condition surveys, it was observed that the center longitudinal joint was not apparently functioning in many locations where longitudinal cracking had occurred. The location and amount of crushed and uncracked center joints is given in Table III. This condition was subsequently verified by core specimens taken at the center joint in designated areas. Photographs of several uncracked cores may be seen in Figure 10. It is quite possible that the rigidity of the center joint may have been responsible, to a certain extent, for the longitudinal cracking of the slabs. In practically all cases, the longitudinal cracking appeared just outside of the influence of the longitudinal tie bars.

Foundation Conditions During Construction

Construction records reveal that the following subgrade conditions were encountered during the construction of the project: (1) subgrade soils consisted, primarily, of Oakhaven clay and Ogeese sandy and fine sandy loam, both of which are very poor soils and require special treatment; (2) high water table prevails throughout project; (3) shallow fill over previous narrow township road with attendant ditches all within present pavement edges except for excavated sections; (4) subgrade soil and

sand cushion became badly disturbed and intermixed by trucks prior to placement of slab. This was caused by unusual rainy conditions which prevailed during construction period; (5) granular borrow materials used in construction of sand backfills and sand cushion was very fine, unstable and difficult to compact, and (6) old road bed contained excessive amounts of objectionable organic material which had to be excavated and wasted.

In order to overcome the objectionable features associated with the above existent subgrade conditions, several types of subgrade treatment were recommended and carried out during the construction of the project. The major treatments employed are illustrated graphically in Figures 11 and 12. The location of each type of subgrade preparation, in respect to the entire project, is shown in Figure 1. In addition, Figure 1 shows the location of the longitudinal cracked areas in relation to type of subgrade treatment.

As noted in Figure 1, the longitudinal crack pattern is too general to be directly associated with any particular type of foundation treatment employed on the project.

Results of 1948 Condition Survey

A complete condition survey, made in November 1948, revealed that longitudinal cracking has increased by a total of 572 linear feet within the year. For the most part, the cracking was a continuation of former cracking. However, cracking in new locations has occurred. The amount and location of new cracking is presented in Table IV. The location of new cracking is also shown in Figure 1.

Raveling of Pavement Surface

To ascertain whether or not the shoulders were bearing sufficiently

to cause longitudinal cracking, a transverse profile of the pavement was made at several cracked areas while the frost was still in the ground (April 8, 1949). The cross section profiles are shown in Figure 15. The graphs plainly indicate considerable distortion and loss of crown in the pavement slab. This phenomena can no doubt be attributed to non-uniform volume changes in the pavement foundation.

Conclusions

From the facts disclosed by the investigation, it may be concluded that the unusual longitudinal cracking is due, primarily, to two major factors; namely, (1) questionable foundation conditions and (2) the absence of reinforcement steel and load transfer devices.

Questionable foundation conditions may be attributed to a number of factors inherent in the design and construction of the project, such as:

1. The grade line was established too close to normal ground level, in view of existing poor subgrade soil and high water table.
2. Construction of sections of the new pavement on shallow fill over previous narrow road bed whose shoulder and ditch lines member inside of present pavement edges.
3. Insufficient thickness of subbase in view of unfavorable construction conditions, and the loose incoherent characteristics of subbase material.
4. Rutting and intermixing of subbase and subgrade materials which would destroy the lateral drainage in the subbase, causing high moisture content. Freezing and thawing of subbase under these conditions may result in sufficient heaving to crack the pavement.
5. Inadequate and non-uniform consolidation of the subbase and

subgrade material.

5. Generally poor subgrade soil throughout the project, which is susceptible to heaving under frost action.

The presence of load transfer devices would have caused the individual 20-foot slabs to act more or less as a unit under imposed warping conditions. Thus, the tendency for the pavement to crack longitudinally outside of the center joint would be greatly reduced. In addition, a greater degree of structural integrity would have been preserved in the pavement by the presence of steel reinforcement.

TABLE I

SUMMARY OF FLEXURAL STRENGTHS

Station	7 Day lbs. per sq. in.	28 Day lbs. per sq. in.
411+20	640	851
389+50	645	854
368+30	706	858
351+10	717	881
336+80	761	851
328+75	804	869
301+85	717	859
284+85	780	857
266+95	716	862
259+15	737	814
230+21	711	859
217+20	800	840
202+40	671	868
178+40	665	838
161+45	635	868
147+85	585	826
132+10	582	827
113+50	595	800
88+80	619	832
58+80	615	----
27+10	525	----
5+30	558	828
75+52R	585	719
72+16L	628	880
Average	655.70	820.04

TABLE II

SUMMARY OF CORE STRENGTHS, PROJECT F 17-42,02

For Pavement Completed in 1941		For Pavement Completed in 1942	
Core No.	Compressive Strength p.s.i.	Core No.	Compressive Strength p.s.i.
1226	5680	457	5575
1227	5130	458	5395
1228	4785	459	5335
1229	5650	460	5910
1230	6555	461	4885
1231	4520	462	4480
1232	5570	463	6090
1233	6506	464	4825
1234	5550	465	5635
1235	6610	466	5590
1236	5955	467	4875
1237	6900	468	4700
1238	6255	469	5235
1239	5755	470	6480
1240	4615	471	6755
1241	6680	472	4885
1242	5795	473	6140
1243	6440	474	4455
1244	5595	475	6600
1245	5285	476	6145
1246	6310	477	5300
1247	4665	478	5695
1248	6780	479	6520
1249	6100	480	5550
1250	5570	481	6035
1251	5505		
1252	5715		
Average	5648.1		5551.2

TABLE III

EXTENT OF LONGITUDINAL CRACKING AND
CONDITION OF LONGITUDINAL CENTER JOINT AT CRACKED AREAS

Survey - October, 1947

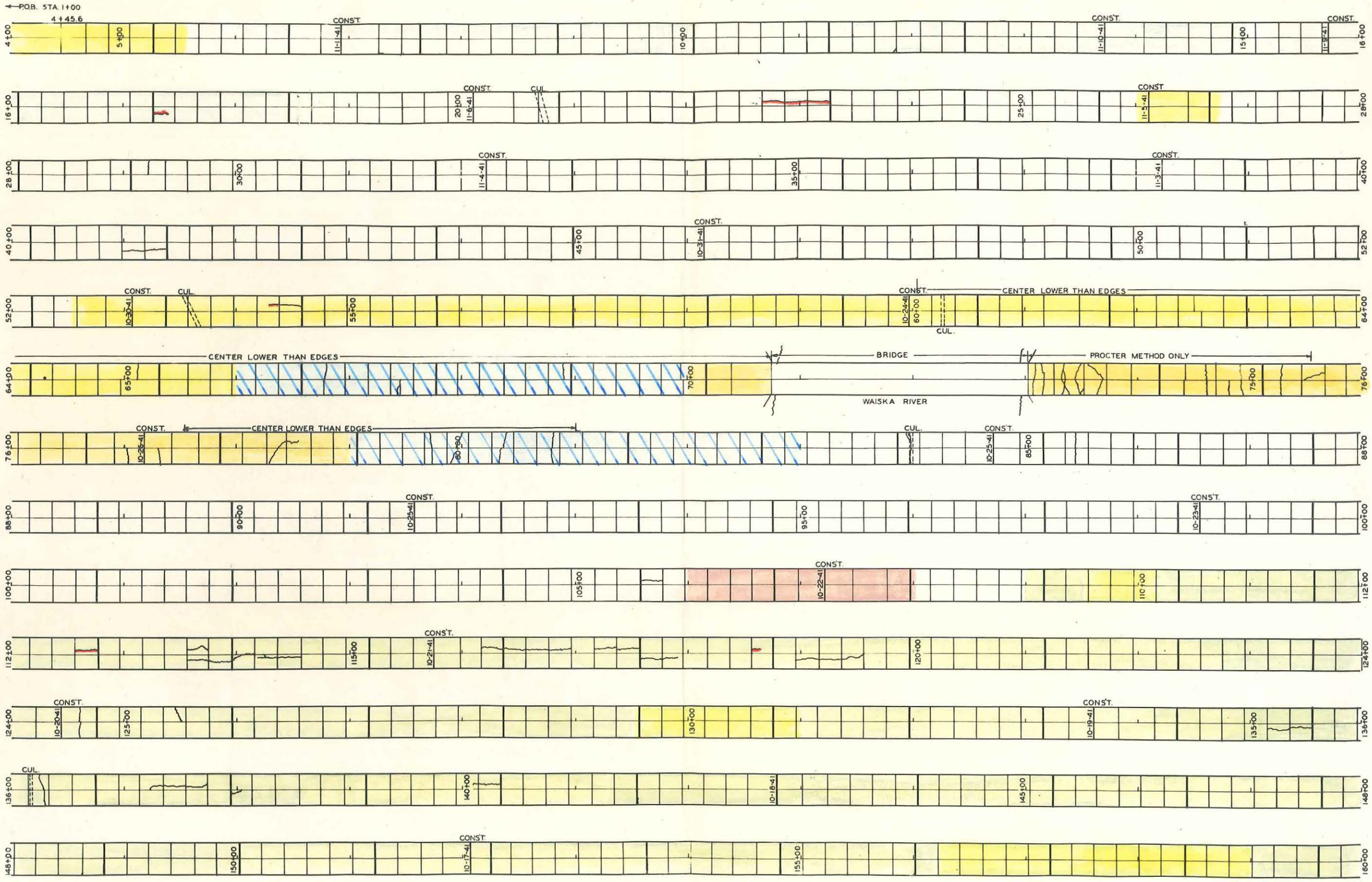
Length of Cracked Pavement		Condition of Longitudinal Joint at Cracked Area			
From Station	to Station	Not Cracked ft.	Cracked But Closed ft.	Cracked And Open ft.	Remarks
22+67	23+09	42	--	--	
23+09	23+27	16	--	--	
33+75	38+00	--	525	--	
41+00	41+40	--	40	--	
54+40	54+60	--	20	--	
75+50	75+70	--	20	--	
78+32	78+60	28	--	--	
105+60	105+80	20	--	--	
113+60	114+10	50	--	--	
114+10	114+28	18	--	--	
114+28	114+60	32	--	--	
116+20	117+00	80	--	--	
117+00	117+20	--	--	20	
117+20	117+60	40	--	--	
117+60	117+90	30	--	--	
118+60	118+70	--	--	10	
119+05	119+25	--	--	20	
119+25	119+65	40	--	--	
131+95	132+03	--	--	8	
135+10	135+50	40	--	--	
137+35	137+45	--	--	10	
137+45	137+65	20	--	--	
137+65	137+85	--	20	--	
138+05	138+15	10	--	--	
140+17	140+25	--	--	8	
140+25	140+45	20	--	--	
188+50	188+80	30	--	--	
198+75	199+15	40	--	--	
199+15	199+35	20	--	--	Core No. 530, 199+25
199+35	199+95	60	--	--	
201+62	201+79	17	--	--	
202+18	202+35	--	17	--	
247+55	248+15	60	--	--	
258+25	258+75	50	--	--	
259+85	261+10	25	--	--	Core No. 531, 260+50
261+10	261+25	--	15	--	
264+78	264+98	20	--	--	
294+50	294+70	--	20	--	
294+70	294+80	--	--	10	
295+30	295+50	--	20	--	
295+50	295+70	20	--	--	
308+00	308+20	--	20	--	
308+40	309+15	75	--	--	
323+20	323+40	--	20	--	
325+20	325+40	--	20	--	
327+60	328+00	40	--	--	
327+80	330+00	--	--	20	
330+00	330+20	--	--	20	
330+20	330+40	20	--	--	
336+00	336+40	40	--	--	Core No. 532, 344+76
345+70	345+90	20	--	--	
345+90	346+10	--	--	20	Core No. 533, 346+00
346+10	346+30	20	--	--	
359+90	362+10	220	--	--	Core No. 534, 360+00
362+10	362+20	--	--	10	Core No. 535, 361+00
380+55	381+00	45	--	--	
381+75	381+95	--	20	--	
382+35	382+55	--	--	20	
	Grand Total	1308	777	176	Total 2261 Linear feet of Cracked Pavement
	Per Cent of Grand Total	57.85	34.36	7.78	

TABLE IV

NEW LONGITUDINAL GRADE RATIO DEVELOPED

BETWEEN 10-14-47 AND 11-12-48

Station	to	Station	Minor Part
17 + 23		17 + 40	17
22 + 55		23 + 25	30
54 + 30		54 + 40	10
112 + 60		112 + 80	20
118 + 60		118 + 70	10
140 + 10		140 + 20	10
202 + 00		202 + 30	30
234 + 40		234 + 20	20
307 + 00		307 + 30	30
308 + 30		308 + 60	30
327 + 50		327 + 70	20
546 + 10		546 + 20	10
577 + 00		577 + 15	15
581 + 55		581 + 85	30
591 + 50		592 + 15	25
595 + 75		596 + 05	30
420 + 75		420 + 85	10
421 + 10		421 + 40	30
		Total Length	372



CONDITION SURVEY (11-12-48)

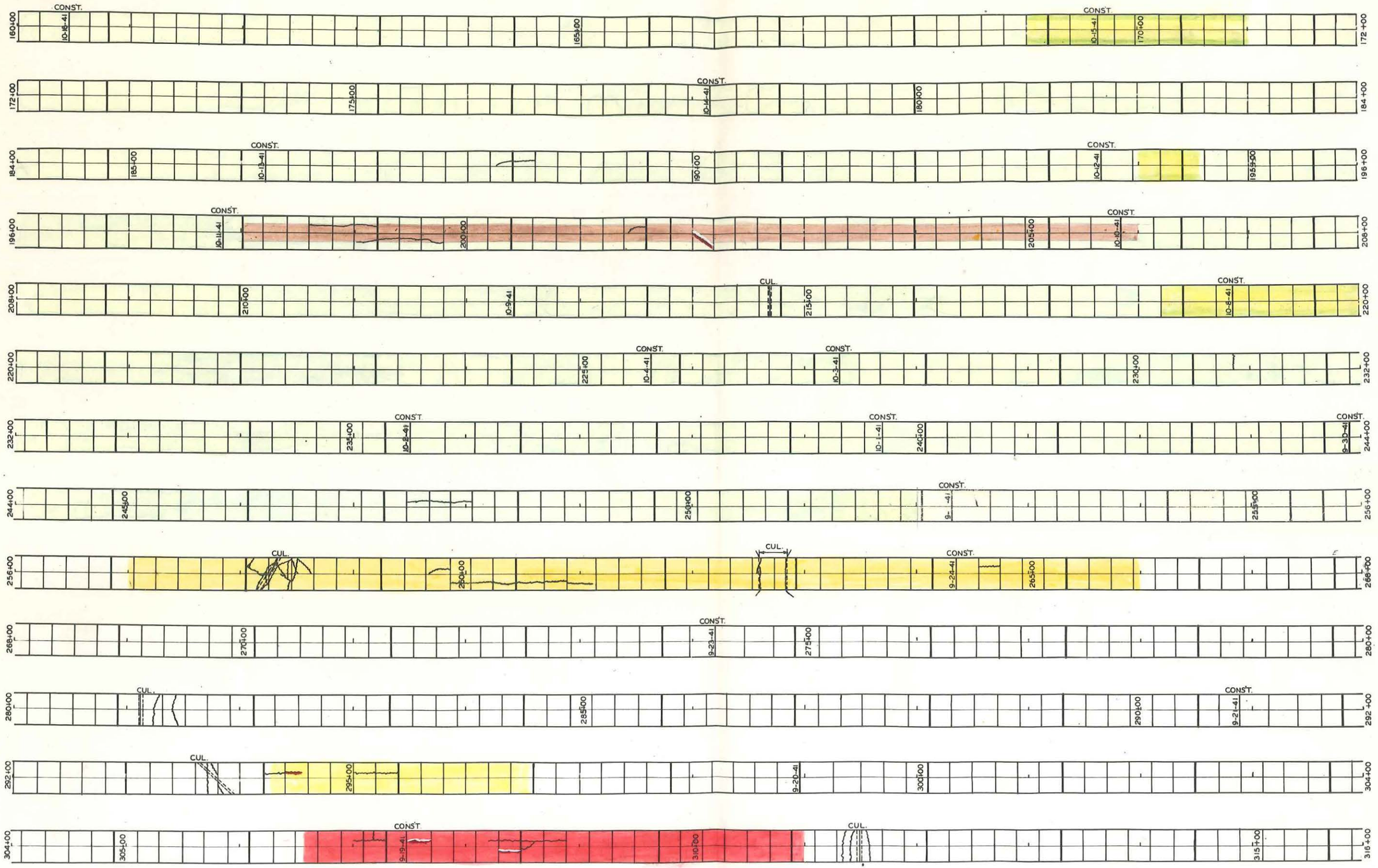
PROJECT F17-42

STA. 4 + 45.6 (P.O.B.) TO 160 + 00

SHEET 1 OF 3

RESEARCH PROJECT 39F-7(14)

C535



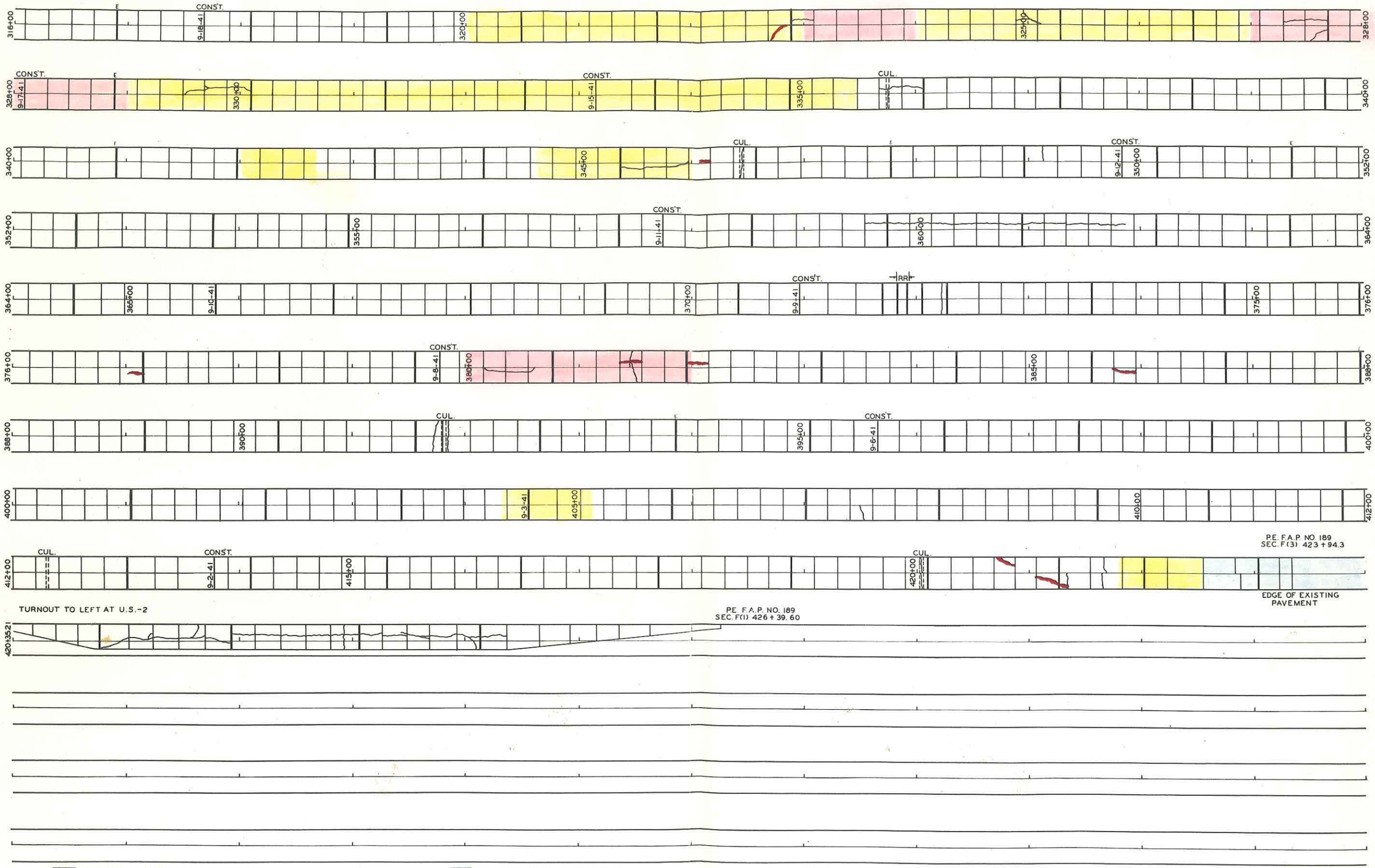
CONDITION SURVEY (11-12-48)

PROJECT F17-42

STA. 160 + 00 TO 316 + 00

SHEET 2 OF 3 RESEARCH PROJECT 39F-7(14)

C536



CONDITION SURVEY (11-12-48)

PROJECT F17-42

STA. 316 + 00 TO 423 + 94.3 (P.O.E.)

SHEET 3 OF 3

RESEARCH PROJECT 39F-7(14)

Figure 2. Typical longitudinal cracking, Station 325+50. Note width of cracks.

Figure 3. Typical longitudinal cracking, Station 330+00.

Figure 4. Opening of center joint where tie bars were not used, Station 396+50 to US-2.

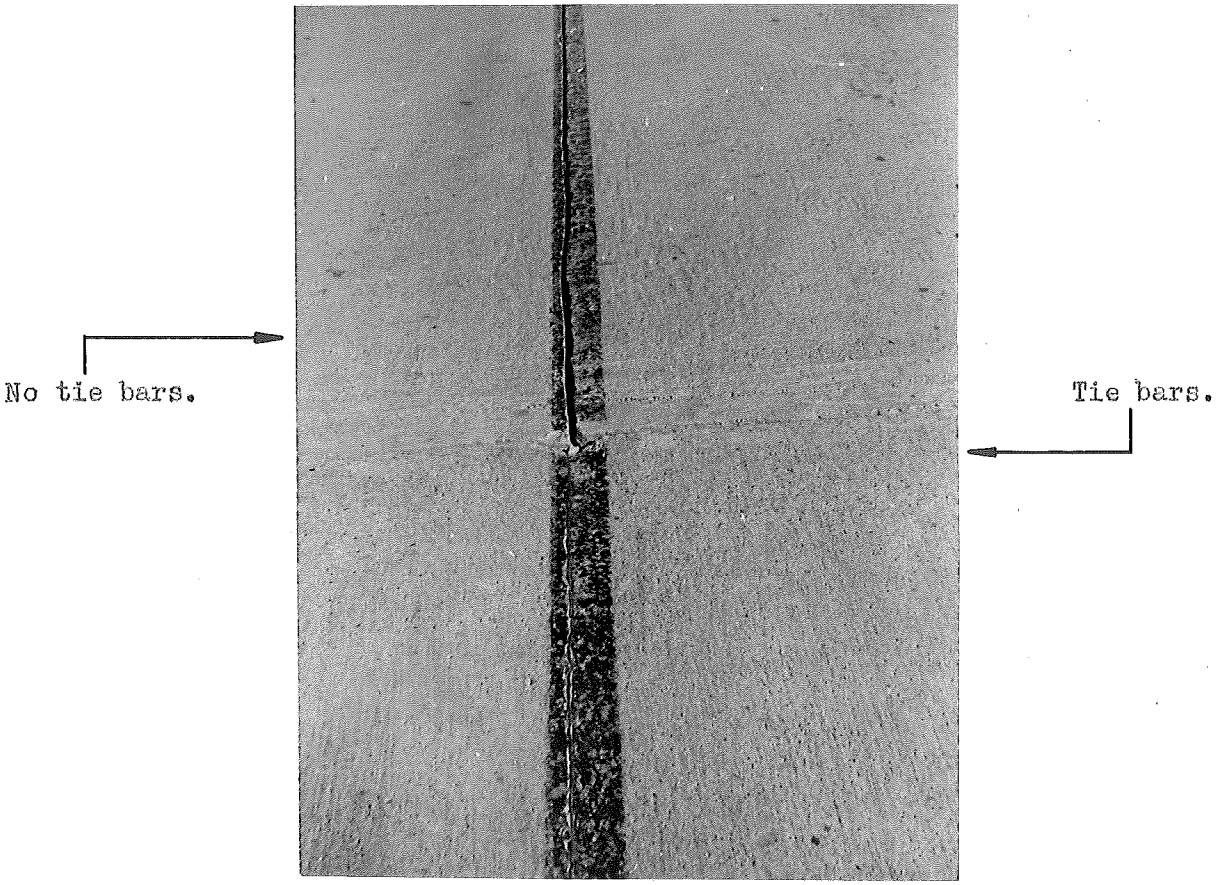


Figure 5. Showing condition of longitudinal joint with and without tie bars, Station 396+00.

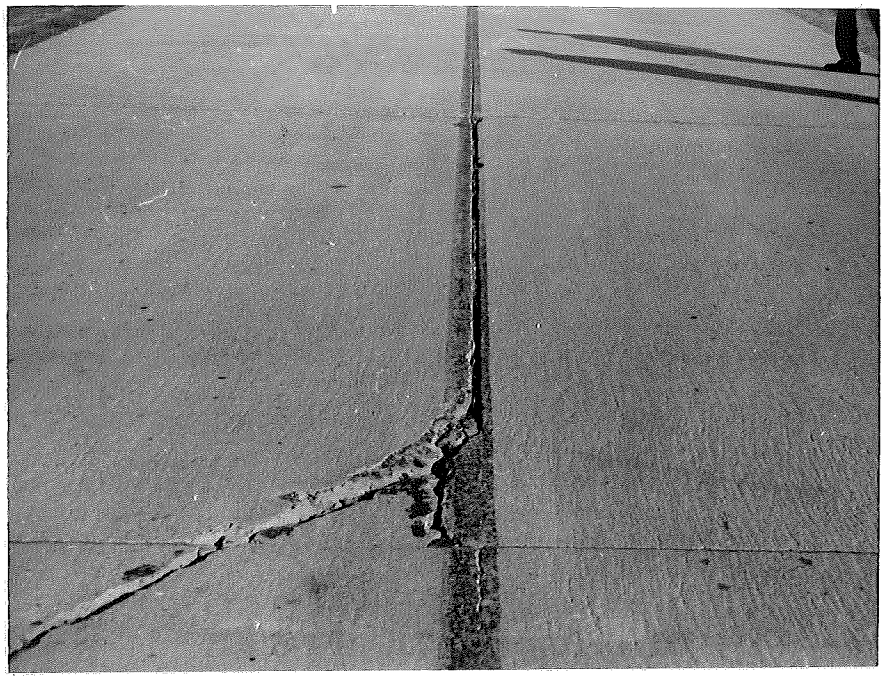


Figure 6. Center joint open 1 inch; evidently tie bars were left out of this slab during construction. Slab displaced sideways. See Figure 7. Station 325+50.

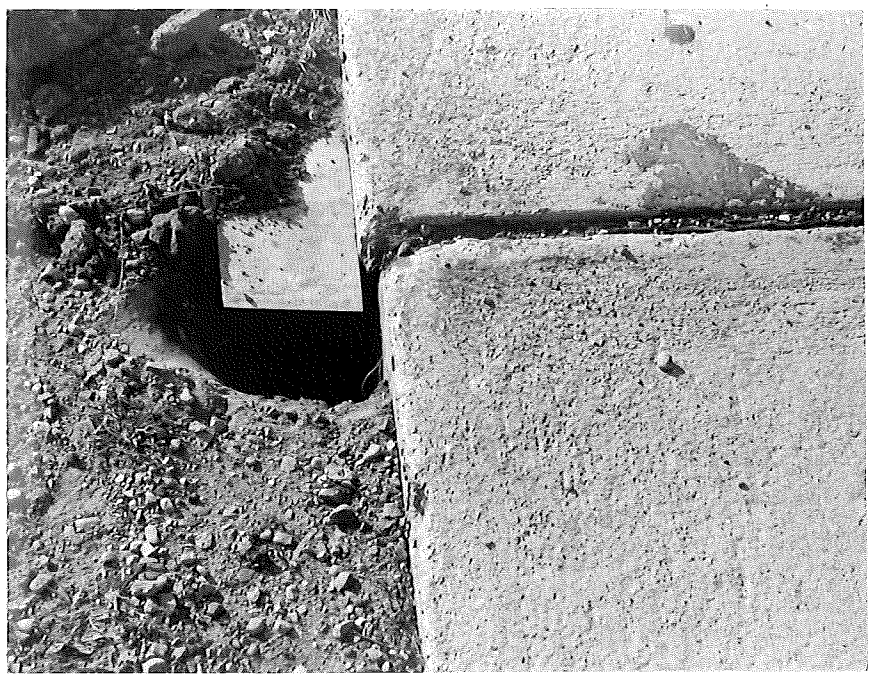


Figure 7. Displacement of slab section at Station 325+50.

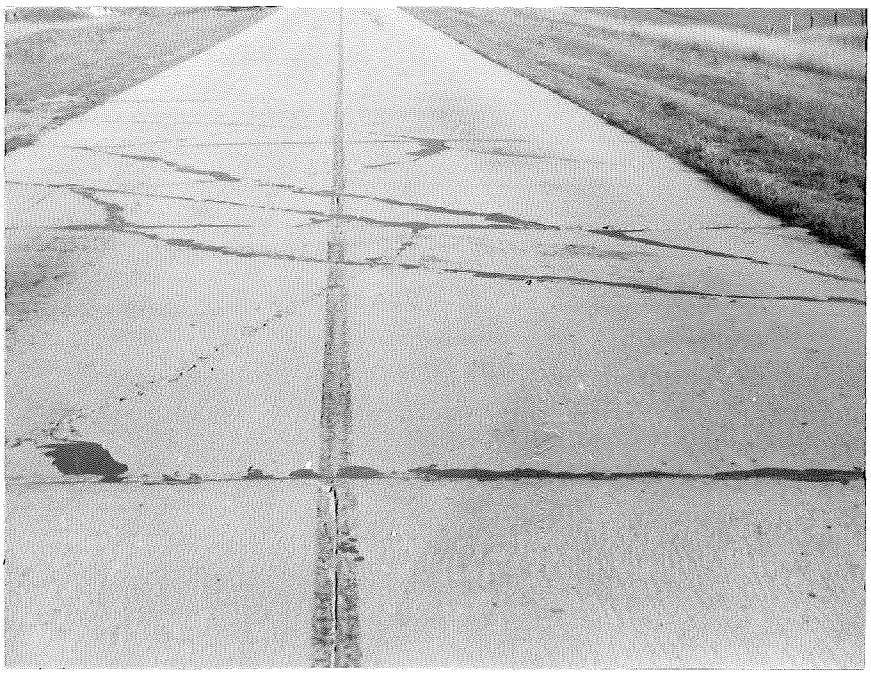


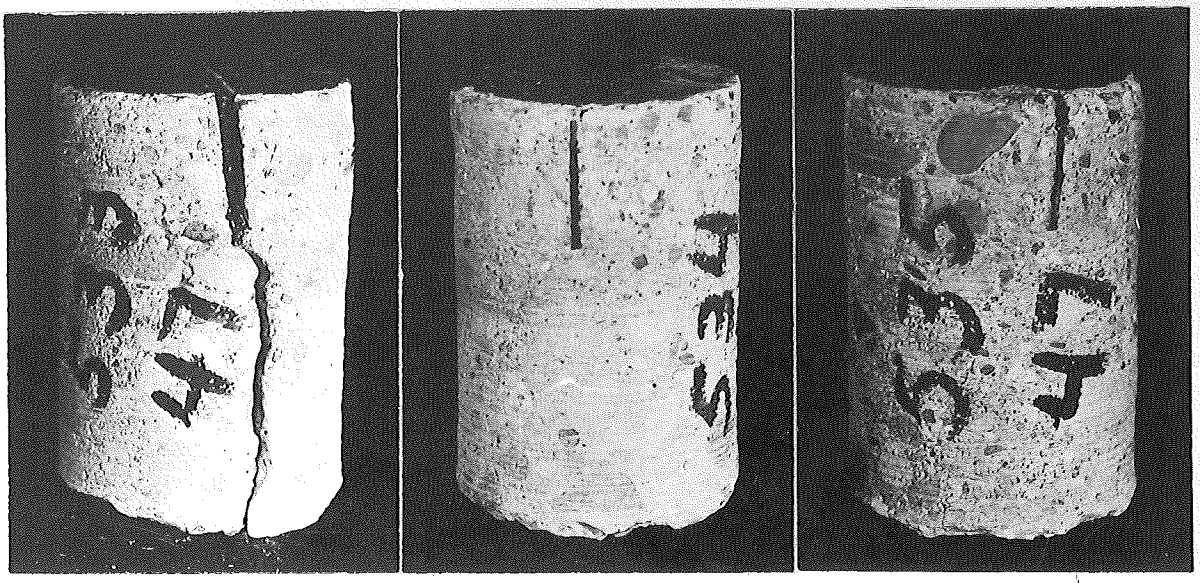
Figure 8. View of cracking over culvert at Station 258+50.

Figure 9. Typical cracking of 14 foot width pavement forming north leg of Wye at intersection with US-2.

STATION 199+25
CENTER JOINT NOT CRACKED

STATION 260+50
CENTER JOINT NOT CRACKED

STATION 244+76
CENTER JOINT NOT CRACKED



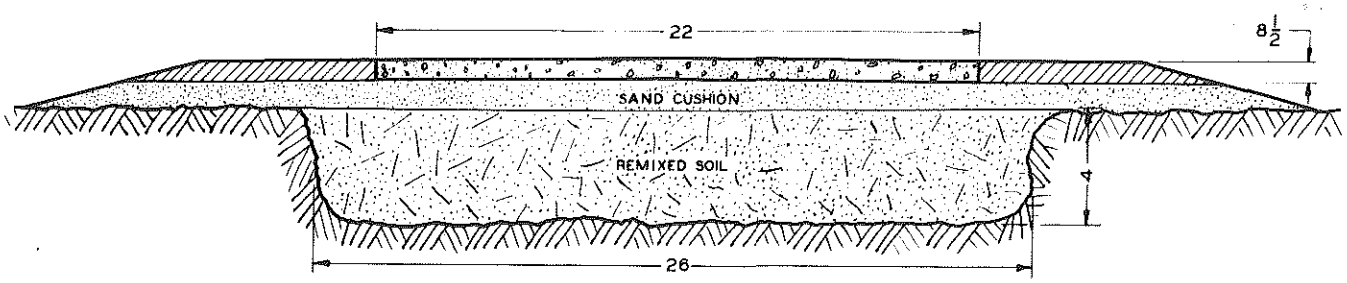
STATION 346+00
CENTER JOINT CRACKED

STATION 360+00
CENTER JOINT NOT CRACKED

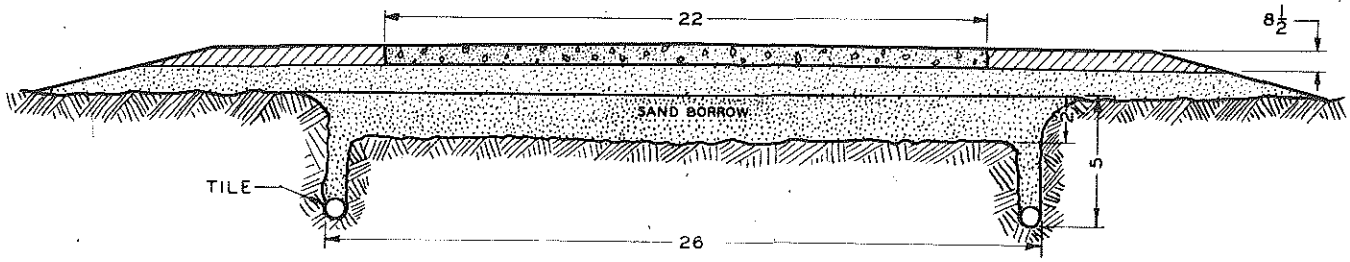
STATION 361+00
CENTER JOINT NOT CRACKED

CORES SHOWING CRACKED *and* UNCRACKED CONDITION *of* LONGITUDINAL JOINT

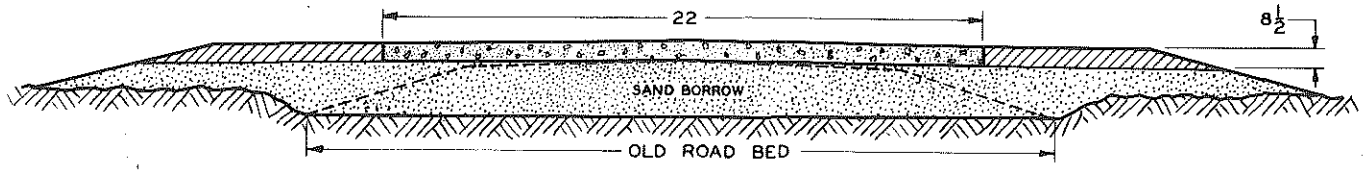
Figure 10



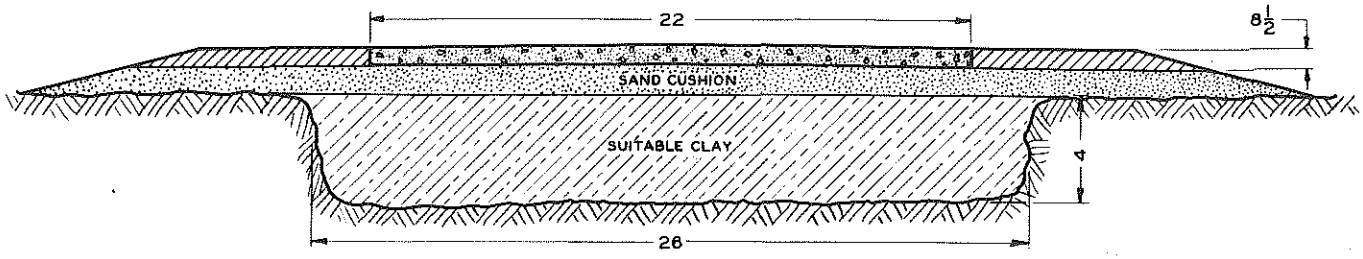
EXCAVATE, REMIX AND REPLACE EXISTENT SOIL.



EXCAVATE AND REFILL WITH SAND.



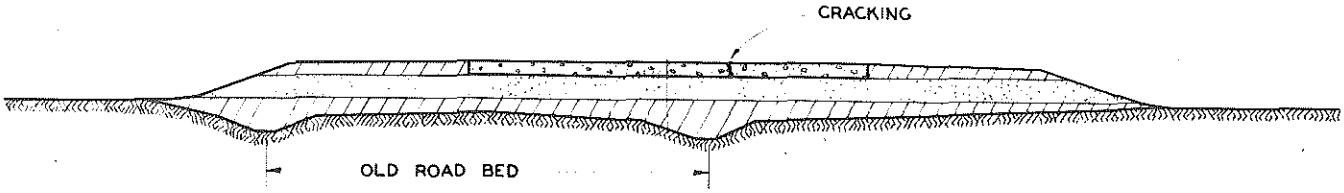
LOWER OLD ROAD GRADE TWO FEET BEFORE RECONSTRUCTING SUBBASE



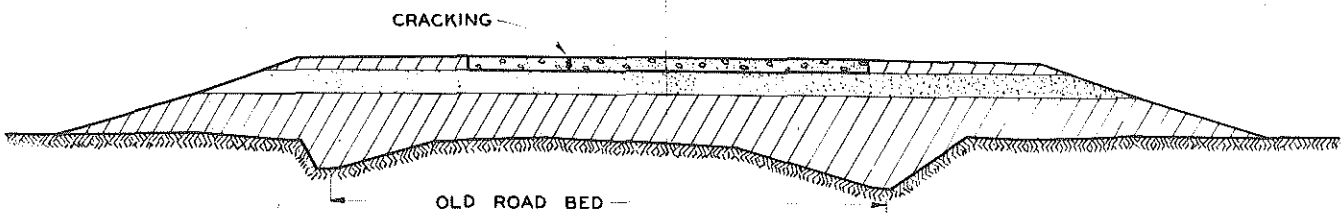
EXCAVATE AND REFILL WITH SUITABLE CLAY

TYPICAL KINDS of FOUNDATION PREPARATIONS EMPLOYED on PROJECT 17-42 C1-2

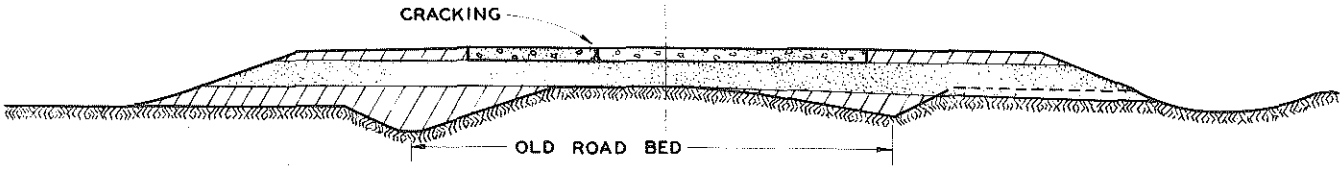
Figure 11



STA. 114+00



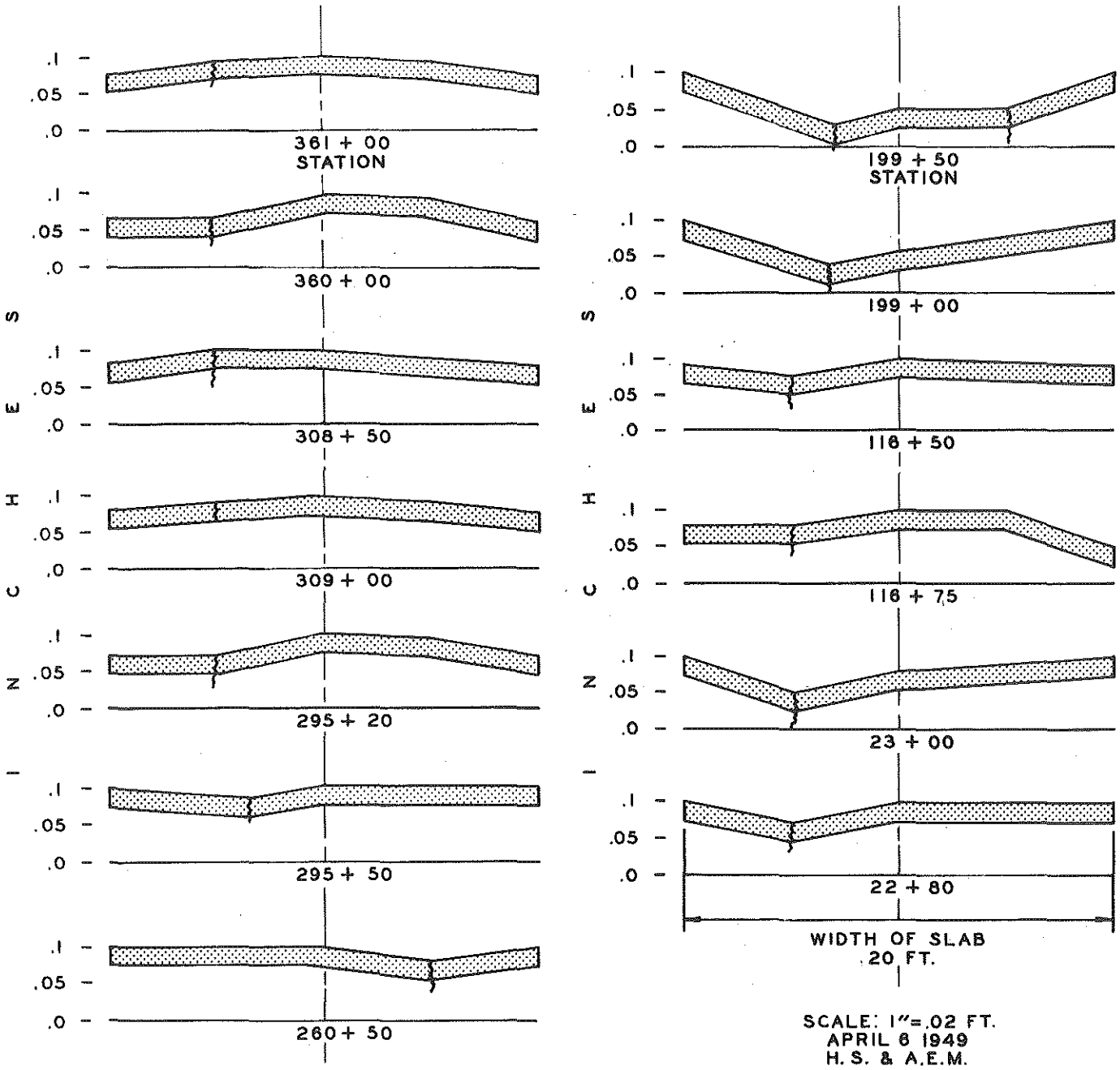
STA. 140+00



STA. 189+00

TYPICAL LONGITUDINAL CRACKING of PAVEMENT CONSTRUCTED on SHALLOW FILL over OLD ROADBED

Figure 12



PROFILES of PAVEMENT SURFACE at SEVERAL CRACKED AREAS

4-732

Figure 13