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INVESTIGATION OF REFRACTORY MORTARS

by

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SUMMARY OF RESULTS

Physical and pyrophysical properties were determined on 46 brands of refractory mortars, 32 of the mortars were air-setting and 14 were heat-setting. The air-setting mortars consisted of the following:

15 Class 1, Super Duty, Type A, Wet
6 Class 2, High Duty, " " "
8 Class 1, Super Duty, Type B, Dry
3 Class 2, High Duty, " " "

The 14 heat-setting mortars were all of the super duty Class, Type B.

Of the 15 brands of Class 1, Type A mortars in Table 1, 10 had good to very good workability, 13 met the requirements for particle size, 11 had the prescribed bond strength, and 12 met the refractoriness pier-test requirements. Only 8 brands met all requirements.

Class 2, Type A mortars in Table 2 showed fair to good workability, but had relatively low bond strength and poor refractoriness. Of the 6 mortars, only 2 brands met all requirements.

Class 1, Type B, mortars compared favourably in workability and refractoriness but unfavourably in bond strength with those of Type A in the same class. All requirements were met by

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5 of the 8 mortars in this category.

Only 3 brands of Class 2, Type B mortars were evaluated and 2 of these met all requirements.

Of the 14 dry heat-setting mortars 8 had good workability while the other 6 rated from fair to poor. The minimum bonding strength of 100 psi was attained by 8 brands while the other 6 brands failed to meet this requirement. All of the 14 brands met the refractoriness pier-test requirements.

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INTRODUCTION

Throughout this discussion the term "Refractory Mortar" refers to the bonding material applied in laying up fireclay brick in industrial furnaces and other installations designed for operation at relatively high temperatures. Other terms such as "High Temperature Cements" have been applied to bonding materials of this type, but the preferred and generally accepted term is "Refractory Mortars".

The main function of the mortar is to hold the brick firmly together, forming as nearly as possible a wall of monolithic construction. Furthermore, the refractory properties should be adequate to withstand temperatures and operating conditions similar to that of the fire brick with which it is used. The applied mortar provides a cushion between the slightly irregular surfaces of the brick so that one course of the brick work will have a firm bearing on the course below it. It also serves to obstruct leakage of furnace gases through the setting or to prevent penetration of slags into the joints.

Refractory mortars under consideration consist of two main types known as (a) air-setting, and (b) heat-setting. "Air-setting refractory mortar" is defined as a "composition of finely ground materials, marketed in either a wet or dry condition, which may require tempering with water to attain the desired consistency and which is suitable for laying refractory brick and bonding them strongly upon drying and upon subsequent heating at furnace temperatures". Mortars of this type develop their initial bond strength through the aid of air-setting agents incorporated in their preparation. On the application of heat it is highly desirable that adequate strength be maintained throughout the entire range until the temperatures reached have been sufficient to form a strong ceramic bond. In practice, one of the main objectives in applying mortars of this type is to ensure adequate bonding of the refractories regardless of temperature gradients set up through the furnace walls.

Heat-setting mortars contain no air-setting ingredients and their strength depends, almost entirely, on the ceramic bond developed at elevated temperatures.

High-temperature refractory mortars are generally classified according to the service and grade of fireclay refractories with which they are to be used. The several classes of mortar are distinguished in the "Manual of ASTM Standards on Refractory Materials" by their refractoriness test temperatures as follows:

Class	Refractoriness Test Temperature
Super Duty	2910°F (1600°C)
High Duty	2730°F (1500°C)
Medium Duty	2550°F (1400°C)

A considerable amount of technical data on refractory mortars has been derived from the numerous determinations which have been carried out in the Ceramic Laboratories, Industrial Minerals Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa. Under this program a number of commercial mortars marketed under various trade names were fully tested for physical and pyrophysical properties. Some of the results from this work are presented and discussed.

LABORATORY PROCEDURE

Forty-six samples of refractory mortars were evaluated in accordance with methods prescribed in Canadian Government Specifications 10-GP-3 A and 10-GP-6. The former specification (10-GP-3 A) covers two classes of air-setting mortars of both wet and dry types. The latter specification (10-GP-6) deals with heat-setting mortars and is confined to one class only.

Properties evaluated and methods of determination indicated by ASTM designation numbers are as follows:

1. Plasticity and Water Retention: C 178
2. Water Content: C 92

Determined on materials as received and reported in percent of wet weight.

3. Particle Size: C 92

Respective fractions were determined by wet sieve analysis and reported in percent of dry weight.

4. Pyrometric Cone Equivalent (PCE): C 24

Prior to making this determination, the materials were calcined at 2200°F.

5. Bonding Strength: C 198

Reported as modulus of rupture in pounds per square inch;

(a) after drying at 230°F, and (b) after firing at 2500°F.

6. Refractoriness: C 199

Prepared specimens were heated under prescribed conditions and "soaked" for 5 hours at temperatures according to class, as follows:

Class 1, Super Duty 2910°F (1600°C)
Class 2, High Duty 2730°F (1500°C)

RESULTS

Properties indicated and results obtained on the 46 brands of refractory mortars investigated, are listed in Tables 1-5 as follows:

Table 1 - Wet, Air-Setting, Class 1
Table 2 - Wet, Air-Setting, Class 2
Table 3 - Dry, Air-Setting, Class 1
Table 4 - Dry, Air-Setting, Class 2
Table 5 - Dry, Heat-Setting (One class only)

TABLE 1

Properties of Refractory Mortars - Wet; Air-Setting; Class 1

No.	Plast. and Water Ret.	Water Content %	Particle Size Tyler Sieve No. (%) +20	-20 +35	-35	P.C.E.	Bond Strength M of R psi 230°F	2500°F	Refractoriness 2910°F
1	V.G.	17.4	-	0.4	99.6	30	400	830	S
2	V.G.	16.2	-	0.2	99.8	28+	730	1330	S
3	F	21.3	-	0.2	99.8	8	540	1060	N.S.
4	G	17.9	-	0.2	99.8	32½	390	380	N.S.
5	F	17.0	0.1	0.2	99.7	30+	260	980	S
6	G	18.4	-	0.4	99.6	23	1000	1200	S
7	F	20.7	-	0.1	99.9	31½	270	230	S
8	G	19.5	-	0.3	99.7	31½	460	250	S
9	F	20.7	-	1.3	98.7	29+	670	780	N.S.
10	G	21.2	-	7.2	92.8	30+	570	230	S
11	G	19.5	-	0.1	99.9	32½	450	160	S
12	F	15.4	4.6	13.7	81.7	32	120	<50	S
13	G	16.4	-	2.7	97.3	31½	<50	<50	S
14	V.G.	19.3	-	2.2	97.8	31	170	240	S
15	G	19.0	1.9	7.8	90.3	31½	120	100	S

Plasticity and Water Retention

V.G. = Very good
G = Good
F = Fair

Refractoriness

S = Satisfactory
N.S. = Not satisfactory

TABLE 2

Properties of Refractory Mortars - Wet; Air-Setting; Class 2

No.	Plast. and Water Ret.	Water Content %	Particle Size Tyler Sieve No. (%)			P.C.E.	Bond Strength M of R psi		Refractoriness
			+20	-20 +35	-35		230°F	2500°F	2730°F
1	V.G.	21.4	-	1.4	98.6	30	110	50	S
2	F	18.6	-	0.1	99.9	18	260	460	N.S.
3	G	30.3	0.2	1.4	98.4	23	100	80	N.S.
4	G	19.9	0.1	0.6	99.3	18	540	570	S
5	G	19.8	0.1	0.1	99.8	18	190	180	N.S.
6	F	21.6	-	2.1	97.9	20-23	230	100	S

Plasticity and Water Retention

V.G. = Very good
G = Good
F = Fair

Refractoriness

S = Satisfactory
N.S. = Not satisfactory

TABLE 3

Properties of Refractory Mortars - Dry; Air-Setting; Class 1

No.	Plast. and Water Ret.	Particle Size Tyler Sieve No. (%)			P.C.E.	Bond Strength M of R psi		Refractoriness
		+20	-20 +35	-35		230°F	2500°F	2910°F
1	G	-	0.4	99.6	32+	640	510	S
2	V.G.	-	0.3	99.7	31½	270	150	S
3	F	0.1	11.5	88.4	35	50	<20	S
4	G	-	0.1	99.9	31½	260	330	S
5	G	-	0.1	99.9	29	280	180	S
6	G	-	0.1	99.9	31½	170	110	S
7	G	-	0.4	99.6	28	380	570	S
8	F	3.7	16.0	80.3	20	160	340	N.S.

TABLE 4

Properties of Refractory Mortars - Dry; Air-Setting; Class 2

No.	Plast. and Water Ret.	Particle Size Tyler Sieve No. (%)			P.C.E.	Bond Strength M of R psi		Refractoriness
		+20	-20 +35	-35		230°F	2500°F	2730°F
1	F	-	-	100	20-23	240	690	N.S.
2	G	-	0.4	99.6	26	450	240	S
3	G	-	0.2	99.8	28	210	170	S

Plasticity and Water Retention

V.G. = Very good
G = Good
F = Fair

Refractoriness

S = Satisfactory
N.S. = Not satisfactory

TABLE 5

Properties of Refractory Mortars - Dry; Heat-Setting

No.	Plast. and Water Ret.	Particle Size Tyler Sieve No. (%) +20	-20 +35	-35	P.C.E.	M of R psi 2500°F	Refractoriness 2910°F
1	F	0.1	7.3	92.6	31	60	S
2	P	-	0.1	99.9	30	570	S
3	F	-	0.2	99.8	33+	290	S
4	G	-	0.3	99.7	32+	< 20	S
5	G	-	0.4	99.6	32	490	S
6	F	0.1	0.1	99.8	34	< 20	S
7	G	-	2.0	98.0	34	80	S
8	G	-	0.1	99.9	32	530	S
9	G	-	0.1	99.9	34	< 20	S
10	P	5.6	17.0	77.4	32 $\frac{1}{2}$	< 20	S
11	F	0.2	3.7	96.1	31 $\frac{1}{2}$	< 20	S
12	G	-	0.1	99.9	33+	60	S
13	G	-	0.2	99.8	32	40	S
14	G	0.5	1.0	98.5	34	150	S

Plasticity and Water Retention

G = Good
F = Fair
P = Poor

Refractoriness

S = Satisfactory

DISCUSSION OF RESULTS

Plasticity and Water Retention

The mortar when tempered with water should be of such plasticity and workability to enable it to be spread easily with a trowel, and should have sufficient water retention to permit a 1/16 inch joint to be made with a trowelling consistency. When tempered to dipping consistency the mortar should adhere to the dipped brick. Plasticity and water retention values of the fifteen mortars in Table 1 indicate 5 fair, 7 good and 3 very good. Similar results are shown in Tables 2, 3 and 4.

Water Content

The Specification on water content provides for an upper limit of 25 percent. Thus, mortars having proper trowelling consistency can be supplied and at the same time an undue excess of water can be guarded against. It might be pointed out that because of variations in the amount and kind of plasticizing agent used in different mortars of this type, variations in the percentage of water of plasticity required to give them optimum workability are to be expected. The porosity of the non-plastic material, as well as the percentage of fine non-plastics present also have a bearing on optimum water content. In Table 1, the water content varied from 15.4 to 21.3 percent with an average of 18.7 percent.

Particle Size

In order that the mortar may have smooth working properties and freedom from grit it is desirable that the greater portion of the material should pass a No. 35 mesh Tyler sieve. The presence of even a few coarse particles may be detrimental and adversely affect the thickness of mortar joint. The specification states that the material retained on No. 20 Tyler sieve shall not exceed 0.5 percent of the dry weight.

Pyrometric Cone Equivalent and Refractoriness

In making P.C.E. determinations on mortars containing chemical ingredients such as sodium silicate a preliminary calcining of the material to 2200°F is recommended in order to obtain consistent results. Although the P.C.E. value is not usually regarded as being one of the more important characteristics, nevertheless, it serves to indicate the degree of refractoriness. Air-setting mortars which successfully meet the refractoriness test were found to have P.C.E. values ranging as follows:

	Range in Cones
Type A, Class 1	28 - 32 1/2
Type A, Class 2	18 - 30
Type B, Class 1	28 - 35
Type B, Class 2	26 - 28

The low P.C.E. value of item 3, Table 1 clearly indicates that this mortar does not qualify for the class in which it was entered. All of the heat-setting mortars in Table 5 meet the refractoriness test at 2910°F. The P.C.E. values in this class were found to lie between cones 30 and 34.

Bonding Strength

In performing this test, using the A. S. T. M. butt-joint method, great care must be exercised in preparing the test specimens if consistent results are to be obtained. The same brand of firebrick having uniform texture and porosity should be used throughout. Another factor known to effect results is the consistency of the mortar. According to the values shown in Table 1 the modulus of rupture after drying at 230°F ranged from 50 to 1000 psi. Firing at 2500°F, in some cases, is attended by increase in strength but in other cases the reverse effect is in evidence. Average values in Tables 2, 3 and 4 are considerably lower than those in Table 1. Nine of the fourteen heat-setting mortars in Table 1 show relatively low bonding strength while the average of the remaining five exceeds 400 psi.

General

In order that the results obtained in this investigation may be compared with the work of other authors and to permit further discussions on the subject, several references (Nos. 1-9) are listed at the end of this report.

CONCLUSIONS

Properties of the refractory mortars investigated showed considerable variation in workability, particle size, bonding strength and refractoriness.

Only 17 of the 32 air-set mortars being evaluated were found to meet all requirements in Specification 10-GP-3 A, and only 5 of the 14 heat-set mortars conformed entirely to Specification 10-GP-6.

Low bonding strength and lack of sufficient refractoriness were the chief causes of failure in air-set mortars. All of the heat-set mortars had adequate refractoriness but over 60 percent of the number were deficient in bonding strength on being fired at 2500°F.

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