NATIONAL BUREAU OF STANDARDS REPORT

2419

QUARTERLY REPORT

ON

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

by

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U. S. DEPARTMENT OF COMMERCE
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QUARTERLY REPORT
ON
EVALUATION OF REFRACTORY QUALITIES OF CONCRETES
FOR JET AIRCRAFT, WARM UP, POWER CHECK, AND
MAINTENANCE APRONS

Current Technical Requirements

The preparation and mixing of each batch of concrete of the same composition must be so controlled as to result in a nearly constant air and water content.

The concretes must be of such a consistency as to yield a 2-in. slump when tested in accordance with A.S.T.M. Designation: C143-52[1a/]. If a concrete is not sufficiently workable to be placed properly at a 2-in. slump then this requirement may be modified.

The concrete must develop a flexural strength of 600-650 psi after a 28-day curing and aging treatment.

Resistance of the concrete to destruction when exposed to rapidly increasing and fluctuating temperatures is necessary.

The compressive strength shall be determined on each concrete after the 28-day combined curing and aging treatment.

I. INTRODUCTION

The objective of the investigation is the determination of such 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. Additional shipments of the three types of cement, portland, portland-pozzolan, and high-alumina hydraulic were received during this quarter. Lack of sufficient space in our cement storage room necessitates such periodic purchases. The cements were subjected to the same physical and chemical tests* as previous shipments. Although slight differences were indicated in the results between materials received at different periods such differences were considered not to be significant.

Aggregates. All aggregates were purchased in two grades, namely, the coarse grade to pass a 1-inch sieve and the fine to pass a No. 4 sieve. Additional crushing, screening, and recombining was necessary to obtain proper gradation.

The sieve analysis and the fineness modulus of the five dense aggregates, which are given in table 1, replace those given in a preceding report [2]. A comparison of the results given in the two tables indicates some differences. These are caused by adjustments in the gradation of the aggregates "as received" and "as used" in the concretes. The screen analysis given in table 1 indicates that the gradation of the coarse aggregates, with the exception of olivine, conforms to the requirements for coarse

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* Made by the Concreting Materials Section, Mineral Products Division, National Bureau of Standards.

aggregate in table II, A.S.T.M. Designation: C33-52T [1b/]. The fineness modulus of the combined fine and coarse aggregates, calculated in accordance with the respective proportions used in the mix, fall below 5.2. The recommended combined modulus of the aggregates for concretes of from seven to nine sacks of cement per cubic yard is 5.7 to 6.0 for the maximum-size aggregate of 1 inch. [3/]

Four of the dense aggregates were subjected to the Los Angeles Abrasion Test and the results are also given in table 1. The method used was that described in A.S.T.M. Designation: C131-51 [1c/]. The abrasion loss as determined was less than the maximum permissible loss of 50 percent as specified by A.S.T.M. Designation: C3-52T (Page 4 Abrasion, Paragraph 11a) [1d/].

III. DESIGN OF CONCRETES AND THE PREPARATION, TREATMENT AND TESTS OF SPECIMENS

As a result of information gained from the experimental mixes, four concretes were designed and mixed and five sets of specimens of each fabricated. The size, shape, and number of specimens composing a set have been previously reported. [2/] The composition and properties of the fresh concretes are given in table 2. A detailed description of the methods used in determining the properties was given in a previous report. [2/]

All specimens, after placing, were covered with wet burlap and left in the molds for a period of from 20 to 24 hours. They were then stripped and stored in a fog room for 6 days. After this treatment they were stored at ordinary laboratory temperatures and humidities for 21 days to permit drying preceding the heat treatments.

Twenty-three sets of specimens of ten concretes were tested during this quarter. Six of these concretes were designed and specimens fabricated during the preceding quarter, but the tests had not been completed. Five sets were tested after the 28-day treatment, six sets after an additional treatment of heating at 250°C for 5 hours, three sets at 500, six at 750, and three at 1000°C.

Specimens were subjected to the following tests: Compressive strength after 28-day treatment only; flexural strength, abrasion loss, dynamic modulus, after 28-day treatment, and after one of the following heat treatments - 250, 500, 750, and 1000°C. The linear change and weight loss was measured after each heat. A detailed description of the methods of testing was given in a previous report. 2/

The measurements of the thermal conductivity of eleven concretes were made* using the hot plate apparatus, a description of which is given in a previous report. [2/]

The resistance to freezing and thawing was determined ** of nineteen concretes using specimens measuring 3 x 4 x 16 inches. This test was conducted in accordance with A.S.T.M. Designation: C290-52T[1e/].

The results indicated that a cement content ranging from 5 to 7 bags per cubic yard of concrete designed with selected aggregates, treated and tested by the methods thus far used in this project, did not develop the required flexural strength of 600-650 psi. The cement content was, therefore, increased to range from 7 to 9 sacks. The water and air content were kept reasonably constant for each mix of the same concrete, with the exception of the portland-pozzolan-sand and gravel concrete. The slump measurements for all concretes was 2 inches ± 0.5 inches, the portland-pozzolan-sand and gravel concrete again being the exception. The variation in water content and the non-uniform and high air content of that concrete was due to the presence of an excessive amount of moisture, subsequently determined to be above that necessary for a saturated surface dry condition.

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

** Made by the Concreting Materials Section, Mineral Products Division, National Bureau of Standards.

IV. RESULTS AND DISCUSSIONS

Table 3 gives the results of the tests of cured and heat-treated concretes. These results are in agreement with those given in the previous report [4] and may be summarized as follows: The pozzolan-olivine concrete is the only concrete tested that, under the conditions of our tests, developed 600 psi flexural strength. This strength was developed after a heat treatment of 250°C for 5 hours. The additional test results indicate that the resistance to abrasion decreases with increasing heat treatments.

The linear change due to heating varies with the type of aggregate in the concrete. The linear change ranges from an expansion of 1.28 to a shrinkage of 0.8 percent. The weight loss due to heating ranged from approximately 4.5 to 14 percent.

Limestone is being investigated as a possible aggregate for heat-resisting concrete. It is referred to as "bluestone" in table 3 where some of the properties of the concrete designed with it are given. Also, figure 1 shows two specimens of this concrete. Specimen 1 received the 28-day treatment only whereas specimen 4 received that treatment and in addition was heated at 750°C for 5 hours. After removal from the kiln air slaking started almost immediately under ordinary laboratory atmospheric conditions resulting in deterioration of the specimen. The temperature at which specimen 4 was heated and the resulting deterioration would indicate that the limestone is of the dolomitic type. Dolomitic limestone (or calcium-magnesium-carbonate) decomposes at 730-760°C.

Figure 2 shows the thermal conductivity (k) of eighteen concretes measured at a mean temperature of approximately 115°F plotted against their densities (oven dry) in pounds per cubic foot

The key to the composition of the concretes shown in figure 2 is the same as indicated by note (a) of table 3. The first letter identifies the type of cement, namely: P = Portland; Z = Portland-pozzolan; L = Lumnite. The second letter denotes the type of aggregate, i.e., W = Waylite; R = Rocklite; H = Haydite; L = Lelite; B = Crushed building brick; BS = Bluestone; O = Olivine The numeral on the end is merely a laboratory identification. The concretes designed with light-weight aggregates which bear the numbers 1 to 13 are grouped together below the "4.5" k value. They have a density of less than 102 pounds per cubic foot. The other aggregates, designated in our reports as "dense" show a straight-line relation between conductivity and density.

The durability factor was calculated of 61 specimens of 19 concretes. The tests were made* and the durability factor determined in accordance with A.S.T.M. Designation: C290-52T [1e/]. The results of these tests, given in table 4, indicate that in most instances the ability of the concretes to withstand freezing and thawing was lessened when specimens were subjected to a temperature of 1000°C. For specimens heated at lower temperatures no definite trend in the durability factor was apparent.

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* Made by the Concreting Materials Section, Mineral Products Division, National Bureau of Standards.

Conference

Mr. M. P. Harrington, Bureau of Yards and Docks, and Mr. S. L. Bugg, U. S. Naval Civil Engineering Research and Evaluation Laboratory conferred at this Bureau on March 25, 1953. They discussed this project with R. A. Heindl and W. L. Pendergast of the Refractories Section, and B. E. Foster and R. A. Clevenger of the Concreting Materials Section of this Bureau. The purpose of the conference was to discuss specific procedures in designing, fabricating, curing and testing of refractory concretes. Suggestions were made on gradation of aggregates, control of air content, maximum cement content, and methods and time of curing which when applied should be of value in bringing the flexural strength requirement to the specified minimum of 600-650 psi.

Bibliography

1. A.S.T.M. Standards on Mineral Aggregates, Concretes and Nonbituminous Highway Materials, October, 1952.

    (a) Standard Method of Test for Slump of Portland-Cement Concrete, page 187.

    (b) Tentative Specifications for Concrete Aggregates, page 3.

    (c) Standard Method of Test for Abrasion of Coarse Aggregates by Use of the Los Angeles machine, page 27.

    (d) Tentative Specifications for Concrete Aggregate, page 4. Paragraph 11(a).

    (e) Tentative Method of Test for Resistance of Concrete Specimens to Rapid Freezing and Thawing in Water, page 161.

2. National Bureau of Standards Report 1817.

3. Extending Application of the Fineness Modulus, Journal of American Concrete Institute, Part 2, December 1947. Proceedings v. 43.

4. National Bureau of Standards Report 2198.

Bulk Specific Gravity S.S.Dry c/	Water Absorption Percent by weight	Los Angeles Abrasion d/ Percentage of wear
2.74	0.24	21.3
2.64	1.06	
2.26	8.93	
2.27	9.60	47.6
2.37	6.10	
2.52	4.76	23.5
2.50	5.03	
2.97	3.20	--
3.09	1.00	
2.64	0.30	40.5
2.63	0.30	

e Aggregates", ASTM Standards on

Table 1. Properties of Aggregates

Materials: Identification	Materials: Size	Sieve Analysis — Amount passing U. S. Standard Sieve, percent by weight: 1"	3/4"	1/2"	3/8"	Nos. 4	8	16	30	50	100	200	Fineness Modulus of Aggregates a/: Coarse & Fine	Combined	Unit Weight lbs/ft^3: Loose	Jigged b/	Bulk Specific Gravity: S.S.Dry c/	Water Absorption: Percent by weight	Los Angeles Abrasion d/: Percentage of wear
Bluestone	Coarse	100.0	99.1	71.6	22.7	3.1	2.0	—	—	—	—	—	6.73	4.88	83.6	98.0	2.74	0.24	21.3
	Fine	--	—	—	100.0	99.4	81.9	56.3	35.0	21.5	14.6	11.2	3.01		99.8	113.0	2.64	1.06	
Building Brick	Coarse	100.0	99.1	66.8	15.2	4.4	3.9	—	—	—	—	—	6.77		61.4	71.9	2.26	8.93	
	Medium	—	—	100.0	98.3	16.5	5.4	4.3	—	—	—	—	5.75	5.07	60.5	70.3	2.27	9.60	47.6
	Fine	—	—	—	100.0	99.9	73.1	54.1	40.7	29.1	17.5	7.5	2.85		80.1	91.9	2.37	6.10	
Flint-clay Raw	Coarse	100.0	81.2	53.0	28.7	—	—	—	—	—	—	—	6.90	5.15	86.0	101.5	2.52	4.76	23.5
	Fine	—	—	—		100.0	70.7	49.2	29.1	15.9	8.2	1.9	3.30		80.9	95.0	2.50	5.03	
Olivine	Coarse	—	100.0	85.3	70.9	54.3	45.6	40.2	34.4	23.6	10.2	—	4.20	3.88	124.8	146.7	2.97	3.20	--
	Fine	—	—	—	100.0	99.9	99.3	82.7	66.8	37.6	13.6	4.0	2.00		114.4	130.5	3.09	1.00	
White Marsh Gravel	Coarse	100.00	84.76	59.5	35.3	3.5	—	—	—	—	—	—	5.96	5.16	101.1	110.9	2.64	0.30	40.5
Sand	Fine	—	—	—	100.0	97.9	80.00	64.9	49.5	22.0	4.1	1.2	2.82		100.4	112.0	2.63	0.30	

a/ Indicates distribution of sizes of aggregate as determined by ASTM method C125-43 "Standard Definitions of Terms Relating to Concrete and Concrete Aggregates", ASTM Standards on Mineral Aggregates, Concrete and Nonbituminous Highway Materials, Sept. 1948, page 70.

b/ Indicates bulking or fitting together of various sizes of aggregates.

c/ "S.S." Saturated aggregate - Surface Dry.

d/ Grading B aggregate was used in all cases with the exception of the Sand and Gravel where grading A was used.

Labo
ident

L-C
L-C
L-C

Z-S
Z-S
Z-S

Z-R
Z-R
Z-R

P-E
P-E
P-E

a/

Table 2. Properties of the fresh concretes.

Laboratory identification a/	Proportions by weight., Cement to fine and to coarse aggregate	Cement content	Vinsol resin by weight of cement	Water content	Air content	Slump	Weight	Workability Notes
		Sacks/yd^3 of concrete	%	Gal/yd^3 of concrete	%	in.	Lb/ft^3	
L-O-A	1:0.55:3.24	8.8	0.02	51.2	0.45	1.50	162.7	Excellent - fatty - slight bleeding
L-O-B	1:0.55:3.24	8.8	0.02	51.5	0.65	2.50	162.2	" " "
L-O-C	1:0.55:3.24	8.8	0.02	50.7	1.10	1.75	161.7	" " excessive bleeding
Z-S-A	1:1.59:2.26	7.8	0.01	30.4	7.80	9.50	140.5	Excellent workability
Z-S-B	1:1.59:2.26	7.8	0.01	26.0	9.90	5.50	140.0	" "
Z-S-C	1:1.59:2.26	7.8	0.01	26.0	10.20	6.75	139.5	" "
Z-RC-A	1:1.24:1.56	9.3	0.01	54.5	3.44	1.75	139.3	Fair workability - rich
Z-RC-B	1:1.24:1.56	9.4	0.01	54.0	2.83	2.12	140.5	Good workability - "
Z-RC-C	1:1.24:1.56	9.3	0.01	54.9	3.16	2.12	139.5	Fair workability - "
P-RC-A	1:1.24:1.56	9.3	0.01	53.2	2.64	2.00	140.7	Poor - sticky - rich
P-RC-B	1:1.24:1.56	9.3	0.01	52.3	3.29	2.06	140.5	" " "
P-RC-C	1:1.24:1.56	9.3	0.01	52.3	2.80	2.00	140.7	" " "

a/ The first letter indicates the type of cement, namely: P = portland, Z = portland-pozzolan; L = lumnite.

The second letter indicates the type of aggregate: O = olivine; S = sand and gravel; RC = raw flint clay.

The third letter indicates different batches of the same concrete. Several batches of each concrete were necessary to cast the required amount of specimens.

Table 3. Properties of cured and heat-treated concretes

Laboratory identification a/	Proportions by weight. Cement to fine and to coarse aggregate	Compressive strength 6 x 12 in. cylinders	Flexural strength 6 x 6 x 36 in. beam b/	Abrasion loss	Young's Modulus of Elasticity: Dynamic, Before heating	Young's Modulus of Elasticity: Longitudinally, After heating c/	Linear shrinkage after heating	Weight loss during heating
		lb/in 2/	lb/in 2/	gm	lb/in2/x 10^6		%	%
Z-O-1	1:0.58:3.40	4205	425	45.5	5.190	—	—	—
Z-O-2	do	5800	600	56.6	5.138	3.585	0.18	5.40
Z-O-3	do	—	455	73.2	5.257	2.736	0.02	4.48
Z-O-4	do	—	198	155.9	5.190	1.460	0.50	5.10
Z-O-5	do	—	145	351.8	4.653	0.972	0.55	6.92
P-O-1	1:0.55:3.24	4240	484	66.9	5.558	—	—	—
P-O-2	do	—	514	89.2	5.530	3.831	0.18	5.05
P-O-3	do	—	459	80.5	5.722	2.899	0.04	6.18
P-O-4	do	—	148		5.425	0.856	0.45	7.72
P-O-5	do	—			5.962			
L-O-1	1:0.55:3.24	5890	378	82.5	5.684	—	—	—
L-O-2	do	—	400		6.045	2.778	-0.04	6.22
L-O-3	do	—			5.913			
L-O-4	do	—			5.960			
L-O-5	do	—			5.627			
Z-BS-1	1:1.43:1.59	4620	405	15.2	5.132	—	—	—
Z-BS-2	do	—	360	23.0	5.273	2.694	-0.16	5.39
Z-BS-3	do	—	155	25.9	4.876	0.702	-0.73	6.43
Z-BS-4	do	—	— e/	44.5	4.937	0.299	-1.25	13.88
Z-BS-5	do	—	— e/	—	4.876	—	—	—
P-BS-1	1:1.55:1.72	4000	420	14.9	5.470	--	—	—
P-BS-2	do	—	340	13.1	5.710	3.051	-0.18	4.78
P-BS-3	do	—	150	28.1	5.647	0.689	-1.04	6.25
P-BS-4	do	—	— e/	--	5.353	0.213	-1.28	10.59
P-BS-5	do	—	— e/	—	5.471	—	—	—
Z-B-1	d/ 1:0.86:0.66:0.99	4890	395	15.7	2.910	—	—	—
Z-B-2	do	—	550	31.5	2.866	1.865	0.02	6.32
Z-B-3	do	—	529	34.5	2.929	1.392	0.16	7.83
Z-B-4	do	—	276		2.910	0.767	0.08	9.64
Z-B-5	do	—	140	68.0	2.911	0.734	0.21	9.80
L-[illegible]	1:0.82:0.63:0.95	5300	300	26.3	2.733	—	--	—
L-B-[illegible]	do	—	350	54.5	2.573	1.257	0.14	6.89
L-B-3	do	—	300	62.0	2.775	0.770	0.19	8.90
L-B-4	do	—	148		2.874	0.550	0.11	11.30
L-B-5	do	—	151	59.5 f/	2.819	0.560	0.08	12.11
P-RC-1	1:1.24:1.56	4010	238		3.458	—	—	—
P-RC-2	do	--			3.342			
P-RC-3	do	--			3.413			
P-RC-4	do	—			3.515			
P-RC-5	do	—			3.426			
Z-RC-1	1:1.24:1.56	3400	269		3.055	—	—	—
Z-RC-2	do	—	312		3.089	2.001	0.30	10.70
Z-RC-3	do	—			3.009			
Z-RC-4	do	--			3.090			
Z-RC-5	do	—			3.125			
Z-S-1	1:1.59:2.26	4440	426	52.9	4.295	—	—	—
Z-S-2	do	—	416		4.298	2.550	-0.05	5.6
Z-S-3	do	—			4.261			
Z-S-4	do	—			4.290			
Z-S-5	do	—			4.284			

a/ The first letter indicates the type of cement, namely: P = portland; Z = portland pozzolan; L = Lumnite
The second letter indicates the type of aggregate: BS = bluestone; B = building brick; RC = raw flint clay; S = sand and gravel; O = olivine.
The numerals indicate: 1 = cured to 28 days only; 2,3,4, and 5 = cured to 28 days and heat treated at 250°C, 500°C, 750°C, and 1000°C respectively, for 5 hours.

b/ All blank spaces indicate that specimens have been fabricated and cured but not heat treated and tested.

c/ Specimens were heated at an approximate rate of 50°C per hour to maximum temperature. After equilibrium was reached they were held at this temperature for 5 hours. (See note a/ for details of heat treatments.)

d/ Cement : Fine : Medium : Coarse aggregates.

e/ Disintegrated on cooling

f/ Failure of apparatus after 4 minutes operation.

Table 4. Results of Freezing and Thawing Tests

Identification a/	Durability factor b/	Identification a/	Durability factor b/	Identification a/	Durability factor b/
P-H-1	27.2	L-R-1	22.6	Z-W-1	75.8
P-H-2	16.2	L-R-2	4.4	Z-W-3	78.9
P-H-3	28.8	L-R-4	11.2	Z-W-4	15.7
P-H-5	6.8	L-R-5	8.0	Z-W-5	5.6
L-H-1	23.1	P-R-1	33.4	Z-P-1	18.0
L-H-2	10.0	P-R-2	36.0	Z-P-2	9.6
L-H-2	2.6	P-R-4	21.7	Z-P-4	9.0
L-H-4	16.6	P-R-5	14.0	Z-BS-2	1.9
Z-H-2	14.2	Z-R-1	24.0	Z-BS-3	1.1
Z-H-3	50.8	Z-R-2	29.0	Z-BS-4	Disintegrated
Z-H-4	27.0	Z-R-4	22.5	P-BS-1	133.0
Z-H-5	2.3	Z-R-5	3.6	P-BS-2	19.9
P-L-1	4.2	P-W-1	11.6	P-BS-3	1.0
P-L-4	2.0	P-W-2	10.9	P-O-1	33.2
L-L-1	22.4	P-W-4	3.2	P-O-3	22.9
L-L-3	3.0	P-W-5	13.0	Z-O-4	3.4
Z-L-1	9.0	L-W-1	11.2	Z-B-2	33.6
Z-L-3	8.6	L-W-2	16.6	Z-B-3	28.6
Z-L-4	3.7	L-W-3	18.0	L-B-2	29.0
		L-W-4	22.0	L-B-3	15.0
		L-W-5	20.0	L-B-5	16.9

a/ The first letter indicates the type of cement, namely, P = Portland; Z = Portland-pozzolan; L = Lumnite. The second letter or letters indicates the type of aggregate, namely, H = Haydite; L = Lelite; R = Rocklite; W = Waylite; P = Pumice; BS = Bluestone; O = Olivine; and B = Building brick.

The numerals indicate the temperature at which heat treatment took place, namely, 1 = Room temperature; 2 = 250°C; 3 = 500°C; 4 = 750°C; and 5 = 1000°C.

b/ Durability factor in freezing and thawing is based on reduction of sonic modulus of elasticity. 100 implies no change whereas 0 denotes poor resistance.

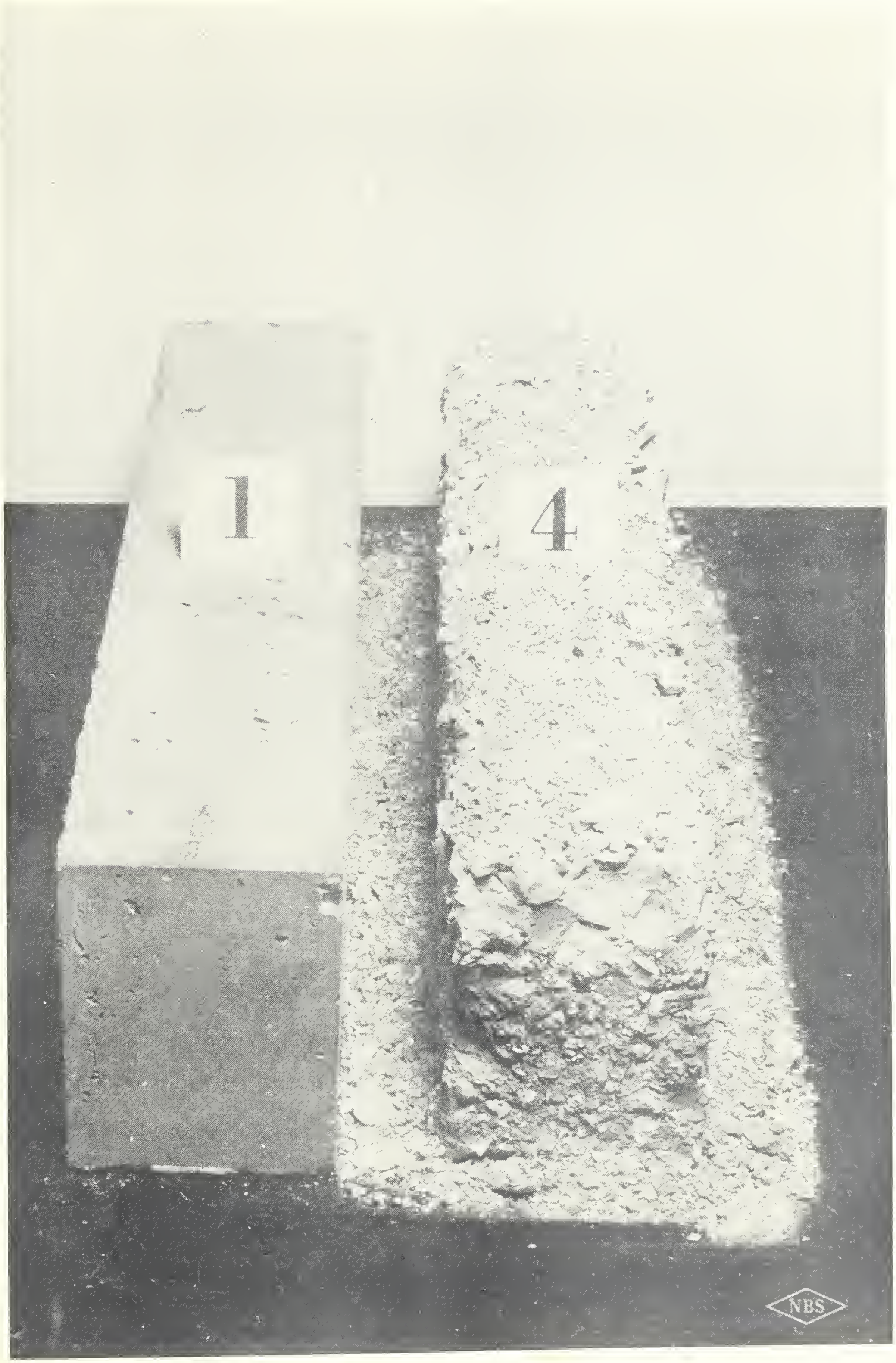

FIG. 1

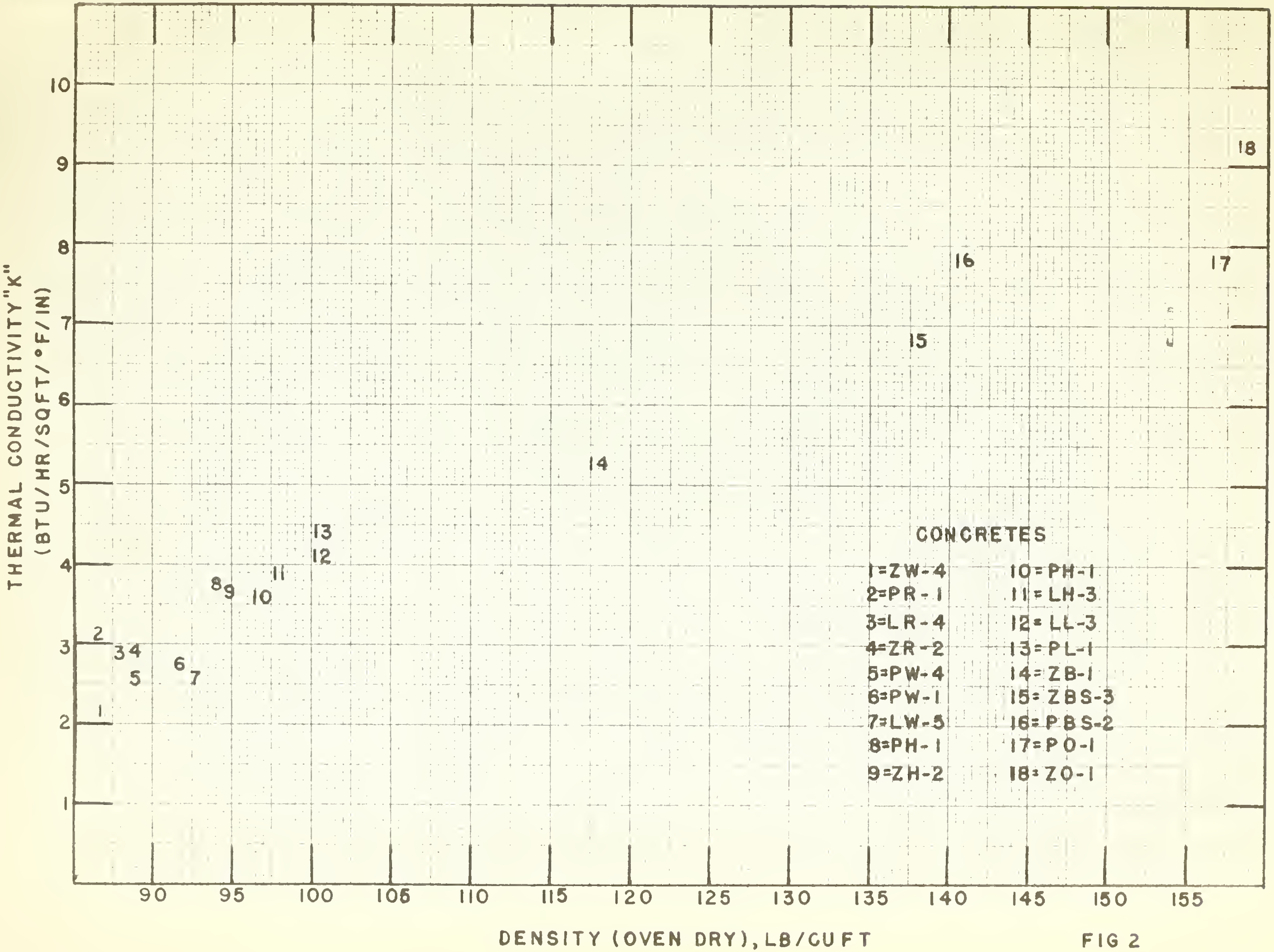
THERMAL CONDUCTIVITY "K"
(BTU/HR/SQFT/°F/IN)
10
9
8
7
6
5
4
3
2
1
90
95
100
105
110
115
120
125
130
135
140
145
150
155
DENSITY (OVEN DRY), LB/CUFT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
CONCRETES
1=ZW-4
2=PR-1
3=LR-4
4=ZR-2
5=PW-4
6=PW-1
7=LW-5
8=PH-1
9=ZH-2
10=PH-1
11=LH-3
12=LL-3
13=PL-1
14=ZB-1
15=ZBS-3
16=PBS-2
17=PO-1
18=ZO-1

FIG 2

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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