E-SY ALUMINA FOR EASY TO USE HIGH-PERFORMANCE CASTABLES

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5

INTRODUCTION

Modern castable design essentially depends upon the right choice of matrix fines.
Reactive aluminas have become the key product in the matrix, enabling the development of many and various monolithic concepts for vibration, self-flow or gunning placement.
Over the past few years the development of bi-modal, and especially multi-modal reactive aluminas have led to overall castable improvement. They have also become one of the most important products for use in state-of-the-art monolithic concepts.
Well controlled particle size distributions allow castables to be adjusted to give the best flow properties with the lowest possible water demand. This enables the design of monolithic products with excellent thermal and mechanical properties.
However this often results in highly dilatant mixes which require heavy duty mixing equipment. In addition, they exhibit long wet-out times and also transfer of castable by pneumatic systems or by pumping is difficult and sometimes impossible to achieve.
The focus of attention for castable development today is on ease of mixing, quick castable wet-out and straightforward on-site installation with easy workability.
This leads to overall cost savings in both equipment and processing and gives secure linings with optimised service life.
The reactive aluminas E-SY 1000 and 2000 were developed to meet these challenges. Their versatility allows the formulation of low dilatancy, low water demand vibration or self-flow castables with optimised rheology, enabling low energy mixing with lower cost equipment, fast wet-out and soft flow properties.
Their global availability fulfils the demand for products minimising individual regional development efforts.

E-SY ALUMINAS TYPICAL PRODUCT PROPERTIES

The typical chemical and physical product properties of E-SY 1000 and E-SY 2000 reactive aluminas are listed in table 1.

Tab. 1: E-SY 1000 and E-SY 2000 typical product data

Chemical Composition		E-SY 1000 typical	E-SY 2000 with Spinel typical
Al_2O_3	[%]	99.5	88.0
Na_2O	[%]	0.20	0.10
Fe_2O_3	[%]	0.03	0.04
SiO_2	[%]	0.03	0.10
MgO	[%]		11.0
CaO	[%]	0.02	0.03
Grain size distribution		bi- modal	
Properties			**typical**
Specific surface area / BET		2.00 m²/g	2.30 m²/g
Particle Size / D50 Cilas		1.7 µm	1.7 µm
Particle Size / D90 Cilas		8.0 µm	8.0 µm

E-SY 1000 is a high chemical purity bi-modal reactive alumina whereas E-SY 2000 contains besides alumina a defined amount of ultrafine alumina-rich spinel, giving the advantage of incorporating fine dispersed spinel into the castable matrix for optimised product performance, e.g. improved slag resistance, if required by the application.
The typical bi-modal particle size distribution (PSD) of the E-SY aluminas is measured by laser diffraction method with Cilas 1064 (figure 1). The PSD is practically identical for both products.

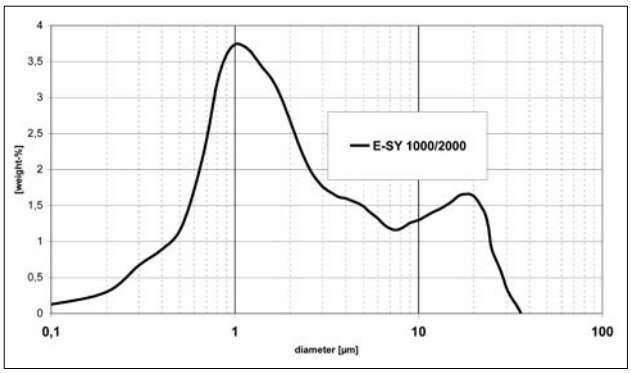

Fig. 1: Typical particle size distribution of E-SY 1000 and E-SY 2000

MIXING TRIALS WITH LOW DILATANCY VIBRATION CASTABLES

The main focus of the experimental work was to demonstrate easy mixing, good castable flow behaviour and workability under process conditions in industrial equipment commonly used for castable preparation. Therefore three low cement (5% CA-14 M calcium aluminate cement) vibration (VIB) test-castables with different aggregate top sizes were prepared with E-SY 1000 reactive alumina as the matrix component.
Table 2 shows the test castable compositions.

Tab. 2: Composition of test castables

Castables		VIB 6 CL	VIB 8 E-SY	VIB 15 E-SY	VIB 25 E-SY
Tabular T60/T64 coarse	%				
10 - 25 mm	%				20
6 - 15 mm	%			15	7
up to 8 mm	%		80	65	53
up to 6 mm	%	75			
Tabular T60/T64 fines - 20 MY	%	7			
Reactive Aluminas					
CL 370	%	13			
E-SY 1000	%		15	15	15
Cement					
CA-14 M	%	5	5	5	5
Additives					
ADS / W	%	1	1	1	1
Water	%	4.3	3.8	3.7	3.3

Test mix VIB 6 CL is included for comparison purposes only, representing a commonly used high performance LC vibration castable concept exhibiting good vibration flow and overall excellent physical properties. As a common, long term established concept it was excluded from subsequent industrial scale mixing and castable conveying/pumping trials.
When comparing the required amount of matrix fines below 45µm (tabular fines + reactives + cement), this is normally 25% for the well established VIB 6 CL, but only 20% for the VIB test castables using E-SY 1000 reactive alumina. That provides a potential cost saving as matrix fines account for a significant proportion of the cost of the overall castable formulation. Furthermore, mixes using E-SY aluminas should avoid a combination with commonly added -45µm(-325 mesh) matrix fines as this alters the non-dilatant soft flow behaviour. This will provide a further contribution to cost saving.
VIB 8 E-SY uses T-60/64 tabular alumina with a top size of 8mm, VIB 15 E-SY uses the 6-15 mm size introduced in 2007 and VIB 25 E-SY the new developed coarse 10-25 mm size. Proper mixing and workability of coarse aggregate-containing castables is considered to be particularly challenging for commonly used mixing equipment.
To get the best castable flow properties with low mixing water requirement, the proportions of dispersing aluminas ADS-3 and ADW-1 were adjusted to a working time of 45-60 minutes which was suitable for the mixing trial conditions.

The mixing and flow behavior of VIB 8 E-SY was tested in a low energy gravity mixer using a 50 kg dry castable mix. This test mix showed very easy mixing and good flow and soft castable texture at very low water demand. During mixing the castable appeared quite "fluffy" with no tendency to form lumps (figure 2).

Fig. 2: VIB 8 E-SY in gravity mixer; no lump formation during mixing

Short wet-out was observed in addition to short mixing time. Intermediate stops compact the mix, but it was immediately dispersed back to the "fluffy" consistency after re-starting the gravity mixer without any consequential lump formation. The resulting castable consistency did not show any dilatant flow behaviour after discharge and could be easily shovelled. The test castable was easily vibrated into standard test-bar moulds for lab investigations.

Another mixing trial was performed in a Zyklos ZK 150 HE rotary pan mixer from Pemat Mischtechnik GmbH at the manufacturer's location in Rohrbach/Germany shown in figure 3.

Fig. 3: Rotary paddle mixer with tiltable mixing pan (Zyklos ZK150HE, courtesy Pemat Mischtechnik GmbH, Germany)

This type of mixer is frequently used for smaller batches of about 150 kg. The offset mixing paddles rotate simultaneously and at the same proportional speed to the mixing pan, hence providing high levels of shearing and kinetic energy release at a maximum energy consumption of 4 kW.
Three 150 kg batches of VIB 25 E-SY were mixed easily with no consequent problems, especially considering the 25mm coarse tabular alumina. All components of the pre-mixed dry castable, including the coarse tabular alumina fraction, were charged at the same time. The normal two-step process of adding the coarse fraction after some mixing time was not necessary. Wet-out of the mixes occurred very quickly, typically at around 50 seconds. Total mixing time was 4 minutes. The mixes were soft, easily workable and exhibited good flow. Also, when the mixer was stopped it could be restarted without any difficulty. The mixes could be easily shovelled and vibrated into test panels for lab investigations of physical properties.

The test mixes VIB 15 E-SY and VIB 25 E-SY were selected for a comprehensive castable mixing and conveying trial with the Estromat 850 from UELZENER Maschinen GmbH/Germany (Figure 4) which is commonly used for LC-and ULC- refractory castables.

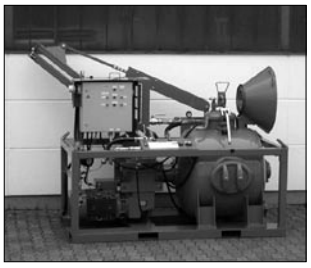

Fig. 4: Mixing and conveying vessel unit (Estromat 850, courtesy Uelzener Maschinen GmbH, Germany)

This machine consists of an 850 l mixing vessel with horizontal agitating paddle arms working as a compulsory mixer. Water addition is precisely controlled by an automatic system; it took 30-40 seconds for the pre-determined mixing water amount to be added. The machine requires an auxiliary compressor which gives the mixing vessel the pressure to discharge the castable through a 100mm diameter hose.
Also here the test batches of 750 kg showed a very short wet-out time and perfect mixing. Good castable consistency was achieved after 4 minutes total mixing time. The castables were easily conveyed through the 10m long hose by low air pressures of about 2-3 bar – this is considered as standard. A 90° bent nozzle was attached to the end of the hose to enable the discharge of the castable into a collecting container (figure 5) thus allowing samples to be taken for lab evaluation of the mixes.

Fig. 5: Discharge of VIB 25 E-SY castable into the collecting container

The tests have proved that even coarse grained vibration castables like VIB 15 E-SY and VIB 25 E-SY can be easily mixed and conveyed or pumped with standard machine settings even at very low mixing water additions. The machine operating technician noted that the castables could be actually pumped over a longer distance than 10m, up to 20m or even 30m. This is only possible with castables showing soft flow behaviour and a non-dilatant rheology.

5

TEST RESULTS WITH E-SY ALUMINA CONTAINING MIXES

The results of the mixes VIB 8 E-SY, VIB 15 E-SY and VIB 25 E-SY which were selected for the industrial scale mixing and conveying/pumping trials are shown in table 3, again using VIB 6 CL for comparison purposes.

Tab. 3: Physical data of test mixes; for VIB 25 E-SY the longer SFL cone was used for flow measurement (see text)

Castables		VIB 6 CL	VIB 8 E-SY	VIB 15 E-SY	VIB 25 E-SY
Wet-out time	s	60	50-60	50-60	45-55
VIB-Flow					
10 min	cm	23.6	18.2	18.9	(21.5)
30 min	cm	22.5	18.0	18.7	with SFL
60 min	cm	22.3	18.0	17.8	cone
C MoR					
20°C / 24h	MPa	6	6	6	7
110°C / 24h	MPa	18	23	14	18
1000°C / 5h	MPa	12	16	9	13
1500°C / 5h	MPa	49	56	45	37
CCS					
20°C / 24h	MPa	19	25	36	58
110°C / 24h	MPa	80	103	88	175
1000°C / 5h	MPa	74	112	88	150
1500°C / 5h	MPa	180	172	> 130	257
Density					
110°C / 24h	g/cm³	3.16	3.26	3.25	3.29
1000°C / 5h	g/cm³	3.10	3.22	3.20	3.22
1500°C / 5h	g/cm³	3.10	3.16	3.15	3.29
PLC					
1000°C / 5h	%	-0.09	±0	+0.01	-0.02
1500°C / 5h	%	-0.24	+0.18	+0.51	+0.24

All mixes showed very short wet-out times of one minute or below, regardless of mixing equipment used. These short wet-out times eliminate the risk of overwatering a castable during on-site mixing. This is a frequently expressed concern of monolithic refractories suppliers.

The vibration flow properties were measured with the standard ASTM procedure using the flow cone with 100mm lower and 70 mm upper diameter and a height of 50mm. The coarser the top size of the aggregate in the castable, the more questionable are the flow property results obtained by this measurement method, as it is prone to predict inferior flow compared to actual flow behaviour. Therefore a non-standard cone (SFL cone) with 100mm lower and 70mm upper diameter and a height of 80 mm was used for VIB E-SY 25. All mixes achieved very good flow properties at the lowest possible mixing water addition.

In order to complete the results from the mixing trials, physical data – cold modulus of rupture (CMoR), cold crushing strength (CCS), density and permanent linear change (PLC) – were measured. Both CMoR and CCS show generally high levels compared to those typical for high performance castables. Even the green strengths achieved at 20°C room temperature are quite high and considered as adequate for safe de-moulding and the subsequent handling of large pre-cast shapes. The coarse aggregate VIB 25 E-SY test mix shows higher CCSs as specimens for strength measurement were cut out of cast panels and carried out on larger than standard test bars (64x54x230mm) and provides data consistent with this method.

Densities and PLCs achieved are in the typical range of dense high alumina castables, whereas VIB 25 E-SY shows the highest density level because it contains 20% of the new 10-25 mm coarse tabular alumina.

CONCLUSION

The very successful mixing trials performed with E-SY alumina clearly demonstrate the outstanding performance that can be achieved with this reactive alumina. It is also extremely versatile when used in castable formulations containing both regular and coarse aggregate sizes.

E-SY alumina as a matrix component enables low energy mixing at very low water addition. The short wet-out times eliminate the risk of castable overwatering during on-site castable mixing.

The soft flow properties of vibration castables together with their non-dilatant rheology enable the use of “light” mixing devices e.g. common gravity mixers or similar low power equipment.

As well as exhibiting easy mixing, the overall castable flow properties allow the castable to be transported or pumped over longer distances without the use of high pressure pumping equipment.

All these factors makes E-SY alumina the material of choice for modern castable design in many and varied applications and satisfies the need for easy workable, safe and perfect placement of high performance monolithic castable concepts.

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