NATIONAL BUREAU OF STANDARDS REPORT

2832

QUARTERLY REPORT
ON
EVALUATION OF REFRACTORY QUALITIES OF CONCRETES
FOR JET AIRCRAFT WARM UP, POWER CHECK,
AND MAINTENANCE APRONS

by
W. L. Pendergast, R. A. Clevenger, Edward C. Tuma

U. S. DEPARTMENT OF COMMERCE
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Technical Requirements

The technical requirements are the same as those given in the NBS Report 2632 with a change in two of the five conditions of exposure of the concrete specimens before testing. The exposures before testing are as follows:[1/]

1. Twenty eight days in fog-room
2. Seven days in fog-room, 21 days in ordinary laboratory air.
3. Cured as in No. 2 plus heating at 500°C
4. Cured as in No. 2 plus heating at 750°C
5. Cured as in No. 2 plus heating at 1000°C

I. INTRODUCTION

The objective of the investigation is the determination of the physical properties of concretes that will evaluate their suitability for use in jet aircraft warm up, power check, and maintenance aprons.

II. MATERIALS: PREPARATION AND TESTING

Cements. The three cements included in this project, portland, portland pozzolan, and high alumina hydraulic were used in the design of concretes mixed, placed, cured, heat treated, and tested during this reporting period.

Aggregates. Additional shipments of Bluestone, olivine, Kentucky flint clay (raw and calcined), and West Virginia hard burned face brick were received this quarter.

The Bluestone (dolomitic limestone) has been crushed, graded, recombined in accordance with the technical requirements, and used in the three concretes prepared during the reporting period. The correction factor for the air meter was determined for this aggregate.

Four tons of olivine were screened using the 11 screens necessary in grading the coarse and fine fractions of aggregate. The -1 + 3/4 inch aggregate is the most difficult to obtain in grading olivine.

Concretes. In the preceding report [2/] information was given relative to the properties of both the fresh and cured concretes containing White Marsh aggregate. The testing of specimens, fabricated from these three concretes, after curing and heating at 500, 750, and 1000°C respectively, has been completed.

During the current quarter twenty-five one-cubic foot trial batches of concrete with Bluestone aggregate were designed and specimens fabricated. Eight of these concretes contained portland cement, six portland pozzolan cement, and eleven high-alumina hydraulic cement. The cement content, the ratio of coarse to fine aggregate, the amount of mixing water, and the amount of air-entraining agent, were systematically varied in these concretes.

III. RESULTS AND DISCUSSION

Table I gives the results of the tests for the three concretes designed with White Marsh aggregate after six different exposures. These results indicate that two of the concretes definitely failed to meet the specified strength requirements (600 - 650 psi).

The precision of the method used in measuring the length changes is accurate to 0.02 inches. Values of a lower magnitude serve only as an indication of length change.

The decrease in strength as given or indicated by a decrease in elastic modulus is attended by a loss in weight.

The three concretes were designed using a 6-sack mixture. A redesigning of these concretes by which the cement content would be increased to a 6 1/2 or 7-sack mix, would probably have resulted in a concrete of the required strength after the 28-day curing period. However, the rapid decrease in strength after heat exposures at 500°C and above indicate that concretes containing natural siliceous aggregate of this type are possibly not suitable for such exposures.

TABLE 1 - PROPERTIES OF CURED AND HEAT-TREATED CONCRETES

Laboratory Identification	Proportions by Weight: Cement to Coarse and to Fine Aggregate	Treatments Preceding Tests[a]	Compressive Strength psi	Flexural Strength psi	Abrasion Loss gms	Young's Modulus of Elasticity Dynamic: Longitudinal lbs/inch^2 x 10^6	Total[b] Linear Change %	Total[c] Weight Change %
P - W M	1 : 3.57 : 1.95	1	3080	540	----	5.199	d/	e
		2	----	----	4.7	5.330	+0.01	-0.86
		3	----	403	27.9	3.678	+0.01	-5.31
		4	----	170	22.5	1.325	-0.01	-6.47
		5	----	15	----	.740	----	----
		6	----	10	----	.103	+0.24	-8.20
Z - W M	1 : 3.58 : 1.94	1	4290	640	----	5.510	-0.02	+0.84
		2	----	----	12.6	5.527	-0.03	+0.17
		3	----	560	22.0	3.787	-0.05	-4.67
		4	----	----	----	1.245	-5.32	-5.32
		5	----	40	143.7	.119	----	----
		6	----	10	----	.092	+3.77	-7.45
L - W M	1 : 3.58 : 1.93	1	3435	490	----	4.450	+0.06	-2.95
		2	----	----	43.5	3.950	-0.01	-2.74
		3	----	450	----	1.604	+0.07	-6.93
		4	----	110	----	.254	0.00	-8.13
		5	----	35	269.0	.178	----	----
		6	----	20	593.0[f]	.071	+0.47	-7.90

a/ The results of tests given in line 1 were obtained after 28 day fog-room curing: line 2 treatment (1) plus 7 days under ordinary laboratory conditions; line 3 treatment (2) plus drying at 110°C; line 4 treatment (3) plus heating at 500°C for 5 hours; line 5 treatment (3) plus 750°C for 5 hours; line 6 treatment (3) plus 1000°C for 5 hours.

b/ Based on length after 24 hours in mould.

c/ Based on weight after 24 hours in mould.

d/ Based on length after 28 days in fog-room.

e/ Based on weight after 28 days in fog-room.

f/ Loss after 3 minutes in abrasion test (usual test is of 5 minute duration).

TABLE 11 - PROPERTIES OF FRESH [a] CONCRETE

Identification [b]	Proportions by Weight; Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by Weight of Cement	Water Content	Air Content Gravimetric Method	Air Content Air Meter Method	Slump	Weight of Fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
		Sacks/yd³ of Concrete	%	Gals/yd³ of Concrete	%	%	Inches	lbs/ft³			psi	
P-BS-A	1 : 2.50 : 2.44	6.26	.015	39.0	5.95	[illegible].30	3.00	143.07	0.55	Over sanded: slightly high in air content and slump.	630	50 percent pull outs: small aggregate fractured.
P-BS-B	1 : 3.30 : 1.70	6.66	.015	32.6	2.70	3.[illegible]	1.50	151.08	0.43	Good workability for this type aggregate: Slightly low in air content and slump.	845	
P-BS-C	1 : 3.30 : 1.70	6.52	.025	31.8	5.00	[illegible].50	2.00	147.19	0.43	Good placability	710	Large aggregate pulled out about 60% fracture.
P-BS-F	1 : 3.40 : 1.60	6.53	.020	33.[illegible]	3.8[illegible]	4.60	1.50	148.48	0.45	do	705	do
P-BS-D	1 : 3.07 : 1.55	6.92	.025	32.7	3.10	c	1.75	146.75	0.42	Fair workability: harsh	720	50 percent pull outs.
P-BS-G	1 : 3.16 : 1.45	7.11	.020	32.9	4.00	3.95	1.87	150.22	0.41	Harsh but placed well	700	do
P-BS-E	1 : 2.97 : 1.33	7.58	.025	33.6	2.20	3.17	0.75	151.95	0.39	Harsh: hard to place	690	All below 3/4 inch: aggregate fractured
P-BS-H	1 : 2.97 : 1.33	7.37	.020	32.7	4.80	4.18	1.75	147.62	0.39	Very good	820	Most aggregate fractured
P-BS-1	1 : 1.33 : 1.57	6.47	.020	31.1	5.40	5.30	2.00	143.72	0.43	Good workability; slightly sticky		Large aggregate
P-BS-2	do	6.49	.020	31.4	5.00	4.75	2.25	144.70	0.43	do		
P-BS-3	do	6.53	.020	30.7	4.70	5.40	1.75	146.75	0.42	do		
Z-BS-A	1 : 3.40 : 1.60	6.70	none	34.8	1.55	1.70	1.00	151.75	0.46	Good workability for this type mortar; harsh	685	90 percent aggregate fractured
Z-BS-D	1 : 3.40 : 1.60	6.66	.010	34.6	2.00	2.40	1.00	151.08	0.46	do	630	Large aggregate pulled out
Z-BS-B	1 : 3.16 : 1.45	7.12	none	33.8	2.50	2.10	2.50	151.08	0.42	do	675	do
Z-BS-E	1 : 3.16 : 1.45	7.13	.015	33.8	2.50	2.90	2.125	151.08	0.42	Fair workability: harsh	810	Very few pull outs: nearly all aggregate fractured.
Z-BS-C	1 : 2.97 : 1.33	7.54	none	35.4	1.80	1.99	2.00	151.51	0.41	Good workability: harsh	790	50 percent pull outs
Z-BS-F	1 : 2.97 : 1.33	7.46	.020	34.2	3.20	2.85	1.50	149.78	0.40	Fair workability	780	50 percent pull outs
Z-BS-1	1 : 3.16 : 1.45	7.08	.020	31.3	4.20	3.10	1.875	149.35	0.40	Fair workability: slightly stiff to place easily		
Z-BS-2	do	6.99	.020	31.5	4.90	4.00	1.75	147.62	0.40	do		
Z-BS-3	do	7.03	.020	31.9	4.50	3.57	2.00	148.48	0.40	do		
L-BS-A	1 : 3.40 : 1.60	6.38	.025	30.9	7.10	3.70 d	[illegible].50	144.15	0.43	Set too quickly to place well	505 e/	Numerous voids: aggregate fractured
L-BS-B	do	6.52	.020	35.5	3.10	2.80	1.50	148.49	0.48	Thin: large aggregate may have settled out some	625 e/	do
L-BS-C	do	6.59	.015	36.8	1.70	2.00	8.00	150.22	0.49	Placed well	640 e/	40 percent aggregate fractured
L-BS-D	1 : 3.00 : 1.38	7.18	.025	38.3	2.90	2.60	1.50	147.62	0.47	Fair; set up quickly	675 e/	Slightly honey-combed
L-BS-E	1 : 2.70 : 1.20	7.89	.025	39.9	2.10	2.50	1.25	148.49	0.45	do	675 e/	Badly honey-combed
L-BS-F	1 : 3.33 : 1.57	6.70	.020	35.4	2.50	2.40	Not sufficiently plastic to remain as cone	149.78	0.47	Very good; placed well	565 e/	Large aggregate pulled out
L-BS-G	1 : 2.97 : 1.36	7.26	.025	39.9	2.00	2.30	do	148.48	0.49	do	595 e/	do
L-BS-H	1 : 2.71 : 1.20	7.78	.030	43.7	1.40	2.10	do	147.62	0.50	Started to set before specimens were complete	490 e/	Most all aggregate pull outs
L-BS-I	1 : 2.60 : 1.73	7.20	.025	39.5	2.60	3.00	do	147.19	0.49	do	590 e/	50 percent pull outs
L-BS-J	1 : 2.70 : 1.20	7.67	.030	41.1	4.00	3.95	do	145.02	0.48	Too wet: segregation of aggregate	535 e/	All large aggregate pulled out
L-BS-K	1 : 2.82 : 1.25	7.28	.030	32.0	8.00	d	4.50	139.39	0.39	Placed well	610 e/	Most of aggregate broken
L-BS-1	1 : 3.01 : 1.34	7.53	.015	30.5	3.40	2.60	1.75	151.08	0.36	Harsh: poor placability		
L-BS-2	do	7.44	do	33.7	3.00	2.65	3.50	150.32	0.39	do		
L-BS-3	do	7.42	do	35.3	2.60	2.65	2.40	150.21	0.41	do		

a/ For convenience, the flexural strength of specimens of the trial batches after 28-day fog-room curing are included.

b/ P = Portland Cement; Z = Portland Pozzolan Cement; L = Lumnite Cement; BS = Bluestone aggregate.
The last letters "A" to "K" inclusive, indicate trial mixes made in a 1-cubic foot mixer.
The last numeral 1 to 3 inclusive, indicate final selected mix made in a 5-cubic foot mixer.
Three batches of the selected mix were necessary to fabricate the required number of test specimens.

c/ Above the capacity of air-meter.

d/ Concrete set in air meter.

e/ Flexural strength was determined after four days curing in fog-room.

In designing these particular concretes, air content and slump results obtained from trial batches were the criteria. At that time the strengths of trial concretes were not determined due to the smallness of the batch. In attempts to design a concrete of the specified strength the cement content was based both on work in this project and the results of other research projects. As a result of this practice the flexural strength was often lower than anticipated and below that specified. Consequently a procedure has now been established that also includes flexural strength tests of enlarged trial batches after 28-day fog-room curing

Table II gives the results of tests on the 25 trial batches of concretes. Also some results are given for the three concretes selected as having the specified requirements and from which specimens for a complete series of tests were fabricated. These results indicate that from the data on trial batches, concretes of the portland or portland pozzolan type may be designed that will meet the technical requirements.

Although concretes have been designed with the high alumina hydraulic cement that develop 675 psi flexural strength, the air content is low and the placability is not good. Several methods have been used in mixing this type of concrete. The results indicate that charging the mixes in the following order yielded the most workable concrete: (1) fine aggregate and cement, mix thoroughly (2) coarse aggregate and mix again (3) water and air entraining agent and mix for 1 1/2 minutes only. It is possible, however, that the difficulties encountered in designing and especially mixing concrete containing high alumina hydraulic cement, and using a limestone aggregate, may not be encountered with other aggregates.

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[1]. The five conditions of exposure are given in a letter dated June 26, 1953 from U. S. Naval Civil Engineering Research and Evaluation Laboratory, Construction Battalion Center, Port Hueneme, California, signed by Perry H. Petersen, Director Materials Division, Structures Research Department.

[2]. NBS Report 2632.

THE NATIONAL BUREAU OF STANDARDS

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