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Investigation of Appropriate Refractory Material for Laboratory Electritic Resistrance Furnance

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Abstract

There have been numerous efforts to increase the local content of furnaces; hence the choice of appropriate refractory material for lining of locally manufactured furnaces has remained a major concern. This research work investigates the choice of appropriate local refractory material for the lining of laboratory electric resistance furnace.

Electric resistance furnaces are extensively used in the laboratory for heat treatment of metals and alloys. Refractory binders such as silicon carbide were experimented upon for strength and resistance to high temperature.

The results obtained showed that Kankara fireclay containing 15% SiC (5.70 % linear shrinkage , 46.2% apparent porosity, 1.77gkm³ Bulk density, 18 cycles of spalling tests at 1300°C, 5.253KN/m² of cold strength) has appropriate properties for producing grooved bricks for lining of laboratory electric resistance Furnace.

Keywords

Furnance, electric resistance, refractory material, non-metallic minerals, chemical atack

Introduction

Refractory are materials, mostly non-metallic minerals that have enormous heat capacities and can withstand high temperatures, as well as other strains exerted on them such as abrasion, impact, thermal shock, chemical attack and high level loads at elevated temperatures. They are commonly applied in lining of furnaces.

Refractory are classified based on composition, (such as alumina content) and physical or industrial characteristics like thermal stability. They are commonly classified into "Basic and Acidic" types with a third and intermediate group.

Basic refractory include magnesia-chromates or chromate-magnesia, forsterite and dolomite. Acid refractory include the alumino-silicates e.g. the clays, kyanites, silimanite, andeladsite anpolymsphis, and Alumina refractory. The third category, which usually have relatively limited application than the major categories, include Zircon and Zirconia, graphite, silicon-carbide and carbon.

Refractory are required to satisfy primarily some or all of the following characteristics depending upon the service condition.

(i) High refractoriness
(ii) Resistance to chemical reaction with any substance in contact during service.
(iii) Ability to withstand the load of the material at the operating temperature
(iv) Resistance to thermal shock caused by alternate heating and cooling
(v) Porosity (volume and nature)
(vi) Low volume charges at the service temperature (both permanent and reversible)

Materials and Methods

Materials

The following major equipment and materials were used for the experimental work Kiln, Electric Furnace, Metal mould Box (grooved type), Strength testing machine, Fireclay (Kankara clay), Silicon carbide, Sawdust and Water.

Brick Production

The raw clay was soaked in water for three days and dried in open air for one week, to remove alkalis and some dead organic matters. The dried clay was crushed and ground into powder form, using jaw crushers and pulverizing machine. The ground clay was sieved to pass through a sieve of 250μm aperture size.

The freshly sieved clay was made with various percentages of 5-25% silicon- carbide and 5% sawdust. The clay mixture was found to be plastic at 16% water content level. The mixed blend was packed into a metal moulding box and pressed using ram and peg to enhance homogeneity and surface smoothness of the specimen. The mould bricks were dried in open air for four days, followed by drying in oven for 12 hours at 110°C. Firing was carried out in an electric heating furnace preset at a heating rate of 7°C per minute. The firing procedure used involved heating and soaking the samples at various temperatures as shown below:

(i) At 250°C for 6 hours

(ii) At 650°C for 4hours

(iii) At 950°C for 3hours

(iv) At 1100°C for 8hours

After firing, the bricks were then allowed to cool in the furnace at a cooling rate of about 1°C/min.

Test Procedure

The fired bricks were tested for linear shrinkage, visual inspection, apparent porosity, bulk density, Thermal shock (spalling) resistance.

Linear Shrinkage Test

The bricks were pressed in green condition in a fabricated metal box of size 46X42X40mm. The linear shrinkage was calculated using the formula below:

Linear shrinkage = percentage of dried shrinkage + percentage of fired shrinkage.

Two samples were measured for each blend and the average shrinkage was calculated. The results obtained are as shown in Table 2.1 and Figure 2.1.

Apparent Porosity and Bulk Density

The fired brick was kept in the oven at 110°C for 12hours to obtain a constant weight W; the bricks was then suspended in distilled water and boiled on a hot plate for 30minutes. After boiling, the water was measured. The test specimen was then removed from the water and Weight W_3 in air was measured.

$$Pa = (W_3 - W_1) / (W_3 - W_2) \times 100\%$$

where W_1= Constant weight, W_2= Weight in cold water, W_3= Weight in Air

$$B_d = W_1 / (W_3 - W_2)$$

Two samples were used for each blend, and the average was taken.

Thermal Shock Resistance Test

A standard brick was put in the furnace, which was maintained for 30minutes. The bricks was then brought out to cool in air for 10minutes and tested for failure. If failure does not occur, the brick is put back in the furnace and heated for a period of 10minutes. This cycle of heating, cooling and testing was repeated until failure occurred.

Cold Crushing Strenght Test

The fired bricks were tested for both crushing strength in direction of forming and direction normal to forming using hydraulic strength testing machine.

Result and Discussions

Physical Appearance

The physical appearances of the dried and fired bricks with the addition of SiC are shown in Table 1. There were slight color changes in the bricks containing 5% SiC after firing at 1100°C from light cream to dark cream. For other percentages of Sic addition, no color changes were observed after firing. A minimum of 15% SiC was required to produce bricks without cracks.

Linear Shrinkage Test Results

Table 2 shows the linear shrinkage of the bricks made from six (6) blends.

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The linear shrinkage for 100% raw clay was 7.25%. On addition of 5% SiC, there was a decrease in linear shrinkage from 7.25% to 6.10%. This decreased continuously to 2.2% at 25% addition of SiC. This means that higher percentage of SiC could be tolerated to practically reduce the shrinkage to zero. The clay + 15% SiC, with 5.70% total linear shrinkage were used for producing the brick used for this research work. This is in view of the increase cost of further addition of SiC without significant change in vital properties.

Apparent Porosity Test Result

Table 3 shows the result of apparent porosity. The apparent porosity of the bricks made from 100% clay was 56.0%. This value decreased to 50.0% at 5% addition of SiC. This decreased continuously to 36.4% at 25% addition of SiC. It was observed, that addition of SiC above 25% level could be tolerated. Hence the porosity could still be brought down to the acceptable level of 15 to 30% as recommended for fire clay (Gilchrist, 1963).

Bulk Density Test Result

The result of the bulk density test is shown in table 4. The result shows that 100% clay have the lowest bulk density value of 1.61 g/cm^3. The value of bulk density was recorded at 5% addition of SiC with the value of 1.83g/cm^3. The bulk density at 25% addition of SiC is 1.91g/cm^3.

Typical value of bulk density for dense fire clay bricks is about 1.90g/cm^3 (Gilchrist, 1963). Only 100% clay could be considered to have a very low value. Other blend ratios had satisfactory bulk density value. Clay + 15% SiC of average bulk density of 1.77g/cm^3 was used for the bricks produced for this research work.

Thermal Shock Resistance Test Result

Table 5 shows the thermal shock resistance of the bricks made from the six blends both at 1100°C and 1300°C.

(Hassan, 19900) adopted the principle below in determining thermal resistance:
>30 Excellent; 25-30, Good; 20-25, Fair; 15-20, Acceptable; 10-15, poor; <10, Very poor.

The spalling resistance at 1100°C for the six blends was poor, since all the blends do not fall within the acceptable range of 15+ cycles. The spalling resistance for 100% clay is still poor at 1300°C, since it falls below 15+ cycles. There is increase in the spalling resistance of the brick as the SiC increases at 1300°C, since the remaining blends fall within the acceptable range of 15+cycle. The 25% addition has the highest number of cycles which is 20. This might be due to the fact that no degree of fusion might have taken place. Higher percentage of Sic beyond 25 in the blend might have resulted in good or excellent thermal shock resistance. During the research work clay+ 15% SiC of 18 cycles at 1300°C was used for the brick produced.

Cold Crushing Strength Result

The result of cold crushing strength test in the direction of forming is shown in table 6. The cold crushing strength value for 100% clay was 7.243kN/m³ in the direction of forming. This increases to 10.85kN/m³ at 25% addition of Sic in the direction of forming. The cold crushing strength value also increased from 3.445kN/m³ to 6.028kN/m³ at 100% clay and 25% addition of SiC respectively in the direction normal to forming. From this result, it is clear that addition of SiC to Kankara clay improved the cold crushing strength characteristics in both directions. Clay+ 15% SiC with 5.253kN/m³ normal to forming direction of cold crushing strength was adopted for the research work.

Conclusion and Recommendation

Conclusion

i) The fire bricks produced from the blend have good and smooth surface as the percentage of SiC increases
ii) The linear shrinkage of the bricks decreased as the SiC increase which indicates that SiC does not easily burn off or fused. Apparent porosity of the bricks decreased with increasing percentage of SiC as there were no tendencies of more pores creation in the bricks.
iii) The cold crushing strength increased as the percentage of SiC increases both in the direction of forming and direction normal to forming. This means that high strength bricks can be made from the blend. The bricks have low thermal spalling at 1100°C since all the blends does not fall within the acceptable range of 15-30 cycles. There is a remarkable improvement in the spalling resistance at 1300°C, with percentage increase in SiC to a level of 20 cycles. It can be higher at 25% and above.

Recommendation

The following recommendations are made based on the various results obtained.

i) A dense fire clay brick capable of possessing high strength at operating temperature can be made by mixing Kankara clay with SiC.

Improved refractory properties such as cold crushing strength value can be obtained from this blends if fired at a temperature above 1100°C. The recommended firing temperature is between 1300°C-1450°C.

ii) Further studies should be carried out on this blend by increasing the percentage of SiC beyond 25% on kankara clay to obtain optimum level for better refractory properties.

Table 1. Surface Appearance After Drying & Firing

	DRIED AT 110°C		FIRED AT 110°C	
Clay &% of SiC	Colour	Crack Formation	Colour	Crack Formation
0	White	No Crack	White	Crack
5	Light cream	No Crack	Dark Cream	Slight Crack
10	Dark Cream	No Crack	Dark cream	Slight Crack
15	Ash Colour	No Crack	Ash Colour	No Crack
20	Ash Colour	No Crack	Ash Colour	No Crack
25	Ash Colour	No Crack	Ash Colour	No Crack

Table 2. Result of the Liner Shrikage Test

Clay & Silicon Carbide %		Drying shrinkage %	Average %	Firing Shrinkage	Average%	Total Shrinkage
0	A	5.54	5.02	2.56	2.23	7.25
	B	4.50		1.90		
5	A	5.50	4.60	1.40	1.50	6.10
	B	4.10		1.60		
10	A	4.50	4.50	1.50	1.50	6.00
	B	4.50		1.50		
15	A	4.20	4.20	1.50	1.50	5.70
	B	4.20		1.50		
20	A	4.00	4.00	0.20	0.20	4.20
	B	4.00		0.20		
25	A	2.45	2.03	0.15	0.13	2.20
	B	1.60		0.10		

Table 3. Result of the Apparent Porosity Test

Clay & Silicon Carbide %		W1(g)	W2(g)	W3(g)	Porosity Value	Average Porosity(%)
0	A	100.00	75.00	135.00	58.30	56.0
	B	100.00	70.00	135.00	53.90	

5	A	110.00	80.00	140.00	50.00	50.0
	B	100.00	85.00	140.00	50.00	
10	A	110.00	80.00	140.00	50.00	50.0
	B	110.00	80.00	140.00	50.00	
15	A	115.00	80.00	145.00	46.20	46.2
	B	115.00	80.00	145.00	46.20	
20	A	120.00	80.00	150.00	42.90	42.9
	B	120.00	80.00	150.00	42.90	
25	A	120.00	80.00	146.00	39.40	36.4
	B	120.00	80.00	146.00	33.30	

Table 4. Result of the Bulk Density Test

Clay & Silicon Carbide %		W1(g)	W2(g)	W3(g)	Bulk Density	Average Bulk Density (g) Lcm³
0	A	100.00	75.00	135.00	1.67	1.61
	B	100.00	70.00	135.00	1.54	
5	A	110.00	80.00	140.00	1.83	1.83
	B	100.00	85.00	140.00	1.83	
10	A	110.00	80.00	140.00	1.83	1.83
	B	110.00	80.00	140.00	1.83	
15	A	115.00	80.00	145.00	1.77	1.77
	B	115.00	80.00	145.00	1.77	
20	A	120.00	80.00	150.00	1.71	1.71
	B	120.00	80.00	150.00	1.71	
25	A	120.00	80.00	146.00	1.82	1.91
	B	120.00	80.00	140.00	2.00	

Table 5. Result of the Thermal Shock Resistance Test

Clay & Sic %	Spalling Test at 1100°C		Spalling Test at 1300°C	
	No of Cycles	Remarks	No of Cycles	Remarks
0	10	Poor	14	Poor
5	10	Poor	15	Acceptable
10	11	Poor	16	Acceptable
15	12	Poor	18	Acceptable
20	14	Poor	19	Acceptable
25	14	Poor	20	Fair

Table 6. Result of the Thermal Shock Resistance Test

% of SiC	Cold Crushing Strenght Value KN/m²	
	Direction of Forming	Normal to Forming Direction
0	7.243	3.445
5	7.492	4.392
10	7.754	4.892
15	8.612	5.253

20	9.559	5.770
25	10.851	6.028

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