CEMENT CONTENT OF PAVEMENT CONCRETE
US 12 South of Paw Paw (BI 80024, C2RN)

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On December 2, 1959, the Research Laboratory Division received samples of six series of beams cast and broken during construction of the new US 12 interchange with M 40 and M 119 south of Paw Paw (Project BI 80024, C2RN). Project records indicated a possible cement shortage in the area represented by these beams, and it was requested that their cement content be determined by chemical analysis. Samples of project cement and aggregates were also sent for use in making the determinations.

Cement contents were determined by procedures based on ASTM Method C85-54, as described in Research Report No. 300, "Determination of Cement Content of Pavement Concrete: Project F 62031, C2U, C3U" (Nov. 1958), with the results shown in the column titled "Original Results" in Table 1. Cement contents may ordinarily be determined using these procedures with accuracy within approximately 1/2 sack per cu yd, when original cement and aggregate samples are available for corrections. In this case the laboratory cylinder made with materials from the project combined in chart proportions had a cement content of 5.6 sacks per cu yd. Therefore, the apparently higher cement contents of beam ends from Series 5, 6, and 7 could not be accounted for at that time.

The Project Engineer's memorandum accompanying the beams stated that fine and coarse aggregates for this project were from the Larson Pit (3-44), and silica extracts from these aggregates were used to correct the silica contents of the hardened concrete in all the laboratory cement calculations. However, further examination of the records disclosed that from September 21 through October 2, 1959, the source of the coarse aggregate had been changed to the Kellogg Pit (41-46). Thus, four of the six beam series actually had been fabricated with Kellogg rather than Larson aggregates.

Additional aggregate samples were secured from each pit and new silica corrections were determined with the cement content results shown in the "New Values" column in Table 1.

TABLE 1
CEMENT CONTENT AND FLEXURAL STRENGTH OF BEAMS

Beam Series	Date Cast	Station	Modulus of Rupture, psi		Cement, sacks/cu yd*		Agg Source
			7 days	14 days	Original Results	New Values	
1	9-11-59	134+60	503	658	5.5	5.5**	Larson
2	9-14-59	110+50	657	767	5.8	5.8**	Larson
4	9-21-59	1089+00	616	678	5.4	4.5	Kellogg
5	9-23-59	1129+50	596	644	6.5	5.6	Kellogg
6	9-23-59	1094+50	702	701	6.0	5.0	Kellogg
7	9-28-59	1071+00	588	681	6.1	5.2	Kellogg

*Aggregate Correction, percent

Larson	0.77	0.81	0.78	avg 0.79
Kellogg	1.31	1.29		avg 1.30

** These values now too high by an undetermined amount

It should be noted that the aggregate silica correction is considerably higher for the Kellogg than for the Larson pit. This agrees with the petrographic examination of the two materials, which indicated a considerably higher percentage of igneous rocks in the Kellogg gravel. The higher silica correction accounts for the drop in computed cement content of almost 1 sack per cu yd for beams of Series 4 to 7 inclusive.

Shortly after completing the first tests, the Laboratory was informed by J. C. Brehler of another construction expedient that now makes it almost impossible to determine with confidence the cement content of the concrete outside the area where Kellogg coarse aggregates were used. It seems that Larson coarse aggregates used at the beginning of the project had trouble meeting specifications and had been "sweetened" by spreading Kellogg bank run gravel over Larson bank run before putting it through the screens. Since there is a wide difference in the silica correction, and the proportions of aggregates from the two sources are not known, it is impossible to establish an accurate silica correction for determining cement content of concrete in the areas where this coarse aggregate was used.

In any case, it is now apparent that the cement content of the Series 4 beams was deficient. These beams were cast on Sept. 21 when a minus inventory of cement was first noted in the record. The cement contents of the Series 1 and 2 beams must also be lower than the values given in

the table, but there is no way of finding out how much lower because of the combination of aggregates from the two sources mentioned above.

There was a great deal of trouble with the two cement scales on this job. They were not within specification tolerances on Sept. 8, 1959, when first checked, although they were reading light, giving about 1.1 and 1.7 percent excess cement, respectively, at batch quantities. They were checked again on Sept. 24 when scale No. S5277 was found to be 96 lb heavy, thus making a shortage of almost 1 sack per cu yd in the alternate batches when this scale was used. After adjusting the knives on both scales, they were again reading light by the same amounts as in the first check. On Sept. 25, the plant inspector noted in the daily report that the scales were not working properly, but did not say what the trouble was. Again, on Sept. 29, he noted that the hopper on the cement scales did not clean out properly. This was brought to the attention of the contractor but there was no note on when it was corrected.

A check of the cement records for the entire paving operation gave the following data:

Estimated cement required		66,903 bbl
Cement used, batch tickets		68,510 bbl
Cement received		68,134 bbl
Cement on hand after completion	minus	376 bbl
Actual overrun, percent	$\left(\frac{68,134 - 66,903}{66,903} \times 100 \right)$	1.8

Length measurements of 97 cores from the project averaged 9.4 in., which would normally create an overrun of more than 4 percent. The actual overrun was only 1.8 percent, which accounts for little more than the excess resulting from the scale calibration. The fact that the bins were full on Sept. 23 when a minus inventory of 424.5 bbl was noted would indicate a shortage of about 1600 bbl up to that point. The first minus inventory (42 bbl) occurred two days earlier, but the amount actually in the bins was not determined at the time. A summary of pouring operations and other information from the project records is shown in Table 2.

Summary

From what can be learned from the records and from cement determinations in the laboratory, it is probable that there was a cement deficiency in some areas of this project shortly after construction began. Part of the shortage was caused by the 96-lb underweight delivered by scale No. S5277 before the scales were checked on Sept. 24. This fact accounts for the lower cement content found in beams of Series 4. However, the fact that there should have been an overrun of at least 4 percent due to pavement thickness and calibration of the cement scales indicates an actual deficiency of considerably more than the 376 bbl shown by the cement records for the entire job. Whether this deficiency is significant

or not depends on the extent of the area or areas where shortages may have occurred.

Because of the circumstances surrounding construction--that is, cement deficiencies in alternate batches and the uncertainty of coarse aggregate proportions--it doesn't seem feasible to attempt to pinpoint the areas of possible shortage by cement determinations in the laboratory.

TABLE 2
CONSTRUCTION DATA SUMMARY
Extracted from Daily Reports of Concrete Proportioning

Report No.	Pour Date (1959)	Pour Location			Pour Area, sq yd	Cement Inventory, bbl					Remarks
		Stationing		Description		On Hand	Received	Total	Used	Net on Hand	
		From	To								
1	9-10	140+30	133+14	NB POE [1]	1909	0.00	872.00	872.00	682.00	190.00	Series 1 Beams (134+60)
2	9-11	133+14	131+50	NB	2757	190.00	1220.50	1410.50	961.00	449.50	
		128+50	124+40	NB							
		124+00	119+40	NB							
3	9-14	119+40	109+00	NB [2]	3140	449.50	1218.75	1668.25	1104.50	563.75	Series 2 Beams (110+50)
		109+00	107+50	NB [3]							
4	9-15	121+68	121+90	NB	1132	563.75	522.50	1086.25	399.25	687.00	Type III Cement
		14+00	5+95	Ramp A [4]							
5	9-16	140+30	131+53	NB POE [5]	1339	687.00	349.25	1036.25	471.25	565.00	
		128+48	124+30	NB							Series 3 Beams (126+00) not tested, steel reinforced
6	9-17	123+53	122+16	NB	3525	565.00	1043.00	1608.00	1261.50	346.50	
		121+84	120+68	NB							
		1033+95	1046+22	EB POB							
7	9-18	1046+22	1059+30	EB [6]	6864	346.50	2441.25	2787.75	2509.00	278.75	
		1059+30	1071+91	EB							
8	9-21	1071+91	1083+56	EB [7]	6043	278.75	1880.50	2159.25	2201.00	-41.75	First incidence of minus inventory Series 4 Beams (1059+00)
		1083+56	1095+47	EB							
9	9-22	1095+47	1105+10	EB	5632	-41.75	1539.25	1497.50	2022.75	-525.25	
		1105+10	1116+59	EB							
10	9-23	1116+59	1130+10	EB	6126	-525.25	2270.75	1745.50	2170.00	-424.50	Series 5 Beams (1129+50) cement bins full
		1130+10	1138+64	EB							
		1137+30	1136+38	WB							
11	9-24	1136+38	1130+80	WB [8]	5432	-424.50	1398.50	974.00	1914.25	-940.25	
		1130+80	1115+77	WB							
12	9-25	1115+77	1105+68	WB	6357	-940.25	2098.50	1158.25	2232.00	-1073.75	Cement scales not working properly Series 6 Beams (1094+50) (8:30 a.m.)
		1105+68	1092+07	WB							
		122+00		[9]							
13	9-28	1092+07	1078+55	WB	6693	-1073.75	2898.75	1825.00	2247.50	-422.50	16 sacks used for culvert headwalls Series 7 Beams (1071+00)
		1078+55	1066+97	WB							
14	9-29	1066+97	1054+93	WB	6296	-422.50	2091.25	1668.75	2224.25	-555.50	Cement hopper not discharging properly Contractor notified
		1054+93	1043+36	WB							
15	9-30	1043+36	1033+95	WB	2509	-555.50	1041.75	486.25	868.00	-381.75	Series 8 Beams (1035+25)
16	10-1	12+65	60+25	Ramp D [10]	1836	-381.75	349.00	-32.75	662.50	-695.25	2 batches wasted due to water valve failure
17	10-2			Ramps A + C [11]	1486	-695.25	521.75	-173.50	562.00	-735.50	
18	10-7	140+30	131+51	SB POE	3328	-735.50	804.50	69.00	1177.75	-1108.75	
		128+49	124+80	SB							
19	10-8	124+63	107+50	SB [12]	4507	-1108.75	1746.50	637.75	1569.50	-931.75	Series 9 Beams (123+75)
20	10-9	120+68	110+00	SB [13]	1682	-931.75	1219.50	287.75	591.00	-303.25	
21	10-10	0+00	5+45	Ramp A [14]	1212	-303.25	349.50	46.25	426.25	-380.00	
22	10-12	1138+64	1151+60	EB [15]	7472	-380.00	2096.00	1716.00	2635.00	-919.00	Series 10 Beams (1156+75)
		1151+60	1166+73	EB							
23	10-13	1166+73	1177+17	EB	6245	-919.00	2441.00	1522.00	2193.25	-671.25	
		1177+17	1190+15	EB							
24	10-14	1190+15	1204+21	EB	7709	-671.25	2612.25	1941.00	2673.75	-732.75	Stone scales not working properly Series 11 Beams (1214+00)
		1204+21	1219+06	EB							

NOTE: Aggregates used

9-10 to 9-18 Larson
9-21 to 10-2 Kellogg
10-7 to 11-11 Larson

NOTE: 60024, C2 (UB 12) - Sta 1033+95 to 1300+00 (WB-EB)
60072, C1 (M 40) - Sta 140+30 to 116+20 (NB-SB)
60024, C1 (M 40 - M 119) - Sta 116+20 to 91+50 (NB-SB)
60111, C2 (M 119) - Sta 91+50 to 47+00 (NB-SB)

[1] 8" base-course laid to tie into old pavement
[2] 24' slab
[3] 22' slab
[4] 12' slab
[5] 33' x 12' between RR tracks (44 sq yd)
[6] Increased 5' for curve
[7] 99' gap 1074+74 to 1075+73 (M 119 intersection)
[8] Lineal ft reduced 24' for box culvert
[9] 37 sq yd at Kalamazoo St
[10] 54' curve header (5 batches - 39 sacks)
[11] Ramp A: 4' widening; Ramp C: 12' slab; plus 02' curve header (6 batches - 46.5 sacks)
[12] Less 29' for RR, plus 6' for curve
[13] Plus 9' widening NB, and Ramp D 4' radius widening
[14] On Ramp A 595 lineal ft (536 sq yd), plus two 99' pours on M 119 (24' x 198'), and pour at Berrien St (9' x 48')
[15] Decreased 7' for curve

TABLE 2 (continued)
CONSTRUCTION DATA SUMMARY
Extracted from Daily Reports of Concrete Proportioning

Report No.	Pour Date (1959)	Pour Location			Pour Area, sq yd	Cement Inventory, bbl					Remarks
		Stationing		Description		On Hand	Received	Total	Used	Net on Hand	
		From	To								
25	10-15	1219+06	1233+40	EB	7357	-732.75	2614.00	1881.25	2618.00	-736.75	
		1233+40	1246+65	EB							
26	10-16	1246+65	1255+05	EB	5787	-736.75	1718.00	981.25	2057.50	-1076.25	
		1255+05	1268+35	EB							Series 12 Beams (1256+25)
27	10-17	1268+35	1281+20	EB	7171	-1076.25	3470.00	2393.75	2507.00	-113.25	
		1281+20	1295+24	EB							
28	10-19	1295+24	1300+00	EB POE	6309	-113.25	1645.25	1532.00	2189.50	-657.50	
		1300+00	1294+20	WB POB							
		1294+20	1281+10	WB							Series 13 Beams (1287+00)
29	10-20	1281+10	1266+65	WB	7098	-657.50	2425.25	1767.75	2666.00	-898.25	
		1266+65	1252+33	WB							
30	10-21	1252+33	1238+25	WB	7651	-898.25	3091.50	2193.25	2666.00	-472.75	
		1238+25	1223+64	WB							Series 14 Beams (1240+50)
31	10-22	1223+64	1206+96	WB	8381	-472.75	3135.75	2663.00	2910.25	-247.25	
		1206+96	1192+21	WB							
32	10-23	1192+21	1178+60	WB	6339	-247.25	2231.25	1984.00	2216.50	-232.50	
		1178+60	1168+44	WB							Series 15 Beams (1173+00)
33	10-26	1168+44	1154+80	WB [16]	6589	-232.50	2276.25	2043.75	2297.75	-254.00	
		1154+80	1143+80	WB							Series 16 Beams (1148+00)
34	10-27	1143+80	1137+30	WB	1733	-254.00	674.50	620.50	611.00	9.50	
35	10-28	140+30	131+47	SB POE	1793	9.50	350.25	359.75	593.00	-233.25	3 lb chloride (Peladow) added per batch before 9:00 and after 4:30
		102+00	99+92	SB							
36	10-29	99+92	88+10	SB	6384	-233.25	1845.75	1612.50	2247.50	-635.00	3 lb chloride added after 4:00
		88+10	75+98	SB							
37	10-30	75+98	63+85	SB	6435	-635.00	2442.00	1807.00	2286.25	-479.25	
		63+85	51+85	SB							
38	10-31	51+85	47+00	SB POB	1293	-479.25	870.25	391.00	449.50	-58.50	
39	11-2	0+20	11+35	Ramp C [17]	2191	-58.50	522.00	463.50	767.25	-303.75	3 lb chloride after 4:00
		11+35	11+75	Ramp C [18]							
		11+75	12+40	Ramp C [19]							
40	11-3	121+66	107+50	[20]	2571	-303.75	1398.25	1094.50	901.00	193.50	465 Batches
41	11-5	20+02	3+13	Ramp B [21]	3227	193.50	454.75	648.25	1123.75	-475.50	
		3+13	1+00	Ramp B [22]							
42	11-6	102+00	93+54	[23]	1159	-475.50	350.00	-125.50	410.75	-536.25	3 lb chloride and straw covering
		13+54	92+54								
43	11-7	102+00	95+35		1264	-536.25	518.00	-18.25	447.25	-465.50	3 lb chloride and straw covering
		107+50	106+06								
		129+50	[24]	[25]							
44	11-9	129+50	[26]	[27]	838	-465.50	524.50	59.00	312.00	-253.00	
		107+50	106+06	[28]							
45	11-10	130+50		[29]	798	-253.00	174.75	-78.25	284.75	-363.00	Straw covering
		107+50	100+06								
		101+15	102+00								
46	11-11	130+50			519	-363.00	175.25	-187.75	187.75	-375.50	Straw covering
		102+00	101+00								

[1] Increased 7' for curve
[2] 16' slab
[3] 16' to 12' slab
[4] 12' slab
[5] Plus 262 lineal ft for bridge at 129+75 (699 sq yd), and radius pour for Ramp A (50 sq yd)
[6] 16' slab
[7] 17' to 2', including 60' curve header (15 sacks)
[8] (Stationing represents 996 sq yd), plus Ramp A - Kalamazoo St (83 sq yd) and Berrien-Kalamazoo Sts (80 sq yd), including 20' curve header (8 sacks)
[9] Limit-of-pour station not given (349 sq yd)
[10] Plus two radii for Ramp A, and including 50' curve header
[11] "Sa. Bridge"
[12] Three radii for Ramps B and C (294 sq yd)
[13] 11' - 11' variable
[14] 262' of 9' (262 sq yd) and 113' of 12' (150 sq yd)