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MICHIGAN
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INVESTIGATION OF BICHLER BROTHERS GRAVEL

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The purpose of this progress report is to summarize the work done thus far by the Research Laboratory in regard to an investigation of Bichler coarse aggregate and, in particular, its possible weakening effect on pavement and bridge projects utilizing this source. The results of a field survey of construction projects using this material are contained in this report.

This investigation was initiated by a letter from W. W. McLaughlin dated March 31, 1954 concerning below specification flexural strengths of Bichler concrete field test beams on Project SSB2 of 49-4-3,C1. Similar low results on other bridge and pavement projects, notably 21-8,C3, 21-6,C13 and 21-32,C3 were reported in a letter from E. W. Krause to the Research Laboratory, dated December 16, 1953.

The project files at Ann Arbor were examined and a summary of the available field beam strength results is given in Table 1. The majority of these tests meet Department specifications but a few are unusually low. Erratic molding and testing procedure probably was to blame for some of these low strengths, together with low temperature curing. This was found to be especially true on Projects B1 and B2 of 21-9-12.

Samples of 2NS sand and 6A gravel were received August 13, 1953 and also on December 18, 1953. Numerous tests were performed on this material and also on air-entrained concrete beams molded from it. Test results were reported by letter dated March 29, 1954. The freeze and thaw beams have now gone through 300 cycles of slow freezing and thawing in water with the results shown in Table 2.

TABLE 1

CONSTRUCTION PROJECTS UTILIZING BICHLER GRAVEL IN DELTA COUNTY

Field Beam Test Data

Project Number	Flexural Strengths, psi Ave. of all tests		Pour Date	Remarks
	7 Days	28 Days		
	550	650	MSHD Specifications	
		Pavements		
21-8-C_2	741	816	Oct.-Nov. 1936	Inland 4A & 10A
	651	783	" " "	" " & Bichler 10A
21-16-C_4	658	763	October, 1948	Bichler C.A.
	486	694	" "	Ambeau C.A.
21-6-C_{10}	545	754	May-June, 1931	
21-6-C_3	540	718	June-Oct. 1929	
21-15-C_3	662	812	August, 1936	Capped with bit. concrete
21-8-C_3 21-6-C_{13} 21-32-C_3	509	$541^{(14)}$	1952 1953 1953	Widening Projects
		Structures		
X_1 of 21-6-1,C_1	687	852	Aug.-Oct. 1936	
B_1 of 21-8-21,C_1	627	682	July-Oct. 1948	
B_2 of 21-8-21,C_3	534	$540^{(10)}$ $615^{(21)}$	Feb.-Mar. 1932	
B_1 of 21-9-12	443	444	Sept.-Oct.1935	
B_2 of 21-9-12	440	746	Sept.-Oct.1935	
B_1 of 21-12-23	536	720	Sept.-Oct.1941	Grade B
	588	792	June - 1942	Grade A
B_1 of 21-13-2	554	749	June-Sept.1941	Grade B
	624	756	June-Sept.1941	Grade A
B_1 of 21-14-2,C_2	655	790	Sept.-Oct.1935	
<u>Projects not in Delta County</u> --				
SSB_1 of 2-5-6, C_2	573	629	1953	
SSB_2 of 49-4-3,C_1	469	467	1952	

Note: All strengths measured at 7 and 28 days field curing except where indicated ( ).

TABLE 2

DURABILITY OF LABORATORY MOLDED SPECIMNES

Number of Cycles	Percent of Original Dynamic Modulus	Weight Change %	Length Change %
100	89	-0.84	.011
200	89	-1.46	.023
260	71	-2.50	.050
280	65	-2.69	.061
300	54	-3.05	.062

These beams held up quite well for over 260 cycles of freeze and thaw before dropping to 70 percent of original dynamic modulus. When compared to the performance of other gravel sources as graphed in Research Report 195, dated September 3, 1953, the Bichler gravel beams would be among the best in durability insofar as resistance to slow freezing and thawing in water is concerned. Two of the three beams are shown in Figure 1 after 300 cycles. One of the three beams failed at about 260. At the conclusion of this test the beams had lost three percent of their original weight from scaling and small pop-outs.

The Bicher gravel pit, (21-12), was visited on July 15, 1954, and the gravel deposit was studied. The present area of better material was being depleted and it was learned that in the spring of 1955 the plant will be located 1/4-mile to the east where gravel from that area will be used for production. In the southwest corner of the present locality, there appeared to be a darker coloration to the gravel bank due, presumably, to leaching and oxidation by swamp or marsh water in this area. Some of the absorbent stone in this spot could be broken up in the hands. This location is shown in Figure 2. The 1954 production was coming from gravel to the east of this bad area and along the south portion of the pit, Figure 3.

The upper portion of this gravel deposit is a mixture of fine sand and gravel laid down in an old river delta or alluvial fan on the shore of post-glacial Lake Algonquin. The lower portion contains coarser sand and gravel. A good share of this stone was originally part of the underlying upper Cambrian and lower Ordovician sandstones and limestones which generally would be absorptive and somewhat soft in nature. This softness is apparent in the Los Angeles abrasion loss of 33.5 percent on gravel samples received at this laboratory in August and December of 1953. This material was examined and separated petrographically with a breakdown of rock types shown in Table 3. As a comparison, the average results of a similar petrographic sorting on six typical natural gravels from the Lower Peninsula are also included in the table.

The limestone and dolomite in the Bichler gravel was very heterogeneous as compared to that found in other natural gravels. Almost all of it contained non-calcareous granular particles ranging in size from clay to sand. Usually, in other natural gravels, the limestone and dolomite are more uniform in texture and harder, this being the reason for placing them among the "hard" rock types in Table 3. The ratio of "hard" to "soft" stone in the Bichler gravel can be seen to be about 1:1 where, in the average of six other gravels, the ratio runs about 9:1 or 8:1 assuming that some of the limestone would be considered partially soft in nature.

Field Survey of Existing Pavements

A field survey has been made in Delta County of eleven paving projects which contain Bichler aggregates. See Table 4. The older pavements contained quite a bit of transverse and longitudinal cracks as shown in Figures 4 and 5. The first four projects having 100-foot slabs and all expansion joints

TABLE 3

PETROGRAPHIC SEPARATION OF BICHLER GRAVEL
No. 4 to 1-inch Material

Rock Type	Percent of Sample: Bichler*	Percent of Sample: Aver. of Six Natural Gravels
More durable, hard stone		
granite	16.7	7.0
diorite	5.6	6.6
felsite	1.9	6.7
rhyolite	4.1	-
basalt	17.4	6.1
quartzite	4.3	7.0
limestone and dolomite	-	51.7
chert	0.7	6.9
Total hard stone	50.7	92.0
Softer rock types		
sandstone and conglomerate	4.8	3.3
argillaceous limestone and dolomite	27.9	-
yellow sandy limestone	15.4	-
calcareous - purple sandstone	1.2	-
calcareous sandstone	-	4.6
shale	-	0.8
iron bearing clay	-	0.8
Total soft stone	49.3	9.5

* Note: Los Angeles abrasion loss was 33.5 percent on this material.

TABLE 4

PAVEMENT PROJECTS UTILIZING BICHLER AGGREGATES

Project	Year Built	Joint Spacing	Condition Observations: Scaling	Pop-Outs	Transverse Cracking	Longitudinal Cracking	Remarks
Non Air-entrained Concrete							
21-6,C2	1928	100' expn.	Many spots of med. to heavy scale	Occasional	Many	Occasional	Slabs broken up into 8 or 10' pieces. Scaling also along cracks.
21-6,C3	1929	100' expn.	Moderate - mostly along joints and cracks	Few	Numerous	Occasional - connecting transverse cracks	Some joints and cracks faulted.
21-6,C10	1931	100' expn.	Mainly along cracks and joints	Numerous - but small sized	Numerous - 2 to 3 per slab	Occasional	
21-16,C2	1932	100' expn.	Mostly at joints and cracks	Many small ones	About 2 per slab	Very few	Badly scaled and cracked limestone section.
21-28,C2	1935	60' expn. 30' dummy	Some along joints and cracks	Very few	Quite a few toward east end of Project	None	
21-15,C3	1936	Covered with bituminous concrete cap.					
21-32,C2	1936	30' slabs 60' expn.	Slight, at joints	Very few	None	None	
Air-entrained Concrete							
21-16,C4	1948	100'	None	Very few small ones	None	None	Changed to Ambeau aggregate toward end of Project.
21-6,C11	1951	100'	None	None	None	None	Good condition throughout.
21-8,C3	1952	Widening jobs, all in good condition.					
21-6,C13	1953						
21-32,C3	1953						

contained most of the transverse cracking, averaging about two to three per slab. The newer air-entrained concrete pavements with the same slab length exhibited very little or none of this cracking. However, some of the old projects contained patched sections of limestone concrete which were cracked and scaled as badly or worse than the original pavement (see Figure 6). Poor subgrade conditions undoubtedly contributed to the very badly cracked areas in the older pavements. Although the older pavements of long slab length contained a good deal of transverse cracking, the concrete itself appeared to be quite sound. Most of the scaling present was found to occur along the cracks and around some of the transverse and longitudinal joints. An example of an older pavement in good condition is shown in Figure 7, Project 21-32,02, about 18 years old. The postwar pavement projects appear to be in good condition throughout.

Field Survey of Bridge Projects

In general, the bridge projects, totaling 17 surveyed and listed in Table 5, were in good shape except for occasional deterioration exemplified by Figures 8, 9 and 10. This sort of breakdown consisted of sporadic areas of yellowish stained cracks and, in some cases, spalling along these cracks. About seven of the seventeen structures contained this type of defect. This condition was probably caused by freeze and thaw action on numerous absorptive sandstone and limestone particles in the coarse aggregate and consequent leaching and oxidation to produce the yellow stain. Figure 11 illustrates one of the ten structures of seventeen surveyed, which was found to be in sound condition and containing no unusual defects of the concrete in particular.

Project B4 of 21-11-12 exhibited extensive damage due to a feature of design rather than through any fault of the concrete. Figure 12 illustrates the

TABLE 5

BRIDGE PROJECTS UTILIZING BICHLER AGGREGATES

Project	Year	No. of Spans & Length	Type	Condition Observations					
				Roadway	Sidewalk or Wheelguard	Pilasters	Abutments	Wingwalls	Piers
B_1 of 21-13-11	1929	7 at 50'	I beam	Black top	Trans. cracks in s.w.	O.K.	Light scale at waterline	Few fine hair cr.	Top of so. pier broken up.
X_2 of 21-13-11	1930	48'	E.T.G.	RR tracks	None	O.K.	Some breakdown of concrete on top edge, and cracks in face	O.K.	None
B_3 of 21-11-2	1931	2 at 40'	I.B.	Black top	S.W. good	O.K. some fine hair cracks	Some fine hair cracks, yellowed	O.K.	O.K.
B_2 of 21-8-21	1932	3 at 60'	I.B.	Light scale along edge	W.G. good	O.K.	O.K.	O.K.	O.K.
B_1 of 21-14-2	1935	35'	I beam	Black top	W.G. light scale on edges	Lt. cracking and disintegration	Lt. & med. scale on tops	Lg. crack along base of backwall	None
X_1 of 21-11-12	1935	3 at 36'	I.B.	Black top	W.G. some small cracks	O.K.	About 4 vert. cracks down abut. face	O.K.	Some hair line cracking
B_1 of 21-11-13	1936	60'	I beam	Black top some trans. cracks in bottom of deck	W.G. - O.K.	Some disint. cracks in tops	Some light cracks	Light scale on top	None
B_1 of 21-12-2	1936	104'	Steel Truss	Deck & sides all steel construction			-Light scale on tops-		None
B_2 of 21-12-2	1936	35'	I beam	Black top	W.G.-lt. scale	Fine yellowed cr.	Light scale on top		None
B_4 of 21-11-2	1936	5 at 60'	I.B.	Black top	W.G.-lt. scale & sm. pop-outs	Cracked up thru deck	Few vert. cracks	Med. scale on tops. Cracking down side	Both ends of pier tops cracked & disintegrated
B_2 of 21-9-12	1936	60'	I.B.	Black top	W.G.-few pop-outs	Fine cr. in top surface	O.K.	Fill washed out behind ends. Cracking at base	None
B_1 of 21-9-12	1936	50'	I.B.	Black top	W.G. O.K.	O.K.	O.K.	Yellow stained cracks	None
X_1 of 21-6-1	1936	1 at 61' 2 at 9'	T.P.G. . . .	RR bed on Steel I beams	O.K.	- -	2 long cr. down face	Some cracking on top	Some fine yellow cr. in surface of pier columns
B_1 of 21-4-2	1940	2 at 24'	C.S.	Lt. scale	W.G. - lightly scaled	Some corner spalling	Lt. scale & hair cracks on top surfaces	O.K.	O.K.
B_1 of 21-13-2	1941	3 at 60'	I beam	Numerous sm. pop-outs	W.G. O.K.	O.K.	O.K.	Several cr. down faces	O.K.
B_1 of 21-12-23	1942	3 at 35'	C.T.B.	Good condition	W.G. good	O.K.	O.K.	O.K.	O.K.
B_1 of 21-8-21	1948	70'	D.P.G.	O.K.	W.G. O.K.	Numerous yellow-stained cracks	O.K.	Many fine yellow cracks	None

design of the load-bearing portion of all four piers. The use of 100-lb A.R.A. rail for the bearing points in pier tops has been discontinued for some time. This type of construction has produced large cracks over the entire length on both sides of all four piers along the top corners. Top views of the pier ends are shown in Figures 13 and 14. A side view is shown in Figure 15. These cracks carry right up through the deck edge and many of the pilasters. This damage should be repaired before more advanced deterioration takes place from freezing and thawing within the cracks now present, such as is shown in Figure 16, or additional cracking of the piers occurs.

Summary

In general, the projects, both pavements and bridges, do not show extensive cracking which could be attributed to flexurally weak concrete resulting from an inherent weakness of Bichler coarse aggregate. The quality of the gravel does seem to run bad occasionally as is shown by periodic areas of yellow-stained cracks and pop-outs in the concrete surfaces of certain structures and in some of the pavements. The presence of higher concentrations of weathered siliceous limestone and sandstone in gravel produced in the past may have resulted in some of the low flexure tests of field beams besides showing up in the form of the yellow cracked areas previously mentioned. This may have been the case in Project B2 of 49-4-3,C1 where the 6A stone had an unusually high absorption of 1.96 percent.

The stone from the new location will probably contain a high percentage of sandstone and siliceous limestone but whether this is badly leached, nondurable, absorbent material is something that will have to be determined from an adequate number of test samples. It is suspected that this gravel will always tend to give fairly high abrasion losses but not necessarily in excess of the allowed 36 percent.

Apparently this material is satisfactory for 6A aggregate when properly inspected to exclude areas of lower grade material occurring in the pit. The relatively high deleterious particle content makes it unsuitable for 6B in its present condition.

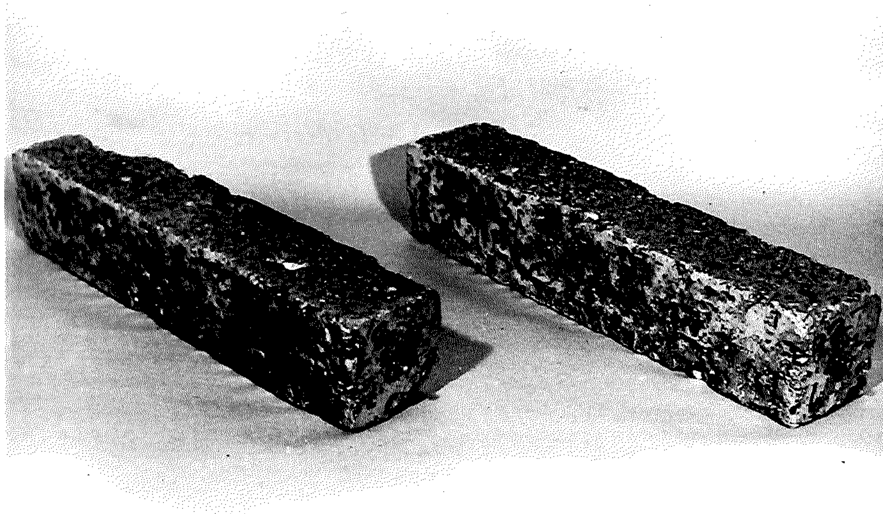


FIGURE 1. AIR-ENTRAINED CONCRETE BEAM CONTAINING BICHLER COARSE AGGREGATE AFTER 300 CYCLES OF SLOW FREEZE AND THAW IN WATER.

FIGURE 2. SOUTHWEST CORNER OF BICHLER PIT 21-12 SHOWING AREA OF LEACHING INFLUENCE CONTAINING SOFT NON-DURABLE SANDSTONE AND SANDY LIMESTONE.

FIGURE 3. SOUTH PORTION OF BICHLER PIT WHERE 1954 PRODUCTION WAS BEING TAKEN.

FIGURE 4. BADLY CRACKED AREA IN PROJECT 21-6-C3 NORTH OF ESCANABA ON US-2. PAVEMENT 25 YEARS OLD.

FIGURE 5. SECTION OF 21-6-C10 CONTAINING MANY TRANSVERSE CRACKS. 23 YEARS OLD.

FIGURE 6. PATCHED AREA WITHIN PROJECT 21-28-C2 CONTAINING LIMESTONE AGGREGATE, CRACKED MUCH WORSE THAN OLDER BICHLER PAVEMENT. MORE RECENT THAN 19 YEAR OLD PROJECT.

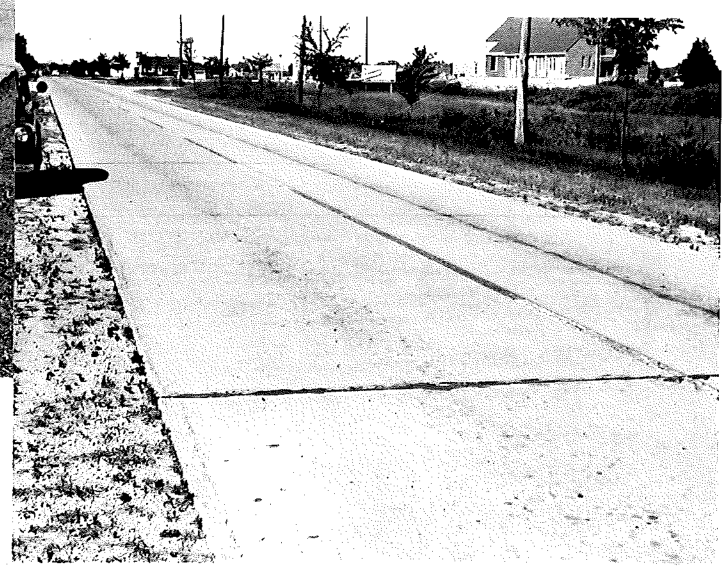
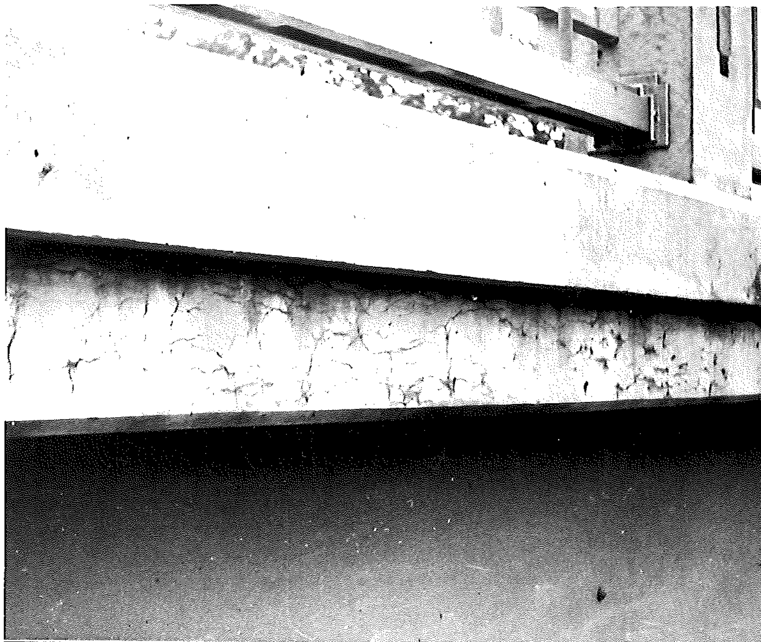
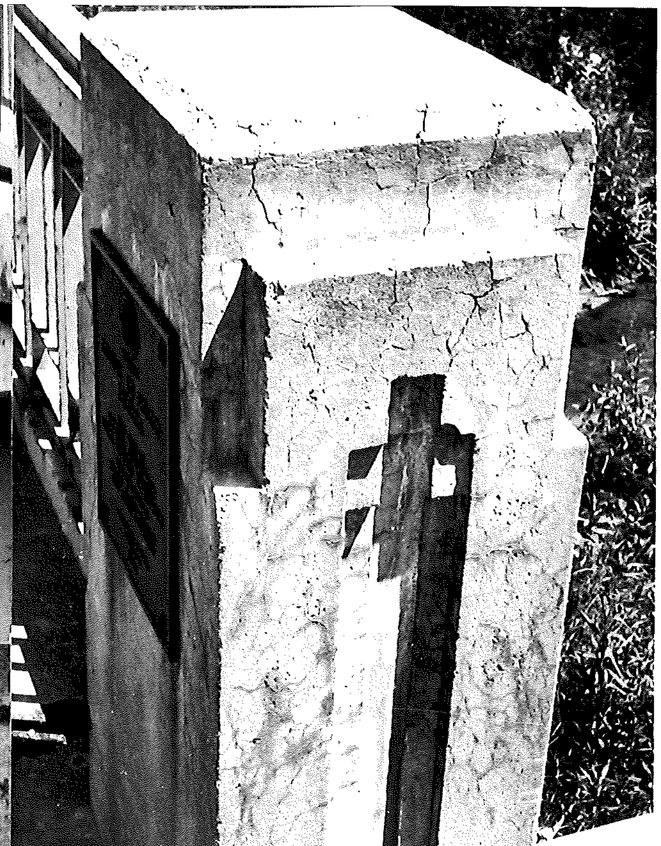


FIGURE 7. EXAMPLE OF PRE-WAR PAVEMENT IN GOOD CONDITION WITH NO CRACKING AND VERY LITTLE SCALING. CONCRETE ABOUT 18 YEARS OLD.





FIGURES 8 AND 9. EXAMPLES OF YELLOW STAINED CRACKS IN BRIDGE SURFACES DUE TO LIMONITIC SANDSTONE IN IN COARSE AGGREGATE. B2 OF 21-9-12 AND B1 OF 21-14-2, BRIDGE 18 AND 19 YEARS OLD RESPECTIVELY.

FIGURE 10. YELLOWED CRACKS AND SPALLING FROM SANDSTONE PARTICLES IN WINGWALL SURFACE. B1 OF 21-8-21. ONLY 6 YEARS OLD.

FIGURE 11. TYPICAL STRUCTURE IN GOOD CONDITION. B1 OF 21-12-23 ABOUT 12 YEARS OLD.

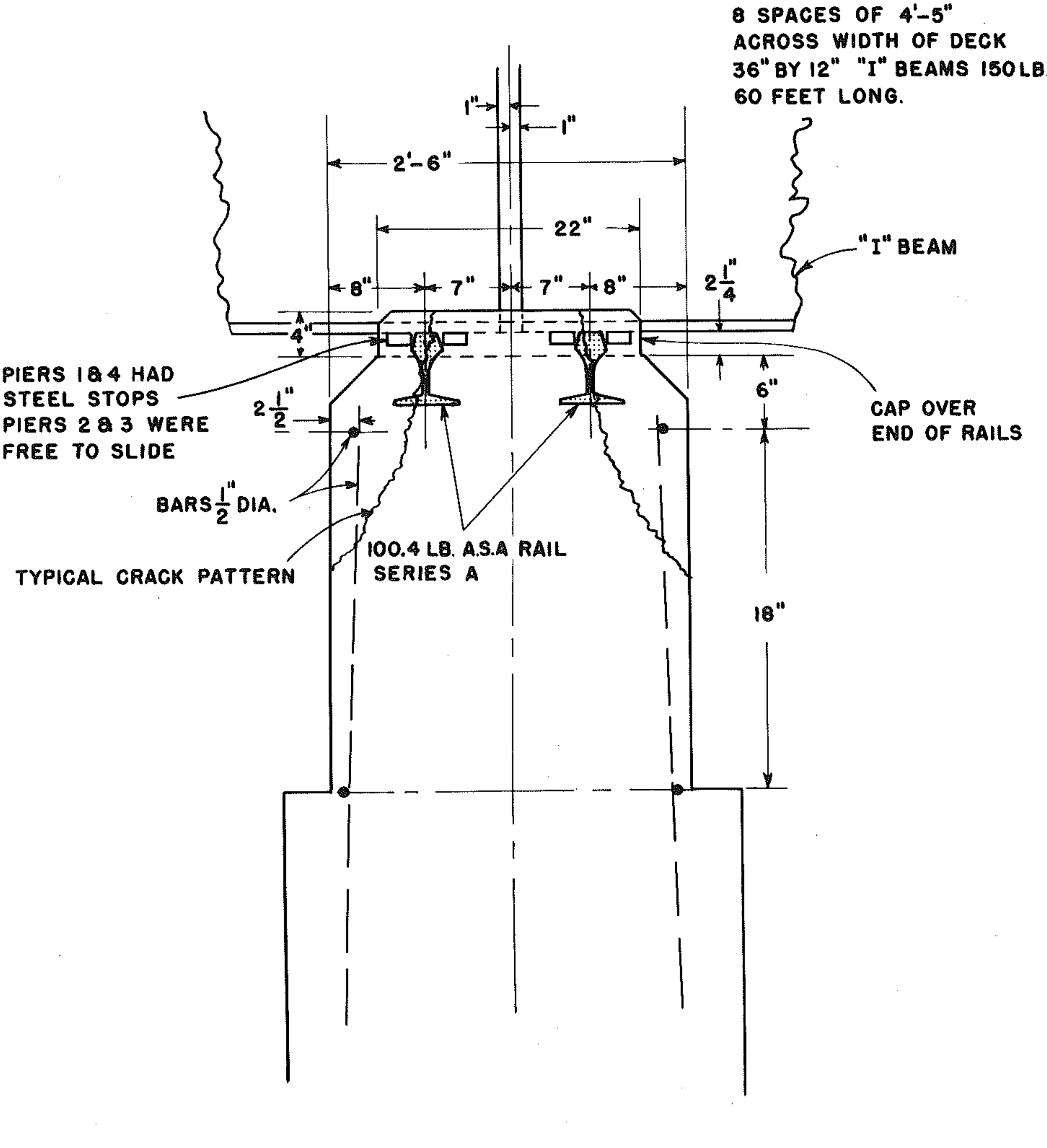


FIGURE 12. CROSS SECTION OF ALL FOUR PIERS SHOWING LOCATION OF 100 LB. RAIL IN PIER TOP FOR BEARING LOAD OF BRIDGE DECK.

FIGURE 13. TOP VIEW, NORTH END OF 2 ND. PIER FROM WEST END OF BRIDGE SHOWING CRACKING DOWN THROUGH CORNERS. B4 OF 21-11-2. BRIDGE 18 YEARS OLD.

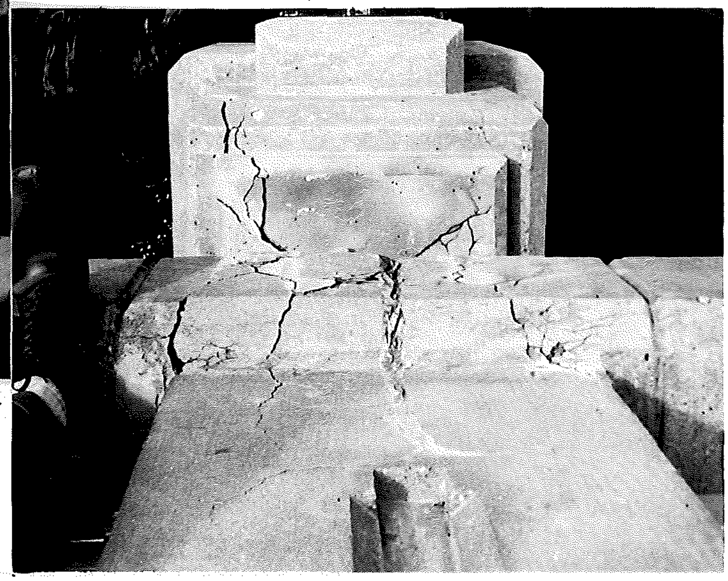


FIGURE 14. SOUTH END OF FIRST PIER ON EAST END OF BRIDGE SHOWING CRACKED PIER AND CRACKS UP THROUGH DECK AND PILASTER.

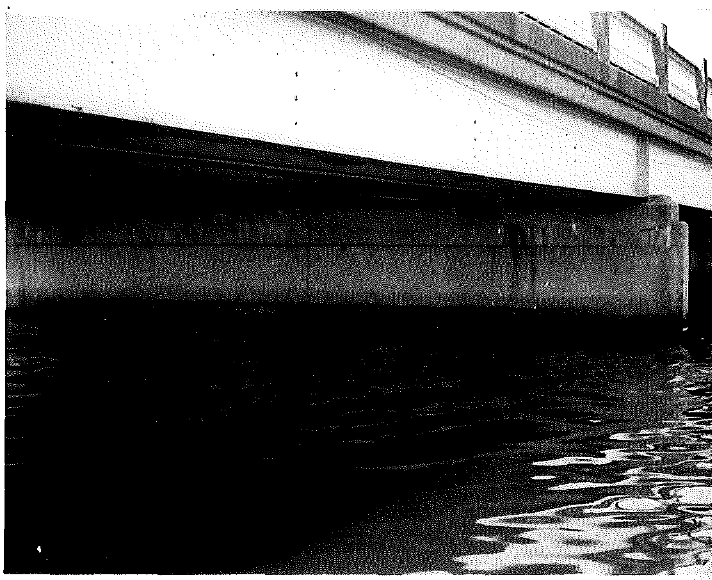


FIGURE 15. TYPICAL CRACK FOR ENTIRE LENGTH OF PIER ABOUT ONE FOOT DOWN FROM THE TOP EDGE. THIS OCCURRED ON BOTH SIDES OF ALL FOUR PIERS.

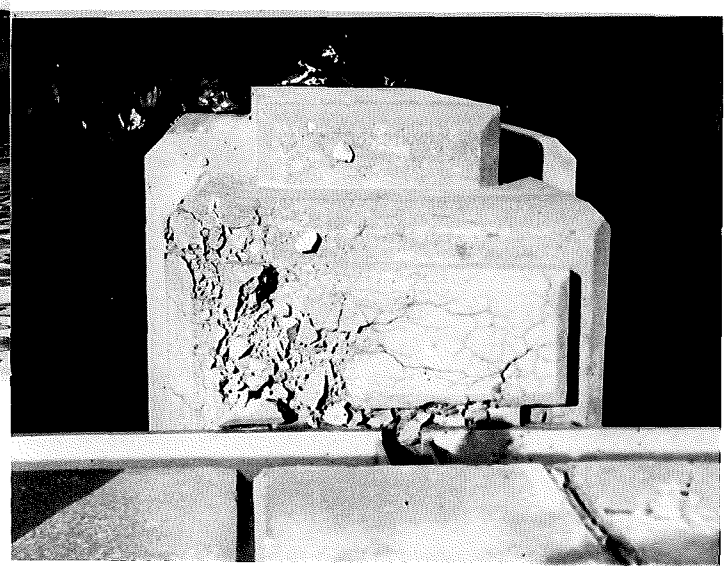


FIGURE 16. MORE ADVANCED DETERIORATION IN SOUTH END OF FIRST PIER FROM WEST END OF BRIDGE DUE TO FREEZE AND THAW ACTION.