NATIONAL BUREAU OF STANDARDS REPORT

5855

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, L. E. Mong

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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
0903-20-4428	April 16, 1958	5855

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Refractories Section
Mineral Products Division

Sponsored by

Department of the Navy
Bureau of Yards and Docks

Reference: NT4-59/NY 420 008-1
NBS File No. 9.3/1134-C

Approved:
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Chief, Refractories Section

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1. INTRODUCTION

This phase of the project includes the determination of the cause or causes of failure that occur in concrete aprons and runways exposed to jet exhaust gases. A combustion chamber that delivers hot gases at velocities and temperatures approximating those of field conditions is being used. The approach includes instrumentation of the concrete test panels to determine the heat gradients and stresses set up during flame impingement at several locations on the test area and at varying depths below the surface.

2. ACTIVITIES

2.1 X-ray Examination

X-ray examination of hydrated Alcoa cement, which had been heat treated under pressure in the bomb test and subsequently in steps to 700°C in air, indicated that no detectable change occurred in the hydrates as a result of the last heat treatment. The results from X-ray examination from lower heat treatments on this cement are given in Table II of N.B.S. Report 5736. Since mercury was in contact with the cement during the bomb test and was volatilized later at approximately 200°C, a second bomb was charged, and the cement, which is now being cured, will be subjected to the bomb test without mercury. Weight losses will be obtained

and samples for X-rays taken in the same manner as for the first sample. This procedure should determine to what extent the mineralogical changes are accompanied by weight changes. Samples of portland and Lumnite cement are being heat-treated and sampled in a manner similar to that of the first sample of Alcoa. Some X-ray patterns have been taken, and the result will be reported later.

2.2 Water in Concrete During Curing and Drying

In the study of the correlation of the concentration of water with the humidity within cured concrete, a new set of tiles, five in number and four inches in depth, have been drying at 35% relative humidity and 77°F after 28 days fog-room curing.

These tiles were cast using concrete similar in design to that of the first series. The concrete was designed with crushed building brick aggregate, passing No. 4 screen, seven sacks of portland cement per cubic yard, and a W/C ratio of 0.69. The percentages of mixing water, water gained during curing and total water present after curing are given in Table I.

The weight loss of the tile and the relative humidity, at three depths from the exposed surface, have been determined at seven day intervals. This series of tile is being studied to indicate the causes and magnitudes of the uncontrolled variations that were present in the first set reported in N.B.S. Report 5736.

Table I. Water Additions to Tile for Relative Humidity-Weight-Loss Studies.

Specimen	Water Added During: Casting, % on dry batch weight	Water Added During: Curing, 28 days, % on cast weight	Total Water: % on dry batch weight	Total Water: % on cured weight
P-B - B	15.67	1.92	17.89	15.17
P-B - T	"	1.68	17.61	14.97
P-B - T_s	"	1.77	17.72	15.05
P-B - P	"	1.50	17.40	14.82
P-B - T_u	"	1.55	17.46	14.86

The hygrometers in the cavities nearest the exposed surface of each tile indicated humidities above 100% (maximum 103%) on removal from the fog-room (at the start of the drying period). The hygrometers near the opposite face indicated lesser values averaging 100%.

Some of the causes of discrepancies that appeared in the data given for the first set of tiles have been eliminated. Jacketing the tile by cementing the polyethelene envelope to the five unexposed surfaces and sealing the exposed assembly joints of the hygrometers with glyptol paint corrected many of the discrepancies evident in Figure 1 of N.B.S. Report 5736.

Table II gives a summary of the weight loss - relative humidity data for the second series of tile.

The relative humidities in the cavities furtherest from the exposed surfaces were 100% for an appreciable length of drying time. In this respect the data is similar to that

given by Gause and Tucker[a]. Beyond these drying periods the rate of decrease in relative humidity with time was constant, for a given tile, during the total drying time of ten weeks.

Table II. Summary of Weight Loss - Relative Humidity Data, for 3 x 3 x 4 inch Tile Dried with one 3 x 3 inch Face Exposed to Air at 35% Relative Humidity and 77°F.

Specimen	Cavity Location Relative to Exposed Surface					
	Furthest		Middle		Nearest	
	Days at 100% R.H.	Drying Slope % R.H. per week	Days at 100% R.H.	Drying Slope % R.H. per week	Days at 100% R.H.	Drying Slope % R.H. per week
P-B - B [1]	21	1.43	7	1.80	4	3.40
P-B - T [1]	14	1.8	11	1.74	0	3.37
P-B - T_s [2]	14	1.7	7	1.55	0	4.07
P-B - P [1]	21	1.17	7	1.87	0	2.57
P-B - T_u [3]	13	1.14	14	1.23	0	2.27

[1] Fabricated by different operators.

[2] Cast 5″ long, sawed to four inch dimension during curing. Sawed surface exposed during drying.

[3] Upended in fog room, bottom surface as cast was exposed during drying.

These rates were not greatly different for the different tile even though different operators or different procedures were used in fabricating them. The rate of change of relative

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[a] Method for Determining the Moisture Condition in Hardened Concrete, J. of Research, National Bureau of Standards, Vol. 25, No. 4 (October 1940).

humidities in the cavity nearest the exposed surface was greatest for the specimen having the sawed surface exposed and least for the specimen having the bottom surface, as cast, exposed.

During this ten week drying period, the rate of change of relative humidity is greater in the cavity nearest the exposed surface and grades to the smallest value in the cavities furthest from the exposed face (one exception).

The extent of the correlation of the relative humidity in the mid cavity with water loss for the whole specimen is illustrated in Figure 1. This graph shows that considerable water, amounting to approximately eight per cent of the total water present at the end of curing (or 1.2% of the cured weight), is lost before the humidity of the mid cavity falls below 100%. It is believed that the humidity in the mid cavity approximates the average for the whole tile, but the humidity in the cavity nearest the exposed face is less than 100% at a much earlier time in the drying treatment while the opposite is true for the cavity furthest from the exposed face.

After this initial loss of water, the relative humidity in the mid cavity is inversely proportional to the water loss as shown in Figure 1. The data indicates a linear relation for the 10 week drying period. The slopes of the lines are characteristic to the individual tile. The smallest

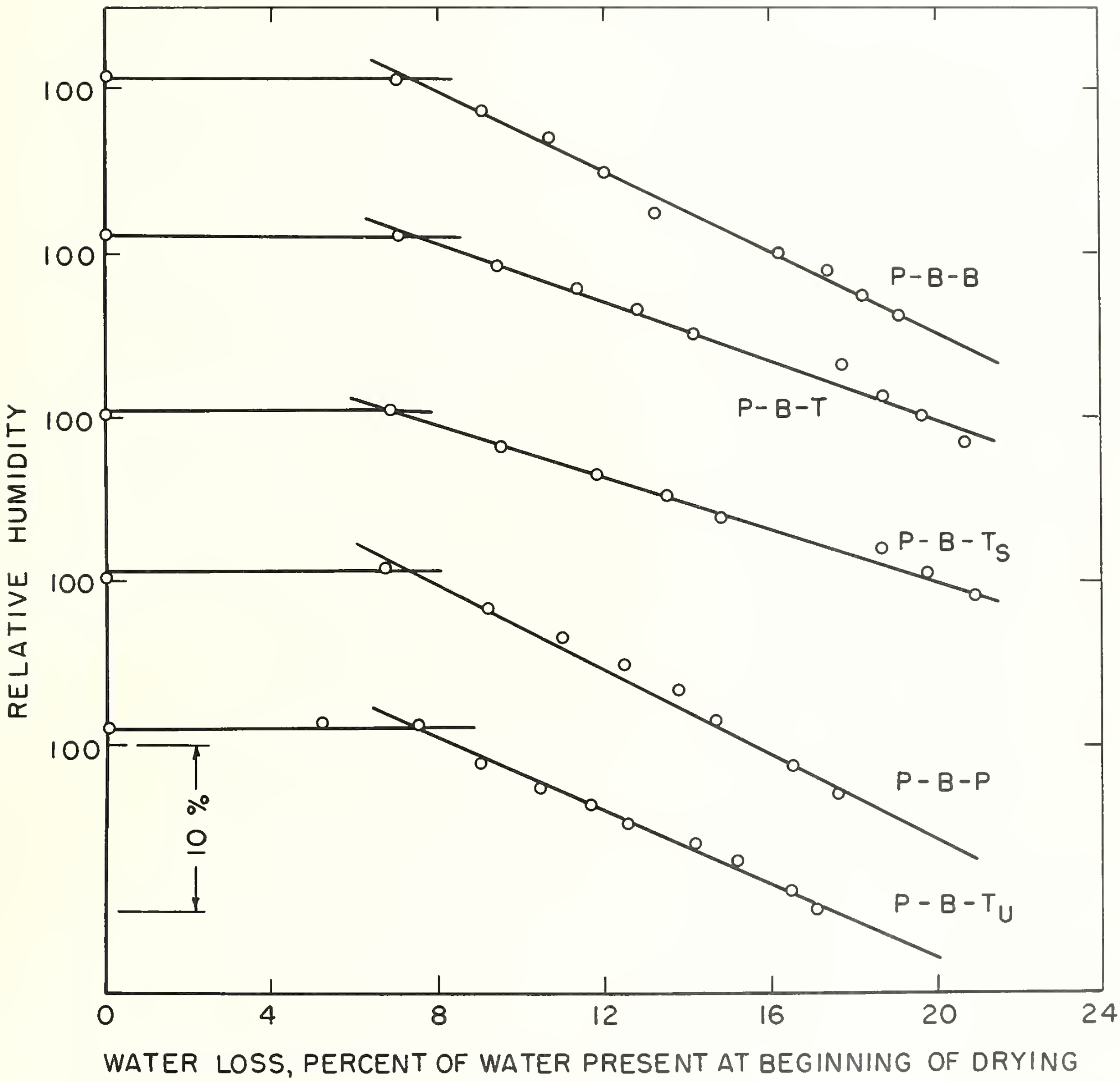

FIGURE I WATER LOSS AND RELATIVE HUMIDITY DURING DRYING OF TILES.

slope is associated with the tile having a sawed exposed surface which was probably more permeable. The three different operators B, T, and P introduced differences in the properties of the tile as indicated by the slopes of the lines.

2.3 Vacuum Processed Concrete

Appearing in one of the publications listed in this report, under Literature [3], it was concluded that if concrete was evacuated after placing, small channels and openings were created. This structure would be ideal to permit the egress of steam that is generated by rapid heating in the jet impingement test.

For comparative purposes one concrete was mixed using a design similar to that given in N.B.S. Report 5123. Another[b/] concrete was mixed containing the same diabase aggregate, and portland cement. In this second batch the maximum size of aggregate was +1/2 inch, and the ratio of coarse to fine aggregate was reduced to 56/44. The cement content was also reduced from seven to five sacks per cubic yard and the W/C ratio increased from 0.45 to 0.62. This change in design was made on the assumption that a wet short mix would accentuate the beneficial effects of vacuum processing more than would a plastic one.

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b/ This change was suggested by Mr. J. J. Creskoff, Consulting Engineer, for Billner Vacuum Concrete, Inc.

Six test panels were fabricated using the vacuum process. These will be exposed to our jet impingement test. Four were fabricated using our conventional diabase aggregate concrete; two of these four were evacuated from the bottom surface and two from the top surface. The other two panels made from the modified design were evacuated from the bottom surface. All panels were evacuated for 45 minutes.

The panels made from the conventional diabase-aggregate-concrete having a W/C ratio 0.456 lost 5.6 pounds of water when evacuated from the bottom, reducing the W/C ratio to 0.414. The panels evacuated from the top lost 3.8 pounds of water, reducing the W/C ratio to 0.428.

The modified concrete having a W/C ratio of 0.618 evacuated from the bottom lost considerable more, or 7.6 pounds of water, which reduced the W/C ratio to 0.480.

A vacuum of 23 inches of mercury column was obtained when evacuating from the bottom of the panel. The vacuum obtainable when evacuating from the top of the panel was considerably less, 12 inch of mercury column. This difference in the obtainable vacuum was due to the greatly different distances from the evacuating mat to free atmosphere.

The six panels have been cured and are undergoing drying treatment preparatory to testing.

Literature

A review of the following articles was made during this quarter.

[1] Investigation of Vacuum Treatment of Mass Concrete Surfaces. Technical Memorandum No. 6-353, Conducted for Office Chief of Engineers by Waterways Experiment Station, Vicksburg, Mississippi.

Summary

A description of the vacuum process.

[2] Vacuum Processes Concrete, United States Department of the Interior, Bureau of Reclamation, Materials Laboratories Report No. C-232.

Summary

Field experience has shown the vacuum process to be practical. The process does not interfere with nor delay normal operations in concrete placing. The ordinary form generally used in concrete placing is sufficiently rigid and tight. Laboratory tests indicated that concrete of a superior quality could be obtained by the vacuum process due principally to the reduction of the water content. This reduction was effective to depths of three inches.

[3] Current Applications of Vacuum Concrete. United States Department of Interior, Bureau of Reclamation, Concrete Laboratory Report No. C-355.

Summary

This report is not particularly pertinent to the project. However, a statement on page 2, paragraph 5 was of interest. "...small channels and openings created by the vacuum process."

[4] Vacuum Processes Applied to Precast Concrete Houses. K. P. Billner and Bert M. Thorud, J.A.C.I., Vol. 21, No. 2.

Summary

Not pertinent to this project.

[5] Structure and Physical Properties of Hardened Portland Cement Paste. T. C. Powers, J.A.C.S., Vol. 41, No. 1 (January 1958).

Summary

Methods of studying the submicroscopic structure of portland cement paste are described, and deductions about structure are presented. The main component, cement get, is deposited in water-filled space within the visible boundaries of a body of paste.

Space filled with gel contains gel pores; space not filled by gel or other solid material is capillary space. Hygroscopicity of cement gel, and capillary pores, accounts for various aspects of the properties and behavior of concrete. Data on gel and paste structure are used in discussing strength, permeability, volume stability, and action of frost.

Conference

A conference was held at this Bureau, January 26. The names of those attending follow:

P. P. Brown Melvin Herman P. Knoop L. A. Palmer	Bureau of Yards and Docks
W. L. Pendergast S. Zerfoss	National Bureau of Standards

The object of the conference was to discuss a suitable design for concrete to be used in fabricating test cells for jet engines and prepare specification based on the work completed for the aggregate to be used in the concrete. A brief review of the work accomplished during the first nine months of the fiscal year was reported and discussed.

Approved:

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *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, Colo., 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 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. Nuclear Physics. Radioactivity. X-rays. Betatron. 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 Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.

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

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