NATIONAL BUREAU OF STANDARDS REPORT

1575

Quarterly Report

on

Investigation on Aggregates and Concretes Used in Rigid Pavements Subjected to High and Fluctuating Temperatures.

For Quarter Ending March 31, 1952

Sponsored by

U. S. Naval Civil Engineering Research and Evaluation Laboratory, Construction Battalion Center, Port Hueneme, California.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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15. **MISSILE DEVELOPMENT.** Missile Engineering. Missile Dynamics. Missile Intelligence. Missile Instrumentation. Technical Services. Combustion.

NBS PROJECT

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NBS REPORT

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Investigation on Aggregates and Concretes Used in Rigid Pavements Subjected to High and Fluctuating Temperatures.

For Quarter Ending March 31, 1952

Prepared by

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Sponsored by

U. S. Naval Civil Engineering Research and Evaluation Laboratory, Construction Battalion Center, Port Hueneme, California.

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INTRODUCTION

As stated in the last report the object of this project is to study certain properties of heat-resisting concrete for the purpose of developing a rigid pavement for the general ground circulation of jet-type aircraft and especially for warm-up and take-off operations of these aircrafts. In continuation of the tests carried out and partially recorded in the preceding report, the work accomplished during this quarter dealt with the completion of tests on additional aggregates and the designing, mixing, curing, and testing of a few of the thirty-three concretes to be investigated.

AGGREGATES

Tests Completed: The tests conducted on all the aggregates, except the one obtained by crushing common building brick, have been completed. The brick were of a medium hard grade (8.7% water absorption). The results of these tests, approximately ten percent of which were included also in the last progress report, NBS 1362, are shown in the attached Table 1. All tests were conducted in accordance with the methods referred to in the last report. The data appearing in the table are necessary for the designing of concrete mixes suitable for the specified service. These data may also be used as a reference in future work of this type.

CONCRETES

The cement-aggregate ratio used in designing the various mixes was obtained from data appearing in the publication, "Light Weight Aggregates", by the Housing and Home Finance Agency. These mixes were adjusted, however, to compensate for differences existing in the sizes of the aggregates used in this study and compared with those listed in the publication referred to. Nine concretes were designed, using each of three cements, namely, Portland, Portland-pozzolan, or Lumnite, respectively, with each of three aggregates, namely, Pumice, Haydite, and Waylite. Specimens were fabricated, cured, and tested. These mixtures were proportioned by volume and mixed in a three cubic foot tilt-drum mixer. The water and aggregate were mixed for one minute, the cement and vinsol resin was then added in that respective order and mixed for three minutes. From each mix one lot of specimens were cast consisting of four 6 x 2-inch cylinders, two 3 x 4 x 16-inch bars, and one 2 1/4 x 24 x 24-inch slab. The specimens were removed from the molds after 24 hours, fog-cured for 7 days and stored at laboratory temperature and

humidity for 21 days. Because it is planned to test most of the concretes after six different heat treatments it was necessary to fabricate six such lots of specimens of each concrete on subsequent days.

TESTS

The tests considered as indicative of the desired properties in these concretes were: refractoriness, thermal expansion, resistance to abrasion, heat transfer, compressive strength, and Young's modulus (determined dynamically). The tests were conducted on specimens of the concretes both before and after each of several different heat treatments.

Refractoriness:

The refractoriness, as indicated by the pyrometric cone equivalent (pce), was determined in accordance with A.S.T.M. designation C24-46. The pce has been determined of the three concretes containing pumice. Cones have been prepared of each of the three concretes containing Haydite, four of the aggregates and two of the cements. These materials have not as yet been tested.

Resistance to Abrasion:

For this test the apparatus developed by Schuman and Tucker and described in their publication "A portable apparatus for determining the relative wear resistance of concrete floors", National Bureau of Standards RP1252, will be used. Thus far thirteen slabs of nine different concretes have been tested. The results obtained did indicate a difference in the resistance to abrasion of these nine concretes as well as of the same concretes after the heat treatment at the several elevated temperatures. However there was some doubt as to the accuracy of the results. Therefore, a complete overhauling of the apparatus was considered desirable and this work is underway at present.

Young's Modulus of Elasticity and Compressive Strength:

The cylindrical specimens were used for these tests and the results are given in Table 2. Young's modulus was determined dynamically on the sound specimen in three directions, namely, in flexure, in torsion, and longitudinally. However, the longitudinal modulus only is tabulated. Some cylinders, especially those containing pumice as the aggregate developed many minute

Materials: Identification	Si	y(c)	Water Absorption Percent by weight	Crushing strength lbs/in² (d), Compaction, inches: 1	2	3	
Bluestone	Coa Fin		0.24	(f)			
Haydite ✓	Coa Fin		11.28 8.61	1,535	13,863	41,062 (f)	
Lelite ✓	Coa Fin		8.42 5.50	561	3,244	39,824 (f)	
Waylite ✓	Coa Fin		17.10 2.61	264	943	8,450	
Pumice ✓	Coa Fin			396	1,563	6,465	
✓ Rocklite (e)	Coa Fin		9.70 17.10	2,780 (ee)	28,299 (ee)	41,026 (ee)	
Flint-clay Calcined	Coa Fin		0.90 0.80	3,930	41,030 (f)		
Flint-clay Raw	Coa Fin		4.76 5.03	778	13,074	40,682 (f)	
Olivine	Coa Fin		3.20 1.00				
White Marsh Gravel Sand	Coa Fin		0.30 0.30				

'8" and 3/4" divided by 100.

(a) Indicates

(b) Indicates

(c) "S.S."

(d) Grading –

(e) Incorrect

(ee) Rocklite

(f) Bluestone
Flint cl
Haydite
Lelite
Flint Cl

Table 1. Properties of Aggregates

Materials: Identification	Materials: Size	Sieve Analysis — Amount passing U. S. Standard Sieve, percent by weight: 1"	3/4"	1/2"	3/8"	Nos. 4	8	16	30	50	100	200	Fineness Modulus (a)	Unit Weight lbs/ft³: Loose	Jigged(b)	Bulk Specific Gravity S. S. Dry(c)	Water Absorption Percent by weight	Crushing strength lbs/in² (d) Compaction, inches: 1	2	3
Bluestone	Coarse	100.0	99.1	71.6	22.7	3.1	2.0						6.73	83.6	98.0	2.74	0.24	(f)		
	Fine				100.0	99.3	79.6	50.7	26.7	11.5	3.7	11.3	3.28	99.8	113.0					
Haydite	Coarse	100.0	100.0	95.3	71.1	11.1	1.8						6.16	53.8	62.1	1.66	11.28	1,535	13,863	41,062(f)
	Fine				100.0	99.8	95.3	70.7	43.5	27.4	18.3	12.6	2.45	68.1	97.5	2.08	8.61			
Lelite	Coarse	99.9	97.9	75.5	40.3	8.5	6.8						6.46	42.4	47.9	1.65	8.42	561	3,244	39,824(f)
	Fine					100.0	97.3	68.0	42.7	26.6	16.8	10.8	2.48	63.9	73.1	2.09	5.50			
Waylite	Coarse			100.0	94.2	16.8	8.8						5.80	33.2	39.4	1.68	17.10	264	943	8,450
	Fine				100.0	99.9	97.3	84.6	54.9	32.0	15.2	5.9	2.16	60.4	72.2	2.38	2.61			
Pumice	Coarse	100.0	98.7	82.5	51.0	16.8	15.4						6.18	29.2	32.1	1.26		396	1,563	6,465
	Fine				100.0	76.3	46.2	32.8	21.8	14.3	8.1	13.5	4.01	38.6	43.9	1.43				
Rocklite(e)	Coarse	90.7	25.5	4.1	4.1	4.1	4.1						8.70	39.0	43.8	1.28	9.70	2,780(ee)	28,299(ee)	41,026(ee)
	Fine				100.0	99.8	78.3	38.9	19.2	7.9	2.2	1.8	3.53	65.8	72.7	1.97	17.10			
Flint-clay Calcined	Coarse	100.0	99.6	85.3	70.4	44.2	24.9						5.60	87.7	101.7	2.65	0.90	3,930	41,030(f)	
	Fine				100.0	75.1	38.0	20.2	10.6	5.2	1.8	0.9	4.49	89.4	101.3	2.65	0.80			
Flint-clay Raw	Coarse	100.0	99.8	83.2	69.8	45.5	29.3						5.55	86.0	101.5	2.52	4.76	778	13,074	40,682(f)
	Fine				100.0	76.3	37.3	20.1	10.2	4.6	1.5	1.9	4.50	80.9	95.0	2.50	5.03			
Olivine	Coarse		100.0	85.3	70.9	54.3	45.6						5.29	124.8	146.7	2.97	3.20			
	Fine				100.0	99.9	99.3	82.0	65.5	35.2	10.3	4.0	2.08	114.4	130.5	3.09	1.00			
White Marsh Gravel Sand	Coarse	89.9	76.2	54.1	31.9	3.3							6.88			2.64	0.30			
	Fine				100.0	97.9	8.00	64.9	49.5	22.0	4.1	1.2	2.82			2.63	0.30			

(a) Indicates distribution of sizes of aggregate (method), Represents the sum of the total percentages retained on sieves numbers: 100, 50, 30, 16, 8 and 4, 3/8" and 3/4" divided by 100.

(b) Indicates bulking or fitting together of various sizes of aggregates.

(c) "S.S." Saturated aggregate - Surface Dry.

(d) Grading - 50% through 3/8" ret. on No. 4; 30% through No. 4 ret. on No. 8; 20% through No. 8 ret. on No. 16.

(e) Incorrect sizes of aggregate furnished; results of tests on readjusted sizes of aggregate will be reported later.

(ee) Rocklite - 60% through No. 4 ret. on No. 8; 40% through No. 8 ret. on No. 16.

(f) Bluestone beyond capacity of apparatus at 1" compaction;
Flint clay (calcined) maximum compaction possible with apparatus 1 13/16"
Haydite " " " " " 2 21/64"
Lelite " " " " " 2 23/64"
Flint Clay (Raw) " " " " " 2 9/16"

Laboratory Identification a/	Propo... by we... Cement coars... fine	...mpressive Strength ... x 12 in. cylinder	Young's Modulus of Elasticity c/ Dynamic, Longitudinal Before heating	After heating	Linear Shrinkage c/ Before Heating	After Heating
		...bs/in²	E x 10⁶	lb/in²	%	%
P-P-1	1:1:0	1470				
P-P-2	1:1:0	1610				
P-P-3	do	1150				
P-P-4	do	455			0.000	0.766
P-P-5	do				0.050	
P-P-6	do					
Z-P-1	do	1255	.731			
Z-P-2	do	1500				0.650
Z-P-3	do	665				
Z-P-4	do	385			0.067	0.916
Z-P-5	do		.749			
Z-P-6	do					
L-P-1	do	560	.535		0.116	
L-P-2	do	415				
L-P-3	do					
L-P-4	do				0.083	
L-P-5	do		.743		0.170	
P-H-1	1:1	1750	1.930			
P-H-2	do	2200	2.128	1.373	0.083	0.216

Table 2. Properties of Heat-Resisting Concrete

Laboratory Identification[a]	Proportions by weight Cement to coarse and to fine aggregate	Cement Content	Vinsol resin by weight of cement	Water Content	Air Content	Slump of fresh concrete	Weight of fresh concrete	Weight of Concrete: 7 day Fog 21 day R.T.	After Heating for 5 hours at Temperature °C [b]: 250	500	750	1000	Strength-weight ratio	Compressive Strength 6 x 12 in. cylinder	Young's Modulus of Elasticity [c] Dynamic, Longitudinal: Before heating	After heating	Linear Shrinkage [c]: Before Heating	After Heating
		Bags/yd³ of concrete	%	Gal/yd³ of concrete	%	inch	lbs/ft³	lbs/ft³	lbs/ft³					lbs/in²	E x 10⁶	lb/in²	%	%
P-P-1	1:1:0.4	7.1	0.02	72	14.5	3.00	81	74					19.9	1470				
P-P-2	1:1:0.5	6.8	do	72	16.2	2.25	80							1610				
P-P-3	do	6.4	do	72	18.7	5.75	76							1150				
P-P-4	do	6.6	do	74	13.9		79	73			57		8.0	455				
P-P-5	do	6.6	do	72	15.7	5.50	79	70									0.000	0.766
P-P-6	do																0.050	
Z-P-1	do	6.4	do	71	17.1	5.25	77	70					17.9	1255	.731			
Z-P-2	do	7.1	do	78	9.6	2.25	85		62				24.4	1500				
Z-P-3	do	5.7	do	65	25.5	7.50	68			61			10.9	665				0.650
Z-P-4	do	6.6	do	79	12.1	5.25	80	71			57		6.8	385			0.067	0.916
Z-P-5	do	6.6	do	71	15.8	4.75	78	68							.749			
Z-P-6	do		do															
L-P-1	do	6.9	do	83	7.2	6.75	85	68					8.2	560	.535		0.116	
L-P-2	do	7.1	do	86	12.5	0.25	88							415				
L-P-3	do	6.0	do	74	18.7	7.50	74			61								
L-P-4	do	6.8	do	81	9.5	5.00	83	73									0.083	
L-P-5	do	6.5	do	75	14.1	6.00	79	71							.743		0.170	
P-H-1	1:1.7:1.9	5.2	do	57	11.4	6.75	101	97					18.1	1750	1.930			
P-H-2	do	5.3	do	54	11.2	3.63	101	99	91				24.2	2200	2.128	1.373	0.083	0.216
P-H-3																		
P-H-4																		
P-H-5	do	5.6	do	57	6.6	2.75	107	102				90	3.2	290	2.340	.527	0.217	-0.166
P-H-6																		
P-H-1	do	5.3	do	54	11.5	5.25	102	99						2070	2.032		0.100	
Z-H-1																		
Z-H-2	do	5.1	do	54	13.3	6.63	99	97	89				22.5	2000	1.788	1.160	0.166	0.216
Z-H-3																		
Z-H-4																		
Z-H-5	do	5.4	do	55	10.1	6.00	103	98				88	2.7	240	2.080	.434	0.317	-0.183
Z-H-6																		
L-H-1	do	5.5	do	60	6.8	2.75	106	100					21.5	2145	2.011		0.200	
L-H-2	do	5.5	do	59	6.4	3.50	106	101	94				9.5	890	1.993	.899	0.100	0.316
L-H-3																		
L-H-4																		
L-H-5	do	5.6	do	60	5.2	5.50	107	101				89	3.5	310	2.090	.509	0.316	-0.183
P-W-1	1:0.9:1.5		0.01															
P-W-2																		
P-W-3	do	6.8	do	67	13.4	1.50	101			85			13.5	1150		.719	[illegible]	
P-W-4																		
P-W-5																		
P-W-6																		
Z-W-1																		
Z-W-2																		
Z-W-3	do	6.6	do	62	18.0	2.20	96			62			15.5	965		.629	0.333	
Z-W-4																		
Z-W-5																		
Z-W-6																		
L-W-1																		
L-W-2																		
L-W-3	do	7.0	do	70	10.0		104			85			6.1	520		.366	0.900	
L-W-4																		
L-W-5																		
L-W-6																		

a/ The first letter indicates the type of cement, namely: P= Portland. Z=Portland Pozzolan, L=Lumnite
The second letter indicates the type of aggregate: P=Pumice; H=Haydite, W=Waylite
The numerals indicate: 1=cured for 28 days only. 2,3,4,5 and 6 cured for 28 days and heat treated at 250°C, 500°C, 750°C, 1000°C, 1250°C respectively.

b/ Specimens were heated at an approximate rate of 50°C per hour to maximum temperature. After equilibrium was reached they were held at this temperature for 5 hours.

c/ The modulus of elasticity and the linear shrinkage were determined on each cylinder of each mix after the 28-day curing. These determinations were made to compare concrete mixes of the same design (See column "laboratory identification") but made on different days. The results, when compared with those obtained after the several heat treatments, will show changes in structure of the cylinder that these properties may indicate.

cracks as a result of the heat treatments. Because of this condition of the specimen the natural frequency of vibration could not be identified and consequently Young's modulus calculated.

The compressive strength was determined on all cylinders in accordance with A.S.T.M. serial designation C39-44. The specimens were tested after the 28-day curing treatment and also after this curing period plus one of several different heat treatments respectively.

RESULTS

The data thus far collected are insufficient to justify any definite conclusions. However, indications are that the minimum strength of 2600 psi specified in the tentative technical requirements cannot be obtained using pumice as the aggregate in the concretes as designed. In general, the concretes using Portland or Portland-pozzolan cements increased in strength when heated at 250°C but decreased successively when heated at 500, and 750°C. When Lumnite cement was used the concretes decreased in strength successively after the 250, 500 and 750°C heat treatments. The blank spaces appearing in table 2 indicate the tests yet to be completed. In these spaces results will be inserted as the work progresses.

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The National Bureau of Standards is the principal agency of the Federal Government for fundamental and applied research in physics, mathematics, chemistry, and engineering. Its activities range from the determination of physical constants and properties of materials, the development and maintenance of the national standards of measurement in the physical sciences, and the development of methods and instruments of measurement, to the development of special devices for the military and civilian agencies of the Government. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various scientific and technical advisory services. A major portion of the NBS work is performed for other government agencies, particularly the Department of Defense and the Atomic Energy Commission. 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. The scope of activities is suggested in 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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