NATIONAL BUREAU OF STANDARDS REPORT

3855

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

by

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

U. S. DEPARTMENT OF COMMERCE
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●Office of Basic Instrumentation ●Office of Weights and Measures.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		**NBS REPORT**
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Refractories Section
Mineral Products Division

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NBS

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NATIONAL BUREAU OF STANDARDS

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TECHNICAL REQUIREMENTS

The technical requirements for the concretes designed with dense aggregates are the same as those given in NBS Report 3012, dated December 31, 1953.

The technical requirement for the concretes designed with lightweight aggregates are: (1) they must develop a flexural strength of 650 psi after curing for 28 days in the fog-room; (2) the maximum cement content shall not exceed nine sacks per cubic yard.

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 thermal length changes from room temperature to approximately 1200°C were measured on specimens of the three types of cements. The neat cement specimens for that purpose were cured for 28 days in the fog-room and oven dried at 105°C for 18 hours before testing.

2.2 Aggregates

A second shipment, totaling ten tons of sintered slag was crushed and screened to required sizes.

The following properties of both the sintered slag and a coated expanded shale, "Rocklite", were determined: (1) wear in the Los Angeles Abrasion Test; (2) the bulk specific gravity; (3) the absorption; (4) the unit weight in pounds per cubic foot.

The thermal length changes, of one of the dense aggregates namely, crushed building brick, were observed from room temperature to approximately 1200°C.

2.3 Concretes

During this reporting period 27 one-cubic foot trial batches of concrete and one 15 cu. ft. final batch, were designed, mixed, specimens fabricated, cured, and tested if the curing period was completed.

Fifteen of the trial batches were designed with a light-weight aggregate "Kenlite", which is an expanded shale, crushed. Eleven of these contained the portland cement as the bond, two the portland pozzolan, and two the high-alumina hydraulic cement.

Six trial batches were designed with the second light-weight aggregate, "Rocklite". Five of these contained the portland cement, and one the portland pozzolan.

Six trial batches were designed with sintered slag (second shipment)* as the aggregate. Two of each of these trial batches were designed with portland, portland pozzolan, and high-alumina hydraulic cements respectively. Using the information obtained from tests on the trial batches, one final fifteen cubic feet, batch of concrete was designed with the high-alumina hydraulic cement as the bond. This concrete has been mixed and test specimens fabricated. One set of specimens is being cured in fog-room for 28 days. Four sets have completed the seven-day fog-room curing and are stored in the laboratory at ordinary temperatures and humidity. These specimens will be tested after two different curing periods and three heat exposures.

3. RESULTS AND DISCUSSION

3.1 Cements

Preliminary observations of the thermal length changes of the three neat cements were made up to that temperature at which either softening or rapid shrinkage occurred. When all tests are completed curves showing the length changes

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* The results of the tests of trial batches of concretes using sintered slag and given in NBS Report 3705, Table 3, indicated that a concrete could be designed that would meet the specified technical requirements. However, because the properties of the second shipment of slag differed considerably from the first; additional trial batches of concretes were prepared and tested.

during actual heating will be given in a future report and discussed in detail. For the present it can be pointed out that the portland cement had a total shrinkage of 7.66% up to 1180°C, which was more than double that of either the portland pozzolan or the high alumina cements.

3.2 Aggregates

Some properties of two of the aggregates are given in Table 1.

Table 1. Properties of Lightweight Aggregates.

Aggregate	Size	Bulk Specific Gravity a/ b/ S-SD	Water Absorption in Percent by Weight b/	Wear in Los Angeles Abrasion Test percent
Rocklite	Coarse Fine	1.24 1.90	6.45 11.45	25.1
Sintered Slag c/	Coarse Fine	1.83 2.72	9.20 0.80	67.5
Sintered Slag d/	Coarse Fine	2.16 2.49	3.86 3.18	45.3

a/ Saturated surface-dry basis.

b/ The gradation of the aggregate was the same as that used in designing the concretes.

c/ First shipment of slag sintered at Armour Institute Laboratories.

d/ Second shipment of slag sintered on contract by Armour Institute.

While the bulk specific gravity of the coarse aggregate of Rocklite, (-1 1/2" to +4) was 1.24, some of the larger size particles are lighter than water. In mixing concrete designed with this aggregate the slump must be kept between two and three inches to prevent the segregation of the larger particles. The 25 percent wear loss in the abrasion test is not a true measure of the strength of this aggregate. The volume of the charge due to its lightweight reduces the impact during the testing and very few of the pieces actually fractured. The indicated loss was a result of wear on the coating.

A comparison of the results of tests of the slags received in the first and second shipments indicates that if the slag was from the same source the method and/or temperature of sintering must have differed.

The thermal length changes for specimens cut from building brick, were characterized by a rapid expansion approximating 5.0 percent caused by bloating, within the range from 1000°C to 1175°C. The total amount of expansion from 25° to 1000°C was 0.72 percent. Graphs showing in detail the length changes are being prepared and will appear in the next report.

3.3 Concretes

Table 2 gives the composition, some properties of the fresh concretes, together with the flexural strengths, of trial batches of mixes designed with the lightweight aggregate "Rocklite". The few mixes designed and tested have not developed the required flexural strength of 650 psi even with a cement content of slightly more than the maximum of nine sacks per cubic yard. This aggregate, when used in concrete, fractures exposing numerous and sizeable air voids. It is, however, probable that a systematic increase in the ratio of coarse-to-fine aggregate may result in a concrete with the required strength. An examination of the fractured beams fabricated from these concretes shows a deficiency in the intermediate sizes of the coarse (-3/4 +3/8). This deficiency may be overcome by the increase in the ratio of coarse-to-fine aggregate, otherwise a change in the fineness modulus of the coarse aggregate will be necessary. The spherical shape of the aggregate will permit the increase in coarse fractions without materially effecting the workability of the concrete.

Table 3 gives information similar to that given in Table 2, but governs mixes designed with the lightweight aggregate, "Kenlite". Of the 14 concretes tested only two, namely, Z-K-C[1] and P-K-E[1] developed the required 650 psi. In both of these the cement content, as calculated, was over the nine-sack maximum permitted.

TABLE 2. PROPERTIES OF FRESH CONCRETES [a]

Identification [b]	Proportions by Weight: Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by Weight of Cement	Water Content [c]	Air Content Gravimetric	Slump	Weight of Fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
		sacks/yd^3 of concrete	percent	gals/yd^3 of concrete	percent	inches	lbs/ft^3			psi	
P-R-A[1]	1 : 0.84 : 0.69	9.15	0.005	39.1	6.78	6.00	96.90	0.38	easily placed	615	few pull-outs; mostly fractured aggregate
P-R-A[2]	1 : 0.84 : 0.69	9.75	0.005	40.3	2.25	3.00	102.50	0.37	placed well; sticky	575	few pull-outs; mostly fractured aggregate
P-R-B[1]	1 : 0.88 : 0.72	9.16	0.005	38.2	4.25	6.00	99.40	0.37	easily placed	535	few pull-outs; large aggregate fractures
P-R-B[2]	1 : 0.89 : 0.73	9.38	0.005	36.9	3.19	2.50	101.60	0.35	easily placed	590	few pull-outs; large aggregate fractures
P-R-C[1]	1 : 1.03 : 0.68	8.97	0.005	34.3	2.82	1.75	99.70	0.34	harsh but placeable	-	-
Z-R-C[2]	1 : 1.04 : 0.70	8.68	none	39.4	2.46	2.25	99.40	0.40	sticky but placeable	-	-

a/ The flexural strength after curing for 28 days in fog-room is included.

b/ The first letters: P = portland cement; Z = portland pozzolan cement.
The second letter: R = Rocklite aggregate.
The third letters: = Batch identification, with superscript[1] indicating that the aggregate was used in the same proportions as received;
Superscript[2] indicating that the aggregate was screened and recombined using the gradation that was used throughout this project, NBS Report 3012, Figure 1.

c/ Mixes charged with saturated aggregate. Coarse and fine aggregate was immersed in water 18 hours and allowed to drain 18 hours before mixing.

TABLE 3. PROPERTIES OF FRESH CONCRETES[a]

Identification[b]	Proportions by Weight:Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by Weight of Cement	Water Content[c]	Air Content Gravimetric	Slump	Weight of Fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
		sacks/yd³ of concrete	percent	gals/yd³ of concrete	percent	inches	lbs/ft³			psi	
P-K-A[1]	1 : 0.88 : 1.10	7.32	0.010	44.5	7.00	too thin	95.00	0.54	bleeds; aggregate segregation	520	all large aggregate fractured; air voids
P-K-A[2]	1 : 0.88 : 1.10	7.82	0.010	34.6	7.05	2.50	97.50	0.39	very good; slightly plastic	550	90% fracture; air voids
P-K-B[1]	1 : 0.95 : 0.78	9.06	0.005	30.0	4.72	1.25	101.00	0.30	slightly harsh	620	practically all large aggregate fractured
P-K-B[2]	1 : 0.95 : 0.78	8.58	0.005	47.9	1.50	3.50	101.60	0.50	good	620	practically all large aggregate fractured
Z-K-C[1]	1 : 0.74 : 0.88	9.47	none	42.8	0.85	1.50	104.80	0.40	slightly harsh and dry	655	few large air voids; all large aggregate fractured
Z-K-C[2]	1 : 0.94 : 0.71	8.81	none	43.4	3.15	2.00	99.70	0.44	slightly harsh	545	few large air voids; all large aggregate fractured
P-K-C[1]	1 : 0.89 : 0.74	8.88	0.005	38.2	5.32	7.50	98.80	0.38	slightly harsh; bleeds some	605	all large aggregate fractured; few large air voids
Z-K-D[2]	1 : 0.91 : 0.69	9.04	none	42.7	2.86	4.00	100.60	0.41	very good	585	all large aggregate fractured; few air voids
P-K-D[1]	1 : 0.98 : 0.65	9.15	0.005	35.0	3.97	1.00	100.30	0.34	slightly harsh	615	2 or 3 pull-outs; all other fractures
P-K-D[2]	1 : 0.99 : 0.66	8.82	0.005	39.0	4.77	6.00	98.40	0.39	easily placed too wet	575	few pull-outs
P-K-E[2]	1 : 0.99 : 0.66	9.35	0.005	39.7	4.02	1.50	102.80	0.37	very good	625	very few pull-outs mostly aggregate fracture
L-K-A[2]	1 : 0.92 : 0.69	9.40	0.005	33.9	8.05	2.00	100.30	0.32	placed well	585	few pull-outs numerous air voids
L-K-A[1]	1 : 0.99 : 0.66	9.26	0.005	30.0	9.14	0.50	98.70	0.29	very harsh	620	few pull-outs numerous air voids
P-K-E[1]	1 : 0.99 : 0.66	9.43	0.005	38.9	3.40	1.00	103.10	0.37	harsh but placeable	690	mostly aggregate fracture
P-K-F[1]	1 : 1.06 : 0.70	8.71	0.005	37.8	5.50	2.25	100.00	0.39	very good	-	-

a/ The flexural strength after curing for 28 days in fog-room is included.

b/ The first letters: P = portland cement; Z = portland pozzolan cement; L = high-alumina hydraulic cement.
The second letter: K = Kenlite aggregate.
The third letter = batch identification, with superscript[1] indicating that the aggregate was used in the same proportion as received; superscript[2] indicating that the aggregate was screened and recombined using the gradation that was used throughout this project, NBS Report 3012, Figure 1.

c/ Mixer charged with saturated aggregate. Coarse and fine aggregate was immersed in water 18 hours and allowed to drain 18 hours before mixing.

An increase in cement content, systematic changes in the ratio of coarse-to-fine aggregate, and a reduction in air and water content have failed to yield a concrete of satisfactory strength. This aggregate is marketed in a top size of +1/2 inch. The ratio of coarse-to-fine aggregate has been increased until the concrete is difficult to place (too harsh). The manufacturer has been contacted for the purpose of obtaining a larger top size aggregate. The introduction of a larger size, but in the same amount, may yield a concrete with good placeability and sufficient flexural strength.

Table 4 gives information similar to that in Tables 2 and 3 but covering trial batches of mixes designed with sintered slag from the second shipment. The results of tests of these trial batches indicate that sufficient strength will develop in concretes with a much lower cement content than first indicated when the slag originally furnished was used. Table 4 also gives the composition and the properties of the fresh concrete of a final, 15 cubic foot batch, of concrete designed with the high-alumina hydraulic cement and using sintered slag from the second shipment as the aggregate. Due to the limited capacity of our mixer, namely five cubic foot, it was necessary to make three separate batches (L-SS-1,2,3) identical in composition,

TABLE 4. PROPERTIES OF FRESH CONCRETES[a/]

"Containing Sintered Slag"

Identification[b/]	Proportions by Weight:Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by Weight of Cement	Water Content[c/]	Air Content Gravimetric	Slump	Weight of Fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Remarks Cured Concrete
		sacks/yd³ of concrete	percent	gals/yd³ of concrete	percent	inches	lbs/ft³			psi	
Z-SS-G	1 : 1.14 : 1.14	9.77	none	49.0	1.30	2.50	129.70	0.44	fair placeability; bleeding	860	50% pull-outs 50% fractured aggregate
P-SS-G	1 : 1.11 : 1.26	9.89	0.005	44.8	1.54	2.25	133.10	0.40	placed well; some bleeding	860	all large aggregate fractured; few pull-outs
L-SS-I	1 : 1.21 : 1.21	8.82	0.005	45.5	8.43	none[d/]	121.40	0.46	placed easily; too thin	520	mostly pull-outs few fractures
Z-SS-H	1 : 1.15 : 1.25	9.60	none	46.8	2.11	1.50	131.30	0.43	fair; slightly harsh	785	50% pull-outs 50% fractured aggregate
P-SS-H	1 : 1.14 : 1.29	9.66	0.005	46.0	1.50	2.75	132.50	0.42	very good	785	50% pull-outs 50% fractured aggregate
L-SS-J	1 : 1.21 : 1.21	9.81	0.005	40.7	3.13	0.75	131.90	0.37	harsh but place-able	735	few pull-outs
L-SS-1	1 : 1.31 : 1.31	9.30	0.005	41.0	1.88	1.50	133.10	0.39	slightly harsh but placeable	-	-
L-SS-2	1 : 1.31 : 1.31	9.35	0.005	41.0	1.36	5.50	133.80	0.39	very good	-	-
L-SS-3	1 : 1.31 : 1.31	9.17	0.005	40.0	3.20	2.25	131.30	0.39	slightly harsh but placeable	-	-

a/ The flexural strength after curing for 28 days in fog-room is included.

b/ The first letters: Z = portland pozzolan cement; P = portland cement; L = Lumnite, a high-alumina hydraulic cement.
The second set of letters; SS = sintered slag, Second Shipment.
The third letters = batch identification.
The third numerals 1, 2 and 3 = the three charges of the same batch.

c/ The mixer was charged with wetted aggregate. The fine portion of the aggregate was immersed in water 18 hours and not drained. The coarse aggregate was drained for one hour before placing in the mixer.

d/ Too fluid for slump measurement.

amount of water added, method of charging mixer, and time of mixing. The results indicate the variation that may be expected in handling this type of concrete.

Table 5 gives the flexural strengths of seven concretes after different curing periods. The results were obtained on prisms 3 x 4 x 16 inches therefore cannot be compared with the results for 6 x 6 x 20-inch beams fabricated from the same concretes. All concretes were designed with the lightweight aggregate "Kenlite" but with varying ratios of cement to coarse-to-fine aggregate. Some producers of lightweight aggregate recommend 35 days fog-room curing, others 42 days and some recommend additional curing or air drying. It is evident from these results that the curing, and curing and drying periods, affect the ultimate strength drastically.

Table 5. The Flexural Strength of Concretes, Containing a Lightweight Aggregate, as Related to Method of Curing.

Identification[a]	Curing Period[b]		Flexural Strength[c]
	Fog-room	Dried at laboratory Temperature	
	days	days	psi
P-K-A^1-1	7	76	440
P-K-A^1-2	83		655
P-K-A^2-1	7	77	265
P-K-A^2-2	84		795
P-K-B^1-1	7	69	270
P-K-B^1-2	76		730
P-K-B^2-1	7	69	245
P-K-B^2-2	76		695
Z-K-C^1-1	7	53	215
Z-K-C^1-2	60		725
Z-K-C^2-1	7	53	395
Z-K-C^2-2	60		655
P-K-C^1-1	7	53	225
P-K-C^1-2	60		695

a/The first letters: P = portland cement; Z = portland pozzolan cement. The second letter: K = Kenlite, the lightweight aggregate. The third letter identifies the composition of the mix and the superscript denotes the gradation of the aggregate. The numeral identifies the specimen. Specimens 1 and 2 were fabricated from same batch. Comparison of strength is intended betwee specimens 1 and 2 of a pair and not between pairs fabricated from different concretes.

b/The length of the curing period is given as a matter of informatio since it indicates the effect of extending the curing and drying on the flexural strength of concrete specimens. It is not neces sarily recommended as a suggested curing period or method. Base on the values of Young's modulus of elasticity, determined periodically by the dynamic method, the indication was that the strength became reasonably constant preceding the final seven days of curing and drying.

c/All specimens had seven days fog-room curing. One set identified by the numeral (1) was removed from fog-room after seven days and stored in laboratory at prevailing temperatures and humidities. The second set identified by the numeral (2) was stored in fog-room until tested. The average flexural strength of the specimen of the seven concretes that were cured for seven days in fog-room and dried in laboratory was 295 psi. The average for those tested out of fog-room was 705 psi.

[illegible]

CONFERENCE

A conference was held at the Bureau of Yards and Docks, December 1, 1954. The names of those attending follow:

Commander Stanley Rockefeller, Bureau of Yards and Docks

M. P. Harrington, Bureau of Yards and Docks

P. Knoop, Bureau of Yards and Docks

L. A. Palmer, Bureau of Yards and Docks

P. P. Brown, Bureau of Yards and Docks

S. E. Matullo, Bureau of Yards and Docks

J. A. Bishop, NAVCERELAB

R. A. Heindl, National Bureau of Standards

W. L. Pendergast, National Bureau of Standards

As a result of the investigative work thus far completed at the National Bureau of Standards the Department of the Navy, Bureau of Yards and Docks, instructed their laboratories at Port Hueneme, California, to place concrete aprons for field tests. The nine concretes selected and recommended for use in these field tests were those containing refractory aggregates. The recommendation was based on the evaluation of suitability tests of the 18 concretes investigated. The final nine concretes were further classified with respect to occurrence and accessibility of the aggregates and the cost of the cement.

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 ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, 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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