

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

W. L. Pendergast, C. R. Enoch, R. A. Clevenger
Refractories Section
Mineral Products Division



U. S. DEPARTMENT OF COMMERCE
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Sponsored by
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QUARTERLY REPORT
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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.

THE HISTORY OF THE CITY OF BOSTON

The city of Boston, situated on a neck of land between the harbor and the bay, was first settled by a few Englishmen in 1630. It was the first of the New England colonies, and its history is a record of the struggle for freedom and independence.

The city was founded by a group of Puritan settlers who had fled from the religious persecution of the Church of England. They established a self-governing community, and their actions were a direct challenge to the authority of the British crown.

The city's growth was rapid, and it soon became the center of the New England trade. Its harbor was the busiest in the colonies, and its ships carried goods to all parts of the world. The city's economy was based on commerce and industry, and its citizens were proud of their achievements.

The city's history is marked by a series of events that led to the American Revolution. The Boston Tea Party, the Boston Massacre, and the Siege of Boston were all part of the struggle for independence. The city's citizens were brave and determined, and their actions inspired the rest of the colonies.

The city of Boston is a city of many firsts. It was the first city to have a public library, the first city to have a fire department, and the first city to have a police force. Its history is a testament to the spirit of freedom and independence that has always been at the heart of the American people.

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

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

The first part of the document discusses the importance of maintaining accurate records of all transactions. It emphasizes that every entry should be supported by a valid receipt or invoice. This ensures transparency and allows for easy verification of the data.

In the second section, the author outlines the various methods used to collect and analyze the data. This includes both manual and automated processes. The goal is to ensure that the data is as accurate and reliable as possible.

The third part of the document provides a detailed breakdown of the results. It shows that there has been a significant increase in sales over the period covered. This is attributed to several factors, including improved marketing strategies and better customer service.

Finally, the document concludes with a series of recommendations for future actions. These include continuing to invest in marketing, improving operational efficiency, and maintaining high standards of customer service.

Prepared by: [Name]

Date: [Date]

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 \pm 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.

* 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 ⁴/₄ 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}/₂. 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.

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

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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	47.6
2.27	9.60	
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		Sieve Analysis											Fineness Modulus of Aggregates ^{a/}		Unit Weight		Bulk Specific Gravity	Water Absorption	Los Angeles Abrasion ^{d/}
Identifica- tion	Size	Amount passing U. S. Standard Sieve, percent by weight											Coarse & Fine	Combined	lbs/ft ³		S.S.Dry ^{c/}	Percent by weight	Percentage of wear
		1"	3/4"	1/2"	3/8"	Nos.									Loose	Jigged ^{b/}			
						4	8	16	30	50	100	200							
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 Sand	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
	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.

Labor
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L-C
L-C
L-C

Z-S
Z-S
Z-S

Z-F
Z-F
Z-F

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	Vinsol	Water	Air	Slump	Weight	Workability Notes
		content	resin by weight of cement	content	content	in.	Lb/ft ³	
		Sacks/yd ³ of concrete	%	Gal/yd ³ of concrete	%			
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.

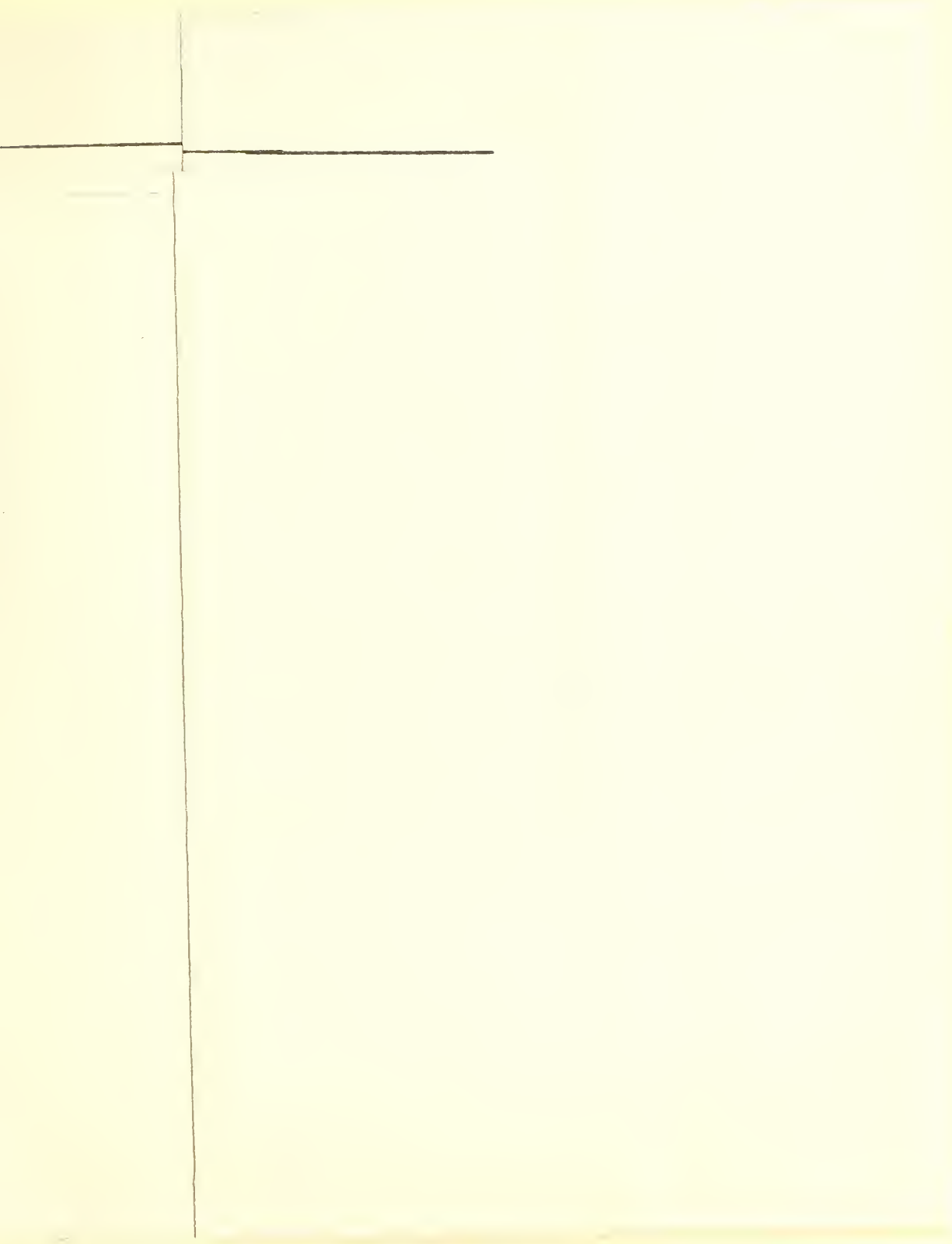


Table 3. Properties of cured and heat-treated concretes

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		Linear shrinkage after heating	Weight loss during heating
					Dynamic	Longitudinally		
					Before heating	After heating ^{c/}		
		lb/in ^{2/}	lb/in ^{2/}	gm	lb/in ² /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-B-1	1:0.82:0.63:0.95	5300	300	26.3	2.733	—	—	—
L-B-2	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

Identifi- cation <u>a/</u>	Durability factor <u>b/</u>	Identifi- cation <u>a/</u>	Durability factor <u>b/</u>	Identifi- cation <u>a/</u>	Durability factor <u>b/</u>
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-4	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-3	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.

THE HISTORY OF THE COUNTY OF MIDDLESEX

Parish	Population	Area	Notes
St. Andrew	100	100	
St. Martin	150	150	
St. Dunstons	200	200	
St. Giles	250	250	
St. James	300	300	
St. John	350	350	
St. Peter	400	400	
St. Paul	450	450	
St. Andrew	500	500	
St. Martin	550	550	
St. Dunstons	600	600	
St. Giles	650	650	
St. James	700	700	
St. John	750	750	
St. Peter	800	800	
St. Paul	850	850	
St. Andrew	900	900	
St. Martin	950	950	
St. Dunstons	1000	1000	
St. Giles	1050	1050	
St. James	1100	1100	
St. John	1150	1150	
St. Peter	1200	1200	
St. Paul	1250	1250	
St. Andrew	1300	1300	
St. Martin	1350	1350	
St. Dunstons	1400	1400	
St. Giles	1450	1450	
St. James	1500	1500	
St. John	1550	1550	
St. Peter	1600	1600	
St. Paul	1650	1650	
St. Andrew	1700	1700	
St. Martin	1750	1750	
St. Dunstons	1800	1800	
St. Giles	1850	1850	
St. James	1900	1900	
St. John	1950	1950	
St. Peter	2000	2000	
St. Paul	2050	2050	
St. Andrew	2100	2100	
St. Martin	2150	2150	
St. Dunstons	2200	2200	
St. Giles	2250	2250	
St. James	2300	2300	
St. John	2350	2350	
St. Peter	2400	2400	
St. Paul	2450	2450	
St. Andrew	2500	2500	
St. Martin	2550	2550	
St. Dunstons	2600	2600	
St. Giles	2650	2650	
St. James	2700	2700	
St. John	2750	2750	
St. Peter	2800	2800	
St. Paul	2850	2850	
St. Andrew	2900	2900	
St. Martin	2950	2950	
St. Dunstons	3000	3000	
St. Giles	3050	3050	
St. James	3100	3100	
St. John	3150	3150	
St. Peter	3200	3200	
St. Paul	3250	3250	
St. Andrew	3300	3300	
St. Martin	3350	3350	
St. Dunstons	3400	3400	
St. Giles	3450	3450	
St. James	3500	3500	
St. John	3550	3550	
St. Peter	3600	3600	
St. Paul	3650	3650	
St. Andrew	3700	3700	
St. Martin	3750	3750	
St. Dunstons	3800	3800	
St. Giles	3850	3850	
St. James	3900	3900	
St. John	3950	3950	
St. Peter	4000	4000	
St. Paul	4050	4050	
St. Andrew	4100	4100	
St. Martin	4150	4150	
St. Dunstons	4200	4200	
St. Giles	4250	4250	
St. James	4300	4300	
St. John	4350	4350	
St. Peter	4400	4400	
St. Paul	4450	4450	
St. Andrew	4500	4500	
St. Martin	4550	4550	
St. Dunstons	4600	4600	
St. Giles	4650	4650	
St. James	4700	4700	
St. John	4750	4750	
St. Peter	4800	4800	
St. Paul	4850	4850	
St. Andrew	4900	4900	
St. Martin	4950	4950	
St. Dunstons	5000	5000	
St. Giles	5050	5050	
St. James	5100	5100	
St. John	5150	5150	
St. Peter	5200	5200	
St. Paul	5250	5250	
St. Andrew	5300	5300	
St. Martin	5350	5350	
St. Dunstons	5400	5400	
St. Giles	5450	5450	
St. James	5500	5500	
St. John	5550	5550	
St. Peter	5600	5600	
St. Paul	5650	5650	
St. Andrew	5700	5700	
St. Martin	5750	5750	
St. Dunstons	5800	5800	
St. Giles	5850	5850	
St. James	5900	5900	
St. John	5950	5950	
St. Peter	6000	6000	
St. Paul	6050	6050	
St. Andrew	6100	6100	
St. Martin	6150	6150	
St. Dunstons	6200	6200	
St. Giles	6250	6250	
St. James	6300	6300	
St. John	6350	6350	
St. Peter	6400	6400	
St. Paul	6450	6450	
St. Andrew	6500	6500	
St. Martin	6550	6550	
St. Dunstons	6600	6600	
St. Giles	6650	6650	
St. James	6700	6700	
St. John	6750	6750	
St. Peter	6800	6800	
St. Paul	6850	6850	
St. Andrew	6900	6900	
St. Martin	6950	6950	
St. Dunstons	7000	7000	
St. Giles	7050	7050	
St. James	7100	7100	
St. John	7150	7150	
St. Peter	7200	7200	
St. Paul	7250	7250	
St. Andrew	7300	7300	
St. Martin	7350	7350	
St. Dunstons	7400	7400	
St. Giles	7450	7450	
St. James	7500	7500	
St. John	7550	7550	
St. Peter	7600	7600	
St. Paul	7650	7650	
St. Andrew	7700	7700	
St. Martin	7750	7750	
St. Dunstons	7800	7800	
St. Giles	7850	7850	
St. James	7900	7900	
St. John	7950	7950	
St. Peter	8000	8000	
St. Paul	8050	8050	
St. Andrew	8100	8100	
St. Martin	8150	8150	
St. Dunstons	8200	8200	
St. Giles	8250	8250	
St. James	8300	8300	
St. John	8350	8350	
St. Peter	8400	8400	
St. Paul	8450	8450	
St. Andrew	8500	8500	
St. Martin	8550	8550	
St. Dunstons	8600	8600	
St. Giles	8650	8650	
St. James	8700	8700	
St. John	8750	8750	
St. Peter	8800	8800	
St. Paul	8850	8850	
St. Andrew	8900	8900	
St. Martin	8950	8950	
St. Dunstons	9000	9000	
St. Giles	9050	9050	
St. James	9100	9100	
St. John	9150	9150	
St. Peter	9200	9200	
St. Paul	9250	9250	
St. Andrew	9300	9300	
St. Martin	9350	9350	
St. Dunstons	9400	9400	
St. Giles	9450	9450	
St. James	9500	9500	
St. John	9550	9550	
St. Peter	9600	9600	
St. Paul	9650	9650	
St. Andrew	9700	9700	
St. Martin	9750	9750	
St. Dunstons	9800	9800	
St. Giles	9850	9850	
St. James	9900	9900	
St. John	9950	9950	
St. Peter	10000	10000	

The following table shows the population of the County of Middlesex in the year 1801, as ascertained by the first general census taken in England since the year 1700. The population of the County in that year was 1,000,000. The population of the County in the year 1801 was 1,200,000. The population of the County in the year 1811 was 1,400,000. The population of the County in the year 1821 was 1,600,000. The population of the County in the year 1831 was 1,800,000. The population of the County in the year 1841 was 2,000,000. The population of the County in the year 1851 was 2,200,000. The population of the County in the year 1861 was 2,400,000. The population of the County in the year 1871 was 2,600,000. The population of the County in the year 1881 was 2,800,000. The population of the County in the year 1891 was 3,000,000. The population of the County in the year 1901 was 3,200,000. The population of the County in the year 1911 was 3,400,000. The population of the County in the year 1921 was 3,600,000. The population of the County in the year 1931 was 3,800,000. The population of the County in the year 1941 was 4,000,000. The population of the County in the year 1951 was 4,200,000. The population of the County in the year 1961 was 4,400,000. The population of the County in the year 1971 was 4,600,000. The population of the County in the year 1981 was 4,800,000. The population of the County in the year 1991 was 5,000,000. The population of the County in the year 2001 was 5,200,000. The population of the County in the year 2011 was 5,400,000. The population of the County in the year 2021 was 5,600,000.

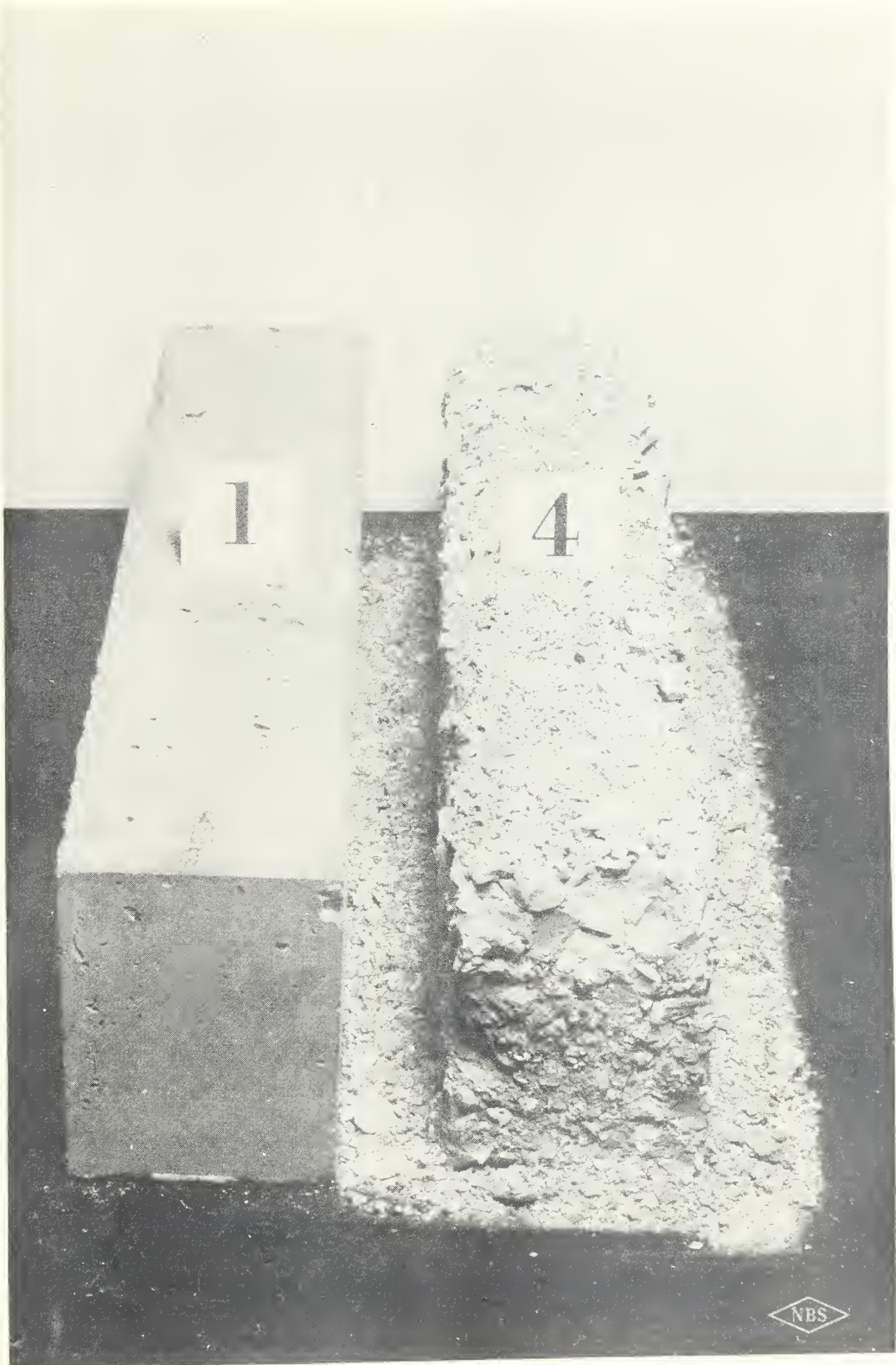


FIG. 1

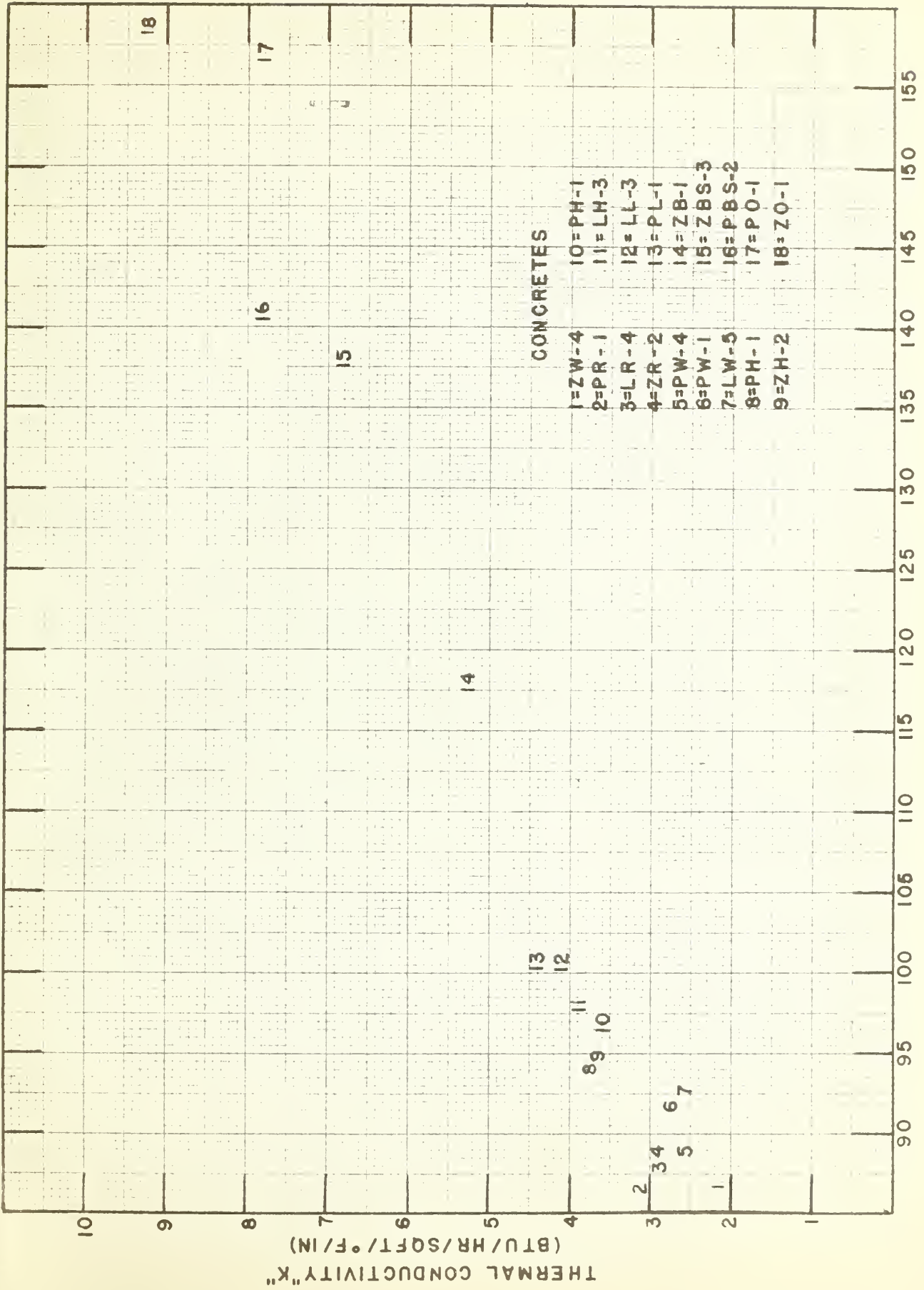


FIG 2

DENSITY (OVEN DRY), LB/CU FT

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.

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