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NATIONAL BUREAU OF STANDARDS REPORT

6562

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

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Approved:
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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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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

2.1 Fabrication of Test Panels

For the purpose of comparing results of jet impingement tests made at NACERELAB, Bureau of Yards and Docks laboratories at Port Hueneme, California, with those obtained at the National Bureau of Standards, tests were made during the last fiscal year at both laboratories. An informal report of the results of the tests conducted at NACERELAB was made by members of the staff of that laboratory at a conference held at the National Bureau of Standards July 15, 1959. The behavior of test panels fabricated and tested at your Port Hueneme laboratory did not compare favorably with those fabricated and tested at the National Bureau of Standards laboratory. The Port Hueneme laboratory reports failure of slabs subjected to full scale jet impingement tests after seven days conventional wet curing and 56 days out-door exposure. Panels of the same design concrete, fabricated at this Bureau, and subjected to our laboratory jet blast showed no failure when given 28 days fog-room curing and 70 days drying at 50% relative humidity and 73°F. There were, however, some differences in the concretes and their curing in the first two sets of panels that will be eliminated in the second comparison. Some of these differences were (1) type of cement used, (2) water cement ratio, (3) method of mixing, (4) wet curing and drying.

To eliminate such discrepancies, six test panels have been fabricated during the period covered by this report. They have been fog-room cured for 28 days, moisture sealed on all but the cast surface and are being dried at controlled humidity, 50%, and temperature, 73°F. The length of the drying period for the panels that are to be shipped to Port Hueneme depends on the results of tests obtained in this laboratory.

In this set of panels, portland Type I cement was used in a seven sack mix with a w/c ratio of 0.42. Virginia diabase was the aggregate. The proportion, by weight, of cement to coarse and to fine aggregate was 1:3.42:1.84. The ratio of the coarse to fine aggregate was 65-35. The gradation of the coarse and fine aggregate conformed with the Bureau of Yards and Docks Specifications for Portland Cement Concrete Pavement for Airports No. 45 Ya. The batch was mixed in a pan type mixer. The aggregate was soaked 16 hours. The coarse and fine aggregate were thoroughly blended in the mixer; the cement added and mixed thoroughly. The water and Vinsol resin were added and the batch mixed for one and one-half minutes. The mixer was stopped for three minutes and then allowed to run for one minute before discharging.

The properties of the fresh concrete, P - D_i - PH, were:

Cement content	6.94 sacks/yd^3 of concrete
Vinsol resin	0.01% by weight of cement
Water content	32.85 gals/yd^3 of concrete
Air content	1.95% gravimetric method
Slump	1.5 inches
Weight of fresh concrete	162.8 lbs/ft^3
Water cement ratio	0.42
Remarks	Fair, slightly harsh

2.2 Fabrication of Permeability Specimens

It has been shown in previous reports that steam pressure is generated in concrete, when it is heated, approximately in accordance with the values given in the Steam Tables. The egress of the steam and subsequent reduction in pressure is dependent on permeability.

For the purpose of studying the permeability of concrete during the progress of fog-room curing and drying at 50% relative humidity and 73°F, ten specimens (9 x 4-1/2 x 2-1/2 inches) were fabricated from a mix similar to the previously mentioned batch. The maximum size aggregate used was 3/4 inch instead of 1 inch, and the design was modified accordingly. Three types of surface finishes were used on these specimens, broom, wood floated, or steel troweled.

2.3 Permeability

The apparatus, mentioned in the last NBS Report (6475), used successfully in measuring the permeability of refractories, has been assembled. For the purpose of checking the apparatus and procedure, the values for permeability of several brands of fire brick were determined in a flatwise position and were found to compare favorably with the values, for the same brands of brick reported by Massengale et al.1/

Table I. Permeability of Fire Brick

Brand of Brick	Permeability		
	Determined	Published Data	
	Average of 2 specimens */	Average of 10 specimens */	Coefficient of variation %
Woodland	0.0478	0.0568	23
A.P. Green D.P.	.0374	.0219	57
Yough (Silica)	.3180	.2800	10
Duro (Acid Proof)	.000017	.0000023	53

$$* \quad \frac{(cm^3)(cm)}{(sec)(cm^2)(gm/cm^2)}$$

1/ Permeability and Some Other Properties of a Variety of Refractory Materials, I and II, J.A.C.S., Vol. 36, No. 7 and 8, July and August, 1953.

Table I shows that the brands of brick are classified in the same relative order by both sets of permeability determinations and that the variability of the specimens of the same brand was large.

A review of the literature on the permeability of concrete, and cement paste [1/] revealed that the concretes to be studied might have a permeability approaching that of the acid proof brick in Table I.

Additional data showed that the permeability of a brick is essentially constant when determined with dry air under pressures ranging from nil to 15 inches of water.

The permeability of several concrete specimens (9 x 4-1/2 x 2-1/2 inches) with variable histories was determined in the flat-wise position. The results appear in Table II.

1/ T. C. Powers - Structure and Physical Properties of Hardened Portland Cement Paste. J. Amer. Ceram. S. 41, 1-6 (1958).

T. C. Powers, L. E. Copeland, J. C. Hayes, and H. M. Mann - Permeability of Portland Cement Paste. J. Amer. Concrete Ins. 26, No. 3, 285-297 (1954).

Table II. Permeability of Concrete

Laboratory Identification 1/	Method of Placing	Fog-room Curing days	Drying at 50% rh, 73°F days	Time of Weathering 2/ months	Method of Procuring Specimen	Data Tested	Permeability Value $\frac{(cm^3)(cm)}{(Sec)(cm^2)(gm/cm^2)}$
$P-D_i-4-1$	Top Evacuated	30	30	18	Sawed from top surface of test panel; cast surface removed	7-29-59	0.00209
						"	.00208
						"	.00209
						7-30-59	.00215 3/
$P-D_i-4-2$	"	"	"	"	Sawed from top surface of test panel; cast surface retained	7-30-59	.00109
						"	.00106
						7-31-59	.00103
						"	.00100
						"	.00095 4/
						"	.00091 4/
						"	.00090 4/
						8-3-59	.00083 4/ 5/
						"	.00087 4/
						"	.00084 4/
$P-D_i-3-3$	Conventional	"	"	26	Same as $P-D_i-4-2$	8-11-59	.0000043
P-BF-5-1	"	14	21	4	Same as $P-D_i-4-1$	7-30-59	.0000054
P-BF-5-2	"	"	"	"	Same as $P-D_i-4-2$	8-4-59	.0000073

1/ The design of the concrete used in fabricating these specimens has appeared in past reports.

P denoting the cement used Type I portland.
The second letter or letters denoting the aggregate. D_i = diabase; BF = blast furnace slag.
The first numeral denoting the mix design, and the second the specimen.

2/ Exposed to out-door atmosphere.

3/ Flow air on 24 hours prior to test.

4/ Specimen inverted.

5/ Flow air on 72 hours prior to test.

When tested flat-wise the diabase concrete specimen (P-D_i-4-1) with six sawed sides was more permeable than the corresponding specimen (P-D_i-4-2) with but five sawed sides, indicating that a concentration of cement at or near the evacuated surface reduced the permeability. The diabase concrete, evacuated after placing, was much more permeable than similar concrete conventionally placed. The concretes made with diabase and that made with blast furnace slag, when conventionally placed, had similar permeabilities. The high permeability of the evacuated diabase concrete was associated with its resistance to jet impingement. However, the blast furnace slag concrete resisted the jet impingement test regardless of its permeability.

A continuing flow of dry air through the specimens, P-D_i-4-1 and 2, while measuring the permeability, or even for 72 hours, affected the results only slightly.

The permeability apparatus in use requires a capillary as part of the flow rate indicator. Since the concretes have such low permeabilities an unusually small bore capillary would be desirable for more accurate determinations. After considerable inquiries, we have been able to locate a supplier of such capillaries.

2.4 Pressure Developed Within Concretes During Rapid Heating

Completed studies with neat cement pastes and concretes have shown that high pressures are developed at temperatures as low as 300°C when tested by the bomb method. Due to the low permeability of concrete, pressures approaching these values might be expected to develop within the concrete itself on rapid heating.

Methods for the measurement of pressures developed within concrete during jet impingement have been considered. Several different types of instruments have been studied. At present, the preferred instrument consists of a small bore, water filled, pressure transmitting (metal) tube connected to an electric transducer by a sealing flange.

Instruments of this type are available within the probable pressure range, temperature compensated, and with responses in the micro-second range. Specifications for the purchase of such an apparatus are being prepared.

2.5 Miscellaneous

A conference was held at the National Bureau of Standards, July 15th. The names of those attending follow:

P. P. Brown Melvin Herman F. Knoop L. A. Palmer	Bureau of Yards and Docks
John Bishop H. Tomita	U.S. NAVCERELAB, Port Hueneme, Calif.
Douglas Parsons R. L. Blaine Bruce E. Foster W. L. Pendergast	National Bureau of Standards

The work accomplished during the fiscal year of 1959 at the National Bureau of Standards and at NAVCERELAB, the Bureau of Yards and Docks laboratories at Port Hueneme, California was discussed. No changes in the method of approach, originally outlined in the proposal submitted by this Bureau for the current fiscal year, were suggested. It was, however, suggested that we include the testing of concrete panels, that will be fabricated on the job, under the supervision of an inspector at the several "turn-up" areas planned. Specifications for the three types of aggregate that are to be used for these areas were discussed.

It was also suggested that four 18 x 18 x 6 inch panels be fabricated in our laboratories using a mix of diabase aggregate and portland type I cement*. These panels, after being fog-room cured and dried, are to be sealed and shipped to NAVCERELAB for test. Panels for test at our laboratories will be fabricated from the same batch, similarly cured, and dried, and subjected to our jet test.

* A more detailed report of this work appears in Section 2.1.

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, 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 headquarters in Washington, D.C., and its major laboratories in 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 and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Radiation Theory. Radioactivity. X-rays. High Energy Radiation. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. 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. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

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

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

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

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research. Radio Warning Services. Airglow and Aurora. Radio Astronomy and Arctic Propagation.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Electronic Calibration Center. Microwave Physics. Microwave Circuit Standards.

Radio Communication and Systems. Low Frequency and Very Low Frequency Research. High Frequency and Very High Frequency Research. Ultra High Frequency and Super High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Systems Analysis. Field Operations.

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