Development of Fast Drying Castable for Blast Furnace Trough

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Abstract

This new castable material for the blast furnace trough using silica sol as a binder has high resistance against steam explosion during drying because of very low water vapor pressure generated with rapid heating, and it needs only two thirds drying time compared to ordinary low cement castable material. Silica sol castable also has the same or higher corrosion resistance than low cement castable, therefore, it has a high future growth potential for shortening trough repairing time.

1. Preface

Today, low cement castable has been applied to almost every blast furnace trough in Japan. Low cement castable has a lot of excellent properties, however, it needs long drying time with careful control because of its dense texture. The proportion of drying time to total repairing time is high, therefore, shorter drying time as well as shorter installation time is sometimes demanded especially in small blast furnaces where it is difficult to ensure long enough time for trough repair. In this case, shortening drying time, which constitutes a high portion of the total repairing time, is one of the most useful countermeasures to satisfy their requests. Using silica sol as a binder seems to be effective method for increasing drying ability of a castable[1]. But an effective method for increasing drying ability is not always clear, and also, there are few reports regarding the service life.

Based on the above situation, we examined the trough castable with silica sol in order to estimate the effectiveness of silica sol or improving the drying ability and the influences on durability in actual service.

2. Test Method

The tested formulations are shown in Table 1. These formulations are based on alumina-spinel-silicon carbide-carbon materials which are typically used for trough castable. In order to distinguish the influence of binder, each formulation was composed of completely the same materials except for the binder and evaluated on many items including steam explosion resistance, air permeability, strength after curing, distribution of pore size,

Table 1　Chemical composition and binder of tested samples

	LC (Low cement system)	SS1 (Silica sol system)	SS2 (Silica sol system)
Chemical composition /mass%			
Al_2O_3		64.5	
MgO		15	
SiC		15	
C		4	
Binder type	Alumina cement	Silica sol	
Density of silica in binder /mass%	–	a	1.5a
Water content /mass%		5.2	

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internal temperature change at rapid heating, properties after heating and corrosion resistance.

Evaluation of steam explosion resistance was done by rapid heating method. A sample of $\phi 80 \times 80$mm after curing was put into an electric furnace which was kept at certain temperature and whether the sample was exploded or not was checked. The maximum temperature at which the sample did not explode was called the explosion limit temperature. At the same time of this test, temperature inside sample was measured with a thermocouple placed at the center of the sample.

Air permeability was measured by the high pressure air permeability measurement method. The side surface of the sample was sealed with rubber by N_2 gas pressure(7kgf/cm^2), the bottom of the sample was pressured by N_2 gas with 2kgf/cm^2, and the volume of gas from the top of sample was measured.

The curing strength was the modulus of rupture of the sample after 24 hours curing at 40℃.

Properties of the samples including the modulus of rupture, compressive strength and apparent porosity were measured after drying at 105℃ for 24 hours and heating at 1000℃ or 1500℃ for 3 hours in a reduction atmosphere.

Corrosion test was done by high-frequency induction furnace method. 10kg of Iron and 0.5kg of blast furnace slag (C/S=1.15) were used as a corrosive agent and the slag was changed every one hour. The test temperature was 1550℃ and time was 7 hours.

3. Results and Discussions

3. 1 Drying ability

The results for the explosion test (Table 2) show the silica sol castable has a higher explosion limit temperature than low cement castable by 200℃ or more, this indicates that silica sol castable can be dried with more rapid drying in actual use. The main factors which determine explosion resistance are thought to be strength of material and water vapor pressure inside the material, that is to say, if the material has high enough strength to withstand the water vapor pressure caused by heating, the material does not explode[2)]. Silica sol castable has lower strength after curing than low cement castable (Fig. 1), and this point is a disadvantage for explosion resistance. But, silica sol castable has much higher air permeability as shown in Fig. 2, therefore, water vapor pressure in silica sol castable is much lower than low cement castable, and this contributes to the high explosion resistance of silica sol castable.

Table 2 Results of explosive spalling test

Test temperatures (℃)	LC	SS1	SS2
900	×××	△△	○○
800	××○	○○	○○
700	×○○	○○	○○
600	○○	○○	○○
500	○○	○○	○○

○ : No explosion △ : Cracks × : Explosion

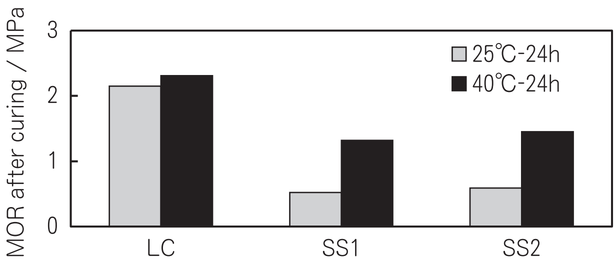

Fig. 1 Comparison of modulus of rupture after curing.

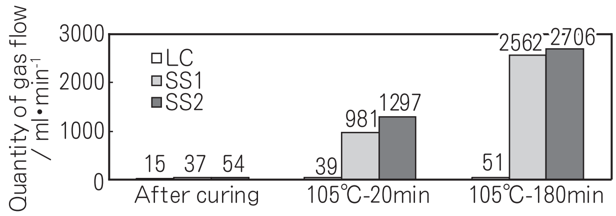

Fig. 2 Gas permeability of tested sample.

Fig. 3 shows the pore size distribution of the materials tested this time. In silica sol castable, there are much larger pores of about 15μm. This existence of large pores is thought to be the direct cause of high air permeability of silica sol castable.

Next, we will discuss how much drying time the silica sol castable can save. Based on the test results which ensure high explosion resistance, silica sol castable could be dried by more rapid heating than low cement castable. In these test conditions, the low cement castable took 8 minutes to be dried by 700℃ heating, on the other hand, silica sol castable could be dried in 5 minutes by 900℃ heating with no explosion, that is to say, the drying time

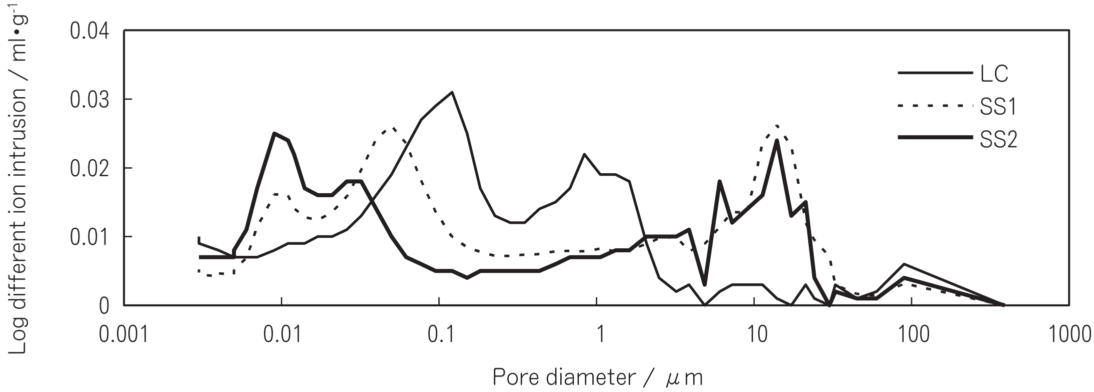

Fig. 3 Pore diameter distribution.

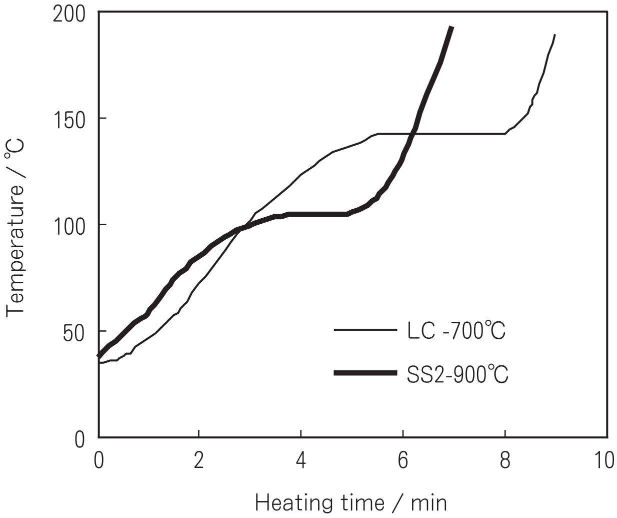

Fig. 4 Change of internal temperature during rapid heating.

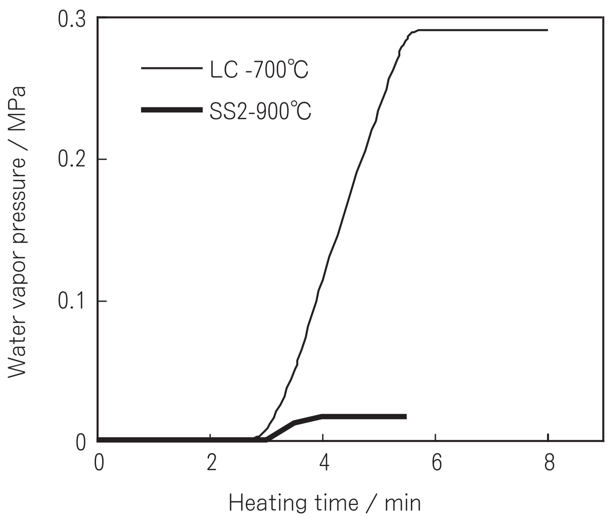

Fig. 5 Change of internal water vapor pressure during rapid heating.

decreased by two thirds with silica sol castable (Fig. 4). Fig. 5 shows the change of water vapor pressure in the materials during heating. As shown in this figure, the water vapor pressure generated in the silica sol castable is very much lower than low cement castable. Based on these results, it is thought that silica sol castable is thought to require only two thirds the drying time of low cement castable also in actual use, if it is dried under the proper conditions.

3. 2 Durability

Fig. 6 shows the corrosion test results. Silica sol castable shows better corrosion resistance, if the index number of the corrosion volume of a low cement castable (LC) is 100, the index number of SS1 (silica sol castable) is 91. Silica sol castable doesn't contain cement, and this is thought to be one of the cause of high corrosion resistance. Table 3 shows the physical properties after heating. It is thought that there will be no problems with the properties of silica sol castable after heating because they are almost the same as the properties of ordinary low cement castable.

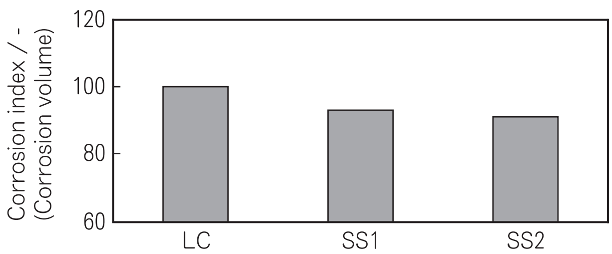

Fig. 6 Comparison of corrosion resistance.

Table 3 Physical properties of tested samples

		LC	SS1	SS2
MOR after curing / MPa	25℃-24h 40℃-24h	2.15 2.31	0.52 1.32	0.59 1.45
MOR after heating / MPa	105℃-24h 1000℃- 3h 1500℃- 3h	4.4 3.0 2.4	2.7 5.8 4.7	3.3 8.1 3.9
CCS after heating / MPa	105℃-24h 1000℃- 3h 1500℃- 3h	25.2 39.2 13.5	13.1 33.2 23.8	21.7 39.8 25.6
Apparent porosity after heating / %	105℃-24h 1000℃- 3h 1500℃- 3h	13.3 16.4 15.9	13.0 15.7 15.0	12.1 14.6 14.8

4. Conclusion

We examined the trough castable with silica sol binder for rapid drying and got the following conclusions.

- Silica sol castable has higher drying ability than low cement castable. This is thought to be because silica sol castable has much higher air permeability due to the existence of large sized pores.
- Silica sol castable can be dried more rapidly than low cement castable because of low risk of steam explosion during heating. There is a good possibility to shorten drying time to two thirds that of low cement castable.
- Silica sol castable has the same or higher corrosion resistance compared with low cement castable, therefore, it is thought that there will be no problems in actual service life.

References

1) M.R.Ismael, R.Salomao, V.C.Pandolfelli : Refractories Manual, pp34-39 (2007)
2) H. Sasaki : The 73rd Refractory Committee Report (2), pp61-69 (2002)