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MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

F #58

A STUDY OF

CONCRETE PAVEMENT CRACKING ON PROJECT 42-7, C1

Research Project 44 C-27

RESEARCH LABORATORY
TESTING AND RESEARCH DIVISION
September 8, 1944

MICHIGAN
STATE HIGHWAY DEPARTMENT
LANSING 13

CHARLES M. ZIEGLER
STATE HIGHWAY COMMISSIONER

HARRY T. WARD
CHIEF DEPUTY COMMISSIONER

HARRY C. COONS
DEPUTY COMMISSIONER,
CHIEF ENGINEER

September 8, 1944

Mr. E. E. McLaughlin
Testing and Research Engineer
Michigan State Highway Department
Lansing, Michigan

Dear Mr. McLaughlin:

In compliance with the request of H. C. Coons, Deputy Commissioner - Chief Engineer on August 18, a study has been made of the pavement cracking which has developed on project 43-7, C1 located on U. S. 2 north of St. Ignace. The basis of Mr. Coon's request is an inter-office communication of August 16 to R. R. Downey, Maintenance Engineer from D. H. Miles, District Engineer containing a proposed concrete patching program for the project. The communication is attached to this report.

The survey was made by the author and Elmer Beckonen, Upper Peninsula Soils Engineer on August 22 and 23. The report attached hereto contains a brief history of the project and a complete description of all cracked areas including maps, pictures and soil survey notes as well as conclusions and recommendations.

In general the study indicates that a good crack sealing job is needed on the project and furthermore, no long distances of patching should be undertaken without a major subgrade correction program in conjunction with the patching operations. However, there are a few locations which perhaps should receive immediate attention. It is difficult to visualize from summer conditions just how badly the cracked areas will behave during the winter and spring seasons. Therefore, observations at that time of year may modify our present concepts concerning the seriousness of the present cracks.

Yours very truly

E. A. Finney

E. A. Finney
Assistant Testing and Research
Engineer in charge of Research

EAF:GT

FORM 1400

MICHIGAN

STATE HIGHWAY DEPARTMENT

LANSING 13

CHARLES M. ZIEGLER
STATE HIGHWAY COMMISSIONER

INTEROFFICE COMMUNICATION

August 16, 1944

B. R. Downey

Concrete Patching on US-2, North of St. Ignace

When I was with you in St. Ignace recently, you suggested that I measure up the sections of concrete that should be replaced on US-2, north of St. Ignace in Mackinac County. You stated that you might possibly let this concrete patching by contract.

Following is the stationing and square yards of sections that need replacing.

PROPOSED CONCRETE PATCHING
ON US-2, NORTH OF ST. IGNACE IN MACKINAC COUNTY
MAINTENANCE SEC. 31-1

STATION TO STATION			AREA IN SQ. FT.		
162 + 93.5	to 163 + 80.5	(R)	87 x 10	-	870
203 + 81	to 205 + 77	(R)	196 x 10	-	1960
207 + 36	to 209 + 11	(R)	175 x 10	-	1750
210 + 43	to 212 + 71	(R & L)	228 x 20	-	4560
213 + 44	to 214 + 34	(R)	90 x 10	-	900
216 +11	to 216 + 41	(R)	30 x 10	-	300
217 + 72	to 218 + 71	(R)	99 x 10	-	990
217 + 95	to 218 + 57	(L)	62 x 10	-	620
221 + 16	to 223 + 70	(R)	254 x 10	-	2540
235 + 29	to 236 + 75	(R)	146 x 10	-	1460
227 + 05	to 227 + 27	(R)	22 x 10	-	220
229 + 31	to 232 + 33	(R)	302 x 10	-	3020
233 + 09	to 233 + 42	(R)	33 x 10	-	330
243 + 10	to 243 + 56	(R)	46 x 10	-	460
243 + 10	to 244 + 13	(L)	103 x 10	-	1030
245 + 36	to 245 + 68	(R)	32 x 10	-	320
283 + 77	to 284 +17	(R)	40 x 10	-	400
285 + 44	to 285 + 59	(R)	15 x 10	-	150
286 + 59	to 287 + 11	(R)	52 x 10	-	520
292 + 57	to 292 + 93	(R)	36 x 10	-	360
293 + 10	to 293 + 23	(R)	13 x 10	-	130
299 + 07	to 299 + 36	(R)	29 x 10	-	290
299 + 62	to 300 + 02	(R)	40 x 10	-	400
300 + 63	to 301 + 03	(R)	40 x 10	-	400
303 + 50	to 305 + 79	(R)	229 x 10	-	2290
307 + 31	to 308 + 23	(R)	92 x 10	-	920
346 + 37	to 346 + 65	(L)	28 x 10	-	280
			Sub-Total		27470

FORM 1400

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STATE HIGHWAY DEPARTMENT

LANSING 13

CHARLES M. ZIEGLER
STATE HIGHWAY COMMISSIONER

INTEROFFICE COMMUNICATION

August 16, 1944

B.R. Downey

Station to Station				Area in Sq. Ft.		
				FORWARDED	-	27470
347 + 54	to	347 + 98	(R)	44 x 10	-	440
347 + 87	to	347 + 97	(L)	10 x 10	-	100
352 + 59	to	353 + 72	(L)	113 x 10	-	1130
353 + 72	to	354 + 76	(R)	74 x 10	-	740
354 + 76	to	355 + 08	(R)	32 x 10	-	320
356 + 67	to	357 + 05	(R)	38 x 10	-	380
363 + 50	to	364 + 09	(R)	59 x 10	-	590
380 + 07	to	380 + 33	(R)	26 x 10	-	260
383 + 20	to	383 + 49	(R)	29 x 10	-	290
405 + 28	to	405 + 48	(R)	20 x 10	-	200
406 + 25	to	406 + 42	(R)	17 x 10	-	170
410 + 70	to	411 + 03	(R)	33 x 10	-	330
412 + 50	to	414 + 50	(R)	200 x 10	-	2000
416 + 69	to	417 + 14	(R)	45 x 10	-	450
418 + 03	to	419 + 30	(R)	127 x 10	-	1270
420 + 00	to	420 + 81	(R)	81 x 10	-	810
421 + 59	to	422 + 36	(R)	77 x 10	-	770
421 + 90	to	422 + 36	(L)	46 x 10	-	460
				Total		38180 Sft.

$\frac{38180}{9}$ - 4243 Syds

Yours very truly

/s/ Don. H. Miles
District Engineer

DHM:BEO

A STUDY OF CONCRETE PAVEMENT CRACKING ON PROJECT 49-7, C1.

This is a report of a survey made on August 22 and 23 of project 49-7, C1, located on U. S. 2, north of St. Ignace, to determine the extent and cause of the unusual cracking which has developed in the pavement slabs. The survey included a careful inspection of all cracked areas and subgrade conditions underneath. Each cracked area was mapped, borings were made to a depth of four feet below the slab and pictures were taken of a great many of the cracked areas.

The report presents a brief history of the project, some pertinent facts concerning the physical condition of the concrete and a condensed description of the cracked areas followed by a summary and recommendations.

History of the Project.

Project 49-7, C1, was constructed during the summer and fall of 1928. Concrete operations were started August 10, 1928, at Station 440+00 and the last concrete was laid on September 19, 1928, at Station 156+12.6. The project is 5.3 miles in length. The slab is 20 feet wide with a 9"-7"-9" cross section. The contractors were Marsman and Taber of Grand Rapids, Michigan.

The materials which were used in the construction of the concrete slab are as follows: Petoskey cement from Petoskey, natural sand from Sarnia by Dolomite Inc. of Sturgeon Bay, Wisconsin and crushed limestone coarse aggregate from Sturgeon Bay, Wisconsin. Some trouble was experienced in obtaining suitable aggregate. Considerable sand was rejected because it was too fine and the coarse aggregate in several instances was too dirty and had to be rewashed on the job. In some cases it was rejected.

The pavement was constructed using 100' Expansion joints but with no intermediate contraction or dummy joints. Mesh reinforcement was used only over culverts.

Physical Condition of the Concrete.

From visual observations the concrete appears to be in excellent physical condition and of good quality. On the south end of the project from Station 158+22 to approximately Station 300+00 the concrete surface has scaled in varying amounts but not heavily. The remaining portion of the project is entirely free of scale. Normal transverse cracking has occurred between expansion joints. The cracks vary in number from 1 to 7 cracks per slab length. The riding qualities of the surface are very satisfactory and the present cracking contributes no inconvenience to traffic since the cracking under question is primarily longitudinal in character, occurring for the most part in the center of the right or left lane. At some locations longitudinal cracking has occurred in both lanes.

The concrete must be in excellent physical condition because throughout the entire project no spalling was noted either adjacent to the cracks or at the joint edges. This statement is confirmed by illustrations in the report.

Core strengths at the end of five months are given in Table I. These values are consistent with concrete of unquestionable quality.

No data on moduli of rupture tests were found in the files.

TABLE I.

CORE STRENGTHS

Core Number	Compressive Strength, pounds per Square Inch.
517	3720
521	4630
522	6480
523	7140
525	3200
526	5670
527	7530
528	6000
529	5820
550	6420

Survey of Cracked Areas.

The survey revealed that the cracked areas could be definitely grouped according to certain subgrade conditions which prevail throughout the project. Therefore in the following discussion the cracked areas will be combined into groups having a common subgrade condition.

A complete record of cracked areas together with notes on subsoil conditions is presented at the end of this report under illustrations and condition survey maps.

162+93.5 to 165+80.5 (R) No longitudinal cracking was noted in this area.

205+81 to 205+77 (R) Frost heave material was found to a depth of 5 feet below top of slab on right side. Soil on left side consisted of a sandy loam gravelly material to a depth of 5 feet. This material was evidently used in constructing the old road bed since it was found quite consistently throughout the project. Cracking in this area was apparently due to differential heaving of subgrade material. See figure 1 for general condition of slab and character of cracking.

207+38 to 208+11 (R) Right edge of slab has settled 3 to 4 inches below grade in this area. This settling may be corrected by mudjacking. Subgrade on right side consisted of sandy loam to a depth of 2 feet below top of slab. The old road bed on left side consists of sandy loam gravelly with high clay content overleying loamy sand. Longitudinal cracks in this area have opened from 1/2 to 3/4 inch. No serious faulting has occurred at cracks. This is one of the worst areas on the project and appears in the background of figure 1 on the curve.

210+43 to 233+42 (Rt.) Subgrade conditions were fairly constant throughout this area. Cracking occurred on both sides. Left slab has raised along longitudinal cracks, while on right side the slab was depressed at the longitudinal cracks. Note in figure 2 how snow plows have removed joint sealing compounds from longitudinal crack on left side. The slab in this area was constructed on a fill section.

Sandy loam gravelly material was used for fill over peat, the fill varying in depth from 1 to 3 feet below top of slab. Peat varied from 0.5 to 1.0 foot in depth under fill. Water table was located at 3 feet. The old road bed on left side was also placed over peat. Cracking was apparently caused by unequal heaving and settlement of non-uniform subgrade material throughout the cross section augmented by the presence of peat and a high water table. Since major longitudinal cracks are in the center of each lane they cause no inconveniences to traffic. Figure 3 illustrates present condition of cracks. Figure 4 shows cracked area from Station 222+00 looking north. Figure 5 shows typical cracking at Station 226+00 looking south. Figure 6 shows general condition of cracked areas.

243+10 to 245+68 (Rt.) Cracking here was transverse and diagonal in character. The cracked area is located on high fill approaches to a culvert. One small triangular piece of concrete marked "x" in figure 7 has settled slightly below adjacent slabs. Cracking is no doubt due to settling of fill adjacent to culvert augmented by peat underneath. This spot may need attention soon.

283+77 to 301+03 (R) The pavement throughout this area was constructed on an Alpena gravelly beach line consisting of coarse gravelly material which should be ideal for subbase material. Borings showed same material to exist

on both sides of slab. Cracking consists of short longitudinal cracks in right lane only. See figure 8. Cracking may be caused by non-uniform compaction of subgrade or the presence of small localized pockets of undesirable subgrade materials. The definite cause of cracking in this region was not ascertained. Pavement and cracks are in excellent condition.

305+50 to 308+25 (R) Slab was constructed on a fill section composed of one foot of sandy loam over peat 0.5 foot to 1 foot thick, the peat overlying sand. Sandy clay encountered at 3 to 4 feet below slab. Water table at 3 feet. Cracking probably due to unequal heaving and settlement of subgrade material. Typical cracking shown in figure 9.

346+37 to 347+38 (R&L) On left side there was one foot of sand fill over old road bed material. Subgrade on right side consisted of a uniform sand fill. Cracking apparently due to non-uniform subgrade materials. See figure 10 for typical cracking at this location.

352+59 to 364+09 (R&L) Subgrade on left side consisted of 2 feet sand over old road bed material composed of sandy loam gravelly material with high clay content. Right side consisted of 2 foot ideal sand fill. Cracking eventually due to non-uniform subgrade conditions such as would exist in a side hill cut and fill section. See figure 11 for typical cracking and general subgrade conditions.

390+07 to 414+50 (R) Left side in cut section composed of Eastport sand making ideal subbase material, while right side was constructed on fill section consisting of from 0 to 2 feet of sand, silt and very fine sand fill material over sand. Cracking apparently caused by non-uniform subgrade conditions. See figure 12 for typical cracking in this area.

416+69 to 422+36 (R) Ideal sand cut section on left to Station 421+50. On right there was a 2 to 3 foot fill of loamy sand over a 0.5 to 1.0 foot thick layer of peat over sand. Water table was at 3 to 4 feet. Cracking apparently caused by non-uniform subgrade conditions. Pavement badly cracked at Station 422+15 near wye intersection. This area perhaps should be replaced. See figure 13 for typical cracking in this area. Figure 14 is a close view of an unusually bad area at Station 422+15 which will need attention. Figure 15 shows unusual construction procedure at wye intersection.

From the above discussion of the various cracked areas it is quite obvious that the abnormal cracking of the concrete slab in localized areas is not due to any structural weakness in the concrete slab but rather due to excessive volume changes in the subgrade. Such volume changes may be directly or indirectly attributed to; first, the presence of frost heave material in the subgrade including silt, clay and peat augmented by a high water table; second, by the presence of different kinds of fill material in the same cross section; third, location of the slab for great distances over a side hill cut and fill section and finally, lack of uniform compaction in fill sections. At the time this pavement was constructed it was evidently not customary to pay much attention to such factors when constructing the subgrade.

SUMMARY

The information drawn from the construction record and survey warrant the following conclusions:

1. The abnormal longitudinal cracking which prevails at the present time throughout the entire project is unquestionably due to existing subgrade conditions and not to any structural weakness of the concrete slab. It is quite evident that very little attention was given to the removal of undesirable subbase materials, to the provision of uniform fill materials or to proper consolidation of the subgrade during construction. Thus there has resulted non-uniform heaving and settling of the subgrade in localised areas causing cracking of the concrete slab.

2. It is apparent from the plan and from soil observations that the right side of the new pavement was constructed mainly on new fill material practically throughout the entire length of the project. Thus most of the longitudinal cracking has taken place on the right side.

3. Heavy northbound traffic may have had some influence on the prevalence of cracking on the right side of the pavement.

4. It is believed from the apparent physical condition of the pavement that the majority of the longitudinal cracks have been in existence for a long period of time. However, many fine transverse cracks were observed normal to the longitudinal cracks, which might indicate that the slab sections between the longitudinal cracks and the slab edge are progressively breaking into small slabs with time. In most cases these latter cracks are not of sufficient importance at the present time to require maintenance.

5. The physical condition of the concrete itself is excellent for a pavement 16 years old with no steel reinforcement. The concrete is sound adjacent to all cracks and joints, which is unusual. The cracks have sharp edges with no spalling. Some faulting has occurred at a few cracks and joints but not enough to warrant special attention.

6. The pavement has the usual number of transverse cracks for a pavement 16 years old. They vary in number from 1 to 7 per slab length. The average number is approximately 3 to 4 cracks per slab.

7. The entire project is in need of a good joint and crack sealing job.

8. Since the major cracks are longitudinal in character and occur principally in the center of either the right or left traffic lanes, the riding qualities of the pavement as a whole are not impaired to the extent that they cause any material inconvenience to traffic.

RECOMMENDATIONS

1. The question of whether or not the project should receive a major concrete patching job at this time is no doubt a matter of personal opinion and Departmental policy. From the standpoint of traffic, concrete patches will add but little to the riding qualities of the pavement. From the aesthetic standpoint such repair operations will naturally improve the general appearance of the surface, but from the standpoint of improving the structural integrity of the concrete surface it is believed that concrete patching on a large scale would be a folly unless major subgrade correction operations are included in the patching contract.

2. The survey does not disclose that the concrete pavement has cracked or disintegrated sufficiently at the present time to warrant a major concrete patching program. It is believed that a good crack sealing operation with perhaps a few small concrete patches is all that is necessary to maintain the pavement in satisfactory condition for the traffic it is required to carry for a considerable period of time.

3. It would seem a wiser course to continue the pavement in its present condition for a few years longer at which time it may be found desirable to relocate certain portions of the highway and at the same time reconstruct the bad sections. At such a time proper subgrade corrections can be incorporated into the reconstruction program.

4. However, there are at least three areas which are in need of immediate attention. At Station 207+36 to 208+11 on the right mudjacking may temporarily correct the settlement of the slab in that location. At Station 243+50 a small cracked portion of concrete slab has faulted and may be corrected with either a

bituminous or concrete patch. At Station 422+28 the pavement is badly cracked and will need a concrete patching operation within the near future.

PICTURES AND CONDITION SURVEY NOTES

Figure 1. 40-7, C1, General view of cracking at Station 205+00. Note concrete is in excellent condition adjacent to cracks and cracks have not faulted. View looking north.

Figure 2. 40-7, C1, General view of cracking at Station 211+00 to 212+50.looking south. Heaving occurred at crack on right, settlement at crack on left. Note how snow plows have scraped crack on right.

Figure 3. 49-7, C1, Close view of cracking shown in figure 2. Crack width varied from 1/2 to 3/4 inch. Note condition of concrete adjacent to crack. Looking south.

Figure 4. 49-7, C1. General view of cracking at Station 222+00. Looking north. Slabs settled along longitudinal crack, however, slabs have not faulted. Crack about 1/2 inch wide at top.

Figure 5. 49-7, C1, General view of cracking at Station 226+00 looking south. Slight faulting is noted near center of cracked area.

Figure 6. Typical condition of cracked areas. Station 232+00 looking south. Project 49-7, C1.

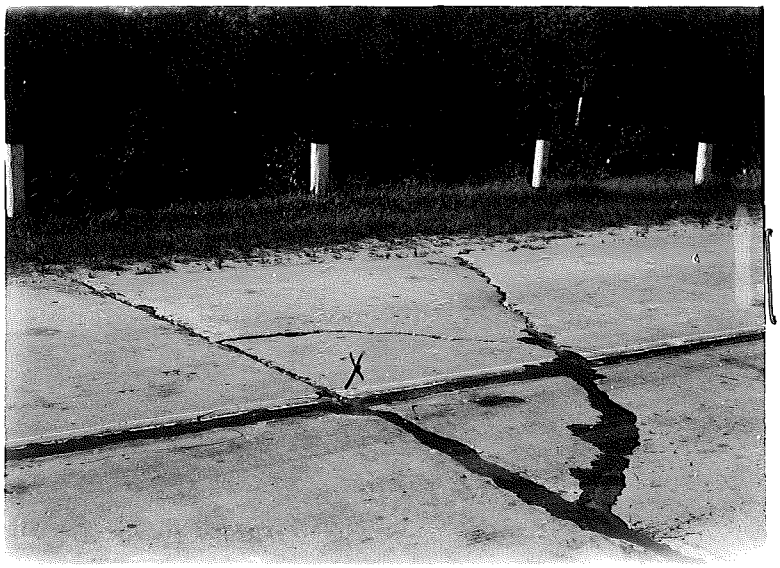

Figure 7. 49-7, C1, View of cracking at Station 245+52 Triangular shaped piece "x" has faulted. This area will need attention soon.

Figure 8. 49-7, C1, Typical cracking at Station 284+00 looking south. Pavement in excellent shape.

Figure 9. 49-7, C1, Cracking at Station 347+50, looking south.

Figure 10. 49-7, C1, Cracking at Station 353+00, looking south. Note that this area is where old road joins new pavement.

Figure 11. 49-7, C1, View at Station 564+00 looking south. Slab on side hill cut. Old road bed on left. Sand ridge on right.

Figure 12. 49-7, C1, View at Station 583+00, looking south. Pavement on cut and fill section. Cracks need sealing.

Figure 13. 49-7, C1, View of cracking looking south from Station 414+00. Slab constructed on cut and fill section.

Figure 14. 49-7, C1, View at Station 422+10 looking south showing bad break up in this area. Note soundness of concrete adjacent to cracks.

Figure 15. 43-7, C1, General view of wye looking north at Station 422+00. Note unusual construction procedure at wye emphasized by curved cracks joining the center line of US 2 with center line of County Road (1). Also note similar curved crack joining the right edge of the slab on US 2 with that on County Road (2)