OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

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To: L. T. Oehler, Director
Research Laboratory Section

From: H. L. Patterson

Subject: Investigation of Low Flexural Strengths on Project U17032-005. Research Project 67 B-86. Research Report R-673.

On October 4, 1967, J. A. Herbst, District 2 Materials Supervisor, reported that low modulus of rupture values were obtained from flexure beams cast between August 28 and September 8, 1967, on the subject project. J. C. Brehler, Engineer of Materials, in his memorandum of October 6, 1967, requested that the beam ends be shipped to the Research Laboratory for testing along with samples of the cement, fine aggregate, and coarse aggregate.

The testing program included the following standard tests: Compression Strength of Concrete using Portions of Beams Broken in Flexure (ASTM C116-65T); The Linear Traverse (Rosiwal) Method for Determination of Air-Void Content in Hardened Concrete (ASTM C457-67T); and the Determination of Cement Content of Hardened Portland Cement Concrete (ASTM C85-66).

In applying the compression test (ASTM C116-65T) to portions of 6- by 6- by 36-in. flexural beams, the beam portion is capped and placed between two smooth six-in. square steel plates and loaded in compression through these plates. This method is intended for use in the laboratory for determining relative compressive strength values for various concrete mixtures. It is not intended as an alternate for ASTM Method C39, Test for Compressive Strength of Molded Concrete Cylinders, and the test values obtained by these two methods are not interchangeable nor necessarily comparable.

Table 1 shows the modified cube compressive strength values of all of the subject flexural beams and the compressive strengths of the laboratory control cylinders. Since the relationship between the modified cube and cylinder compressive strength values varies with the type of aggregate, mix design, and age of the concrete, it is impossible to determine an accurate factor that will relate them without extensive testing. However, in this case the modified cube compressive strengths were multiplied by an approximate factor of 0.90*. Because this factor is only approximate, it must be remembered that these values are not necessarily equivalent to test cylinder values.

The compressive strengths of the beams (Table 1) follow in approximately the same order of magnitude as the modulus of rupture test values. The latter are included in Table 2 along with other pertinent data summarized from field forms and included in this report for the reader's convenience.

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* See Highway Research Record 210, page 70.

The entrained air measurement and the chemical cement determination analysis were performed on the grade AA curb and gutter flexure beams having the lowest (14A) and highest (11B) compressive strengths and on the grade A pavement beam with the lowest (21A) compressive strength. The results of these tests are also given in Table 1.

To aid in determining the cement content, it was necessary to have laboratory-controlled concrete using identical materials to that used in the flexural beams and proportioned in accordance with the design mix charts. Laboratory control cylinders were poured from the sample materials submitted from the project. Four-in. diameter by eight-in. standard test cylinders were poured to represent the curb and gutter concrete while six-in. diameter by twelve-in. standard test cylinders were poured to represent the pavement concrete. Normally, six of each size would have been poured such that three could have been tested in compression at seven and twenty-eight days respectively; however, the amount of 6A aggregate available limited the number to four cylinders of each size. Thus, one of each size was tested at seven days and three were tested at twenty-eight days.

Cement content results received from the Spectrochemistry Unit of the Laboratory utilizing ASTM Standard Method of Test for Cement Content of Hardened Portland Cement Concrete (C85-66) were calculated on a soluble silica basis. This method has been found to be accurate to within 0.5 sacks per cubic yard. Since the chemical composition and fineness of grind of cement produced by the same mill will vary from day to day, and since a cement sample of the same batch used in the beams was not available for analysis, the results reported in Table 1 are only estimates of the actual cement content. However, they do show the relative cement content of beam sample 67 CR-134 (14A) to be considerably lower than that of 67 CR-131 (11B) or 67 CR-137 (21A).

In observing and comparing the values shown in the two tables, the cement content and the minimum strength values allowed by the Standard Specifications should be kept in mind for each grade of concrete. These values are as follows:

Description	28 Day Comp. Str. psi	Modulus of Rupture, psi	
		7 Day	14 Day
Grade AA C&G Conc. (6-1/2 Sacks of cement/cu yd)	4,000	600	650
Grade A Pav't. Conc. (5-1/2 sacks of cement/cu yd)	3,500	550	600

In general it can be concluded from Tables 1 and 2 that beams 8A, 9A, 11B, 12B, and 22A meet or exceed the minimum compression strengths required by specifications. They also meet or are within ninety percent of the minimum modulus of rupture strengths required by specifications. It can further be concluded that the remaining beams failed to meet either the minimum compressive strength or, in most cases, the minimum seven or fourteen day modulus of rupture strengths.

Data from Research Laboratory files indicate that a three sack per cubic yard concrete rarely tests to more than 1500 psi compressive strength after curing 28 days. For this reason, it is concluded that the cement content of beam 14A exceeds three sacks, and would more likely be in the vicinity of five sacks per cubic yard. The Spectrochemistry Unit, however, appears correct in its assertion that this beam was deficient in cement content.

As stated earlier, ASTM Method C85 is only accurate to within 0.5 sacks per cubic yard when samples of precisely the same lots of cement, and fine and coarse aggregates as used in the concrete, are supplied for testing. The unusual result obtained on beam 14A might possibly be explained if it were known that some changes in the source of cement or aggregates was made on that particular day.

An exact picture of the flexural strength of the curb or pavement concrete is very difficult to obtain from the results in Table 2. It is unfortunate that only two beams were made for each series since, in some cases, only the seven or the fourteen day break is in question. The considerable strength variation of the test beams could reflect the influence of molding, handling, curing, and testing to a greater degree than minor variations of air or cement content.

Since this project has not been cored as yet, we suggest coring the areas in question in both the curb and gutter pours and the pavement pours. Four-inch cores would be adequate from the curb apron since only 6A aggregate was used. These cores would then form a better basis for assessing the current strength of the concrete.

TESTING AND RESEARCH DIVISION

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HLP:sjt

TABLE 1
RESEARCH LABORATORY TEST DATA

Flexure Beam No.	Report No.	Laboratory Sample No.	Modified Cube Compressive Strength psi [1]	Air Content, (%) [2]	Cement Content, sacks/cu yd [3]
GRADE AA CURB AND GUTTER FLEXURE BEAM CONCRETE					
8A	21	67 CR-129	4060	----	----
9A	22	67 CR-130	4650	----	----
11B	24	67 CR-131	5380	3.3	6.6
12B	25	67 CR-132	4520	----	----
13A	26	67 CR-133	3770	----	----
14A	27	67 CR-134	3450	3.6	2.4
14B	27	67 CR-135	3730	----	----
15A	28	67 CR-136	3550	----	----
16A	29	67 CR-138	3640	----	----
GRADE A 9 INCH PAVEMENT FLEXURE BEAM CONCRETE					
21A	8	67 CR-137	3330	6.0	5.9
22A	9	67 CR-139	3560	----	----

LABORATORY CONTROL CYLINDERS

Cylinder, Size, In.		Grade of Conc.	Calculated Cement/cu yd (sacks)	Calculated Water/sack of Cement, (gal)	Slump, In.	Measured Air Content of Fresh Concrete, percent	Avg. Compressive Cyl. Strength, psi		Cement Content, sacks/cu yd [3]
Dia.	Lgth.						7 Day 1 Cyl.	28 Day 3 Cyl.	
4	8	AA	6.70	5.27	2-1/2	3.4	3890	4580	6.4
6	12	A	5.60	5.60	2-1/4	3.8	2680	3940	5.0

(1) Compression Strength of Concrete using Portions of Beams Broken in Flexure ASTM C116-65T. Results corrected to approximate 6- by 12-in. diam cylinder values using factor of 0.90. Concrete age--approximately 7 weeks.

(2) Average of Linear Traverse measurements made on two slices cut from opposite ends of beam portion.

(3) Determined by ASTM C85-66 (Silica Method).

TABLE 2
FLEXURAL TEST BEAM INFORMATION (1)

Flexure Beam Series No.	Report No.	Pour Date	Station	Concrete		Use	Slump, (Inches)	Measured Air Content of Fresh Concrete, percent	Average Modulus of Rupture Test Values, psi	
				Grade	Mix Design Chart				7 Days	14 Days
8	21	8-28-67	1534+50 Lt.	AA	67 MV-489	Curb and Gutter	2-3/4	7.8	592(8 Day)	667
9	22	8-29-67	1521+50 Lt.	AA	67 MV-489	Curb and Gutter	2	----	592	642
11	24	8-31-67	1510+25 Rt.	AA	67 MV-489	Curb and Gutter	2-1/2	----	658	642
12	25	9- 1-67	1511+60 Rt.	AA	67 MV-489	Curb and Gutter	2-1/2	----	608	633
13	26	9- 5-67	1517+00 Rt.	AA	67 MV-489	Curb and Gutter	2 Avg.	4.2 Avg.	575	----
14	27	9- 6-67	1517+80 Rt.	AA	67 MV-489	Curb and Gutter	2	4.8	525	583
15	28	9- 7-67	1523+25 Lt.	AA	67 MV-489	Curb and Gutter	2-1/4 Avg.	5.1 Avg.	425	650
16	29	9- 8-67	1534+85 Lt.	AA	67 MV-489	Curb and Gutter	2-1/2	6.6	542	708
21	8	9- 7-67	639+00	A	67 MV-486	9 In. Pav't.	2-1/4 Avg.	7.0 Avg.	450	567
22	9	9- 8-67	636+50	A	67 MV-486	9 In. Pav't.	2-1/2 Avg.	6.8 Avg.	542	650

(1) Summarized from the following forms:

Concrete Proportioning Plant Report	(Form 1174)
Inspector's Report of Concrete Placed	(Form 1174A)
Report on Modulus of Rupture	(Form 1912)