# NATIONAL BUREAU OF STANDARDS REPORT

2632



QUARTERLY REPORT
ON
EVALUATION OF REFRACTORY QUALITIES OF CONCRETE
FOR JET AIRCRAFT WARM UP, POWER CHECK AND
MAINTENANCE APRONS

by
W. L. Pendergast, R. A. Clevenger, Emil Trattner

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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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, AND
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by

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NBS

QUARTERLY REPORT
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Current Technical Requirements

1. All coarse aggregates shall be sieved and recombined to produce a gradation that will conform to BuDocks specification 45Ya [1] paragraph 2-05 for the 1 1/2 inch specified aggregate size. The aggregates shall be recombined in such percentages that the fineness moduli shall not vary more than plus or minus 0.2.

2. All fine aggregates shall be sieved and recombined so that the resulting gradation conforms to BuDocks 45Ya [1] paragraph 2-03. The aggregate shall be recombined to produce a fineness moduli of between 2.3 and 3.1 but for the aggregates now in use it shall not vary more than 0.2.

3. BuDocks 13Yd [2] (Table II) shall serve as a guide in arriving at the ratio of fine to coarse aggregates.

4. The upper limit for cement content shall be 7.5 bags per cubic yard of concrete. The lowest cement content concrete that develops the required flexural strength is desirable.

5. The concretes shall be mixed, specimens fabricated and cured in accordance with ASTM Designation C192-52T [3]. The curing treatment shall be 28-day fog room storage.

6. The air content of the concrete shall be limited to 4.5 plus or minus 1.5 percent. The air content shall be measured in accordance with ASTM Designation C231-52T [3].

7. The concrete must be of such a consistency as to yield a 2-inch slump when tested in accordance with ASTM Designation C143-52 [3c]. If, however, a concrete is not sufficiently workable this requirement may be modified.

8. The concrete must develop a flexural strength of 600-650 psi after 28-day fog room curing.

9. The compressive strength shall be determined on each concrete after the 28-day fog room curing period.

10. Resistance of the concrete to destruction when exposed to rapidly increasing and fluctuating temperatures is necessary.

11. Technical requirements 5, 7 are not applicable to Lumnite concretes. The recommendations of the manufacturer should be followed in mixing, placing, and curing these concretes.

## I. INTRODUCTION

The objective of the investigation is the determination of certain physical properties of concretes that will evaluate their suitability for use in jet aircraft warm up, power check, and maintenance aprons.

## II. MATERIALS: PREPARATION AND TESTING

Cements. The specific gravity of the three cements used in designing the concretes follows. The determinations* were made in accordance with ASTM Designation C188-44 [4].

| Identity | Specific Gravity |
|---|---|
| North American Portland | 3.11 |
| Green Bag Portland Pozzolan | 3.13 |
| Universal Atlas Lumnite | 3.09 |

Aggregates. Coarse and fine fractions of aggregate were selected to conform with the Specification for Portland Cement Concrete Pavement for Airports No. 45Ya Sept. 1952, and the technical requirements of NAVCERELAB.

The screen sizes and percentage of each of the sizes resulting from such selection of the aggregates and which will be used in all future concretes are given in Table I.

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* Made by the Concreting Materials Section, Mineral Products Division, National Bureau of Standards

Table I. Screen Sizes of Aggregates

| Coarse Fractions | | Fine Fractions | |
|---|---|---|---|
| Screen No. | Percentage Passing | Screen No. | Percentage Passing |
| 1 1/2 | 100 | 4 | 100 |
| 1 | 78 | 8 | 85 |
| 3/4 | 48 | 16 | 68 |
| 1/2 | 30 | 30 | 50 |
| 3/8 | 15 | 50 | 21 |
| No. 4 | 0 | 100 | 3 |

When aggregates are sized in accordance with the gradation given in Table I the fineness modulus of the coarse will be 7.37 and that of the fine 2.73.

One and one-half tons each of White Marsh gravel and White Marsh sand was screened to meet the gradation requirements. The ratio of gravel to sand in the concretes designed using this aggregate was 3.6 : 1.9 resulting in a combined fineness modulus of 5.74.

Bluestone, a second aggregate,is being screened as purchased. After screening one ton of this material the results indicate that additional crushing and screening will be necessary to obtain the proper yield of the required sizes.

Considerable work has been done to facilitate the selection of a brick for an aggregate. Tests were made on a low-grade fire brick and two dense face bricks. The brick chosen was a West Virginia hard face brick having a flexural strength of 2180 psi. This brick when crushed is angular in shape and the percentage yield of the desired sizes is reasonably satisfactory.

Properties of the three aggregates tested during this quarter for future use in designing concretes are as follows:

| Aggregate | Size | Bulk specific gravity S-S Dry | Water absorption in percent by weight | Los Angeles abrasion percentage wear |
|---|---|---|---|---|
| White Marsh | gravel | 2.64 | 0.30 | 40.5 |
| | sand | 2.63 | 0.30 | |
| Bluestone | coarse | 2.76 | 1.50 | 21.3 |
| | fine | 2.65 | 0.27 | |
| West Virginia hard face | coarse | -- | -- | 26.0 |
| | fine | -- | -- | |

Concretes. The properties of the fresh concretes are given in Table II. Three concretes were designed with White Marsh gravel and sand as the aggregate and either with

Table II. Properties of Fresh [a] Concretes

| Laboratory identification [b] | Proportions by weight: Cement to coarse and to fine aggregate | Cement content | Vinsol resin by weight of cement | Water content | Air content | | Slump | Weight of fresh concrete | Water cement ratio | Flexural [a] strength | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Gravimetric method | Air meter | | | | | |
| | | Sacks per $yd^3$ of concrete | % | Gals/$yd^3$ of concrete | % | | Inches | Lbs/$ft^3$ | | Psi | |
| P-WM-A | 1 : 3.49 : 1.88 | 6.18 | 0.010 | 32.3 | 2.50 | 3.00 | 3.0 | 147.4 | 0.46 | | |
| P-WM-B | do | 6.11 | 0.015 | 30.5 | 3.64 | 4.25 | 2.0 | 145.2 | 0.44 | | |
| P-WM-C | 1 : 3.60 : 1.94 | 6.00 | do | 28.4 | 4.77 | 4.10 | 1.5 | 145.7 | 0.42 | | |
| P-WM-D | do | 6.04 | do | 29.9 | 3.85 | 3.80 | 1.0 | 146.5 | 0.44 | | |
| P-WM-E | do | 5.99 | do | 30.8 | 3.90 | 4.30 | 2.0 | 145.9 | 0.45 | | |
| Z-WM-A | 1 : 3.58 : 1.95 | 5.98 | none | 31.3 | 3.71 | 3.50 | 2.0 | 145.9 | 0.46 | | |
| L-WM-A | 1 : 3.58 : 1.93 | 6.22 | do | 29.5 | 0.91 | 1.60 | 1.0 | 151.3 | 0.42 | 575 [c] | Harsh mix, dense concrete aggregate fracture approx. 75% |
| L-WM-B | 1 : 3.58 : 1.93 | 5.69 | 0.050 | 28.4 | 8.60 | over 8 | 2.0 | 138.5 | 0.44 | 395 [c] | Slightly honeycombed, aggregate fracture approx. 15% |
| L-WM-C | do | 5.95 | 0.020 | 31.8 | 5.20 | 4.20 | 4.5 | 145.5 | 0.47 | 500 [d] | Good workability, dense concrete aggregate fracture approx. 15% |
| L-WM-D | do | 6.03 | 0.015 | 29.8 | 3.10 | 3.40 | 2.0 | 147.2 | 0.44 | 505 [c] | Good workability, dense concrete aggregate fracture approx. 25% |
| L-WM-E | do | 6.02 | do | 30.2 | 3.20 | 3.50 | 2.0 | 147.0 | 0.44 | 500 [d] | Good workability, dense concrete aggregate fracture approx. 50% |
| P-WM-1 | 1 : 3.57 : 1.95 | 5.85 | do | 32.3 | 5.30 | 5.12 | 1.5 | 142.9 | 0.47 | | |
| P-WM-2 | do | 5.81 | do | 32.1 | 5.97 | 6.10 | 2.0 | 142.0 | 0.47 | | |
| P-WM-3 | do | 5.87 | do | 32.4 | 4.96 | 5.60 | 1.5 | 143.5 | 0.47 | 540 [e] | Some air voids, aggregate fracture approx. 10% |
| Z-WM-1 | 1 : 3.58 : 1.94 | 5.91 | do | 32.6 | 4.48 | 3.80 | 2.0 | 144.4 | 0.49 | 640 [e] | Few pull outs, air voids near center, aggregate fracture approx. 50% |
| Z-WM-2 | do | 5.96 | do | 33.0 | 3.54 | 3.40 | 2.5 | 145.9 | 0.49 | | |
| Z-WM-3 | do | 5.98 | do | 33.0 | 3.38 | 3.20 | 2.0 | 146.1 | 0.49 | | |
| L-WM-1 | 1 : 3.58 : 1.93 | 5.98 | do | 30.8 | 4.00 | 3.30 | 3.5 | 145.5 | 0.46 | | |
| L-WM-2 | do | 5.98 | do | 31.8 | 3.40 | 2.70 | 1.0 | 145.9 | 0.47 | | |
| L-WM-3 | do | 5.98 | do | 31.6 | 3.45 | 3.50 | 4.5 | 145.9 | 0.47 | | |

[a] For convenience the flexural strength thus far determined of several of the concretes are included in the table.

[b] P = Portland Cement; Z = Portland Pozzolan Cement;
L = Lumnite Cement; WM = White Marsh gravel and sand
The last letters "A" to "E" inclusive, indicate trial mixes made in a 1-cubic foot mixer
The last numerals 1 to 3 inclusive, indicate final selected mix made in a 5-cubic foot mixer
Three batches of the selected mix were necessary to fabricate the required number of test specimens.

[c] Put in fog room 1/2 hour after placing, cured 21 1/2 hours in fog room in mold, stripped and after 2 hours additional in fog room, tested.

[d] Seven hours in laboratory in mold; stripped and put in fog room for 17 hours, then tested.

[e] Cured for 28 days in fog room.

portland, portland pozzolan, or high alumina hydraulic cements. Trial batches of each concrete were mixed in a 1-cubic foot mixer. As a result of the information gained from these trial batches concrete was designed for fabricating the specimens for the complete series of tests. Five sets of test specimens of each concrete, requiring 3 five-cubic foot charges were fabricated and will be tested after curing and after one of four different heat exposures. Two sets have been cured in the fog room for 28 days, their flexural strengths determined, and are reported in Table II.

## III. DISCUSSION AND RESULTS

The results given in Table II indicate that the properties of the fresh concretes designed and mixed fall within the limits contained in NAVECEIAB letter of April 1, 1953. Only two of the concretes have completed the 28-day curing cycle and have been tested for flexural strength. The concrete designed using portland cement and White Marsh aggregate failed to meet the 600-650 psi flexural strength requirement. This concrete was designed using a 6 sack (per cubic yard of concrete) mix. It is planned to redesign the mix increasing the cement content to 6.5 - 7 sacks per cubic yard.

[1]. Specification for Portland Cement Concrete Pavement for Airposts. Sept. 1952 Department of the Navy

[2]. Specification for Concrete Construction June 1951 Department of the Navy

[3]. ASTM Standards on Mineral Aggregates, Concrete and Non-bituminous Highway Materials.

(a) Tentative Method of Making and Curing Concrete Compression and Flexure Test Specimens in the Laboratory Page 147.

(b) Tentative Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method.

(c) Standard Method of Test for Slump of Portland-Cement Concrete Page 187.

(d) Standard Page 165

[4]. ASTM Standards on Cement (with related information) April 1952. Standard Method of Test for Specific Gravity of Hydraulic Cement.

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NOTE: One full time professional employee assigned to this project permanently transferred to another Division of this Bureau. The employee who replaced him resigned as of June 30. A third employee was appointed effective June 29.

## ADDENDUM A

### Cooperative Tests

For the purpose of determining what variation might be expected in the results of tests of concretes fabricated at different laboratories, three concretes were designed, fabricated, cured, and tested at the U. S. Naval Civil Engineering Research and Evaluation Laboratory. Santa Clara sand and Colton Type I portland cement used in these three concretes were forwarded from that Laboratory to this Bureau during March. The results of tests made on the aggregates by the two laboratories were as follows:

| Laboratory | Material | Specific Gravity | Absorption | Fineness Modulus |
|---|---|---|---|---|
| NAVCERELAB | sand | 2.53 | 1.97 | 3.14 |
| NBS | " | 2.55 | 1.68 | 3.22 |
| NAVCERELAB | gravel | 2.53 | 2.78 | 6.85 |
| NBS | " | 2.51 | 2.98 | 7.06 |

The aggregates were brought to a saturated-surface dry condition. The designated amounts of gravel, cement, sand, and water were added in that order and mixed for 4 minutes. The slump and air content were determined and specimens fabricated.

The properties of the fresh concrete are given in Table A. A sufficient number of 6 x 6-inch beams were fabricated to permit three breaks of each concrete after two different curing periods. The specimens after curing were tested for flexural and compressive strength. The results are given in Table B.

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NOTE: The above three concretes were designed, mixed, fabricated, cured, and tested at the National Bureau of Standards in accordance with instructions given in NAVCERELAB letters of February 25 and May 11, 1953.

Table A. Properties of Fresh Concretes

| Identification [a] | Laboratory [b] | Size of batch [c] | Cement Content [c] | Water | Slump | Aggregate [d] | | Sand | Unit weight of fresh concrete | Air Content | | Water Cement ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | sand | gravel | | | gravimetric method [e] | air meter | |
| | | cu.ft. | Sacks/yd$^3$ | Lbs/yd$^3$ | Inches | Lbs | Lbs | % | Lbs/ft$^2$ | % | % | |
| C-SC-1 | A | 27.30 | 3.50 | 334 | 3.5 | 1730 | 1470 | 54.0 | 140.7 | | | 1.02 |
| | B | 27.33 | 3.46 | 341 | 2.0 | 1719 | 1475 | 53.8 | 141.3 | 0.20 | | 1.05 |
| C-SC-2 | A | 26.34 | 5.50 | 274 | 3.5 | 1475 | 1568 | 48.5 | 144.7 | | | 0.53 |
| | B | 26.28 | 5.64 | 273 | 2.5 | 1471 | 1570 | 48.6 | 144.4 | 0.10 | 1.02 | 0.52 |
| C-SC-3 | A | 27.00 | 7.50 | 315 | 3.5 | 1300 | 1585 | 45.0 | 144.9 | | | 0.46 |
| | B | 26.97 | 7.52 | 315 | 7.0 | 1300 | 1594 | 45.0 | 145.2 | 0.01 | 0.20 | 0.45 |

[a] The letters C-SC denote Colton cement and Santa Clara gravel and sand aggregate
The numerals 1, 2, and 3 denote the cement content, namely, 3 1/2, 5 1/2, and 7 1/2 sacks/yd$^3$ of concrete

[b] A = NAVCERELAB; B = National Bureau of Standards

[c] The values tabulated for National Bureau of Standards (B) were calculated using batch weights and weight per cubic foot of fresh concrete

[d] Weight based on saturated-surface dry conditions

[e] The data furnished by NAVCERELAB for specific gravity and absorption were used in calculating volume; a value of 3.15 was used for specific gravity of Colton cement.

TABLE B. STRENGTH OF CURED CONCRETES

| Identification [a] | Laboratory [b] | Flexural Strength after curing 7 & 21 days [d] | Flexural Strength after curing 28 days [e] | Compressive Strength [c] after curing 7 & 21 days [d] | Compressive Strength [c] after curing 28 days [e] |
|---|---|---|---|---|---|
| | | psi | | psi | |
| C-SC-1 | A | | 351 | | 1450 |
| | B | 200 | 245 | 1455 | 1325 |
| C-SC-2 | A | | 625 | | 4650 |
| | B | 425 | 540 | 4540 | 4340 |
| C-SC-3 | A | | 739 | | 5380 |
| | B | 395 | 620 | 5070 | 4840 |

[a] The letters C-SC denote Colton cement and Santa Clara gravel and sand aggregate
The numerals 1,2, and 3 denote the cement content, namely, 3 1/2, 5 1/2 and 7 1/2 sacks per $yd^3$ of concrete

[b] A = NAVCEREIAB; B = National Bureau of Standards

[c] The compressive strength results obtained at the NBS laboratory were determined on portions of the broken beams used for flexural strength tests

[d] Curing period: 7 days in fog room and 21 days storage in laboratory at prevailing temperatures and humidities

[e] 28 days in fog room

[f] The variation expressed in percent is based on results obtained at NAVCEREIAB.

## DISCUSSION OF RESULTS

The values given in Table A for the properties of the fresh concretes as determined by the two laboratories compare favorably with one exception, namely, the slump for the concrete containing 7 1/2 bags of cement.

A comparison, however, of the strengths, Table B, of the three cured concretes (as determined by the two laboratories) indicates that the values determined at this Bureau are lower than those of NAVCERELAB. The flexural strengths of the concretes ranged from 14 to 30 percent lower and the compressive strengths approximately 10 percent lower.

ADDENDUM B

Experimental Concrete Mixes. A limited number of concrete mixes were designed in which changes were made in the cement to aggregate ratio, the fineness modulus of the fine aggregate, the method of placing, the curing time, and method of curing. The purpose of the work was to learn what could be accomplished in the laboratory that would result in increasing the flexural strength above that previously obtained of cured concretes. The results are given in the following table as a matter of record. In these experimental mixes the two cements used were portland (P) and Lumnite (L). The same aggregate, namely, White Marsh sand and gravel, was used in the mixes.

Experimental Concretes

| Laboratory Identification | Proportion by weight of cement to fine to coarse | Fineness modulus of fine sand | Cement content | Air Content | Method and Time of Curing | Number of days of curing | Flexural Strength |
|---|---|---|---|---|---|---|---|
| | | | Bags/yd$^3$ | % | | | Psi |
| PS-A1 | 1:2.3:3.3 | 2.82 | 5.6 | 2.8 | 24 hrs. in molds under burlap in fog room. 6 days in fog room out of molds. | 7 | 420 |
| PS-A2 | 1:2.3:3.3 | 2.82 | 5.6 | 2.8 | 24 hrs. in molds under burlap in fog room. 6 days in fog room out of molds. 21 days in laboratory air. | 28 | 395 |
| PS-A3 | 1:2.3:3.3 | 2.82 | 5.6 | 2.8 | 24 hrs. in molds under burlap in fog room. 27 days in fog room out of molds. | 28 | 650 |
| PS-B | 1:1.6:2.3 | 2.82 | 8.0 | 3.6 | Same as PS-A1 for comparison of strength with varying cement content | 7 | 525 |
| PS-C | 1:1.6:2.3 | 3.10 | 7.8 | 5.5 | Same as PS-B for comparison of strength with varying fineness modulus of fine sand | 7 | 690 |
| PS-XR | 1:1.6:2.3 | 2.82 | 7.8 | a/ | 4 hrs. in laboratory air in molds uncovered. 20 hrs. in fog room under burlap. 6 days in fog room out of molds | 7 | 610 |
| PS-XV | 1:1.6:2.3 | 2.82 | 7.8 | a/ | Same as PS-XR but vibrated | 7 | 660 |
| LS-A1 | 1:1.2:2.3 | 2.82 | 6.3 | 5.4 | Method & time of curing same as PS-A1 | 7 | 400 |
| LS-A2 | 1:2.3:2.3 | 2.82 | 6.3 | 5.4 | 5 hrs. in molds in laboratory air, no burlap. 19 hrs in molds in fog room 6 days out of molds in fog room | 7 | 425 |
| LS-A3 | 1:2.3:2.3 | 2.82 | 6.3 | 5.4 | 24 hrs. in laboratory air (22 under burlap) 6 days in fog room out of molds | 7 | 500 |

a/ Air content not determined. PS-XR and PS-XV fabricated from same batch.

## 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 ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the 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.


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