NATIONAL BUREAU OF STANDARDS REPORT

4351

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, and R. A. Clevenger

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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 is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Process Technology. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

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

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. 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. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

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

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems.

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

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services.

Radio Propagation Engineering. Frequency Utilization Research. Tropospheric Propagation Research.

Radio Standards. High Frequency Standards. Microwave Standards.

- Office of Basic Instrumentation
- Office of Weights and Measures

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
0903-20-4428	September 30, 1955	4351

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, and R. A. Clevenger

Refractories Section
Mineral Products Division

Sponsored by
Department of the Navy
Bureau of Yards and Docks
Washington, D. C.

Reference: NT4-59/NY 4200 008-1
NBS File No. 9.3/1134-C

Approved:

NBS

Dr. Samuel Zerfoss
Chief, Refractories Section

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

PART I

1. INTRODUCTION

The objective of the first phase of this project is the determination of the physical properties of concretes that will evaluate their suitability for use in jet aircraft warm-up, power check, maintenance aprons, and runways.

2. MATERIALS: PREPARATION AND TESTING

2.1 Cements

A study of the permanent length changes, the water loss, as indicated by the weight loss, and the decrease in strength as indicated by Young's modulus of elasticity (dynamic method) has been completed on the three types of cement included in this project. Specimens of the neat cements were cured for 28 days in the fog-room, heated to apparent constant weight at 100°C, removed from oven, cooled in a desicator, and the length, weight, and elastic modulus determined. This operation was repeated at 100°C intervals to 1100°C.

2.2 Aggregates

The screen analysis of the last shipment of Kenlite, a lightweight aggregate was determined. The bulk specific gravity, absorption, and unit weight in pounds per cubic foot was determined on this material sized according to the same gradation used in designing the concretes.

2.3 Concretes

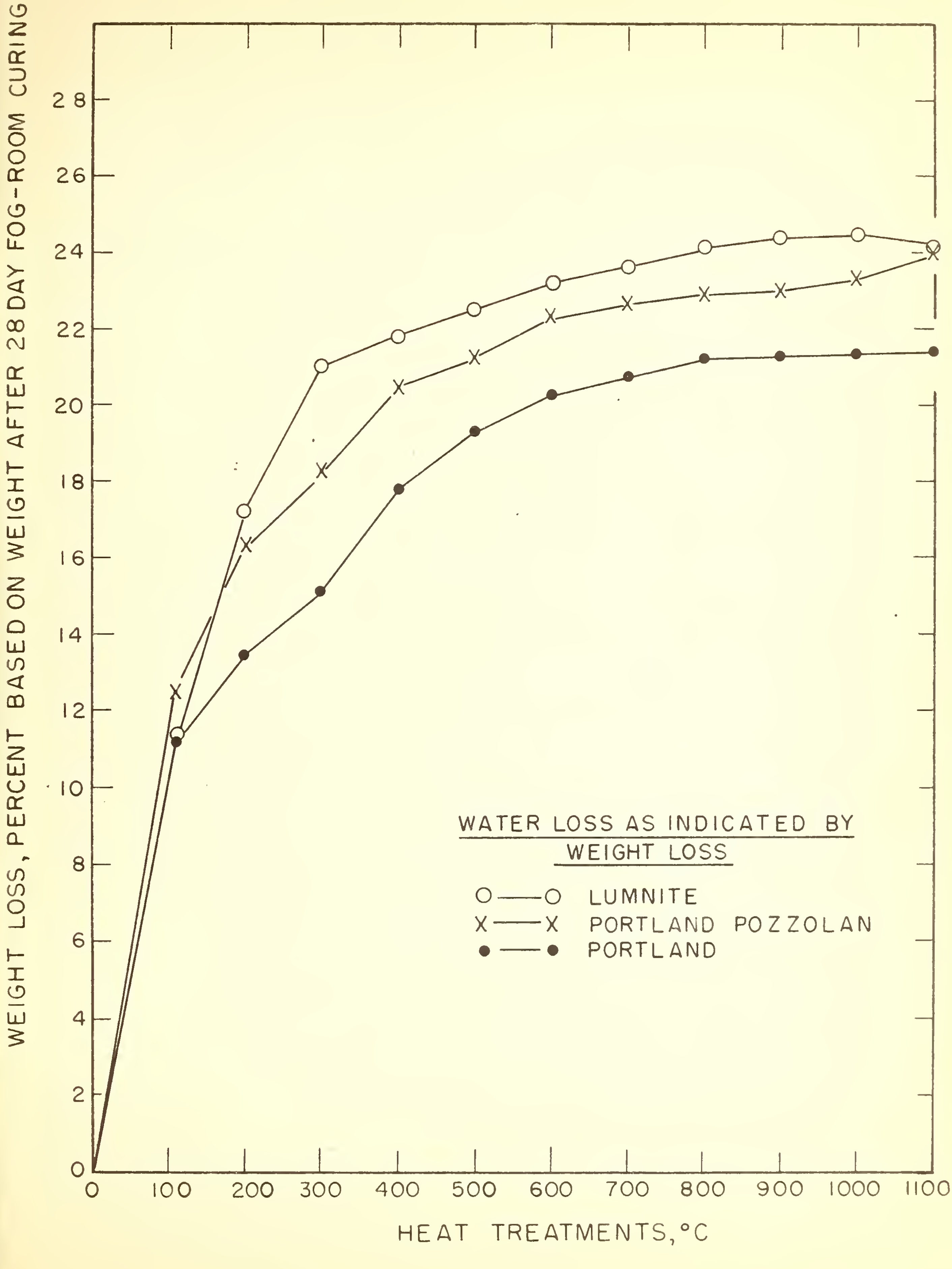
During this reporting period two final 15 cubic foot batches were designed, mixed, and specimens fabricated. Kenlite was used as the aggregate in both batches. Portland cement was used in the first and portland pozzolan in the second. One set of specimens fabricated from the portland cement concrete was cured in the fog-room for seven days and stored under laboratory conditions for 21 days. A second set was cured for 28 days in the fog-room. Specimens from each set have been tested.

The specimens fabricated from three concretes designed with Rocklite aggregate and either portland, portland pozzolan, or high-alumina hydraulic cement made during the last reporting period have been cured, heat-treated, and tested.

3. RESULTS AND DISCUSSION

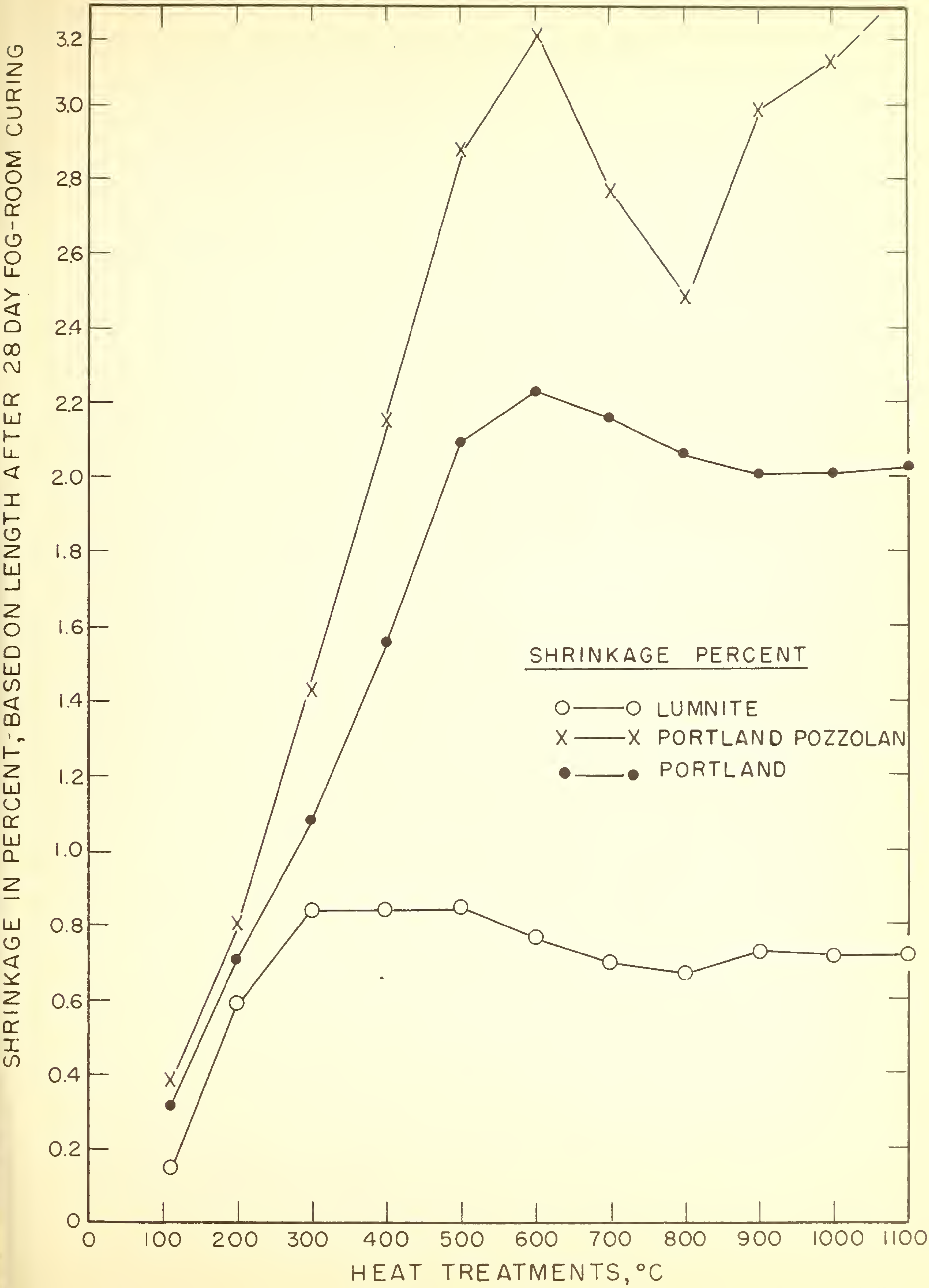
3.1 Cements

The graphs appearing in Figures 1, 2 and 3 show the water loss, as indicated by the weight loss, the length change, and the loss in strength, as indicated by the dynamic modulus. The effect of heating at 100°C intervals to 500°C on these properties was discussed in detail in N.B.S. Report 4200, June 30, 1955. The three cements continue to lose weight but at a uniform and reduced rate from 500°C to the maximum temperature of test 1100°C.

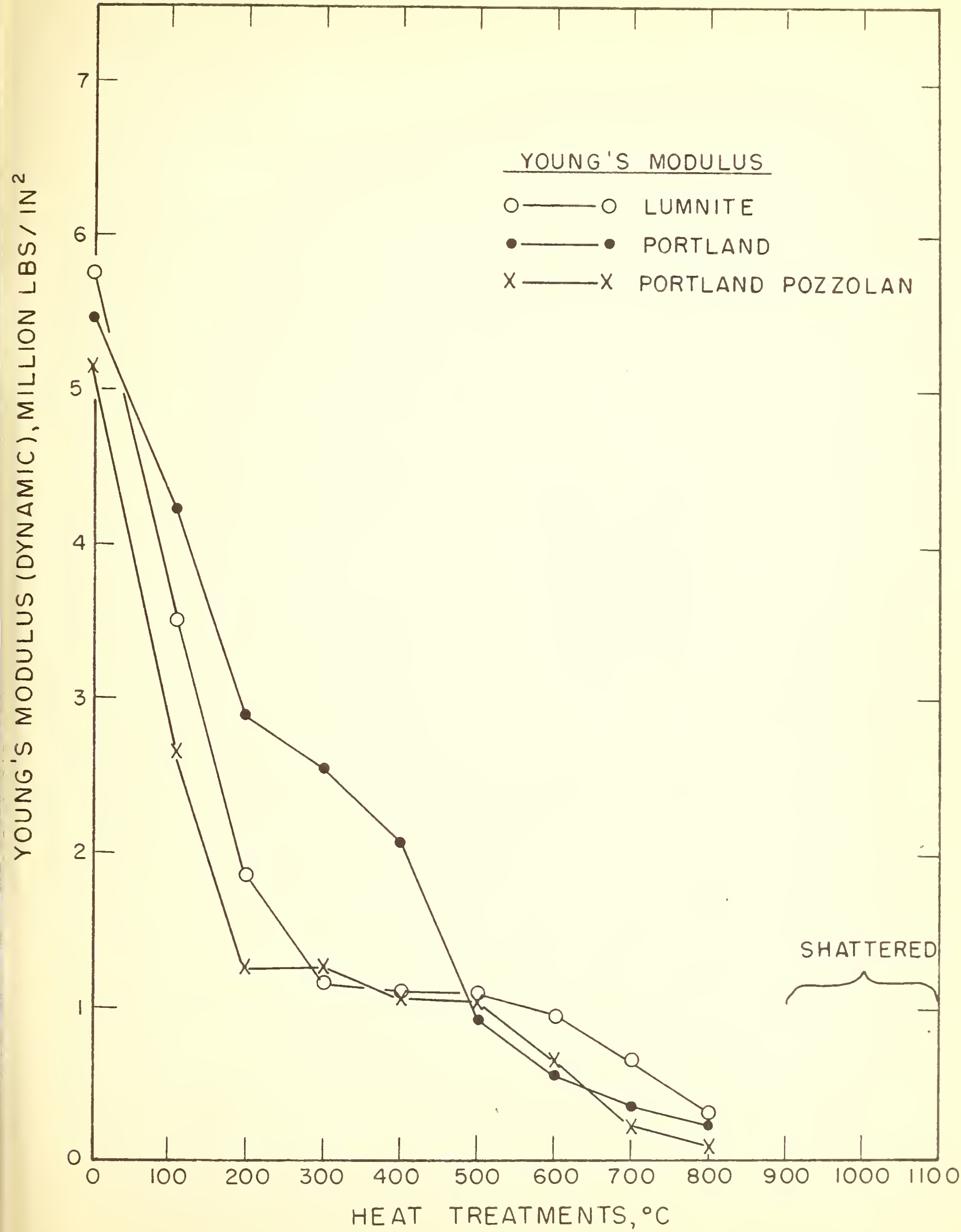


WEIGHT LOSS, PERCENT BASED ON WEIGHT AFTER 28 DAY FOG-ROOM CURING
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
900
1000
1100
HEAT TREATMENTS, °C
WATER LOSS AS INDICATED BY WEIGHT LOSS
O—O LUMNITE
X—X PORTLAND POZZOLAN
● — ● PORTLAND

FIG. 1



SHRINKAGE IN PERCENT, BASED ON LENGTH AFTER 28 DAY FOG-ROOM CURING
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
700
800
900
1000
1100
HEAT TREATMENTS, °C
SHRINKAGE PERCENT
LUMNITE
PORTLAND POZZOLAN
PORTLAND



YOUNG'S MODULUS
LUMNITE
PORTLAND
PORTLAND POZZOLAN
SHATTERED
YOUNG'S MODULUS (DYNAMIC), MILLION LBS/IN^2
HEAT TREATMENTS, °C
0
1
2
3
4
5
6
7
100
200
300
400
500
600
700
800
900
1000
1100

FIG. 3

The Lumnite cement expanded throughout this temperature range 0.1 percent. The portland and portland pozzolan cements continue to ~~expand~~ shrink to 600°C. Portland cement shows a ~~shrinkage~~ expansion of 0.2 percent from 700°C to 1100°C. The portland pozzolan shows a rapid rate of expansion from 600°C to 800°C, totaling approximately 0.70 percent. From 800°C to 1100°C the portland pozzolan has a ~~total expansion~~ shrinkage of approximately 1.0 percent.

The modulus of elasticity continues to decrease from 500°C to 800°C. All cement specimens had shattered so badly at the 900°C interval that the dynamic modulus could not be determined.

3.2 Aggregates

The result of the preliminary tests made on the last shipment of Kenlite varied somewhat from those of other shipments. Because of this variation it was necessary to make some changes in the design of the final batch.

3.3 Concretes

Table 1 gives the properties of the cured and heat-treated concretes designed with "Rocklite" aggregate. The composition and some of the properties of the fresh concretes appeared in N.B.S. Report 4200, June 30, 1955. Using portland or portland pozzolan as the bond, concretes were designed that developed the required flexural strength of 600 psi during 28-day fog-room curing. The original requirements

Table 1. Properties of Cured and Heat-Treated Concretes, with Lightweight Aggregate, Rocklite.

Identification[a]	Proportions by Weight of Cement to Coarse and to Fine Aggregate	Treatment Preceding Test[b]	Compressive Strength	Flexural Strength	Abrasion Loss: Weight of Dust	Abrasion Loss: Depth of Wear[c]	Young's Modulus of Elasticity Dynamic; Longitudinal	Total Linear Change[d]	Total Weight Change[e]
			psi	psi	grams	inches			
Z - R	1 : 1.00 : 0.64	1					1.584		
		2					2.478	+0.006	+ 0.625
		3		205	34.40	0.0113	2.209	-0.006	- 3.621
		4	5010	585	3.20	0.0021	2.717	+0.093	+ 1.121
		5					1.866	-0.031	-10.285
		6		315	30.50	0.0099	1.310	-0.062	-11.702
		7		200	31.40	0.0092	.822	-0.146	-14.135
		8[f]		65				+0.187	-16.591
P - R	1 : 1.01 : 0.73	1					2.185		
		2					2.521	+0.126	+ 0.451
		3		300	23.35	0.0076	2.277	no change	- 4.026
		4	5305	605	3.50	0.0019	2.641	+0.025	+ 0.953
		5					1.929	-0.036	- 9.604
		6		330	23.95	0.0052	1.487	-0.025	-11.233
		7		230	28.90	0.0017	.772	-0.144	-12.394
		8[f]						+0.743	-15.460
L - R	1 : 0.97 : 0.72	1					2.609		
		2					2.711	+0.010	+ 0.755
		3		160	20.95	0.0674	2.581	-0.007	- 1.550
		4	3090	375	37.05	0.0119	2.773	+0.019	+ 2.227
		5							- 6.441
		6		295	50.40	0.0155	1.396	-0.050	- 7.640
		7		235	49.65	0.0151	1.179	-0.095	-10.820
		8[f]		180				-0.100	-12.632

a/ The first letters: Z = portland pozzolan cement; P = portland cement; L = Lumnite, a high-alumina cement.
The second letter: R = an expanded shale, coated lightweight aggregate, "Rocklite".

b/ The results in line 1 were obtained after 20 to 24 hours in mold; line 2 after 7 days in fog-room; line 3 after line 2 treatment plus 21 days at ordinary laboratory conditions; line 4 after 28 days in fog-room; line 5 after line 3 treatment plus drying at 110°C; line 6 after line 3 treatment plus heating at 250°C for 5 hours; line 7 after line 3 treatment plus heating at 500°C for 5 hours; line 8 after line 3 treatment plus heating at 1000°C for 5 hours.

c/ A description of the apparatus and method used in determining depth of wear was given in NBS Report 3201.

d/ Based on length after 24 hours in mold.

e/ Based on weight after 24 hours in mold.

f/ The test specimens after the 1000°C heat exposure failed to retain sufficient strength for handling. The results in this line are unreliable.

of 650 psi was reduced to 600 psi for lightweight aggregate concrete. The concrete designed with Lumnite cement and Rocklite aggregate failed to develop the required strength. The low strength of the concretes designed with the lightweight aggregate "Rocklite" could be attributed to bond failure. An examination of the fractured beams showed very little aggregate fracture. The coating on the aggregate seemed to prevent proper bonding. This was especially evident in the test specimens that had been heat-treated.

The concretes designed with Kenlite aggregate and either portland or portland pozzolan cement have been mixed and test specimens fabricated. These test specimens are being cured in fog-room prior to testing. The composition and some of the properties of the fresh concretes will appear in the next report, together with the results of tests on the cured and heat-treated concretes. The test results on the third concrete designed using this aggregate with the high-alumina hydraulic cement will also be included.

This will conclude that phase of the project concerned with the collection of data on the thermal and mechanical properties of concretes designed with one of three types of cement and a variety of aggregates.

PART II

1. INTRODUCTION

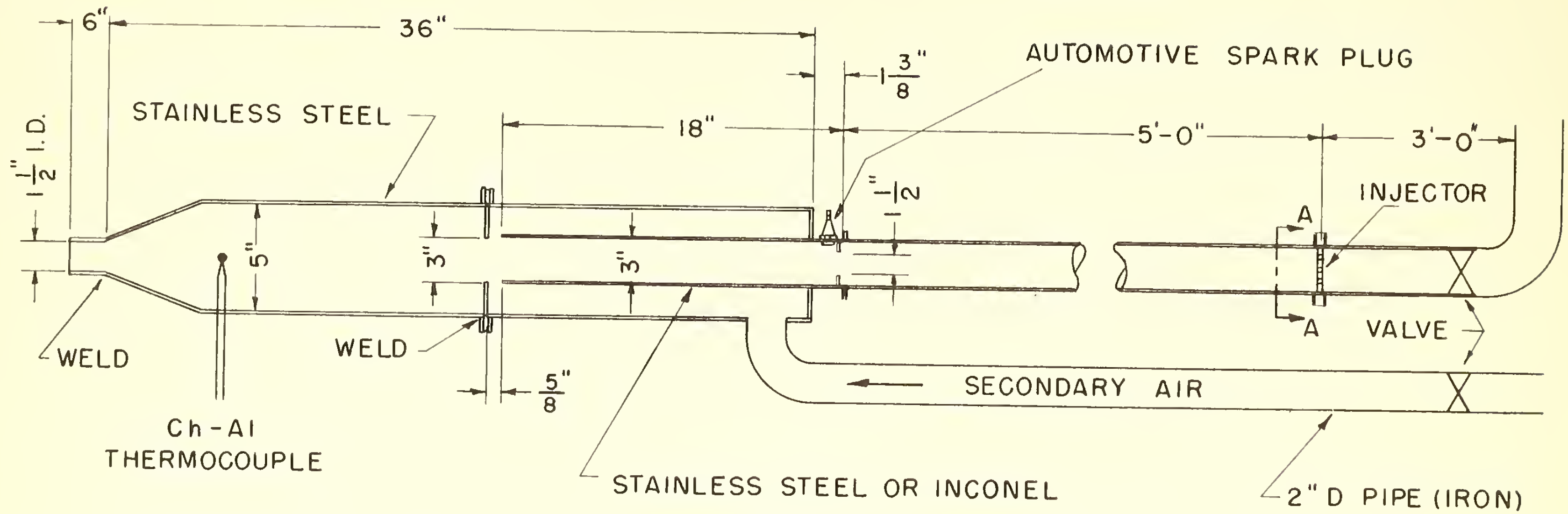
The second part of the project inaugurated in September, 1955, and thus far carried on simultaneously with the first, includes a more basic approach to the cause or causes of failure that occur in concrete aprons and runways exposed to jet exhaust gases. It includes a measure of the heat gradients and stresses set up by flame impingement. Field conditions will be simulated by using a combustion chamber that will deliver hot gases at velocities and temperatures approximating those in actual service.

2. MATERIALS

For the purpose of limiting the scope of this phase of the project portland will be the only cement used and the aggregates will be limited to four, olivine, crushed building brick, sintered slag, and calcined flint clay. The thermal and mechanical properties of the concretes designed with olivine, crushed building brick, calcined flint clay or, sintered slag indicated that the heat exposure up to 500°C effected these concretes the least. The convential sand and gravel concrete will be included for comparative purposes.

3. TESTS

Heat tests will be included to simulate field conditions. A combustion chamber, Figure 4, has been designed by the Mechanics Division, Combustion Controls Section, that will deliver hot gases at 600°F to 1200°F at velocities of approxi-



COMBUSTION CHAMBER

FIG. 4

mately 1200 ft/sec. Test panels will be fabricated containing thermocouples placed on the panel surface and at varying depths from the exposed surfaces to study the heat gradient. Pitot tubes to determine the velocities of the gases in a given direction will be built in the test panels. The moisture content of the panels will be determined by weight loss and the variation in moisture content from surface to maximum depth studied. The moisture content will be controlled by drying. Tests will be conducted at varying water contents. The panels will be vapor proofed on all surfaces except the test face. A panel mould designed for these particular panels has been completed. Gauges indicating the strain set up in the panel during the heat impingement will be included in the second set of panels. The placement of the gauges, and the analysis of the data collected will be carried out with the advice and consultation of the Fire Protection and the Structural Engineering Sections of the Building Technology Division.

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. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published 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 monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

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 ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.

NBS