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

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QUARTERLY REPORT
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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

The tests planned on the three cements in the first phase of this project have been completed. These tests included the chemical analysis, the determination of the mechanical properties, such as the permanent length changes, the water loss, and decrease in strength after heating at increasing temperatures. The results of these tests appear in N.B.S. Reports previously submitted.

2.2 Aggregates

All the mechanical tests on the aggregate, Kenlite, used in the concretes tested during the period covered by this report have been completed and reported.

2.3 Concretes

Two of the three concretes designed with Kenlite aggregate and containing either portland or portland pozzolanic cement were reported as having been mixed and

specimens fabricated in the last N.B.S. Report 4361 (September 30, 1955). The third concrete designed with the same aggregate but containing high-alumina hydraulic cement was mixed and a complete set of test specimens fabricated during this reporting period.

3. RESULTS AND DISCUSSION

3.1 Concretes

Table 1 gives the properties of the fresh concretes designed with Kenlite aggregate and either portland, portland pozzolanic or high-alumina hydraulic cement. The concretes were designed as nine sack mixes but when the cement content was calculated resulted in slightly richer mixes with the portland and portland pozzolan cements and nearly ten sacks per cubic yard for the high-alumina hydraulic cement. The flexural strength as determined on numerous trial mixes of concretes of this type indicated that a minimum of nine sacks per cubic yard would be necessary to develop the required strength of 600 psi.

Table 2 gives the properties of the cured and heat treated concretes. The low flexural strength given in lines three of this table corroborates previously reported results indicating that concretes designed with expanded shale, crushed, aggregate requires longer curing periods than when dense aggregate is used. The type of failure, aggregate fracture, indicates that maximum strength has

Table 1. Properties of Fresh Concrete,[a] with Lightweight Aggregate, Kenlite

Identification[b]	Proportion by Weight Cement to Coarse and to Fine Aggregate	Cement Content	Vinsol Resin by Weight of Cement	Water Content	Air[c] Content Gravimetric	Slump	Weight of Fresh Concrete	Water Cement Ratio	Remarks Fresh Concrete	Flexural Strength	Fracture
		sacks yd^3 of concrete	%	gals/yd^3 of concrete	%	inches	lbs/ft^3			psi	
P-K-1	1 : 0.99 : 0.73	9.24	0.005	38.4	2.10	2.50	104.28	0.37	easily placed		
P-K-2	do	9.21	do	38.7	2.74	2.50	103.84	0.37	do	670[d]	all aggregate fractured, few air voids.
P-K-3	do	9.37	do	37.25	2.12	1.50	104.80	0.35	do		
Z-K-1	1 : 0.76 : 0.95	9.06	none[e]	46.0	3.17	2.50	103.71	0.45	sticky but easily placed		
Z-K-2	do	9.21	do	45.4	2.17	2.50	105.19	0.44	do	635[d]	all aggregate fractured numerous air voids. Some as large as 1/8" diameter.
Z-K-3	do	9.39	do	45.6	0.70	2.00	106.98	0.43	do		
L-K-1	1 : 0.91 : 0.74	9.57	0.005	35.0[f]	6.44	4.50	103.45	0.32	excellent		
L-K-2	do	10.00	do	36.6[f]	2.10	2.50	108.20	0.32	started to set before complete placing	555[d]	few pull-outs, mostly fractured aggregate: Large air voids.
L-K-3	do	9.81	do	35.0[f]	2.07	1.50	106.59	0.31	do		

a/ For convenience the flexural strength of specimens, fabricated from the final mixes and cured for 28 days in fog-room, are included.

b/ The first letters: P = portland cement; Z = portland pozzolan cement; L = Lumnite, a high-alumina hydraulic cement.

c/ The use of the pressure method in determining the air content in concretes with this type aggregate (lightweight) is not recommended.

d/ The value for flexural strength is an average value for specimens fabricated from mix 1, 2 and 3, and cured in fog-room for 28 days.

e/ Green Bag portland pozzolan cement is furnished containing the air-entraining agent.

f/ The aggregate in the concretes designed with Lumnite cement was added to mixer dry.

Table 2. Properties of Cured and Heat-Treated Concretes[a/]

Identification[b/]	Proportions by Weight of Cement to Coarse and to Fine Aggregate	Treatment Preceding Test[c/]	Compressive Strength	Flexural Strength	Type of Failure	Abrasion Loss: Weight of Dust	Abrasion Loss: Depth of Wear[d/]	Young's Modulus of Elasticity Dynamic: Longitudinal	Total[e/] Linear Change	Total[f/] Weight Loss
			psi	psi		grams	inches	$lbs/inch^2 \times 10^6$	%	%
		1						1.930		
		2						2.749	+0.012	+ 0.574
		3		315	all large aggregate fractured	43.60	0.0131	2.770	-0.004	- 2.062
P-K	1 : 0.99 : 0.73	4	5405	670	all large aggregate fractured	21.35	.0084	2.976	+0.021	+ 0.658
		5						1.852	-0.034	-11.130
		6		320	all aggregate fractured: air voids	38.20	.0135	1.440	-0.031	-12.538
		7		270	50% fractured aggregate: 50% pull-outs	51.65	.0166	1.027	-0.187	-14.970
		8		115	surface cracks; pop-outs; 50% aggregate fracture; 50% pull-outs	- [g/]	[g/]	.768	-0.703	-17.091
		1						1.379		
		2						2.646	+0.011	+ 0.416
		3		280	all large aggregate fracture	20.60	0.0082	2.645	-0.004	- 3.888
Z-K	1 : 0.76 : 0.95	4	5860	635	all large aggregate fracture	10.25	.0075	3.069	+0.025	+ 0.314
		5						1.856	-0.034	-13.771
		6		300	all aggregate fracture	23.65	.0091	1.446	-0.062	-15.722
		7		290	50% fractured aggregate; 50% pull-outs	34.45	.0131	1.212	-0.318	-16.985
		8		75	surface cracks; pop-outs: 50% aggregate fracture; 50% pull-outs	- [g/]	[g/]	.750	-0.349	-17.963
		1						2.796		
		2						3.141	+0.005	+ 0.993
		3		210	few pull-outs: fractured aggregate	33.40	0.0113	2.742	-0.059	- 1.609
L-K	1 : 0.91 : 0.74	4	5790	555	large air voids	33.00	.0091	3.160	+0.028	+ 1.855
		5						1.913	-0.034	- 7.024
		6		370	50% pull-outs: 50% aggregate fracture	73.65	.0211	1.460	-0.062	- 9.303
		7		290	mostly pull-outs	51.50	.0159	1.119	-0.143	-12.125
		8		190	surface cracks: pop-outs: 50% aggregate fracture; 50% pull-outs	- [g/]	[g/]	1.248	-0.297	-13.599

a/ Designed with lightweight aggregate, Kenlite.

b/ The first letters: P = portland cement: Z = portland pozzolan cement: L = Lumnite, a high alumina hydraulic cement. The second letter: K = Kenlite. a lightweight aggregate, expanded shale.

c/ 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.

d/ A description of the apparatus and method used in determining depth of wear was given in N.B.S. Report 3201.

e/ Based on length after 24 hours in mold.

f/ Based on weight after 24 hours in mold.

g/ Specimens warped too badly for test.

been developed for concretes designed with this aggregate. The decrease in strength after the 500°C heating indicates the loss of strength in the bond (cement paste). The condition and strength of the concrete after 1000°C indicates that this temperature approaches that of the original calcining.

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

PART II

1. INTRODUCTION

The second part of the project includes a determination of the cause or causes of failure that occur in concrete aprons and runways exposed to jet exhaust gages. The approach includes a measure of the heat gradients and stresses set up by flame impingment. A combustion chamber that will deliver hot gases at velocities and temperatures approximating those in field conditions will be used.

2. MATERIALS

The two concretes used in fabricating test specimens during this reporting period were previously recommended compositions. Portland cement was used in both mixes. White Marsh sand and gravel or crushed building brick was the aggregate.

3. PREPARATION AND TESTING

Four test panels 18 x 8 x 6 inches were fabricated. One panel contained concrete designed with White Marsh gravel (largely quartz and quartzite). The other three panels were fabricated with concrete designed with crushed building brick. Three-inch tile, disks with a one and one-quarter diameter, and brick shape specimens were molded from each concrete. The tile and disks varied in depth from one-half to 2 inches. The bricks were cast edgewise and flatwise and were cured and dried in the same position. All specimens

were sealed with a vapor proof plastic leaving one exposed face. During fabrication of the panels thermocouples were placed at varying distances from the center of the exposed face and at varying depths from this face. Pitot tubes were cast in the panels at varying distances from the center of the exposed face and at decreasing angles to this face.

Electrical connector plugs having exposed terminals were cast in the panels at one-half, one, and one and one-half inches below the exposed surface of the test panel. These were installed for the purpose of measuring the change in resistance of the concrete during the curing and drying periods.

Each test specimen was weighed after one day and 28 days fog-room curing, and after 7, 14, 21, and 28 days laboratory drying. Some specimens have had an additional drying of 21 days at 38°C and 7 days at 75°C.

The resistance of the concrete panels at increasing depths was measured after the same curing and drying periods.

4. RESULTS AND DISCUSSION

The electrical resistance method, used in determining the change in water concentration, at varying depths from the exposed surface of the concrete test panels, shows some inconsistencies in the results. The inconsistencies

may be rationalized by the fact that the conductivity of pure water is very low and a reduction in the concentration of this water, such as occurs in the drying of concrete, should result in conductivities of even smaller magnitude. The presence of ions in this water even in extremely minute concentration causes enormous increases in the conductivity of the resulting solution. The conductivity of such a solution was the property actually measured by the method used and therefore depended far more on the concentration of the electrolytes present in the water than the amount of water in the cement. The source of such ions mentioned could be the Ca^{++} or Na^{+} and K^{+} from the lime and alkalies in the cement paste. In the concretes designed with crushed building brick an additional source was the alkalies than can be leeched from the aggregate.

The resistance of the concrete designed with the White Marsh aggregate at the depth of one-half inch from exposed surface varied from 15,000 ohms after 24 hours in mold to 2,000,000 ohms after an extended curing and drying period. The resistances did not, however, decrease at the one or the one and one-half inch depths in proportion to the amount of water determined by other methods.

Measurements of the movement and the amount of water present in concretes, as indicated by weight changes, indicates that all concrete specimens tested (sealed on

five sides) picked up water during the fog-room curing. This increase in water content was inversely proportional to the thickness of the specimen. The rate of loss in water was also controlled by depth but was in direct relation. During a 28-day drying period under laboratory conditions of temperature and humidity, all specimens of two-inch depth or less had lost the water absorbed during curing. After prolonged heating at 75°C even the thinnest tile still retained approximately four percent of the original mixing water.

Combustion Chamber

The combustion chamber designed to deliver hot gases at 600°F to 1200°F at velocities of 1200 feet per second has been completed. The pressure regulators, indicating gauges, and flow meters necessary for the control of the air and gas have been installed and tested.

Some exploratory tests have been made with this combustion chamber and its exhaust gases to determine its limitations. Specimens of concrete (18 x 18 x 2 1/2 inches) designed with Kenlite aggregate and heated at 250°C were used as test panels. The center line of the panel coincides with the burner axis and is at right angles to the direction of jet. Thermocouples and pitot tubes were positioned radially over the six-inch diameter test area. The temperatures were measured and recorded by a multipoint recorder - potentiometer that records from 40 to 60 times per minute depending on the temperature

differences. The velocity at impingment was measured in pressure and calculated to rate of flow.

The results of the exploratory tests indicate that the combustion chamber as assembled will deliver gases at 1200°F to the surface of a panel at distances from one and one-half inches from the jet opening to six inches. The velocities at which the hot gas is delivered diminishes from 1000 feet per second at the one and one-half inch distance to 800 feet per second at six inches. The temperature at the center of the six-inch diameter test surface, 1200°F, decreased to 700°F on the perimeter of this area and the velocity decreased from 1050 to 350 feet per second when the panel was tested at the one and one-half inch distance from exhaust. When temperatures and velocities were measured at a six-inch distance from exhaust jet there was a 300°F drop in temperature from the center to the perimeter of six-inch test area and an accompanying drop in impinging velocities of 600 feet per second. These results indicate that it will be necessary to increase the rate of the flow of gas in order to obtain the desired velocities. A different type gas compressor is being installed. Several more tests will be made before standardizing distance, velocity, and temperature of test.

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