NATIONAL BUREAU OF STANDARDS REPORT

3399

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
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT | **NBS REPORT**

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NBS

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NATIONAL BUREAU OF STANDARDS

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TECHNICAL REQUIREMENTS

The technical requirements are the same as those given in the NBS Report 3012.

1. 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.

2. MATERIALS: PREPARATION AND TESTING

2.1 Cements

The physical and chemical tests of the cements used in the preparation of concretes during this quarter have been previously reported.

2.2 Aggregates

Six tons of calcined Kentucky flint clay and four tons of raw Kentucky flint clay were crushed and screened during the current quarter. Eleven screens are necessary to grade the aggregate

in accordance with the sizes specified in the Department of the Navy, Bureau of Yards and Docks specification No. 45Ya[1]. Three tons of the calcined clay and two of the raw clay have been screened to the required sizes.

The following properties of both the calcined and flint clay were determined; (1) percent wear in the Los Angeles abrasion test; (2) the bulk specific gravity; (3) the percent absorption; (4) the unit weight in pounds per cubic foot; (5) the correction factor for use with these aggregates when determining the percent entrained air in concrete by use of the pressure method.

Specimens have been cut from pieces of the raw flint clay to be used for flexural and compressive strength determinations. For comparative purposes specimens of the same shape and size were also cut from the building brick, one of the stronger aggregates included in this project.

2.3 Concretes

During the period covered by this report 20 one-cubic foot trial batches of concrete were designed, mixed, specimens fabricated, cured, and tested.

Nine of these trial batches of concretes were designed with the calcined flint clay aggregate, three containing portland cement, three portland pozzolan, and three high-alumina hydraulic cement as the bond.

The remaining 11 of the 20 trial batches of concretes were designed with raw flint clay aggregate. Three of these contained portland cement, three portland pozzolan, and five the high-alumina hydraulic. Using the information obtained from tests on the trial batches three final batches of concrete were designed using calcined clay as the aggregate and one of the three types of cement in each.

The capacity of the mixer, five-cubic feet, necessitated preparing three charges of each concrete in order to yield the 15 cubic-feet used in the fabrication of 5 complete sets of specimens.

One set of specimens of each of the three concretes were cured in the fog-room for 28 days and tested. Four sets of specimens of each concrete were cured in the fog-room for 7 days and stored in the laboratory at ordinary temperatures and humidity and tested. One set of each concrete has been heat-treated at 250°C and 500°C respectively. These six sets have not as yet been tested.

3. RESULTS AND DISCUSSION

3.2 Aggregates

The properties of the six dense aggregates used in designing concretes are given in table 1. The properties of but three of these were determined during the current quarter, the properties of the other three were previously reported and are given again for comparative purposes.

TABLE 1. PROPERTIES OF AGGREGATES

Aggregate	Size	Bulk specific gravity[a/][b/] S-SD	Water absorption in percent[a/] by weight	Los Angeles abrasion percentage wear
White Marsh	gravel sand	2.64 2.63	0.30 0.30	40.5
Bluestone	coarse fine	2.76 2.65	1.50 0.27	21.3
West Virginia hard face brick	coarse fine	2.46 2.60	1.76 0.60	27.0
Olivine	coarse fine	3.17 3.16	0.70 0.20	59.7
Kentucky calcined flint clay	coarse fine	2.63 2.70	1.23 0.70	41.3
Raw Kentucky flint clay	coarse fine	2.49 2.43	5.00 5.88	30.0

[a/] The gradation of the aggregate was the same as that used in designing the concretes.

[b/] "S-SD" = saturated surface-dry basis.

The bulk specific gravities (saturated Surface-Dry Basis) of five of the aggregates compared favorably with that of the natural aggregate, gravel and sand, but olivine was slightly heavier. The water absorption was within the normal limits for aggregates with the exception of the raw flint clay. In the abrasion test olivine again was the exception, having the least resistance to wear. If fifty percent wear was taken as the maximum permissible loss, Federal Specification No. SS-A-281,[2/] olivine would fail to meet that requirement. The low abrasion loss on the raw flint clay was due to the lubricating and cushioning effect of the quickly produced fines. Aggregate of this type often have low wear loss.

If the results of the flexural strength tests on specimens cut from the raw flint clay do not approach the required flexural strength of 650 psi for concretes this would indicate that such an aggregate would be unsuitable.

3.3 Concretes

Table 2 gives the composition and some of the properties of the trial batches of the fresh concretes. The flexural strength of the concretes after curing are also given in this table.

Using as a creteria the data obtained on the trial batches of concretes designed with calcined flint clay and either portland, portland pozzolan, or high-alumina hydraulic cement, three final 15 cubic-foot batches were designed, mixed and complete sets of specimens fabricated. These final batches designed with a 7-sack per cubic yard mix were placable at a 2-inch slump and the air contents were in most instances within the specified range of 4 1/2 percent

TABLE 2. PROPERTIES OF FRESH CONCRETE [a/]

Identification	Proportions by Weight : Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by Weight of Concrete	Water Content	Air Content		Slump	Weight of Fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
					Gravimetric	Air Meter						
		sacks/yd^3 of concrete	%	gals/yd^3 of concrete	%	%	inches	lbs/ft^3			psi	
L-C-A	1 : 2.63 : 1.75	7.32	0.010	35.2	1.40	2.38	1.25	149.01	0.43	harsh but placable	800 (8)[c/]	few pull-outs mostly aggregate fracture
L-C-B	do	7.27	0.015	36.3	1.40	2.60	1.00	148.47	0.44	placed well	620 (8)	50% pull-outs 50% aggregate fracture
L-C-C	1 : 2.90 : 1.93	6.56	0.015	35.7	3.20	4.52	2.00	145.42	0.48	good workability	510 (23)	all large aggregate pulled out large & small air voids
P-C-A	1 : 3.03 : 1.42	7.19	0.010	35.4	1.58	2.90	0.50	148.47	0.44	harsh but placable	725 (20)	95% fractured aggregate
P-C-B	do	7.16	0.015	35.7	1.74	3.03	1.00	148.03	0.44	good placability	680	all large aggregate pulled out: few large & numerous small air voids
P-C-C	1 : 2.71 : 1.27	7.45	do	37.4	5.01	6.49	3.00	141.92	0.45	easily placed	660	do
Z-C-A	1 : 3.07 : 1.40	7.23	none	37.1	0.20	0.10	0.50	150.22	0.46	harsh but placable	730 (20)	98% fractured aggregate
Z-C-B	do	7.02	0.010	39.3	1.50	2.68	1.00	146.91	0.49	do	670	very few pull-outs numerous air voids
Z-C-C	1 : 3.32 : 1.51	6.66	do	36.1	1.82	3.08	0.63	147.60	0.48	do	725	do
L-C-1	1 : 2.66 : 1.77	7.11	0.010	36.5	2.10	2.88	1.50	147.12	0.46	easily placed bleeds		
L-C-2	do	7.08	do	36.4	2.43	3.48	1.75	147.95	0.46	do	740	very few pull-outs mostly aggregate fracture numerous air voids
L-C-3	do	7.14	do	36.7	1.54	2.68	1.75	147.94	0.46	do		
P-C-1	1 : 3.02 : 1.42	7.05	0.015	37.1	2.41	4.78	1.75	146.16	0.47	very easily placed		
P-C-2	do	6.83	do	35.5	2.98	6.01	2.50	141.53	0.46	do	705	very few pull-outs mostly aggregate fracture
P-C-3	do	7.12	do	35.4	2.38	4.48	2.00	147.12	0.44	do		

Table continued on next page.
Footnotes appear at end of table.

TABLE 2 (Continued). PROPERTIES OF FRESH CONCRETE [a/]

Identification[b]	Proportions by Weight : Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by Weight of Concrete	Water Content	Air Content		Slump	Weight of Fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
					Gravimetric	Air Meter						
		sacks/yd^3 of concrete	%	gals/yd^3 of concrete	%	%	inches	lbs/ft^3			psi	
Z-C-1	1 : 2.97 : 1.35	7.35	0.010	36.4	1.20	2.76	1.5	148.73	0.44	very harsh but placable	840	very few pull-outs mostly aggregate fracture
Z-C-2	do	7.16	do	38.3	2.48	4.08	2.0	145.76	0.47	easily placed		
Z-C-3	do	7.26	do	37.6	1.63	3.28	1.75	147.42	0.46	do		
L-RC-A	1 : 2.60 : 1.34	7.24	0.015	30.8	3.85	2.16	1.00	139.30	0.38	too dry to place well	240 (14)[c/]	honey-combed few pull-outs mostly aggregate fracture
L-RC-C[1]	1 : 2.34 : 1.13	7.75	0.010	32.3	5.00	3.67	0.00	137.12	0.37	do	250 (10)	do
L-RC-C[2]	do	7.58	do	38.4	3.69	2.11	d/	136.25	0.45	too wet	260 (10)	large aggregate pulled out. air voids
L-RC-D	1 : 2.30 : 1.18	7.82	do	42.8	1.40	1.15	d/	142.36	0.48	sloppy but easily placed bleeds	380 (7)	do
L-RC-E	1 : 2.34 : 1.18	7.70	0.015	38.8	2.20	1.62	d/	138.43	0.45	do	28-day fog-room curing not completed	
P-RC-A	1 : 3.13 : 1.47	6.23	0.015	36.4	2.64	2.66	3.00	137.99	0.52	very easily placed		do
P-RC-C	1 : 2.66 : 1.24	7.00	0.020	34.7	5.10	4.92	2.50	135.07	0.44	easily placed bleeding		do
P-RC-D	1 : 2.55 : 1.12	7.67	0.015	37.6	1.55	3.08	2.00	140.18	0.44	very easily placed		do
Z-RC-A	1 : 3.13 : 1.47	6.32	0.010	37.6	0.98	2.01	1.50	140.18	0.53	very easily placed		do
Z-RC-C	1 : 2.62 : 1.20	7.15	0.015	39.0	2.97	2.82	1.50	137.12	0.48	do		do
Z-RC-D	1 : 2.54 : 1.14	7.33	do	37.8	3.97	3.43	2.30	136.25	0.46	do		do

a/ For convenience the flexural strength of cured specimens are included if tests are completed.

b/ The first letters: L = Lumnite, a high-alumina hydraulic cement; P = Portland cement: Z = Portland pozzolan cement.
The second letters: C = calcined Kentucky flint clay; RC = raw Kentucky flint clay.
The third letters denote trial batches.
The numerals 1, 2, and 3 indicate the number of final batches, of the same design but different charges.

c/ The number in parentheses indicates the number of days the concrete was stored in the fog-room before testing.
If no curing time is shown the 28-day curing period was used.

d/ Too thin for slump test.

± 1.5 percent. The flexural strength, as indicated by the trial batches, was well above the required 650 psi.

The results of tests on the trial batches designed with raw flint clay aggregate indicate that the technical requirements for the properties of the fresh concrete such as slump, air content, and placability may be obtained. However, the results of the few flexural strength tests made on concretes designed with this aggregate and high-alumina hydraulic cement are far below the required strength. Modulus of elasticity determination, on specimens fabricated from trial batches of concrete, using this aggregate and either portland or portland pozzolan cement indicate low strength also. An examination of the test speci men after test shows no pull-outs but complete aggregate fracture.

Table 3 gives the properties of the cured and heat-treated concretes.

All of these concretes with the exception of the one designed with olivine aggregate and high-alumina hydraulic cement developed the required flexural strength of 650 psi after a 28-day fog-room curing. Data collected on trial batches of the concrete containing the olivine aggregate and high-alumina hydraulic cement, indicated that an increase in cement content would result in an accompanying increase in flexural strength to the required 650 psi. The type of mineral structure peculiar to olivine (laminar, with weak bond between strata) probably accounts for the comparatively low flexural strength of the three concretes containing this aggregate. An examination of the beams after testing showed that fracture occurred principally in the aggregate and along the natural cleaverage lines.

TABLE 3. PROPERTIES OF CURED AND HEAT-TREATED CONCRETES

Identification a/	Proportions by Weight of Cement to Coarse and to Fine Aggregate	Treatments Preceding Test b/	Compressive Strength	Flexural Strength	Abrasion: Weight of dust	Abrasion: Depth of Wear c/	Young's Modulus of Elasticity Dynamic: Longitudinal	Total d/ Linear Change	Total e/ Weight Change
			psi	psi	grams	inches	$lbs/inch^2 \times 10^6$	%	%
L - O f/	1 : 3.16 : 2.11	1	4300				5.894		
		2					6.408	no change	+0.27
		3		490	73.25	0.0142	6.750	-0.02	-0.43
		4		620	28.65	.0056	6.822	no change	+0.55
		5					4.397	-0.03	-3.16
		6		370	85.70	.0112	3.955	-0.03	-3.46
		7		115	200.00	.0382	1.560	-0.08	-5.49
		8		110	432.00	.0756	.883	+0.04	-6.98
P - O f/	1 : 3.50 : 1.50	1	4740				3.803		
		2					6.142	+0.01	+0.41
		3		530	19.75	.0045	6.545	-0.01	-0.99
		4		665	18.15	.0051	7.195	+0.02	+0.61
		5					5.363	-0.03	-3.84
		6		675	66.50 g/	.0155	4.873	-0.06	-4.25
		7		500	96.80 g/	.0219	3.686	-0.13	-4.69
		8		70	616.00 g/	.1138	1.063	-0.13	-6.90
Z - O	1 : 3.45 : 1.54	1	5520				3.166		
		2					5.861	+0.01	+0.38
		3		580	40.20	.0104	6.006	-0.03	-1.31
		4		700	66.50	.0157	6.370	+0.03	+0.61
		5					5.211	-0.06	-4.10
		6		635	72.00 g/	.0179	4.010	-0.09	-5.15
		7		445	83.30 g/	.0200	2.555	-0.12	-5.70
		8		150	378.00 g/	.0691	1.119	-0.28	-7.30
L - B	1 : 2.11 : 1.53	1	6940				4.980		
		2					5.282	+0.01	+0.32
		3		470	33.15	.0098	5.020	-0.01	-1.41
		4		665	43.25	.0115	5.590	no change	+0.72
		5					3.329	-0.02	-6.07
		6		360	70.50 g/	.0179	2.154	-0.03	-6.68
		7		300	109.70 g/	.0271	1.643	-0.11	-9.90
		8		290	230.00 g/	.0511	1.505	-0.10	-11.55
P - B f/	1 : 3.12 : 1.47	1	4430				3.218		
		2					4.750	+0.01	+0.42
		3		435	21.05	.0075	4.619	-0.01	-2.13
		4		685	16.05	.0056	5.280	+0.01	+0.51
		5					3.788	-0.02	-5.49
		6		580	65.15 g/	.0186	3.305	-0.03	-5.76
		7		395	93.70 g/	.0233	2.763	-0.08	-6.54
		8		125	501.00 g/	.1159	1.610	-0.08	-7.73
Z - B	1 : 2.79 : 1.27	1	7790				3.309		
		2					5.232	+0.01	+0.29
		3		560	1.00	.0013	5.292	-0.01	-1.90
		4		820	4.30	.0023	5.598	+0.02	+0.49
		5					4.314	-0.03	-5.68
		6		680	26.30	.0094	3.545	-0.04	-6.27
		7		440	51.00	.0128	2.535	-0.12	-6.97
		8		155	351.50 g/	.0725	1.918	-0.10	-8.51

Continued on next page
Footnotes appear at end of table

TABLE 3 (Continued). PROPERTIES OF CURED AND HEAT-TREATED CONCRETES

Identification[a]	Proportions by Weight of Cement to Coarse and to Fine Aggregate	Treatments Preceding Test[b]	Compressive Strength	Flexural Strength	Abrasion: Weight of Dust	Abrasion: Depth of Wear[c]	Young's Modulus of Elasticity Dynamic: Longitudinal	Total[d] Linear Change	Total[e] Weight Change
			psi	psi	grams	inches	lbs/inch^2 x 10^6	%	%
L - C	1 : 2.66 : 1.77	1					6.120		
		2					6.352	+0.01	+0.23
		3		565	82.10	0.0173	6.273	-0.00	-0.69
		4	5750	740	- [h]	-	6.692	+0.02	+0.66
		5					4.429	-0.01	-3.71
		6		-	-	-	-	-0.02	-4.97
		7		-	-	-	-	-	-
		8		-	-	-	-	-	-
P - C	1 : 3.02 : 1.42	1					3.714		
		2					5.619	+0.00	+0.20
		3		520	34.35	.0094	5.309	-0.02	-1.65
		4	4420	705	-	-	6.535	+0.03	+0.39
		5					-	-0.03	-4.79
		6		-	-	-	-	-0.05	-5.33
		7		-	-	-	-	-	-
		8		-	-	-	-	-	-
Z - C	1 : 2.97 : 1.35	1					3.357		
		2					5.493	+0.00	+0.23
		3		715	25.70	.0063	5.129	-0.01	-2.17
		4	5570	840	-	-	6.668	+0.01	+0.56
		5					-	-0.01	-5.20
		6		-	-	-	-	-0.04	-5.68
		7		-	-	-	-	-	-
		8		-	-	-	-	-	-

a/ The first letters: L = high-alumina hydraulic cement; P = portland cement; Z = portland pozzolan cement.
The second letters: O = olivine aggregate; B = crushed building brick aggregate; C = calcined Kentucky flint clay.

b The results in line 1 were obtained after 20 to 24 hours in mold; line 2 after 7 days in fog-room; line 3 after line 2 treatment plus 21 days at ordinary laboratory conditions; line 4 after 28 days in fog-room; line 5 after line 3 treatment plus drying at 110°C; line 6 after line 3 treatment plus heating at 250°C for 5 hours; line 7 after line 3 treatment plus heating at 500°C for 5 hours; line 8 after line 3 treatment plus heating at 1000°C for 5 hours.

c/ A description of the apparatus and method used in determining depth of wear was given in NBS Report 3201.

d/ Based on length after 24 hours in mold.

e/ Based on weight after 24 hours in mold.

f/ This data appeared in the last report NBS 3201 and is repeated here for comparative purposes.

g/ Coarse aggregate exposed.

h Dash indicates tests have not been completed.

The results of tests on the concretes designed with crushed building brick aggregate indicate that a 6 1/2 sack mix when portland or portland pozzolan cement is used would develop the required strength.

The three concretes designed with calcined flint clay aggregate and either portland, portland pozzolan, or high-alumina hydraulic cement developed the required flexural strength during the 28-day fog-room curing. These three concretes were designed using a 7-sack mix. An examination of the beams fabricated from this aggregate indicated that failure occurred primarily as aggregate fracture. Fractions of this aggregate screened to the required sizes showed cracking which may have been due to the opening up of natural laminations in the clay during calcining.

The results of tests on the concretes designed with either olivine or crushed building brick as aggregate and either portland or portland pozzolan cement indicate an increase in strength after the 250°C heat exposure and but a slight decrease after the 500°C heat exposure. The linear shrinkage, weight loss, or resistance to abrasion is not effected materially by these heat exposures.

Table 4 gives the results of thermal conductivity measurements * made on specimens of concrete designed with the dense aggregates included in this phase of the project.

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* Made by the Heating and Air Conditioning Section, Building Technology Division, National Bureau of Standards.

TABLE 4. RESULTS OF THERMAL CONDUCTIVITY MEASUREMENTS

Specimen	Density lb/ft^3	Thermal Conductivity B. T. U./$hrft^2$ (deg F/inch)	Mean Temperature °F
L-WM	134.2	11.3	116
P-WM	131.5	10.4	115
Z-WM	135.0	10.9	116
L-BS	Specimens not suitable for test		
P-BS	139.8	9.1	117
Z-BS	138.0	6.9	117
L-O	146	8.2	116
P-O	149	9.9	117
Z-O	146	8.3	117
L-B	125	5.3	117
P-B	125	6.0	116
Z-B	118	5.3	119

The procedure used in the measurements of thermal conductivity was as follows:

PROCEDURE

Each specimen was dried for at least 8 hours at about 200°F in a ventilated oven immediately prior to the conductivity measurement.

The thermal conductivity of the specimen was measured in an 8-inch pentane hot plate apparatus constructed for making thermal conductivity measurements of concretes. The results of tests in this apparatus have been found to be in close agreement with results obtained in the 8-inch guarded hot plate apparatus conforming with the requirements of Federal Specification LLL-F-321b and of ASTM Test Method C177-45.

The temperature difference from face to face of the specimen during test was measured by means of a thermocouple pressed against each face by a sheet of resilient rubber 0.1 inch thick.

REFERENCES

1/ Specification for portland cement concrete pavement for air ports. Sept. 1952.

2/ Aggregate for portland-cement-concrete.

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

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