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Communication

Effect of temperature on the mechanical properties of self-flowing low cement refractory concrete

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Abstract

Physical and mechanical tests are applied to the samples prepared from bauxite/fused brown corundum 50%, SiC 15%, calcined alumina 15%, reactive alumina 10%, calcium aluminate cement (CAC) 5%, micro silica 5%. Phases of the samples heat-treated at 110°C, 1000°C, and 1500°C are investigated by using X-ray diffraction (XRD) and scanning electron microscopy (SEM) techniques. Bauxite-based samples, which have higher porosity than corundum-based samples, show higher cold crushing strength (CCS) and modulus of rupture (MOR) than corundum-based samples. Samples fired at 1000°C have higher CCS than those fired at 1500°C for both types of samples. The same behavior is not observed for modules of rupture of bauxite-based samples, but only observed for fused corundum-based samples. It is found that hot modules of rupture of bauxite-based samples at 1000°C and 1500°C are better than corundum-based samples. The possible reason for better properties of bauxite-based samples is the new mineral phase formation obtained by XRD results and pore size distribution. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Thermal treatment; Mechanical properties; Refractory cement; Concrete

1. Introduction

Consumption rate of unshaped refractories in iron–steel and metal industry, cement and waste incineration has been increasing rapidly in recent years. Quality requirement of these products is also increasing. Advantages of using unshaped refractories (SFC) include economy, easy application to thin sections, complex shapes, and regions that are difficult to reach. It is also possible to use it on the damaged refractory lining as a repair mortar [1–3].

Particle size distribution of the SFC products should be designed so as to limit coarse particle interaction. Coarse particle fraction takes place in the well-liquidified binder matrix, which acts as a lubricant. Such behavior of liquidified mixes can only be reached by using high packing density particle structure. High packing density is essential for SFC. This affects the flow behavior and properties of concrete [4–6].

The most important properties of SFC are high strength and high volume stability at high temperature, oxidation resistance at SiC added materials, good flow properties, workability, and environmental safety [7,8]. In this study, behavior of bauxite- and fused corundum-

Table 1
Compositions of the castables

Raw materials	Bauxite-based SFC (wt.%)	Brown fused alumina-based SFC (wt.%)
Sintered bauxite		
3–1 mm	40	–
1–0 mm	10	–
Brown fused Alumina		
3–1 mm	–	40
1–0 mm	–	10
SiC		
0.5–0.2 mm	7.5	7.5
0.2–0.1 mm	7.5	7.5
Calcined alumina CT9 FG	15	15
Reactive alumina CTC 30	10	10
CA-Cement Secar 80	5	5
Microsilica RW Füller D	5	5
Self-flowing values (%)	108	112

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Table 2
Specimen sizes, pretreatment and test methods

Specimen size	Pretreatment	Measured properties	Test method
40 × 40 × 150 mm	Cured 20°C, 24 h	CCS	DIN 51 067
	Cured 110°C, 24 h	CCS	DIN: Germany Industry Norm
	Cured 1000°C, 24 h	CCS	
	Cured 1500°C, 24 h	CCS	
40 × 40 × 150 mm	Cured 20°C, 24 h	Cold MOR	DIN 51 042/2
	Cured 110°C, 24 h	MOR	
	Cured 1000°C, 24 h	MOR	
	Cured 1500°C, 24 h	MOR	
25 × 25 × 150 mm	110°C, 24 h	HMOR	DIN 51 42/1

based SFC products are investigated under several temperature levels.

2. Methods

Andreasen and Andersen [9] distribution with q-value = 0.30 is adopted to design the castable recipes. China-Shanxi bauxite, SiC (SIKA, FG-P, Norway), calcined alumina (Alcoa, CTC9 FG, USA), CAC (Secar 80 Lafarge, France), micro silica (RW-Füller D, Germany) are used for preparation of low cement bauxite-based concrete samples (73% Al_2O_3, 1.0% CaO, 0.7% Fe_2O_3) (Table 1). Fused corundum-based samples (77% Al_2O_3, 1.3% CaO, 0.4% Fe_2O_3) are prepared by keeping the same constituent and just changing the bauxite to brown fused corundum. 6.5% and 6.0% water are added to the bauxite- and fused corundum-based samples, respectively. Both samples are mixed for 8 min. Then, mixture is poured to mould and cured for 24 h at room temperature. Samples are dried at 110°C for 24 h after replacing the mould. Dried samples are fired at 1000°C and 1500°C for 2 h. The format of samples and applied test is given in Table 2. X-ray diffraction (XRD) results are given in Table 3. Flow value measurement is performed by using the truncated flow cone as described in ASTM C230 (Table 1). (Fig. 1) shows a fractured sample after HMDR testing.

Table 3
Temperature dependency of phase amounts, XRD results

Samples	α-Al_2O_3	β-Al_2O_3	Mullite	SiC	Quartz	Cristobalite
Bauxite-based						
Cured 110°C, 2 h	XXX	–	XX	XX	X	–
Cured 1000°C, 2 h	XXX	–	XXX	XX	X	–
Cured 1500°C, 2 h	XXXX	–	XXXX	XX	–	–
Fused corundum						
Cured 110°C, 2 h	XXXX	XXX	–	XX	–	–
Cured 1000°C, 2 h	XXXX	XX	–	XX	–	–
Cured 1500°C, 2 h	XXXX	–	XXX	X	–	X

XXXX = very high, XXX = high, XX = medium, X = low.

3. Results and discussion

Results of applied tests are given in Figs. 2–4. Due to the thermal decomposition of hydrate phases, samples fired at 1000°C have lower density than dried samples. This condition can be seen in Fig. 2 with an increased porosity value (up to 20%) correlation. According to Fig. 3, strength of the bauxite-based refractory concrete is higher than corundum-based concrete. Due to the structural properties of bauxite and better compaction, bauxite-based samples have higher strength than corundum-based samples. Because of the sintering effect, density is increased and porosity is decreased for samples fired at 1500°C. However, better strength values are observed for samples fired at 1000°C.

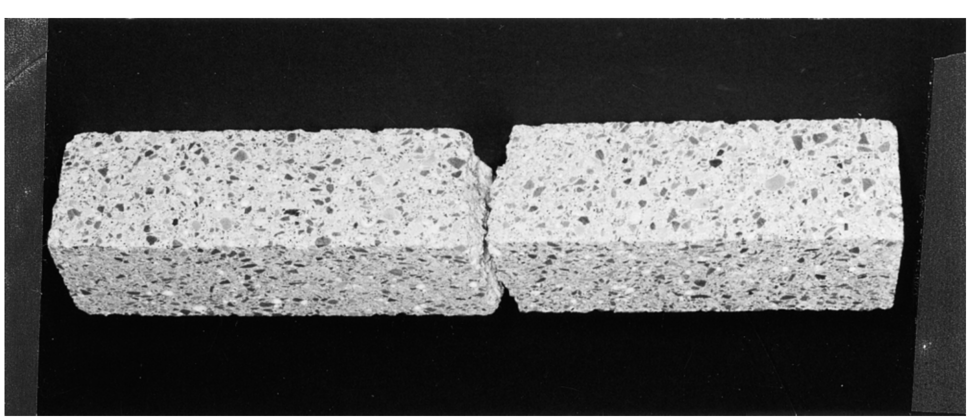


Fig. 1. Cross-section of bauxite based refractory concrete after HMOR testing.

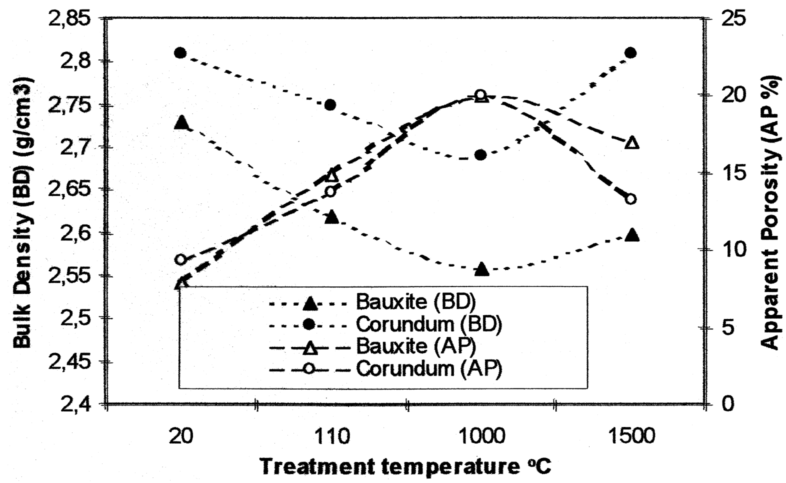


Fig. 2. Physical properties of bauxite- and brown fused corundum-based refractory concrete.

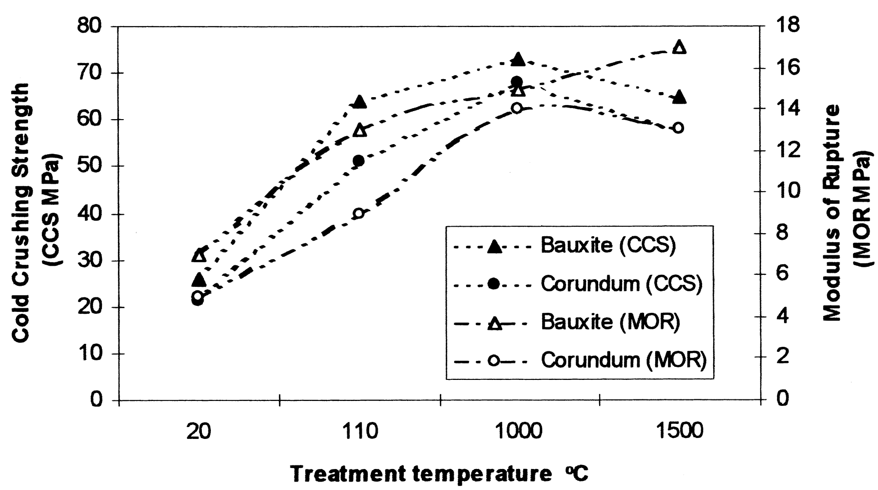


Fig. 3. Mechanical properties of bauxite- and brown corundum-based refractory concrete.

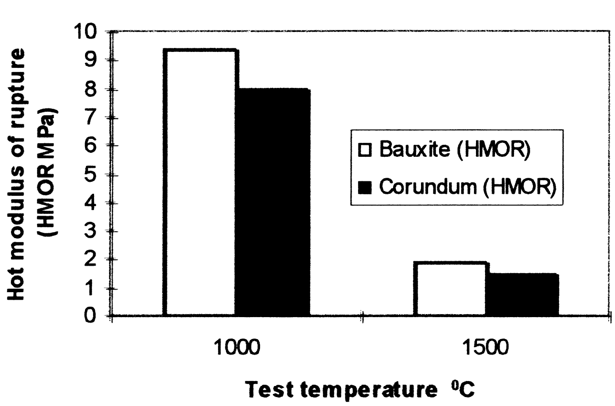
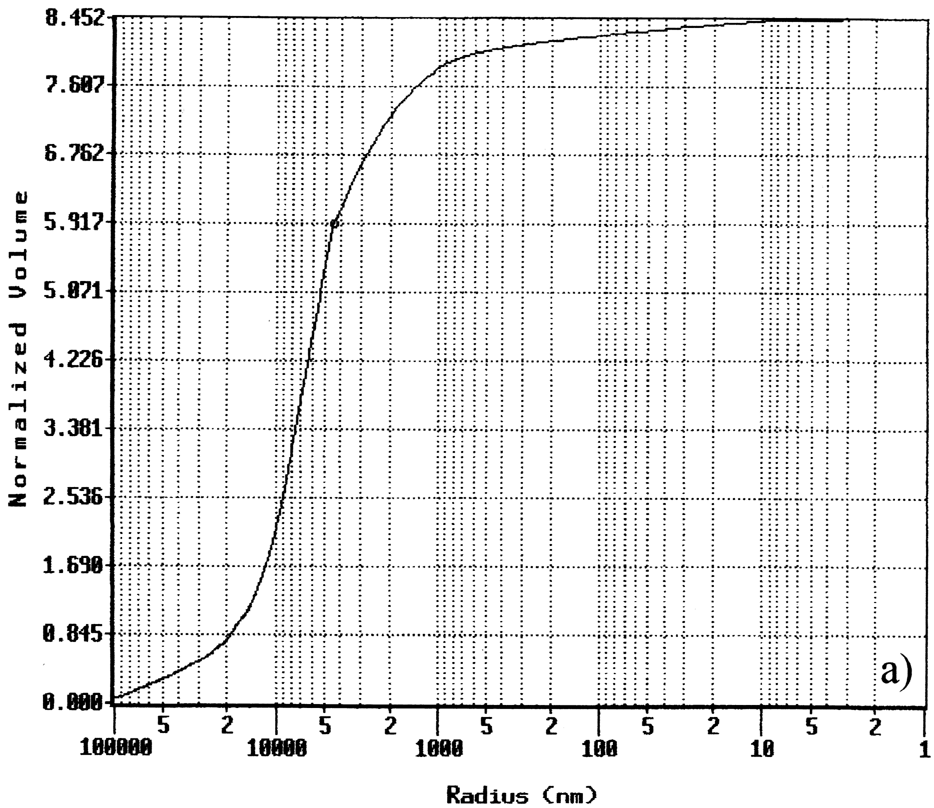


Fig. 4. HMOR properties at 1500°C of bauxite- and brown corundum-based refractory concrete.

This decreasing trend in strength is not observed for bauxite-based samples fired at 1500°C. The reason for this may be differences in the structures of pores, which can be seen in Fig. 5. Small pore fraction is higher for bauxite-based samples.

Hot modulus of rupture (HMOR) test is applied to dried samples at 1000°C and 1500°C. Hot modules of rupture of the corundum-based samples are lower than bauxite-based samples, although with lower porosity (Fig. 4). The possible reason for this is the oxidation of SiC. The reduction in hot modules of rupture is observed for samples fired at 1500°C. Mullite phase is formed due to the crystobalite and alumina (Table 3).

As seen in figure 6, α-Al_2O_3, SiC, quartz, and mullite phases are observed in bauxite-based samples dried at 110°C. Mullite phase is increased due to the reaction between quartz and alumina in samples fired at 1500°C (Table 3).



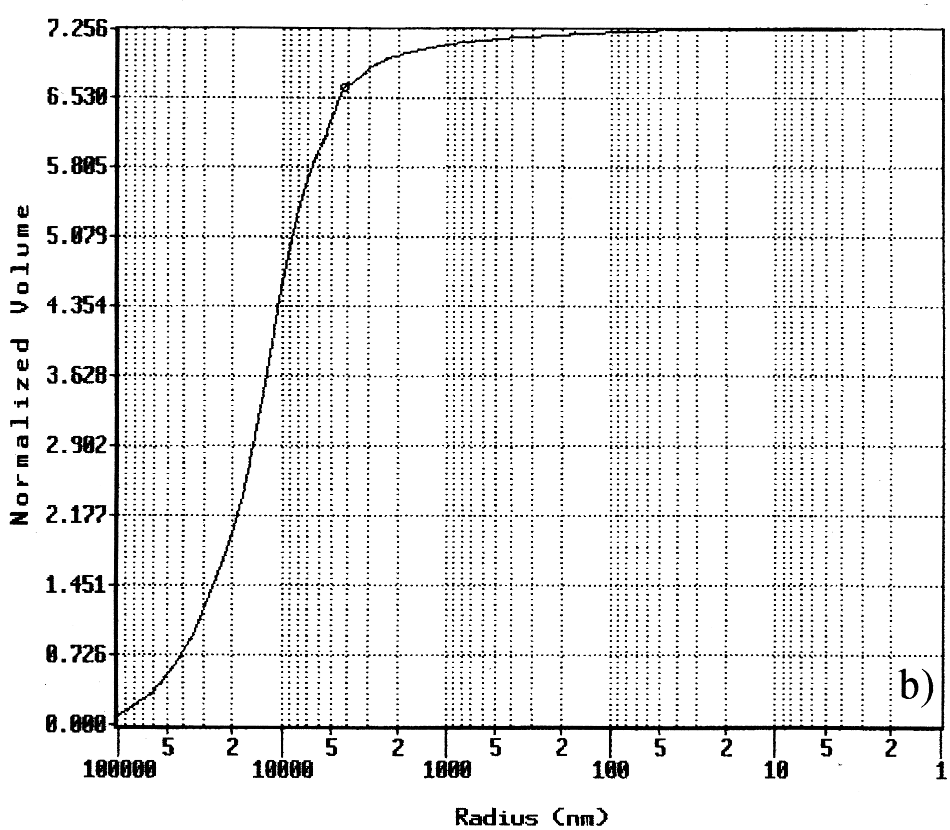


Fig. 5. Pore size distribution of (a) bauxite, (b) fused corundum-based samples fired at 1500°C (measured by Hg-porosimeter).

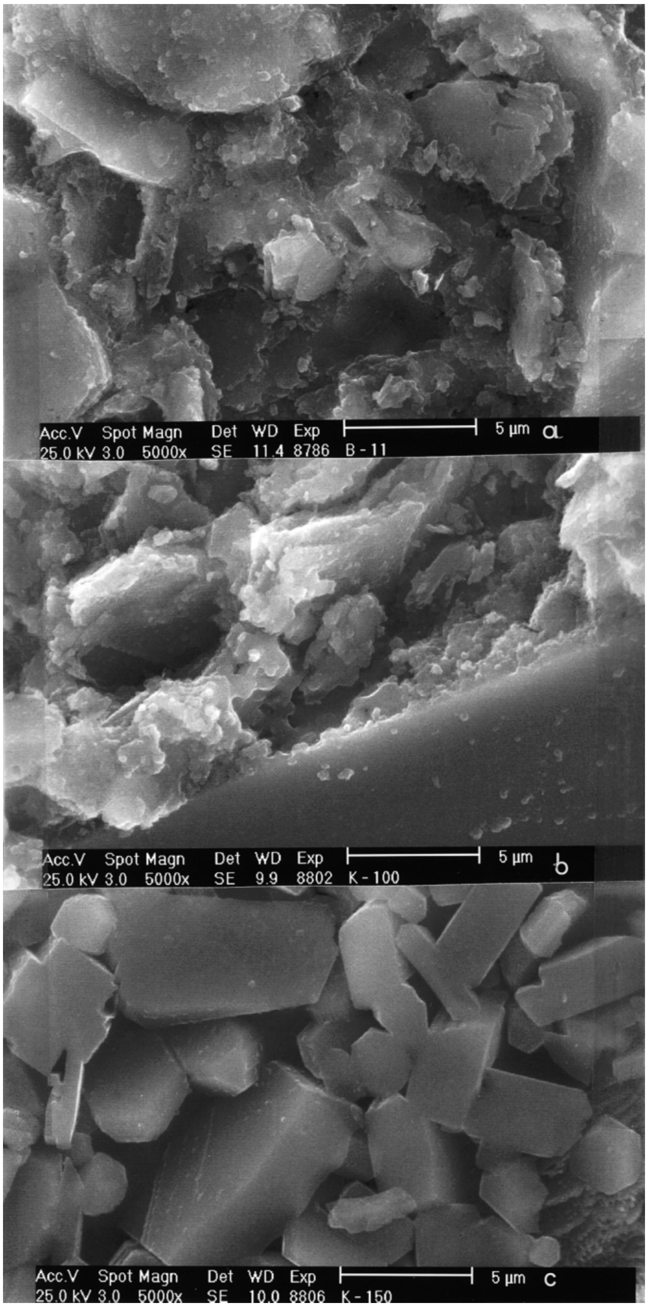


Fig. 6. SEM of (a) bauxite-based sample cured at 110°C for 24 h; (b) fused corundum-based sample fired at 1000°C for 2 h; (c) typical α-Al_2O_3 crystals on fused corundum-based sample fired at 1500°C for 2 h.

4. Conclusions

Although bauxite-based refractory concrete samples have higher porosity, it is observed that cold compression strength, bending strength and high temperature bending strength are better than brown fused corundum-based refractory concrete samples due to the newly formed phases and pore structures.

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