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16. ABSTRACT
This project consisted briefly, of testing 6x12-inch concrete cylinders cured in the field and in the laboratory, and comparing compressive strengths with flexural strengths obtained from laboratory cured and field cured beams. The purpose of this testing was to evaluate the feasibility of utilizing compressive strength testing for control of concrete paving operations in lieu of flexural tests which under present conditions are more difficult to conduct.

Approximately $4400 was spent on this project during the 1969-70 and 1970-71 fiscal years. This project was set up to obtain test data that could be used in conjunction with a large federally financed research project which became active July 1, 1970.

No further work is anticipated under this project. Completed work will be integrated with the federal project.

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Business and Transportation Agency

Memorandum

To : Mr. John L. Beaton
Materials and Research Engineer

Date: June 15, 1971

File : M&R No. 645220

From : Department of Public Works—Division of Highways

Subject: Completion of Research Project 645220
"Concrete Cylinders for PCC Pavement Control"

Attached is the final report on Project 19503-762504-645220.

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Attachment

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CONCRETE CYLINDERS FOR PCC PAVEMENT CONTROL

FINAL REPORT

The planned field and laboratory work for Research Project 645220, "Concrete Cylinders for PCC Pavement Control", has been completed.

The work consisted of making flexural strength beams and comparative compressive strength cylinders in both the field and the laboratory. The field work was conducted on Contract 03-074034, Road 03-ED-50-R3.6/R8.8, near Shingle Springs. The laboratory work was conducted on concrete made with the same aggregate as used in the field project.

Field Testing

Field work began with fabrication of ten 6x12-inch compressive strength cylinders and three 6x6x20-inch flexural beams at the same time as the 6x6x30-inch contract control beams were fabricated. This program was carried out twice a day for one week with the exception of the last day when only one set of specimens were fabricated. In addition to these specimens, four 6x12-inch cylinders were fabricated once a day from Monday through Thursday for autogenous curing. The concrete used to fabricate the test specimens was sampled from the windrow ahead of the slipform paver. Unit weights, penetrations, temperature, and air contents of the fresh concrete were determined for each sample and results are shown in Table 1. Ambient temperatures, wind velocities, and relative humidities were determined and are also included in Table 1.

The job concrete mix design was 5 sacks of cement per cubic yard, 3-1/2% air, 63% coarse aggregate, and 37% sand. The coarse aggregate was divided 84% 1-1/2 x 3/4-inch, and 16% 3/4 x 1/4-inch.

Group 1

The specimens which were autogenously cured were tested at ages 2 and 10 days. The autogenous curing consisted of placing cylinders, within one hour after they were fabricated, into an insulated box placed inside the Resident Engineer's office. They remained in the boxes until test age, at which time they were removed in pairs, stripped, capped, and tested in a portable compression testing machine at the jobsite. A total of eight cylinders were tested at age two days with an average compressive strength of 1640 psi, and varied from 1500 psi to 1800 psi. Eight cylinders were tested at age 10 days with an average compressive strength of 2620 psi, with a variation from 2370 to 2880 psi.

Group 2

Six cylinders from each sample were cured in the field and two each were tested at age of 10, 14, and 28 days. They were left next to the pavement after fabrication until the following morning at which time they were moved and buried near the concrete plant in a sand pile which was kept wet until the 28-day tests were completed. These cylinders were capped in the field and tested in the portable compressive testing machine. The average compressive strength of these specimens were 2420 psi at 10 days, 2760 psi for 14 days, and 3250 psi for 28 days. The coefficients of variation for these tests are 6.1 at 10 days, 7.0 at 14 days, and 7.5 at 28 days.

Group 3

Four cylinders from each sample were cured and tested in the laboratory; two specimens were tested at each age of 10 and 14 days. These were left next to the pavement until the morning following fabrication. They were then transported to the Materials and Research Department where they were stripped and stored in the moist room until tested in the large testing machine in the Concrete Unit. The average compressive strengths were 3075 psi at 10 days, and 3435 psi at 14 days. The coefficients of variation for these specimens are 11.0 at 10 days, and 8.0 at 14 days. Compressive strength data for all test procedures are given in Table 2.

Three flexural strength beams from each sample which were fabricated by Materials and Research personnel were lab tested at 10 and 14 days. These were 6x6x20-inch beams. They were left next to the pavement after fabrication and the surfaces

were sprayed with paraffin based curing compound at the same time as the adjacent pavement was cured. The morning following fabrication, these beams were stripped and one beam was buried in the wet sand pile until age 10 days when it was left tested, and the other two beams were also taken to the Materials and Research Laboratory where they were kept in the moist room until tested. Two beams from each sample were tested at age 10 days and one at age 14 days. These beams were all tested using the third point loading method in the testing machine in the Concrete Section. The average flexural strength at 10 days was 513 psi for the field cured beams, and 514 psi for the laboratory cured beams. The average 14-day flexural strength for the laboratory cured beams was 533 psi. The coefficients of variation for these beams are 6.9 for the field cured beams, 13.7 for the laboratory cured 10-day beams, and 11.7 for the laboratory cured 14-day beams. The ratio of average flexural strength to average compressive strength for 10-day field cured specimens is 21.2%. For the 10-day field fabricated, laboratory cured specimens, the ratio is 16.7% and for 14-days, it is 15.5%.

The beams which were used for PCC pavement control were made by the Resident Engineer's crew at the same time as the research specimens were made. These were 6x6x30-inch beams, cured in the wet sand until tested at ages of 10, 14 and 28 days, and were tested in the field by the midpoint loading method. The average flexural strengths for these beams are 616 psi at 10 days, 685 psi at 14 days, and 736 psi at 28 days. The coefficients of variation for these beams are 7.7 at 10 days, 5.6 at 14 days, and 10.1 at 28 days. Flexural strength data for all testing is given in Table 3. The ratios of average flexural strength of the 30-inch beams to average compressive strength, both cured in wet sand, is 25.5% at 10 days, 24.7% at 14 days, and 22.7% at 28 days. Centerpoint loading typically results in indicated flexural strength about 100 psi higher than third point tests.

Laboratory Tests

Laboratory testing consisted of making two series of tests on concrete using job aggregates. Each series was made in accordance with the cement factor testing program (Test Method No. Calif. 536), with the exception that the second series was made using the aggregate gradings that were used on the paving contract. The aggregate gradings are given in Table 4. Concrete was designed for 5.0 sacks of cement per cubic yard, and 3.5% entrained air. From each of three batches, two 6x12-inch compressive strength cylinders and two 6x6x20-inch beams

were fabricated. All specimens were tested at age 14 days. These specimens were cured in the moist room until tested. The beams were tested using the third point loading method.

The average 14-day compressive strength for cement factor grading was 3270 psi, and for the job grading, was 2990 psi. The average 14-day flexural strength for the cement factor grading was 610 psi, and the job grading was 555 psi. The ratios for flexural strength to compressive strength were 18.7% and 18.6% respectively for the laboratory and job gradings.

Summary

Data from the above tests are plotted on Figures 1 and 2. The limited test data indicates that compressive strength tests are as feasible as flexural beam testing for field control. Other advantages are that for the same effort, two specimens could be used for each test thereby increasing reliability, test molds and specimens are easier to handle, and one man can do all the sampling, fabrication, and testing of cylinders. The disadvantages include more expensive testing equipment and danger of cuts from stripping or burns from capping cylinders.

The values shown are only preliminary and the testing program on other aggregates should be completed before recommendations are made for field control specifications and test methods. The work done under this project is preliminary to work to be done under a large federally-financed project. One of the early objectives of that project is to gather more data to augment this study and to obtain firm strength levels for specifications. In that study, a determination will be made whether a statewide specification can be recommended, or a special provision will have to be made for each aggregate source. It is considered that present strength criteria is adequate and the new criteria will have to provide concrete of equal strength.

A field control test procedure could consist of fabricating six 6x12-inch cylinders where three 6x6x30-inch beams are presently fabricated; transferring specimens still in the molds to a wet sand pile the day following fabrication; stripping, capping, and testing two cylinders at age of 10, 14, and 28 days, or intermediate ages as indicated by the desire to open the pavement to traffic. A minimum opening age of 10 days should also be retained.

No further work is planned under this project, and this transmittal can be considered the final report.

Table 1

Data Relative to Concrete Testing

Date	Time	Avg. Pen. Ins.	Air Content Percent	Unit Wt. lbs./CF	Air Temp. °F	Conc. Temp. °F	Wind Vel. mph	R.H. %
1970								
4-20	AM	3/4	4.0	151.0	59	67	4-7	-----
	PM	1-1/8	3.5	150.9	66	71	4-10	-----
4-21	AM	3/4	3.5	150.9	53	66	0-3	55
	PM	1/2	3.0	151.4	52	68	4-7	42
4-22	AM	7/8	3.3	149.3	60	69	0-4	-----
	PM	7/8	3.8	149.3	67	70	2-8	-----
4-23	AM	1-1/8	3.3	149.9	63	69	0-5	-----
	PM	1	3.4	149.6	69	--	0-6	39
4-24	AM	1-1/8	3.9	148.4	64	67	2-5	40

Table 2

Field Fabricated Concrete Test Results
Compressive Strengths (PSI)*

Date	Time	Auto. Cured		Lab Cured		Field Cured		
		2 days	10 days	10 days	14 days	10 days	14 days	28 days
1970								
4-20	AM	1730	2570	3520	3810	2610	3200	3800
	PM				3170	2230	2560	
4-21	AM			3160	3590	2440	2800	3230
	PM	1790	2870	3610	3640	2670	3000	3520
4-22	AM	1540	2730	3160	3510	2410	2560	3260
	PM			2970	3440	2520	2760	3070
4-23	AM			2740	3330	2320	2540	3010
	PM	1510	2600	2840	3370	2090	2580	3270
4-24	AM			2620	2950	2200	2410	2760
Average		1640	2690	3080	3430	2420	2760	3240

*Each strength is an average of two test cylinders

Table 3

Field Fabricated Concrete Test Results
Flexural Strengths (PSI)

Date	Time	Lab Forces Made & Field Cured * 10 days	Lab Forces Made and Lab Cured * 10 days	Lab Forces Made and Lab Cured * 14 days	Field Forces Made and Field Cured** 10 days	Field Forces Made and Field Cured** 14 days	Field Forces Made and Field Cured** 28 days
1970							
4-20	AM	600	560	515		735	
	PM	505	530	500	636	676	
4-21	AM	530	510	550	619	707	755
	PM	500	610	575	616	727	784
4-22	AM	535	560	605	666	697	815
	PM	540	475	605	680	697	735
4-23	AM	485	405	510	571	625	742
	PM	470	510	485	619	653	720
4-24	AM	450	390	440	520	639	566
Averages		513	514	533	616	685	735

* Third point loading - 18" span
** Midpoint loading - 30" span

Table 4

Aggregate Gradings

Sieve Size	Job Grading	Grading for percent Factor, Test Method No. Calif. 336
1-1/2"	100	100
1"	69	75
3/4"	47	62
3/8"	40	47
No. 4	37	38
No. 8	32	30
No. 16	26	23
No. 30	17	16
No. 50	7	7

Figure 1

Project 645220
Compressive Strength Tests

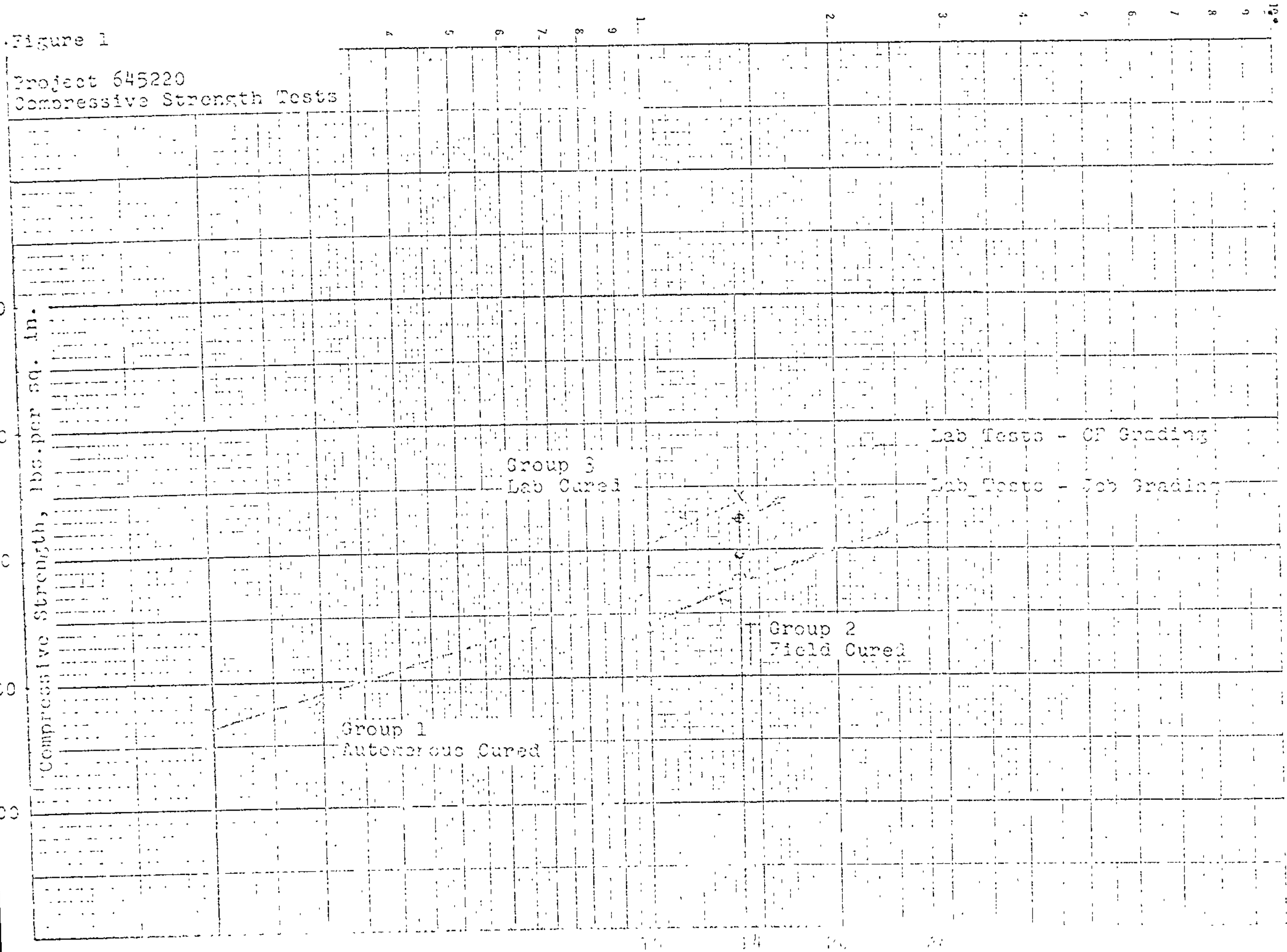

Figure 2

Project 645220
Flexural Strength