NATIONAL BUREAU OF STANDARDS REPORT

8189

Quarterly Report
on
EVALUATION OF REFRACTORY QUALITIES OF
CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK
MAINTENANCE APRONS, AND RUNWAYS

by

J. V. Ryan and E. C. Tuma

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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

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

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards 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, including assistance to industry, business and consumers in the development and acceptance of commercial standards and simplified trade practice recommendations. 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 research are published 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 Central Radio Propagation Laboratory Ionospheric Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also seven series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, Technical Notes, Commercial Standards, and Simplified Practice Recommendations.

A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
1002-12-10472	February 12, 1964	8189

Quarterly Report

on

EVALUATION OF REFRACTORY QUALITIES

of

CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK MAINTENANCE APRONS, AND RUNWAYS

by

J. V. Ryan and E. C. Tuma

Fire Research Section
Building Research Division

Sponsored by:

U. S. Department of the Navy
Bureau of Yards and Docks

Reference: Task Y-F015-15-102

NBS File No. 10.02/10472

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 MAINTENANCE APRONS, AND RUNWAYS

by

J. V. Ryan and E. C. Tuma

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. Present Plan of the Investigation

In an attempt to gain more understanding of the mechanism of spalling and of the factors that determine whether or not a given concrete spalls under jet impingement, specimen sizes were chosen to provide different degrees of restraint to thermal stresses and to the escape of steam from within the concrete. The instrumentation was designed to provide data on pressures and temperatures, including temperature gradients in the 1/2 in. nearest the exposed surface. In addition, electrical resistance elements were embedded in some specimens to provide an indication of their drying. It was decided to keep some specimens in the fog room throughout their conditioning, to condition others in air at 73°F and 50 percent relative humidity, and to attempt to dry others thoroughly.

3. Activities

The specimens of blast furnace slag aggregate concrete and those of Volcanite aggregate concrete were tested during the quarter.

The study of the feasibility of accelerated drying by conditioning in atmospheres at reduced pressures was continued.

3.1 Blast Furnace Slag Aggregate

The blast furnace slag aggregate concrete specimens (BF-2) conditioned in air at 73°F and 50 percent relative humidity were judged to have reached equilibrium early in the quarter. They, and other groups from the same batch, but subjected to different aging conditions, were tested. The specimens of the second group were kept in the fog room until just before test. Those of the third group were removed from the fog room about two weeks before test and dried in an oven at 105°C. The specimen's ages at test were in the range 230 to 237 days.

The data from the jet impingement tests are summarized in Table 1, and those from supplementary tests in Table 3. The pressures for the oven-dried specimens and those for the specimens conditioned at 73°F and 50 percent relative humidity were of the same order of magnitude - fairly low. The spall volumes for the same groups were slight or zero. The close agreement between these two groups indicates that the 73°F/50 rh group was probably conditioned too long. The specimens tested directly out of the fog room all spalled appreciably and several exhibited moderately high pressures. The maximum spall depth was 27/32 in.

Two of the 12 in. diameter by 6 in.-thick specimens conditioned at 73°F and 50 percent relative humidity did not spall. In order to get an indication of the effect of subsequent wetting on once-dried concrete (such as from protracted rain or melting snow cover) they were submerged in a tank of water for 10 days and again exposed to the jet impingement test. A few shallow (est 1/32 - 1/16 in.) isolated spalls or pop-outs developed. The pressures were of the same order of magnitude as those observed originally.

3.2 Volcanite Aggregate Concrete

The specimens of Volcanite aggregate concrete, V-1 conditioned in air at 73°F and 50 percent relative humidity were judged to have reached a suitable condition for testing late in the quarter. The number, sizes, instrumentation, and conditioning programs for the three groups were the same as described in 3.1 for the blast furnace slag aggregate specimens. The durations were somewhat shorter, the specimen ages at test ranging from 117 to 125 days.

The data are summarized in Tables 2 and 3. None of the oven-dried specimens or of those conditioned at 73°F/50rh spalled significantly, but a few small chips popped off several of them. These chips were 1/32 in. or less in thickness and about 1/4 in. in diameter. The pressures for the two groups were very low, of the same order of magnitude as those for the equivalent groups of BF-2 specimens. Each of the specimens kept in the fog room spalled very heavily, and throughout the 5 minute test period. The spall depths were between 1-1/2 and 2 in. Although the spall depths and volumes were much greater than those for the corresponding blast furnace aggregate specimens, the observed pressures were much lower. They were only slightly higher than those for the oven dried and 73°F/50rh conditioned specimens.

The three 12 in. diameter by 6 in.-thick specimens conditioned at 73°F and 50 percent relative humidity did not spall. In order to get an indication of the effect of subsequent wetting on once-dried concrete, they were submerged in a tank of water for 7 days and again exposed to the jet impingement test. The surfaces of the specimens scaled to a minor degree.

In addition to the specimens prepared at the National Bureau of Standards, several blocks and slabs had been delivered from a concrete fabricator who used the aggregate regularly. The markings on them suggested the specimens were several months old when shipped. Three blocks suitable for jet test were stored at 73°F and 50 rh for several weeks and then tested. None of them spalled. No instrumentation for temperature or pressure measurements had been provided.

An unusual phenomenon was observed on several of the Volcanite aggregate specimens, both prefabricated and prepared here. Small protrusions, of about 1/8 in. diameter, developed on the exposed areas during the jet tests. These were broken easily and the interior color was similar to that of the aggregate.

3.3 Vacuum Drying

The blast furnace slag aggregate concrete specimens and the Volcanite aggregate concrete specimens placed in the low pressure chamber were kept at pressures below the vapor pressure of water throughout the quarter. The electrical conductivity continued to fall, indicating continued drying.

Table 1. BF-2 Jet Impingement Summary

Size	Oven Dried				73°F/50% rh				Fog Room			
	Spall Volume		High Pressure		Spall Volume		High Pressure		Spall Volume		High Pressure	
	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
Diameter												
12 x 6	0	0	31.8	52.8	Slight	Slight	14.8	36.0	165	190	85.0	176.0
6 x 6	-	-	-	-	0	0	5.2	8.8	-	-	-	-
3 x 6	-	-	-	-	0	0	18.1	36.	-	-	-	-
12 x 2	0	0	37.6	72.0	Slight	Slight	100.5	150.	167	188	130.5	336.
3 x 2	-	-	-	-	0	0	8.3	11.0	-	-	-	-
Thickness												
12 x 6	0	0	31.8	52.8	Slight	Slight	14.8	36.	165	190	85.	176.
12 x 2	0	0	37.6	72.	Slight	Slight	100.5	150.	167	188	130.5	336.
3 x 6	-	-	-	-	0	0	18.1	36.	-	-	-	-
3 x 2	-	-	-	-	0	0	8.3	11.	-	-	-	-
Retest	Immersed in water for 10 days											
12 6					Slight	Slight	27.3	47.2				

Table 2. Volcanite-1 Jet Impingement Summary

Size	Oven Dried				73°F/50% rh				Fog Room			
	Spall Volume		High Pressure		Spall Volume		High Pressure		Spall Volume		High Pressure	
	Avg.	Max.	Avg.	Max.	Avg.	Max	Avg.	Max.	Avg.	Max.	Avg.	Max.
Diameter												
12 x 6	0	0	21.	64.	0	0	37.	80.	558.	590	41.3	74.6
6 x 6	-	-	-	-	0	0	0	0	-	-	-	-
3 x 6	-	-	-	-	0	0	2.73	8.2	-	-	-	-
12 x 2	0	0	1.7	5.	0	0	10.7	26.4	503.3	510.	10.7	17.
3 x 2	0	0	9.3	14.	0	0	0	0	0	0	43.8	115.2
Thickness												
12 x 6	0	0	21.	64.	0	0	37.	80.	558.	590.	41.3	74.6
12 x 2	0	0	1.7	5.	0	0	10.7	26.4	503.3	510.	10.7	17.
3 x 6	-	-	-	-	0	0	2.73	8.2	-	-	-	-
3 x 2	0	0	9.3	14.	0	0	0	0	0	0	43.8	115.2
Retest - after water immersion												
12 x 6					0	0	18.6	32.				

Table 3. Supplementary Data

Concretes	Modulus of Rupture, Psi		Shear Strength Psi		Compressive Strength, Psi		Moisture Content,%	
	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
BF-2								
Oven dried	1000	1075	-	-	9070	9500	0	0
Vacuum Dried	980	1035	-	-	10310	10750	5.50	5.60
Fog Room	995	1055	-	-	9000	9690	.96	1.10
Volcanite-1								
Oven dried	535	590	-	-	6400	6750	.33	.40
73°F/50% rh	615	640	-	-	6565	7095	6.30	6.67
Fog Room	590	650	-	-	5980	6220	12.25	12.50
Volcanite								
Outside samples	485	570	-	-	4900	5390	-	-

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. High Voltage. Absolute Electrical Measurements.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Volume.

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. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

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

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

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

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

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Far Ultraviolet Physics. Solid State Physics. Electron Physics. Atomic Physics. Plasma Spectroscopy.

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

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering Laboratory. Cryogenic Processes. Cryogenic Properties of Solids. Cryogenic Technical Services. Properties of Cryogenic Fluids.

CENTRAL RADIO PROPAGATION LABORATORY

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

Troposphere and Space Telecommunications. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Spectrum Utilization Research. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

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

RADIO STANDARDS LABORATORY

Radio Standards Physics. Frequency and Time Disseminations. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Microwave Physics.

Radio Standards Engineering. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

NBS LABORATORY ASTROPHYSICS GROUP

USCOMM-NBS-DC

(Joint Institute for Laboratory Astrophysics at Univ. of Colo.)

DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS