NATIONAL BUREAU OF STANDARDS REPORT

7131

QUARTERLY REPORT

ON

EVALUATION OF REFRACTORY QUALITIES OF

CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK,

MAINTENANCE APRONS, AND RUNWAYS

by

W. L. Pendergast, E. C. Tuma, Bruce Foster

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers. These 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 periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

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 ($1.50), available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 1007-20-10472

April 24, 1961

NBS REPORT 7131

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

by

W. L. Pendergast, E. C. Tuma, Bruce Foster
Inorganic Building Materials Section
Building Research Division

Sponsored by

Department of the Navy
Bureau of Yards and Docks

Reference: Task Y-F015-15-102
NBS File No. 10.7/10472

Approved:
Bruce E. Foster, Assistant Chief
Inorganic Building Materials Section

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

QUARTERLY REPORT

ON

EVALUATION OF REFRACTORY QUALITIES OF CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK, MAINTENTANCE APRONS, AND RUNWAYS

1. INTRODUCTION

The purpose of this project is the development of criteria for the fabrication of jet exhaust resistant concretes. Concretes under development are evaluated by exposure to hot gases from a combustion chamber. The combustion chamber delivers these gases at velocities and temperatures approaching field conditions.

2. ACTIVITIES

The results of determinations completed have shown that the type of aggregate used, dense or porous, does not materially effect the permeability of the resultant concrete. It was suggested in the last NBS Report 7069 that the size of the pores and the relatively large pore volume of the blast-furnace slag was a reservoir into which the steam, resulting from the heating of the water present in the concrete during jet impingement, might be accommodated. This mechanism might be a factor in the increased resistance of blast-furnace slag concrete to jet impingement.

From absorption determinations, volume measurements, and published data* on the absolute specific gravity, of the blast furnace slag used, the value for total porosity, on the volume basis, was calculated and found to be 44.50%, the sealed pores 33.39% and the open pores 11.11%. The water absorption was 6.71% and the bulk density 1.65 gms/cm^3.

Since there are no data available on the permeability of blast-furnace slag, and it is used extensively as an aggregate, some work was done on the determination of this property. The National Bureau of Standards was fortunate in receiving from the Birmingham Alabama Steel District a large sample of pit-cooled blast furnace slag. From this piece two, 9 x 4 1/2 x 2 1/2 inch, specimens were sawed. For the purpose of getting representative specimens, one was sawed with the four and one-half inch dimension perpendicular to the top surface of the sample submitted and the other with this face parallel to the top surface. Both specimens were taken, as nearly as possible, from the center of the sample. The permeabilities of both specimens, dried at 110°C, were determined and Figure 1 shows results for specimen 1. The results indicated that the permeability of this type aggregate averaged 0.077 $\frac{cm^4}{(g)(sec)}$ of dry air at room temperature which is in the order of 60,000 times greater than the permeability of hardened concrete made with this type aggregate. Inasmuch as shaping specimens opened some of the normally closed pores of the slag, leaks between the specimen itself and the seal was possible. To avoid such an error in flow readings, these cut pores were wax sealed and the permeability redetermined, Figure 1. This resulted in a reduction in the value for permeability of three percent.

* Temin et al; Rock Products, p. 38, August 1931.

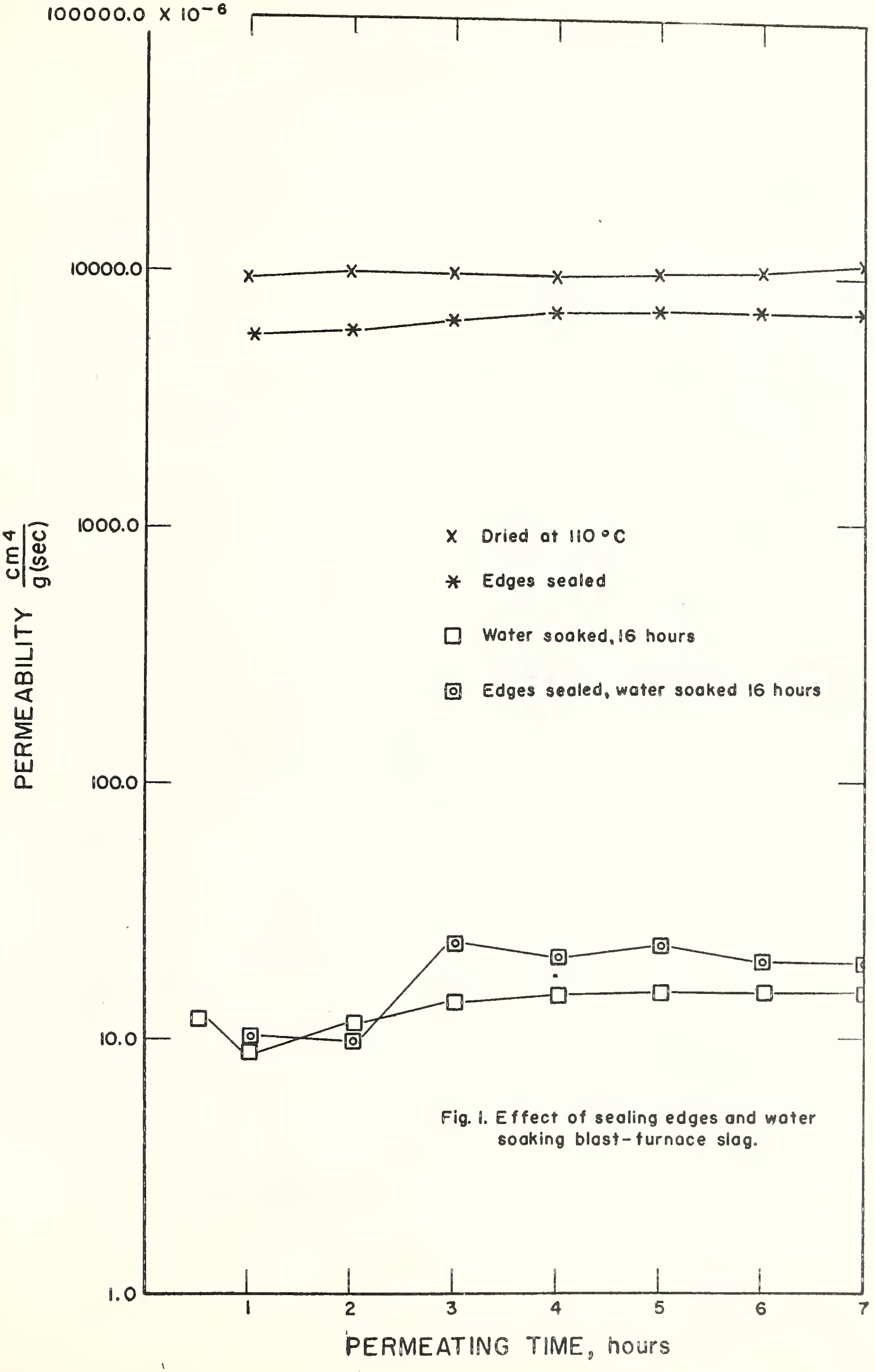

Fig. 1. Effect of sealing edges and water soaking blast-furnace slag.

The pores present in the blast-furnace slag ranged in size from microscopic to one-half inch in diameter. There was an uncertainty as to the sizes of the channels connecting the open pores. An estimate of the sizes was obtained by determining the permeability of the slag after water soaking for 16 hours. The resulting permeability of specimen 1 as shown in Figure 1 indicated that the capillary water had closed many of the smaller connecting channels.

That many of the connecting channels were sealed by capillary water is again shown in Figure 2 in tests, on a soaked specimen, during which the pressure applied was varied and the time of flow, during the test, was kept at a minimum. Pressures from 12 to 18 grams/cm^2 were required to overcome enough of the capillarity of the water to maintain an increased rate of flow. Rates of flow approaching those of a dried specimen were obtained by continued flow of the permeating air which evaporated much of the saturating water. These data seem to indicate that the connecting channels are small relative to the pores. In a fresh batch of concrete those channels of the slag aggregate are partially closed by the mixing water and are easily plugged by cement particles. Thus the resulting concrete becomes quite impermeable.

A Study of Concreting Materials and Concretes for Naval Facilities

In the study of concreting materials and concretes used in jet aircraft power-check facilities at various U. S. Naval Air Stations, ten sets of test panels have been received. In accordance with the instructions contained in a Bureau of Yards and Docks letter, to all Naval Air Stations included in the survey, the panels were to be fabricated using concrete from the mix that was used in placing the power check facilities at the various installations. In most instances such information as requested in the aforementioned letter, such as type of aggregate and cement admixtures, ratio of coarse to fine aggregate, cement content, W/C ratio, slump, air content, and 7 and 28 day flexural strengths was submitted to the National Bureau of Standards. Upon the receipt of the panels, they were stored in the fog room to complete the 28 day moist curing, (when necessary), removed after curing period, sealed on all but the original top face and stored at 73°F and 50% relative humidity for increasing periods of time, before being subjected to the jet impingement test.

Table I gives the type of aggregate and cement used; the brand and amount of admixture, the ratio of coarse to fine aggregate, the cement content, water-cement ratio, slump, air content, and flexural strength of the concrete after 28 days moist curing.

Trap rock was used as the aggregate in seven of the ten concretes received. Blast-furnace slag was used in two and expanded shale in one. Microscopic examination of the dense aggregate showed that six of the seven trap rock aggregates met the requirement of paragraph 2.2.2.1 of NAVDOCKS Specification S-P16. The seventh, a trap rock of the diabase variety, from the 8th Naval District, Kingsville, Texas contained 20% flint pebbles (-1 to +3/4 inch) that are excluded by the specification. Macroscopic examination of the concrete from the 13th Naval District, Whidbey Island, Oak Harbor,

PERMEABILITY, cm^4

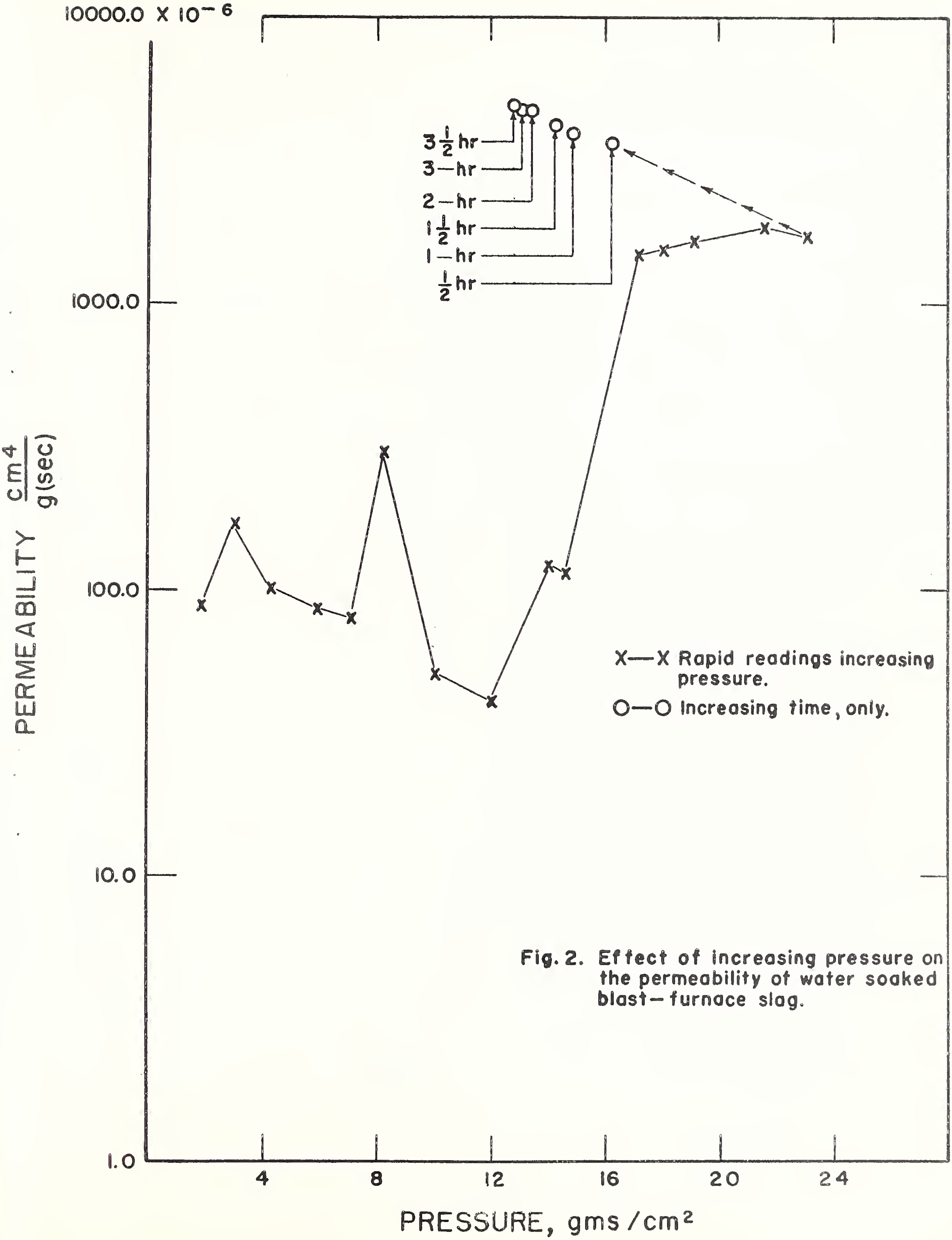

Fig. 2. Effect of increasing pressure on the permeability of water soaked blast-furnace slag.

Table I. Properties of Fresh Concrete[1/]

Identification	Type of Aggregate	Type of Cement	Admixture A. E. A.	Ratio of Coarse to Fine Aggregate	Cement Content	Ratio w/c	Slump	Air Content	Flexural Strength, 28 days
			oz/sack of ct.		sack/yd^3		inches	%	psi
5th Naval Dist. N.A.S. Norfolk, Va.	Trap Rock	I	Darex 1.0	66:34	7	.435	1 to 2	6.2	750
8th Naval Dist. N.A.A.S. Kingsville, Texas	Basalt Variety	I	Darex 1.0	63:37	5.5	.58	2	5.0	650
8th Naval Dist. N.A.A.S. Chasefield Beeville, Texas	Basalt Variety	I	None	63:37	5.5	.61	1.5	2.0	655
11th Naval Dist. M.C.A.S. El Toro, California	Expanded Shale	High[2/] Alumina Hydraulic	None	67:33	6.5	.45	3.25	3/	600
13th Naval Dist. N.A.S. Whidbey, Is. Oak Harber, Wash.	Quarry or Trap Rock	III	Darex 0.75[4/]	63:28	6.5	.42	2.0	5.2	3/
6th Naval Dist. N.A.S. Jacksonville, Florida	Trap Rock	I	Darex 1.40	53:47	7.0	.43	3/	5.8	610[5/]
6th Naval Dist. N.A.S. Sanford, Florida	Blast-Furnace Slag	I	Darex 1.0	58:42	7.5	.39	2.0	3/	755
11th Naval Dist. U.S.M.C.A.A.S. Yuma, Arizona	Blast-Furnace Slag	II	Pozzolith 8AA 4.0	62:38	8.0	.363	3.0	7.7	3/
6th Naval Dist. U.S.M.C.A.A.S. Beaufort, S.C.	Trap Rock	I	Aermix 1.75	57:43	7.0	.43	3.25	5.5	720
6th Naval Dist. N.A.S. Glynco, Georgia	Trap Rock	I	Darex 1.3	66:34	7.5	.40	3/	3/	3/

1/ Taken from reports of testing laboratories

2/ Fondu

3/ Data not received

4/ 0.25 oz. of Pozzolith per sack, also

5/ Average of 9 beams sawed from the panels submitted; as requested by Mr. P. P. Brown, Bureau of Yards and Docks, Washington, D. C.

Washington indicated a deficiency in the +3/4 size aggregate. The concrete from the 11th Naval District, El Toro, California designed with lightweight aggregate contained no 3/4 to 1/2 inch aggregate and the coarse to fine ratio was 67/33 instead of the required 45/55. In the concretes that contained dense aggregate except the one used at the 6th Naval District, Jacksonville, Florida, the ratio of coarse to fine aggregate was kept at approximately 65/35. The cement content varied from 5.0 to 8.0 sacks/yd^3, the W/C ratio from 0.36 to 0.61, the slump from 1.5 to 3.25 inches, and the air content when furnished fell within the specified range of 5.0 to 8.0% except in the mix used at the 8th Naval District, Beeville, Texas, where no air-entraining agent was used.

Of the six 28-day flexural strengths reported, five met the requirements of 650 psi. The lightweight aggregate concrete from the 11th Naval District, M.C.A.S., El Toro, California developed 600 psi in 28 days moist curing.

Table II shows the effect of moist curing and drying, the spalling loss during jet impingement tests after increasing drying periods, and the flexural strength of beams cut from panels after the jet impingement test. Some of the data appearing in this table was given in Table III of NBS Report 7069.

Four additional sets of concrete panels were received during the period covered by this report. The set submitted by the 6th Naval District, Sanford, Florida, was the only one of these four sets received within 28 days after casting. The other three sets, two from the 6th Naval District, Beaufort, South Carolina and Glynco, Georgia and one from the 11th Naval District, Yuma, Arizona were received 120, 50, and 37 days respectively after casting. None of the four shipments were vapor sealed.

Seventeen panels, representing six installations, have been subjected to the jet impingement test. Ten were tested during the period covered by this report. The two sets of panels, one from the 11th Naval District, El Toro, California, and the other from the 13th Naval District, Whidbey Island, Oak Harbor, Washington, evidenced no loss after a six week drying period. The results of tests on the remaining three sets varied from no loss to complete failure depending on the length of the drying period before testing.

The flexural strengths of beams, approximately 18 x 6 x 6 inches, sawed from the outer portions of the test panels, after jet impingement test, was determined. The flexural strengths were considerably lower than that reported by the testing laboratories on the 28 day strength. This decrease in strength, due to the heat treatment, of 400°F maximum during the five minute jet impingement test, was 75% for the lightweight aggregate concrete and from 50 to 60% for the concretes containing dense aggregates. This loss in strength due to the heating of concretes at comparatively low temperatures was reported in the early part of the investigation.

Table II. Data on Panels During Moist Curing, Drying, and Results of Jet Impingement Tests

Identification	Panel Number	Days in Sawdust	Water 1/ Content of Sawdust %	Weight Change 2/ of Panel During Sawdust Storage %	Storage in Fog-room days	Weight Change 2/ of Panel During Fog-room Curing %	Drying Period days	Loss in Drying %	Spalling Loss by Wt. c.c.	Spalling Loss by Sand Volume c.c.	Flexural 3/ Strength psi
5th Naval Dist. N.A.S.Norfolk, Va.	1	15	38	-0.13	13	0.00	36	-0.40	43.6	15.42	480
	2	15	do	-0.26	13	0.00	50	-0.67	45.3	None	465
	3	14	do	-0.13	13	+0.14	68	-0.82	90.6	1.20	455
	4	14	do	-0.13	13	+0.14	84	-0.89	225.3 4/	119.29 4/	395
8th Naval Dist. N.A.A.S.Kingsville, Texas	A	15	60.5	-0.14	13	+0.06	42	-0.63	149.5	70.24 4/	370
	B	15	60.5	-0.58	13	+0.16	58	-0.87	43.9	24.55	430
	C	15	60.5	-0.58	13	+0.16	Note 5/	-----	----	-----	---
	D	17	52.0	-0.43	10	0.00	87	-0.86	87.22	22.63	415
8th Naval Dist. N.A.A.S.Beeville, Texas	A	17	52.0	+0.57	10	0.00	42	-0.57	303.0	225.5 4/	370
	B	17	do	+0.14	10	+0.14	59	-0.83	43.6	26.2	495
	C	17	do	+0.69	10	0.00	70	-0.79	34.5	None	460
11th Naval Dist. U.S.M.C.A.S. El Toro, California	1	28	54.0	+2.26	6/	6/	42	-8.20	67.97	None	135
	2	28	39.0	+3.02	"	"	56	-8.22	206.45	"	130
	3	28	38.0	+1.86	"	"	71	-5.49	96.29	Slight	205
13th Naval Dist. 7/ N.A.S.Whidbey Is. Oak Harbor, Wash.	1	32	61.0	+0.23	6/	6/	43	-1.70	49.85	None	485
	2	32	62.0	+0.34	"	"	56	-2.00	50.69	"	400
	3	32	57.0	+0.21	"	"	71	-2.45	None	"	415
6th Naval Dist. N.A.S.Sanford, Florida	1	28	53.0	+0.76	6/	6/	42	-0.79	50.69	8.98	385
	2	28	53.0	+0.57	"	"	8/	8/	8/	8/	8/
	3	28	53.0	+0.57	"	"	"	"	"	"	"
11th Naval Dist. U.S.M.C.A.A.S. Yuma, Arizona	1	37	60.0	-0.32	6/	6/	8/	8/	8/	8/	8/
	2	"	"	-0.48	"	"	"	"	"	"	"
	3	"	"	-0.16	"	"	"	"	"	"	"
6th Naval Dist. U.S.M.C.A.A.S. Beaufort, S. C.	1	120	47.5	8/	6/	6/	8/	8/	8/	8/	8/
	2	"	"	"	"	"	"	"	"	"	"
	3	"	9/	"	"	"	"	"	"	"	"
6th Naval Dist. N.A.S.Glynco, Georgia	1	50	49.0	+2.31	6/	6/	8/	8/	8/	8/	8/
	2	43	"	+0.71	"	"	"	"	"	"	"
	3	42	"	+2.62	"	"	"	"	"	"	"

1/ $\frac{\text{wet weight-dry weight}}{\text{wet weight}} \times 100$

2/ Based on one-day weight.

3/ Determined on beams cut from panels after jet impingement tests.

4/ Results of this magnitude indicate complete destruction of test surface.

5/ Flexural strength determined on 3 beams cut from panel at request of Budocks.

6/ Considered as moist cured during transit, 28 or more days.

7/ The water in the sawdust was frozen through to the panels on receipt.
Since the concrete from which these panels were fabricated was rejected, as failing to meet flexural strength requirements; additional panels will be shipped fabricated from concrete used in new installation.

8/ Data not complete

9/ Not packed in sawdust

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Analytical Chemistry. Inorganic Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

Atomic Physics. Spectroscopy. Radiometry. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry. Molecular Structure and Radiation Chemistry.

• Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

Radio Systems. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

NBS