NATIONAL BUREAU OF STANDARDS REPORT

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QUARTERLY REPORT ON EVALUATION OF REFRACTORY QUALITIES OF CONCRETES FOR JET A IRCRAFT WARM-UP, POWER CHECK, AND MAINTENANCE A PRONS



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

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT

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

by

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NBS

R. A. Heindl, Chief Refractories Section

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

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.

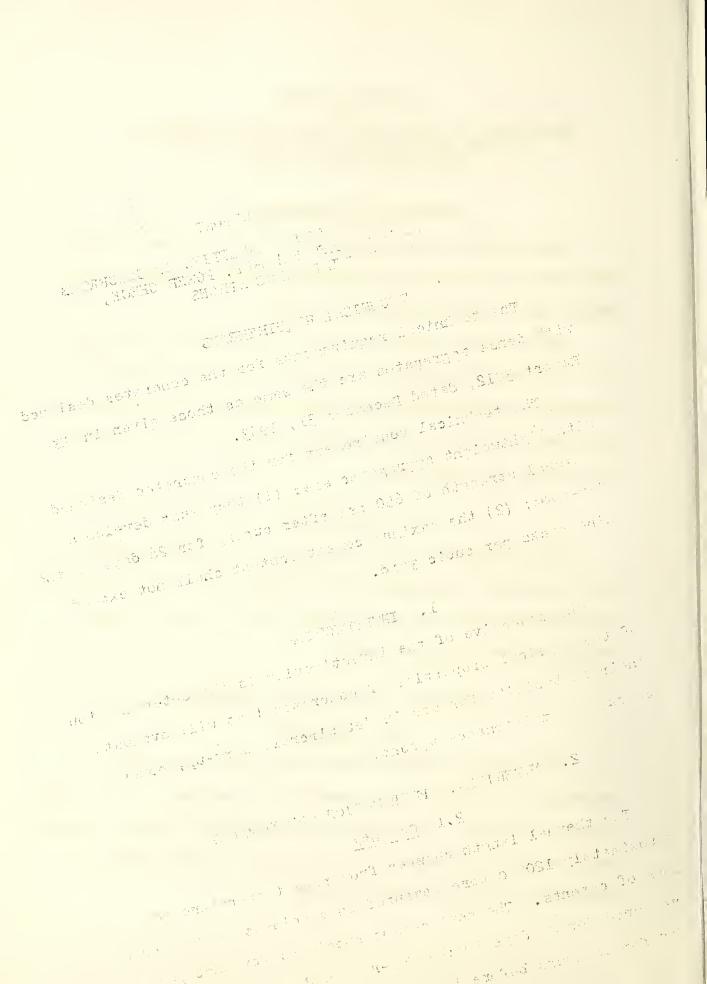
1. INTRODUCTION

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.



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2.2 Aggregates

A second shipment, totaling ten tons of sintered slag

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 lightweight 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 lightweight aggregate, "Rocklite". Five of these contained the portland cement, and one the portland pozzolan.

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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

^{*} 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.

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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.

Aggregate	Size	Bulk Specific Gravity <u>a</u> / <u>b</u> / 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	Coarse	1.83	9.20	67.5
Slag ^C	Fine	2.72	0.80	
Sintered	Coarse	2.1 6	3.86	45.3
Slag <u>d</u>	Fine	2 . 49	3.18	

Table 1. Properties of Lightweight Aggregates.

a/ Saturated surface-dry basis.

- b/ The gradation of the aggregate was the same as that used in designing the concretes.
- <u>C</u> First shipment of slag sintered at Armour Institute Laboratories.
- <u><u>d</u> <u>Second shipment</u> of slag sintered on contract by Armour Institute.</u>

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and the second			4	en de la compañía de Compañía de la compañía de la compañí
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			18 A A 19 19	

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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.

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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-C¹ and P-K-E¹ developed the required 650 psi. In both of these the cement content, as calculated, was over the nine-sack maximum permitted.

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TABLE 2. PROPERTIES OF FRESH CONCRETES⁸/

Rema rkcs	Cured Consrets		few pull-outs;	agregate	few pull-outs; mostly fractured	aggragate few pull-outs;	large aggregate fracturee	few pull-outs; large aggregate	Iractures		1
Flexural	Strength	1:Bd	615		575	535		590	1		1
Remarkes	Fresh Concrete		easily placed		placed well; sticky	easily placed		essily placed	harsh but nlaceahle		sticky but placeable
Water Cement	Ratio		0.38		0.37	0.37		0.35	72.0		0*/*0
Weight of	Fresh Concrete	1be/ft ³	36.90		102.50	07*66		09°101	02.66		66.40
cumi [5	dimen	inchee	é.00		3.00	6 . 00		2 .5 0	1.75		2,25
Air Content	Gravimetric	percent	6.78		2.25	4.25		3.19	2.82		2.46
Water Content®		gals/yd3 of congrete	39.1		40.3	38.2		36.9	34.3		39•4
Vinsol Resin by	Waight of Cement	percent	0.005		0.005	0.005		0*002	0.005		Brion
Cement Content		sacks/yd3 of concrete	9.15		9.75	91.6		9.38	8.97		8.68
Proportions by Weight:Cement	Fine Aggregate		1:0.84:0.69		1:0.84:0.69	1:0.68:0.72		1:0.89:0.73	1:1.03:0.68		02.°0 : 70°T : T
Identification ^b /		,	P-R-A	c	P-R-A <	P-R-B ¹		Б-н-д	P-R-C ¹	~ - <u>~</u> 2	

 $^{\rm M}$ The flexural strangth after curing for 28 days in fog-room is included.

^b The first latters: P = portland cement; 2 = portland pozzolan cement. The second latter: R = Rocklite aggregate. Affine third latters: = Batch identification, with superscript¹ indicating that the aggregate was used in the same proportions as received; Superscript² indicating that the aggregate was acreamed and recombined using the gradation that was used throughout this project, NBS Report 3012, Figure 1. g/ Mixes charged with saturated aggregats. Coarss and fine aggregate was immersed in water 18 hours and allowed to drain 18 hours before mixing.



TABLE 3. PROPERTIES OF FRESH CONCRETES

Rema rks	Cured Concrete		all large aggregate fractured; air voids	90% fracture; air voide	practically all large aggregate fractured	practically all large aggregate fractured	few large air voids; all large aggregate fractured	few large air voide; all large aggragate fractured	all large aggregate fractured; few large air woids	all large aggregate fractured; few air voide	2 or 3 pull-outs; all other fractures	few pull-oute	very few pull-oute mostly aggregate fracture	few pull-oute numerous air voide	few pull-oute mumerous air voids	mostly aggregate frecture	-
Flexural	Strength	pet	520	550	620	620	655	545	605	585	615	575	625	585	620	069	'
Rema rice	Fresh Concrete		bleede; aggregate eegregation	very good; elightly plastic	slightly harsh	good	alightly hareh and dry	slightly harsh	slightly harsh; bleede some	very good	slightly harsh	eaeily placed too wet	very good	placed well	very hareh	harsh but placeable	very good
Water	Ratio		0.54	0.39	00	0.50	0**0	*††	0.38	דוייס	0.34	60	0.37	0.32	0.29	0.37	0.39
Weight	Fresh Concrete	Ibs/ft ³	95.00	97.50	00.101	101.60	104.80	99.70	98.80	100.60	100.30	98.40	102.80	100.30	98.70	01.601	100.001
Clum, IS	Ì	inchee	too thin	2.50	1,25	3.50	1.50	2.00	7.50	4.00	1.00	00. 9	1.50	2 * 00	0*50	1.00	2.25
Air Content	Gravimetric	percent	2.00	7.05	4.72	1.50	0.85	3.15	5.32	2.86	3.97	4.77	4.02	8.05	٩٢.6	3.40	5.50
Water Contents		gals/yd3 of concrete	14.5	34.6	30°0	6*14	4.2.8	43.4	38,2	1.2.1	35.0	39.0	39.7	33.9	30.0	38.9	37.8
Vineol Resin by	Weight of Cement	percent	0.010	010.0	0.005	0.005	euou	euou	0.005	euou	0.005	0.005	0*005	0*005	0.005	0*002	0.005
Cement Content		sacks/yd3 of concrete	7.32	7.82	9.%	8.58	247-6	8.81	8.88	4.04	9.15	8.82	9.35	01.6	9.26	9.43	8.71
Proportions by Weight:Cement	ro coarse and to Fine Aggregate		1:0.83:1.10	01.1 : 0.88 : 1.10	1:0.95:0.78	1:0.95:0.78	1:0.74:0.88	1:0.94:0.71	1:0.89:0.74	1 : 0.91 : 0.69	1 : 0.98 : 0.65	1:0.99:0.66	1:0.99:0.66	l : 0.92 : 0.69	1:0.99:0.66	l : 0.99 : 0.66	1:1.06:0.70
Ident ification ^b /			P-K-A [±]	P-K-A ²	Ъ-К-В ^т	P-K-B ²	2-K-C ¹	2-K-C ²	P-K-C ¹	Z-K-D ⁴	P~K-D ¹	ь-К-0 ²	P-K-E	L-K-A	L-K-A ^L	P-K-E	P-K-P ¹

 $^{\underline{a}/}$ The flectural strength after curing for 28 days in fog-room is included.

^b The first letters: P = portland consert; Z = portland porzolan consert; L = high-alumina hydraulic consert. The second letter: K = Kanlike aggregate. The third letter = batch identification, with supersorpt¹ indicating that the aggregate was used in the same proportion as reselved; aupersorpt² indicating that the aggregate was correened and recombined using the gradation that was used throughout this project, NBS Report 3012, Figure 1, expression is a second in the indicating that the aggregate was correened and recombined using the gradation that was used throughout this project, NBS Report 3012, Figure 1,

^Q 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,

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TABLE 4. PROPERTIES OF FRESH CONCRETES^{3/} "Containing Sintered Slag"

Remarks	Cured Concrete		50% pull-oute 50% fractured aggregate	all large aggregate fractured; few pull-outs	mostly pull-outs few fractures	50% pull-oute 50% fractured aggregate	50% pull-outs 50% fractured aggregate	few pull-oute	ı	ı	t
Flexural	Strength	fed	8%0	860	520	785	785	735	I	ı	ı
Remarka	Fresh Concrete		fair placeability; bleeding	placed well; eome bleeding	placed eacily; too thin	fair; slightly harsh	very good	harsh but place- able	slightly harsh but placeable	very good	slightly harsh but placesble
Water	Ratio		•77*0	07*0	941.0	64.0	0.42	0.37	0.39	0.39	65° 0
Weight of	Fresh Concrete	lbe/ft ³	129.70	133.10	07777	131.30	132.50	131.90	133.10	133.80	131.30
Slumn		inchee	2.50	2•25	noned	1.50	2.75	0.75	1.50	5.50	2.25
Air Content	Gravimetrio	percent	1.30	1.54	8.43	2.11	1.50	3.13	1.88	1.36	3.20
Water Content ^C		gale/yd3 of concrete	0.64	8.44	45.5	146 . 8	0. <i>àt</i> i	1.04	0*17	0.14	0*0†
Vinsol Resin by	Weight of Cement	percent	euou	0*005	0.005	none	0.005	0*005	0.005	0*005	0.005
Cement Content		sacks/yd ³ of concrete	11.6	69*6	8.82	0,60	9°96	9.81	9.30	9.35	71.6
Proportions by Weight:Cement	w voarge ann w Fine Aggregate		1:1.1.4 Hunt	1:11:12	1:1.2:1.2	1:1.15:1.25	1:1.14:1.29	1:1.2:1.2	1:1.31:1.31	1:1.31:1.31	1:1.31:1.31
Identification ^{b/}			2-SS-Z	P-5S-G	I-SS-I	2 -SS-H	H-SS-4	L-SS-J	I-SS-1	Irss-2	L-SS-J

 $^{\underline{3}/}$ The flexonal strength after curing for 28 days in fog-room is included.

^b/ The first lettere: Z = portland pozolan camont; P = portland coment; L = Lummite, a high-alumina hydraulic cement. The second set of lettere; SS = suitered alse, <u>Second Shipment</u>. The third lettere = batch identification. The third numerals 1, 2 and 3 = the three charges of the same batch.

² The mixer was charged with wetted aggregate. The fine portion of the aggregate was immersed in water 16 hours and not drained. The coarse aggregate was drained for one hour before placing in the mixer.

 $\underline{d}/\ \text{Too}$ 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.

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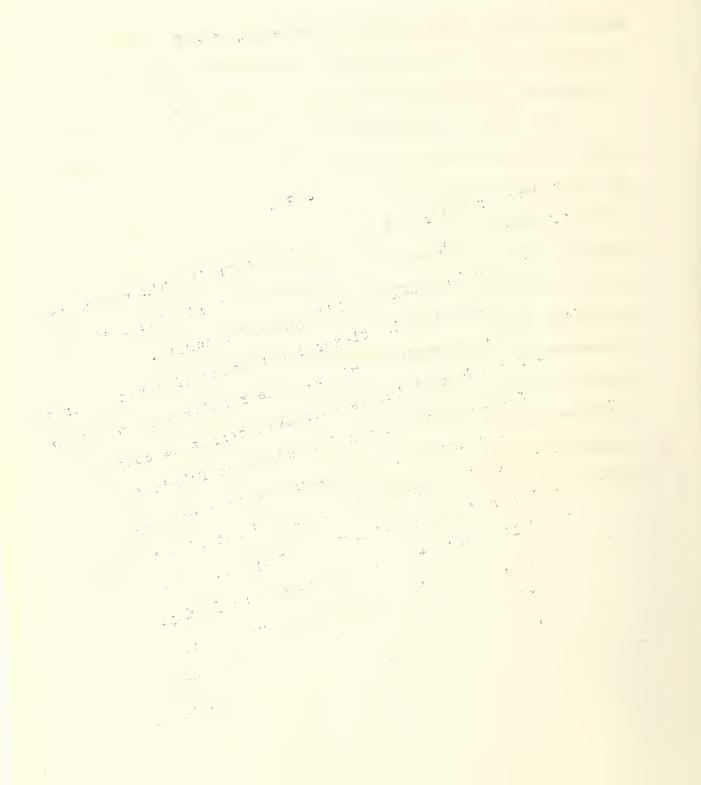
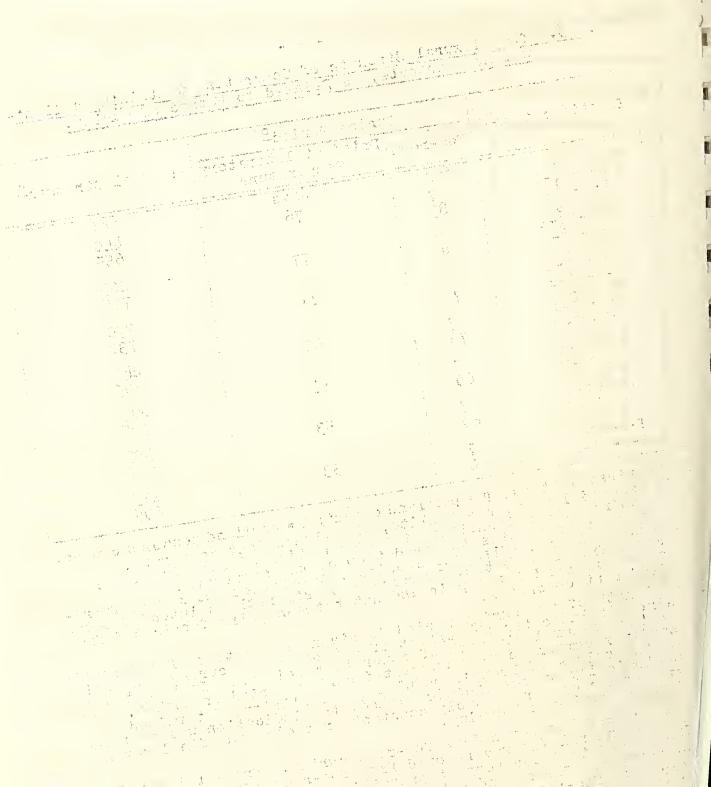


Table 5. The Flexural Strength of Concretes, Containing a Lightweight Aggregate, as Related to Method of Curing.

2/	Cu	uring Period ^{b/}	2/
Identification ^a	Fog-room	Dried at laboratory Temperature	Flexural Strength-
	days	days	psi
P-K-A ¹ -1	83	76	440
P-K-A ¹ -2	83		655
P-K-A ² -1	7	77	265
P-K-A ² -2	84		795
$P-K-B_1^1-1$	7	69	270
$P-K-B_1^1-2$	76		730
P-K-B2-1	7	69	245
P-K-B2-2	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
$\begin{array}{c} P-K-C^{1}-1\\ P-K-C^{1}-2 \end{array}$	7 60	53	225 695

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 l and 2 were fabricated from same batch. Comparison of strength is intended betwee specimens l 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.



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, NAVCEREIAB
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 con;aining 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. A second s

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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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