Projects II - 4

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NATIONAL BUREAU OF STANDARDS REPORT

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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

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THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 0903-20-4428

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Sponsored by

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Chief, Refractories Section

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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

QUARTERLY REPORT
ON
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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 of Neat Cements

No additional data on X-ray examination of neat cements, heated at progressively higher temperatures, have been collected. All samples have been prepared but personnel has not been available for making X-ray examinations.

2.2 Water in Concrete During Curing and Drying

The drying of the set of five tiles, 3" x 3" by four inches in depth, described in N.B.S. Report 5855 has been continued. Data covering the first 161 days drying period, at 35 percent relative humidity and 77°F was given in Figure I of N.B.S. Report 5961. Data for an additional drying period of approximately 100 days appear in Table I.

The distribution of water, as indicated by the relative humidity at three depths has changed very little in the last 100 days drying but the relative humidity values, at the top position, have decreased from 9 to 14 percent.

As shown in Table I, the humidity at the top position of the tile is approaching the humidity of the drying chamber and the lower limit of the hygrometers in use, 41 percent. This lower limit has been reached for the top position of two tile and further reading at this position have been discontinued.

The correlation of the relative humidity, in the mid-cavity, with water loss for the whole specimen, shown in Figure I of N.B.S. Report 5855 continues in a straight line relation. The relative humidity at mid-point ranges from 57 to 63 percent and the percent loss of water (based on that present after 28 day fog-room curing) ranged from 4.38 to 5.35 percent.

Table I

Relative Humidity at Three Depths
from Exposed Face of 3x3x4 inch Tile

Tile	Relative Humidity			Weight Loss[1/] %	Drying Interval Days
	Bottom	Middle	Top		
P-B-B	61.60	63.36	45.50	4.78	259
P-B-T	66.63	58.90	44.41	5.07	259
P-B-P	62.90	57.60	45.10	5.35	266
P-B-T_s	66.80	57.00	43.91	4.79	245
P-B-T_u	61.10	62.00	47.60	4.38	266

1/ This weight loss is attributed to water loss and is based on weight of tile out of fog room after 28 days curing.

2.3 Vacuum Processed Concrete

In comparing the permeance of concrete, evacuated immediately on placing with concrete placed in the conventional way, using the method described in A.S.T.M. Designation E96-55T, no difference was found. As yet we have not been successful in identifying the presence of elongated open end pores that were predicated to have been formed by the evacuation process.

2.4 Sources of Diabase

Four of the test panels designed with diabase from the New York district were subjected to the jet impingement test. The design of these concretes, from which the panels were fabricated, was given in Table III of N.B.S. Report 5961. The panels were fog-room cured for 28 days and stored for either 14, 21, 28 or 35 days before testing. The results of the tests are given in Table II.

The values for spalling loss were approximately equal to those for panels designed with Virginia diabase. The jet impingement test results for Virginia diabase were given in Table I of N.B.S. Report 5353.

X-ray and petrographic examination of the New York deposite of diabase have been completed. As shown in Figure 1 of N.B.S. Report 4869 and Figure 2 of Report 5961, the New York diabase was similar to the Virginia diabase mineralogically with no quartz observed. The thermal expansion for temperatures up to 800°C was determined on samples from both deposites, Figure 1.

The thermal expansion curves were smooth with the exception of an increase in slope in the temperature range from 550 to 625°C. The temperature range of this increase in slope extends above that ordinarily obtained for crystalline quartz.

Table II

Spalling Loss of Panels During Jet Impingement

Concrete 1/	Drying Time 2/ Days	Total Water 3/ Percent	Spalling Loss 4/ cc
P-Di-NY-1	14	7.70	266.2
2	21	7.34	312.2
3	28	8.10	261.3
4	35	7.83	111.54

1/ The four panels were fabricated from the same concrete mix, portland cement and New York diabase aggregate.

2/ All panels were sealed on all but one 18 x 18 inch face, the test face, after removal from fog-room.

3/ Mixing water plus that absorbed during fog-room curing minus that evaporated during storage. Since the panels were fabricated from the same mix the mixing water was the same. The difference in final values was caused by absorption during curing and desorption during storage.

4/ Sand volume method.

2.5 Steam Curing and Jet Impingement

Jet impingement tests have been made on three panels fabricated from concrete using Virginia diabase aggregate and similar in design to those previously tested. These panels were stripped four hours after fabricating and placed in a humidity chamber that approached 100 percent in less than one hour. The panels were cured at three different top temperatures 80, 90, and 100°C. The interval necessary to reach these temperatures was 8, 10 and 16 hours respectively. This temperature was measured at the middle of the panel; i.e. three inch depth. The panels were allowed to cool to ambient temperature and immediately subjected to the jet impingement test. The results of these tests, together with other data on curing and testing, appear in Table III.

Two additional panels were fabricated similar in design to the aforementioned test panels. These panels were stripped, as were the others, four hours after placing. After stripping they were placed under an insulated metal hood that was continually charged with live steam from a supply at 10 psi for one and one-half hours. The center of these panels (three inches below test surface) reached 100°C in three hours. They were allowed to cool to ambient temperatures and subjected to the jet impingement test. The results of these tests appear in Table III.

Table III. Data for Jet Impingement Tests on Steam Cured Concrete Panels.

Panel[1]	Curing			Mixing Water[3]	Water Loss During Curing[4]	Interval Before Testing	Exposure to Jet	Spalling Loss		Temperature During Jet Impingement Test	
	Method	Max. Temp.[2]	Interval to Reach Max. Temp.					Calculated by Weight	Calculated by Vol.	Center on Surface	Center 1/4" below Surface
		°C	hrs.	%	%	days	Min.	cc	cc	°F	°F
P-D_i-1	Humid. cabinet	100	16	7.8	0.9	1	10	81.46	5/	670	323
do						14[6]	15	none	none	881	530
do						35[6]	15	none	none	833	444
" 2	do	80	8	7.7	0.5	1	5	162.92	5/	1134	300
" 3	do	90	10	7.5	0.4	1	5	124.60	5/	887	368
" 4	Live Steam	7/	7/	8.4	0.8	1	10	31.43	5/	7/	7/
" 5	do	100	3	8.3	0.9	1	10	30.58	5/	730	350

1/ All panels were fabricated with concrete of the same design. The mixing water varied slightly.

2/ This temperature was determined three inches below the test face of panel.

3/ Based on dry weight of batch.

4/ Based on weight after stripping.

5/ Not measurable by sand volume method.

6/ Storage at 50% relative humidity and 73°F.

7/ Thermocouples failed to register; wire not insulated for steam.

The losses shown in Table III were either none or too small to be measured accurately by the sand volume method. Panel P-Dj-1 showed no evidence of damage as a result of three tests. During the first test, temperature on the surface and within the panel were considerably lower than those indicated for panels that had been conventionally cured. These temperatures were somewhat higher when this panel was retested after a drying period of 14 days. Panel temperatures were somewhat lower for the other steam cured panels.

This resistence to explosive spalling may be explained by (a) development of a more permeable pore structure; (b) improvement in early strength due to steam curing; (c) a cooling effect caused by the egress of steam toward the heated surface, sometimes described as "sweat cooling."

2.6 Miscellaneous

The Masters Builders Company submitted three panels to be subjected to our jet impingement test. These panels were fabricated with a one inch topping of a proprietary concrete. using crushed iron millings as the aggregate. This topping was placed on a conventional concrete base. Two of the panels when fabricated were instrumented for temperature measurements in accordance with our method. They were subjected to our jet impingement test after seven-day fog-room curing and 21 days storage at 50% rh and 73°F. The temperature, recorded during the jet tests, on the face of the test areas or at varying depths below this face were not affected by the type of aggregate used.

Two of the test panels, the instrumented panels, withstood the jet test without loss. The third non-instrumented panel failed appreciably (in progressive layers that were somewhat thinner than for the other concretes).

Twenty-four hundred pounds of diabase aggregate from the Centerville, Virginia deposite was shipped to the U. S. Naval Civil Engineering Research and Evaluation Laboratory, Construction Battalion Center, Port Hueneme, California.

Literature

Crystal Chemistry of Hydrous Calcium Silicates: III, Morphology and Other Properties of Tobermorite and Related Phases.

G. L. Kalousek and Albert F. Prebus, J.A.C.S., Vol. 41, No. 4, April 1958.

Three very similar hydrous calcium silicates serve as binders for, or are closely related to the bonding material of, autoclaved and moist-air-cured concrete have been differentiated by electron microscopy, X-ray diffraction, differential thermal analysis, infrared absorption, degree of stability to the acetoacetic ester, and oxide composition. Tobermorite, 4-5 $CaO.5SiO_2.5H_2O_3$ is the binder of properly autoclaved concrete and related products.

Properties of Portland Cement Pastes Cured at Elevated Temperatures and Pressures.

N. C. Ludwig and S. A. Pence, J.A.C.I., 1956, 52 (6) pp. 673-87.

The effects of curing at elevated temperatures and pressures on the physical properties of hardened neat cement pastes. Data is included on the heat of hydration, non-evaporable water content, permeability to water at 80 to 400°F at pressures from atmospheric to 7500 psi at ages from 12 hours to 7 days.

The non-evaporable water decreased slightly at temperatures in excess of 220°F. The water permeability of hardened cement pastes was found to be quite low for curing temperature up to 160°F. Above this temperature permeability increased rapidly but strength decreased.

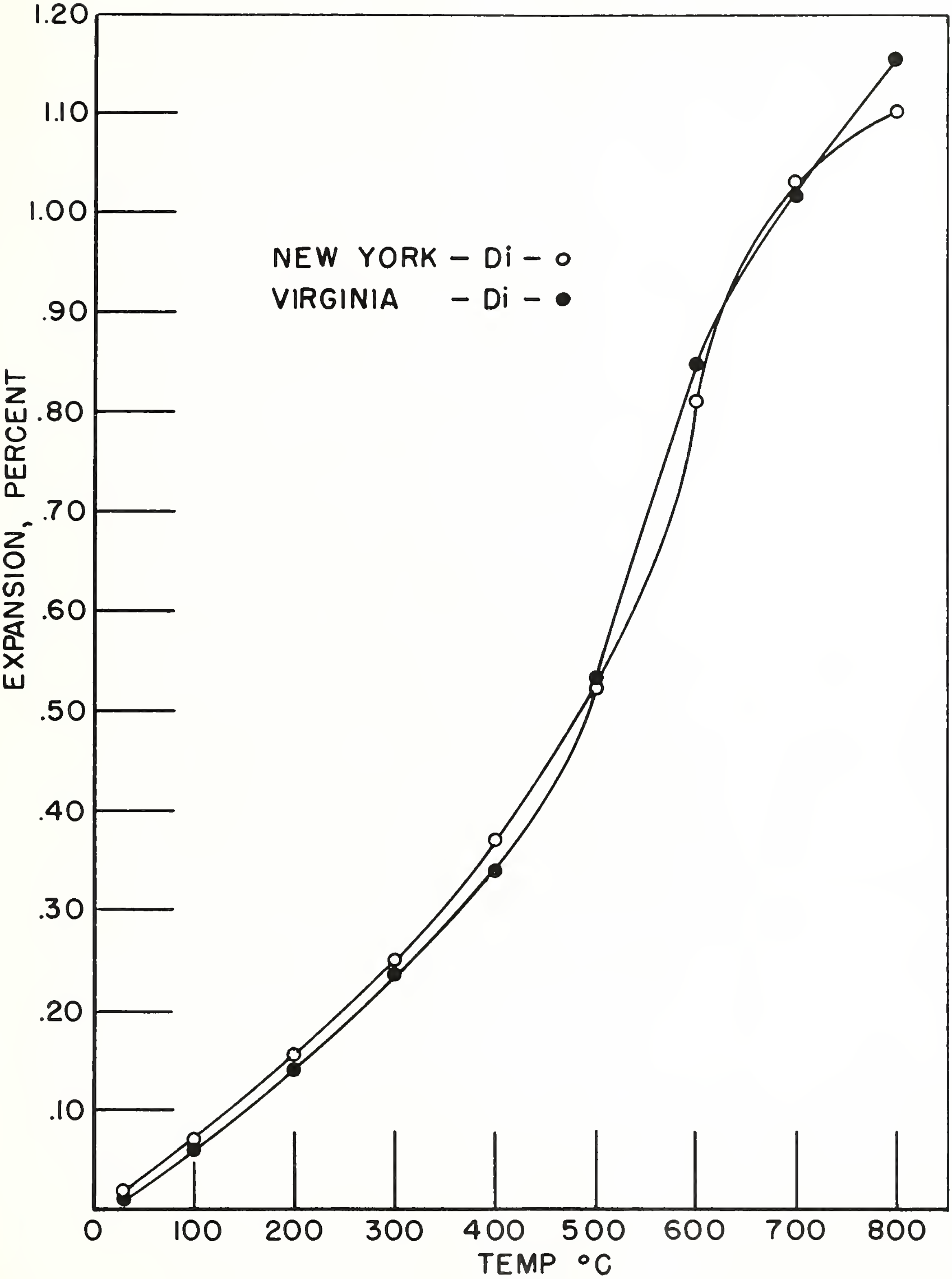

FIG. I THERMAL EXPANSION OF TWO DIABASES

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Sinclair Weeks, *Secretary*

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

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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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