Research on Application of Dispersing Aluminas ZX1 and ZD1

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Abstract：The apparent characteristics , physical and chemical indicators and castable performance of dispersing aluminas ZX1 and ZD1 were analyzed. The application of dispersing aluminas ZX1, ZD1 from Zhejiang Zili and dispersing aluminas A, B from some other company were investigated in the corundum system and the system of corundum containing silicon powder. The results showed that the indicators of dispersing aluminas ZX1, ZD1 and A, B were similar; in the corundum system the best total amount of ZX1 and ZD1 was 0.8% ; in the system containing silicon powder, when using the proportion of ZX1 and ZD1 as 0.5% and 0.3%, the castable has a good flowability and a high mechanical properties.

Key words：Dispersing alumina; Superplasticizers; Corundum based; Aluminum powder; Microsilica

Introduction

Dispersing Aluminas are dispersing agents, which were innovation products. As with the function of dispersing matrix fines combined with the functions of steering the setting behavior of castables, when we use dispersing alumina, no more additives are needed to adjust the workability of castables. Dispersing alumina can also be used to improve the early strength of castables. There are two types of dispersing alumina, one is for setting retardation which was named with X, another is for setting acceleration which was named with D. They are used together in a adjustable ratio for individual setting behavior requirements.

The most common superplasticizers used in corundum system are polycarboxylate, sodium polyacrylate, naphthalene sulphate based, aminophenol sulphate based, sodium tripolyphosphate, sodium hexametaphosphate, etc[1-3]. Through electrostatic repulsive force and teric hindrance, the superplasticizers can play a good dispersing effect[4]. However, without other additive the traditional superplasticizers can not adjust the setting time to individual requirements[5]. The appearance of dispersing alumina can solve the problems that castables had a quick setting behavior in summer and shown a slow condensation. Aluminum powder is usually used as antidetonator, but the high-activity aluminium, the mismatching additives or the unsuitable curing condition may result the bulging phenomenon. Therefore, in the corundum system with silicon powder, the additives have a significant influence on the flow behavior of castables[6-7].

Until now, the mature and stable dispersing alumina products are precious few, therefore, Few reports concern the dispersing alumina. It is also believed that the understanding of its researches of dispersing alumina will be helpful in predicting and improving the properties of castables. In this work, the characteristics and applications of dispersing alumina are investigated. In contrast with the dispersing alumina from some other company, the applications of the Zili dispersing alumina ZX1, ZD1 were investigated.

1. Experimental

1.1 Raw materials

The raw materials used for preparing castables were tabular alumina (5~3mm, 3~1mm, 1.0~0.5mm, 0.5~0mm, ~45μm, 99% Al_2O_3, Zhejiang Zili Alumina Material Technology Co., Ltd., China), reactive alumina powder (~2μm, 99% Al_2O_3, Zhejiang Zili Alumina Material Technology Co., Ltd., China).Additionally, pure calcium aluminate Cement (Secar71, Kerneos, China) was added as binder. Dispersing alumina ZX1/ZD1(Zhejiang Zili Alumina Material Technology Co., Ltd., China) , A/B(Some other foreign enterprises) was added as additives.

1.2 Sample preparation and characterization

The castable compositions comprised reactive alumina as matrix powders and tabular alumina as coarse aggregate grains. 5 wt% calcium aluminate cement (Secar 71, Kerneos, France) were used as binder . In addition to dispersing aluminas ZX1/ZD1(Zhejiang Zili Alumina Material Technology Co., Ltd., China) were used as additives to provide enough workability for the castable. The total water content of the batches was 4.4 wt%. The formulations of specimens are shown in Table.1 and Table.2.

The samples for mechanical test evaluation were cast as cuboid molds (40 mm *40 mm *160mm) and kept in a chamber at 20 ℃ for 24 h during curing and at 110 ℃ for 24 h (drying).

The flowability of the castables was measured according to the GB/T 2419-2005 standard; The cold modulus of rupture(CMOR) of the castables was measured according to the GB/T 3001-2007 standard; The cold crushing strength(CCS) of the castables was measured according to the GB/T 5072-2008 standard.

Table.1. Formulations of specimens(wt%)

	Tabular Alumina (aggregate)	Tabular Alumina (fines)	Reactive Alumina	Cement	Aluminum Powder	A	B	ZX1	ZD1
5A3B	72	15	8	5	0.01	0.5	0.3	0	0
8X0D	72	15	8	5	0.01	0	0	0.8	0
7X1D	72	15	8	5	0.01	0	0	0.7	0.1
6X2D	72	15	8	5	0.01	0	0	0.6	0.2
5X3D	72	15	8	5	0.01	0	0	0.5	0.3

Table.2. Formulations of specimens(wt%)

	Tabular Alumina (aggregate)	Tabular Alumina (fines)	Reactive Alumina	Cement	96 Microsilica	ZX1	ZD1
5X3D-0	72	15	8	5	0	0.5	0.3
5X3D-1	72	15	8	5	0.2	0.5	0.3
5X3D-2	72	15	8	5	0.5	0.5	0.3
5X3D-3	72	15	8	5	1.0	0.5	0.3
5X3D-4	72	15	8	5	1.5	0.5	0.3

2. Results and Discussion

2.1 Technical features of dispersing alumina

The apparent characteristics and physical and chemical indicators of dispersing aluminas ZX1 and ZD1 were analyzed, and the results are shown in Fig.1 and Table.3.

a.A b.B c.ZX1 d. ZD1

Fig.1. The photograph of dispersing alumina

In the photograph of dispersing alumina (Fig 1), the dispersing aluminas from Zhejiang Zili and one foreign company are all light yellow powder.

The chemical composition and particle size distribution of dispersing aluminas are tested and list in Table.3. Dispersing alumina all contains 70%~80% alumina and tiny amounts of CaO、SiO_2 and B_2O_3. Also, there are 18%~22% loss on ignition (L.O.I) at 1050 ℃ in dispersing alumina.

Table.3.The Chemical composition and particle size distribution of dispersing alumina

	ZX1	ZD1	A	B
Al_2O_3	77.82	79.36	74.71	79.38
SiO_2	1.42	1.39	0.63	0.95
CaO	0.65	0.62	1.67	1.41
Na_2O	0.25	0.19	0.65	0.09
B_2O_3	0.80	0.02	0.78	0.07
1050℃ L.O.I/%	19.46	18.03	21.60	17.87
D50	1.79	1.75	1.97	2.30
D90	3.46	3.28	5.15	6.86

2.2 Application of dispersing alumina on corundum castables

The castable performance of dispersing aluminas ZX1 and ZD1 were analyzed.

2.2.1 Effect of ZX1 addition on castable performance

The castables with different amount of dispersing alumina ZX1 were prepared and the castable performance were tested which was shown in Table.4. The condition of the experiments was room temperature(21℃) and the

humidity was 58%.

The batches labeled as 10X, 8X, 7X, 6X and 5X were designed according to the amount of dispersing alumina ZX1, which mean that the ZS1 contents were 1.0%, 0.8%, 0.7%, 0.6%, 0.5%, respectively.

Table.4. The workability and early strength of the castable

Samples	Water Amount /%	Flow Value/mm	Available time; /min	24h demoulding strength/MPa		110℃ drying strength/MPa	
				CMOR	CCS	CMOR	CCS
5A3B	4.4	175	130	4.5	26.0	14.2	78.9
10X	4.4	207	120	5.8	26.3	18.0	109.5
8X	4.4	190	120	6.0	25.0	19.0	102.9
7X	4.4	189	115	4.5	34.5	16.6	92.3
6X	4.4	195	100	4.9	31.7	19.5	107.6
5X	4.4	185	110	5.8	40.8	20.5	113.3

From the data of castables (Table.4), it's believed that the addition of ZX1 between 0.5% and 1.0% can endow the castables with a better flowability. The 24h demoulding strength are all above 4.5MPa and 110℃ drying strength are all above 16MPa, therefore the dispersing alumina from Zhejiang Zili can meet the requirements.

2.2.2 Effect of ZD1 addition on castable performance

The castables with different amount of dispersing alumina ZD1 were prepared and the castable performance were tested which was shown in Table.5. The condition of the experiments was room temperature(15℃) and the humidity was 52%.

The batches labeled as 8D, 7D, 6D, 5D and 4D were designed according to the amount of dispersing alumina ZD1, which mean that the ZD1 contents were 0.8%, 0.7%, 0.6%, 0.5%, 0.4%, respectively.

Table.5.The workability and early strength of the castable

Samples	Water amount /%	Flow value /mm	Available time /min	24h demoulding strength/MPa		110℃ drying strength/MPa	
				CMOR	CCS	CMOR	CCS
5A3B	4.4	165	125	4.0	29.6	17.8	120.9
8D	4.4	190	50	3.9	27.5	20.0	132.5
7D	4.4	210	80	4.6	32.8	19.8	135.2
6D	4.4	200	75	4.6	33.5	18.3	119.3
5D	4.4	220	90	4.5	39.7	18.5	116.9
4D	4.4	195	40	4.1	32.1	17.8	110.6
8X	4.4	185	100	2.5	24.5	17.2	113.2

From the data of castables (Table.4), it's believed that the addition of ZD1 between 0.5% and 0.7% can endow the castables with a better flowability. The 24h demoulding strength are all above 4MPa and 110℃ drying strength are all above 15MPa, therefore the dispersing alumina from Zhejiang Zili can meet the requirements.

But when the amount of ZD1 added too much or too small, it cause the castables to harden, make flow performance worse, and shorten the construction time. Meanwhile, compared 8X with 8D under the same conditions, it's obvious that the early strength of 8D castable is higher than 8S. This result maybe because that ZS1 can coagulate the castable and help to speed up the strength development of cement.

2.2.3 Effect of the ZX1/ZD1 proportion on castable performance

This part studies the proportion of ZX1/ZD1 in corundum castables, when the total amount of dispersing alumina is 0.8%. Due to the influence of the temperature and humidity on the workability and strength development, two experiment conditions were analyzed.

The condition of the experiments was room temperature(25℃) and the humidity was 46%. The results were shown in Table.6.

Table.6.The workability and early strength of the castable

Samples	Water amount /%	Flow value /mm	Available time /min	24h demoulding strength/MPa		110℃ drying strength/MPa	
				CMOR	CCS	CMOR	CCS
5A3B	4.4	175	170	4.5	26.0	14.2	75.4
8X0D	4.4	190	130	4.5	34.5	16.6	82.3
7X1D	4.4	187	130	5.8	40.8	20.5	113.3
6X2D	4.4	185	100	4.9	36.7	19.5	107.6
5X3D	4.4	185	80	4.5	31.8	16.2	87.4

In the corundum system, at 25℃, the ZX1/ZD1 can give the castables a higher early strength and a better workability than A/B. When the total addition of ZX1 and ZD1 was 0.8%, the proportion of ZX1 and ZD1 as 7:1 and 6:2 is more suitable for summer.

The condition of the experiments was room temperature(12℃) and the humidity was 19%. The results were shown in Table.7.

Table.7.The workability and early strength of the castable

Samples	Water amount /%	Flow value /mm	Available time /min	24h demoulding strength/MPa		110℃ drying strength/MPa	
				CMOR	CCS	CMOR	CCS
5A3B	4.4	160	65	4.0	29.6	17.8	120.9
8X0D	4.4	185	75	4.6	42.5	17.6	110.1
7X1D	4.4	190	65	4.1	44.5	16.1	102.7
6X2D	4.4	203	100	4.5	41.5	16.1	90.8
5X3D	4.4	180	90	4.7	43.6	18.2	120.3

In the corundum system, at 12℃, the ZX1/ZD1 can give the castables a higher early strength and a better workability than A/B. When the total addition of ZX1 and ZD1 was 0.8%, the proportion of ZX1 and ZD1 as 5:3 and 6:2 is better for winter.

2.3 Application of dispersing alumina on corundum castables with few silicon powder

In the system containing silicon powder, when using the proportion of ZX1 and ZD1 as 0.5% and 0.3%, the castable performance was tested and the results were shown in Table.8.

The batches labeled as 5X3D-0, 5X3D-1, 5X3D-2, 5X3D-3 and 5X3D-4 were designed according to the amount of microsilica, which mean that the microsilica contents were 0%, 0.2%, 0.5%, 1.0%, 1.5%, respectively.

The condition of the experiments was room temperature(15℃) and the humidity was 27%. The results were shown in Table.8.

Table.8.The workability and early strength of the castable

Samples	Water amount /%	Flow value /mm	Available time /min	24h demoulding strength/MPa		110℃ drying strength/MPa	
				CMOR	CCS	CMOR	CCS
5X3D-0	4.4	180	90	4.7	43.6	18.2	120.3
5X3D-1	4.4	190	75	4.8	40.3	16.5	114.8
5X3D-2	4.4	190	80	4.8	45.7	16.1	92.4
5X3D-3	4.4	190	80	5.0	44.7	17.8	107.7
5X3D-4	4.4	190	82	5.4	45.2	16.3	82.6

With the addition of silicon powder, the flow performance of castable has improved, the construction time become short, therefore, there are no differences in the early strength of castables.

In the system containing silicon powder, when using the proportion of ZX1 and ZD1 as 0.5% and 0.3%, the castable has a good flowability and a high mechanical properties.

3. Conclusions

(1) The apparent characteristics, chemical composition and particle size distribution of dispersing aluminas ZX1 and ZD1 were analyzed. Technical features of dispersing aluminas from Zhejiang Zili and some other company are similar;

(2) The application of dispersing aluminas ZX1, ZD1 from Zhejiang Zili and dispersing aluminas A, B from some other company were investigated in the corundum system, ZX1/ ZD1 can meet the flowability, setting behavior and mechanical properties of the castables.

(3) In the corundum system the best total amount of ZX1 and ZD1 was 0.8%. The proportion of ZX1 and ZD1 as 7:1 is more suitable for summer and 5:3 is better for winter.

(4) In the system containing silicon powder, when using the proportion of ZX1 and ZD1 as 0.5% and 0.3%, the castable has a good flowability and a high mechanical properties.

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