

REGULAR CASTABLES (RC) AND HIGH PERFORMANCE – NO CONTRADICTION ANYMORE

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Presented at Unitecr Conference, Salvador, Brazil, October 2009

ABSTRACT

The paper discusses new formulation concepts for Regular Castable (RC) with drastically increased performance profiles. This performance boost can be brought to RC without compromising on simplicity or moving the system completely out of their actual formulation cost frame. This investigation applies the latest calcium aluminate technology, designed for LCC, to RC-recipes. These new binders SECAR®Plenium and SECAR Xeniom™ yield conventional castables with lower lime contents, lower water demand and consequently lower porosity than achievable with 70% alumina containing calcium aluminate cements (CAC). This improves the strength especially in the range between 500 and 1100°C. These new types of RC rely on a modified microstructure which results in significantly higher hot strength, abrasion and penetration resistance compared to traditional RC. This new RC concept, still very easy to formulate and to use, allows the production of reliable and technologically advanced castables. This concept works without the need of supplementary fillers and deflocculants. Unforeseen raw material interactions are therefore minimised. These new binder concepts for RC will support the refractory industry in their efforts to supply even in difficult economical times remarkable innovations which can easily and rapidly been implemented. It will support the refractory consuming industries in their efforts to work with easy-to-use and economical solutions that are adapted to the required performance level.

1 Introduction

A review of scientific and technological publications of the last 20 years in the field of monolithic refractories can lead to a view that Regular Castables (RC), also called Conventional Castables (CC) represent a technology from a past century. This is difficult to reconcile with the fact that on a global basis a significant part of the CAC bonded refractory castables uses this traditional formulation technology. One factor might be the slow penetration speed of new technologies in a cost but as well security driven industry. But another reason might be found in the sensitivity of the modern castable systems as LCC, ULCC and NCC to several formulation intrinsic and external parameters [1]. RC can be considered to yield a greater tolerance with respect to variable job side conditions. Another plus for conventional castables is their reliable and simple formulation concept and a more secure hardening at low ambient temperatures.

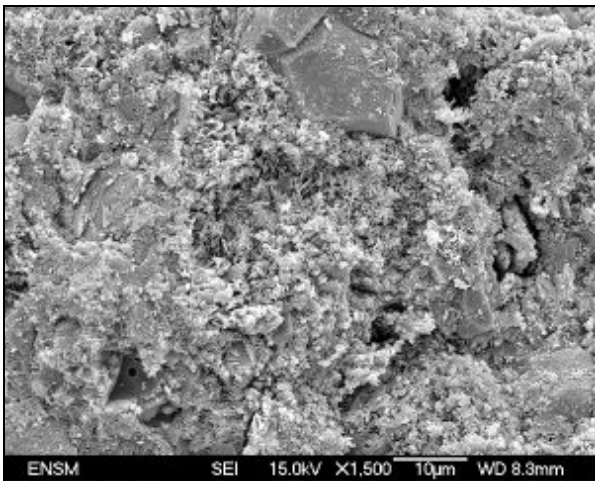


Fig. 1. Microstructure of CC-S80, (15% CAC, 110°C)

REVIEW OF RC TECHNOLOGY

To achieve the reliability of RC, combined with performance characteristics as known from LCC, has been a target since many years [2] and is at the heart of this present investigation. A first step was already accomplished many years ago when the CAC

with a content of 80% Al_2O_3 had been introduced [3]. SECAR[®] 80 as a representative of this class of CAC creates an alumina rich microstructure with a good cohesion between cement hydrates and aggregates and a microporous matrix (Fig. 1). This was the basis for a first significant improvement of RC.

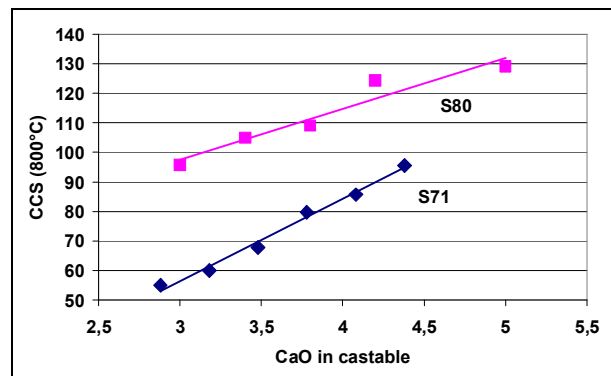


Fig. 2. CCS 800°C as function of CaO content in RC and type of CAC (recipes see Tab. 1)

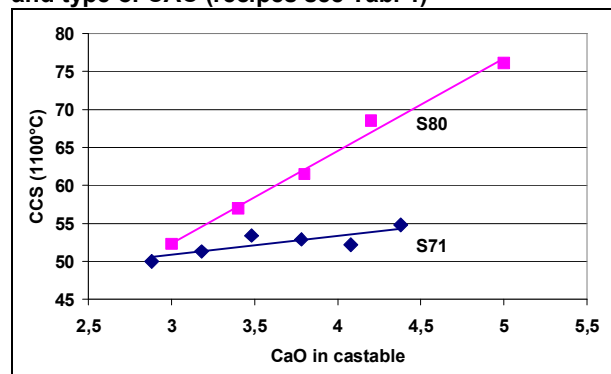


Fig. 3. CCS 1100°C as function of CaO content for CC-S71 and CC-S80 (recipes see Tab. 1)

The strength improvement via the introduction of SECAR[®] 80 can be seen in Fig. 2 and Fig. 3 in comparison to SECAR[®] 71 for different CAC-contents in the RC. At equivalent CaO-content and initial flow, significantly higher strength are achieved with SECAR[®] 80 especially at 800°C but as well at 1100°C when higher amounts of S80 are used in the RC system.

Tab. 1. Regular castable test recipes

	mm	CC S71	CC S80
Tab. Alumina	2-5	32	32
Tab. Alumina	1-2	15	15
Tab. Alumina	0.5-1	10	10
Tab. Alumina	0.2-0,6	13	13-8
Tab. Alumina	0-0.3	10	10-5
Tab. Alumina	0-0.045	5	5
React. Alumina	d50=0.0015	5.4-0.4	0
SECAR 71	4000 cm2/g	9.6-14.6	0
SECAR 80	8000 cm2/g	0	15-25
H2O		7	7-8.2

Two paste compositions (Tab. 2), one based on S71+ reactive alumina and one based on S80, both with equivalent total CaO content, have been chosen for the measurement of the micro porosity via the Hg-intrusion method. After firing at 1100°C the micro pores remain at diameters below 1 µm in case of S80 while with S71 a significant amount of pores were found above 1 µm (Fig. 4, 5). The microstructure modification in the matrix of the CC-S80 at 15% S80 can be seen in Fig. 6. While after drying at 110°C relatively coarse hydrates are visible. They have been re-crystallised in very small anhydrous phases at 800°C and have increased their size along with the pore diameter after firing at 1100°C.

To further improve the RC-system, tests with the latest generation of CAC, SECAR® Plenium (SP) and SECAR Xeniom™ (SX) have been conducted. The CAC properties and test recipes are shown in Tab. 3 and 4.

Tab. 2. Paste composition for micro pore analyses

	mm	P-S71	P-S80
Tab. Alumina	0-0.3	33.33	33.33
Tab. Alumina	0-0.045	16.66	16.66
React. Alumina	d50 = 0.0015	18	
SECAR® 71		32	
SECAR® 80			50
H2O		19	19

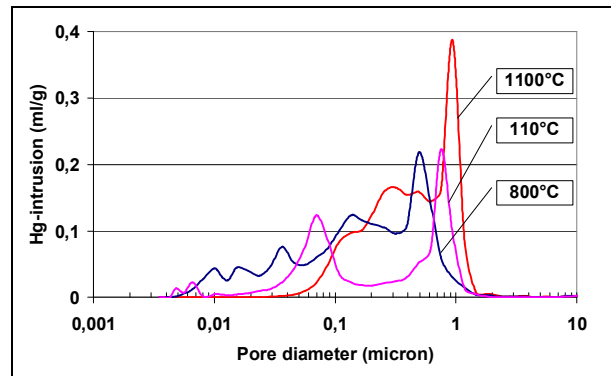


Fig. 4. Micro pore distribution of P-S71

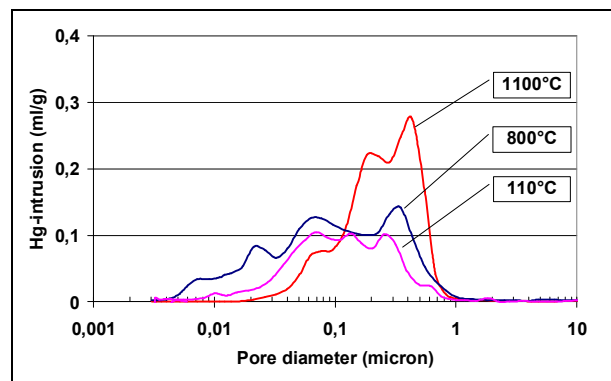


Fig. 5. Micro pore distribution of P-S80

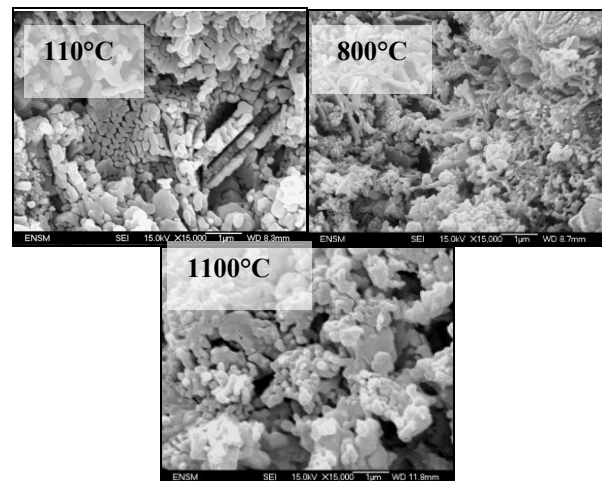


Fig. 6. Microstructure of CC-S80 (15%) after treatment at 110°C, 800°C and 1100°C (magnification 15000x)

2 Test results

The test recipes represent conventional castables of very high purity with a liquidus temperature above 1800°C. At a dosage of 15% CAC, S71 brings 4.4% CaO into the castable. With S80 and SP, the CaO content can be reduced to 2.6% and with SX further down to 2.3%. An initial ASTM vibration flow of 85-95% has been achieved by adjusting the water dosage. Water demand was 8.5% for S71, 7.2% for S80, 6.9% for SX and only 6.4% in case of SP (6.1% with 8% SP). Rheology was in all cases stable during the first 30 minutes. The castable setting has been studied with the ultrasonic method as described in [4]. S80 and SP show a two-step hydration mechanism with SP having a longer open time (Fig. 7). A one-step hydration scheme can be observed for S71 and SX, with a long open time for S71 and a fast reaction for SX. This results after just 6h in a very high flexural strength in case of SX which allows early de-moulding (Fig. 8). After drying at 110°C the compressive strength is outstanding for SP with a 35-50% higher level than for the other cements. This positive trend continuous as well after firing between 800 and 1500°C where the CCS is almost 100% higher compared to S71 and still more than 30% higher compared to S80 for example in the temperature range of 800 to 1100°C (Fig. 9). This is normally the most critical temperature range for RC where cement is already de-hydrated and re-crystallised but strength acquisition through sintering reactions has not fully started yet. Here SP has a clear advantage.

Tab. 3. CAC characteristics

		CAC	
		S71	S80
		Secar [®] 71	Secar [®] 80
CaO	%	29.5	17
Al ₂ O ₃	%	69.7	81
SiO ₂	%	0.4	0.35
Fe ₂ O ₃	%	0.2	0.2
Na ₂ O+K ₂ O	%	<0.5	<0.7
Blaine	cm ² /g	4000	>8000
		CAC	
		SP	SX
		Secar [®] Plenium	Secar Xeniom [™]
CaO	%	17	15
Al ₂ O ₃	%	81	83.5
SiO ₂	%	<0.35	<0.35
Fe ₂ O ₃	%	<0.2	<0.3
Na ₂ O+K ₂ O	%	<0.7	<0.7
Blaine	cm ² /g	>8000	>8000

Tab. 4. RC test recipes with 15 and 8% CAC

	mm	CAC-15	CAC-8
Tab. Alumina	2-5	32	32
Tab. Alumina	1-2	15	15
Tab. Alumina	0.5-1	10	10
Tab. Alumina	0.2-0,6	13	13
Tab. Alumina	0-0.3	10	10
Tab. Alumina	0-0.045	5	5
Calc. Alumina	d50=0.004	0	7
CAC		15	8
PP-Fibre 14µm	6 (length)	+0.1	+0.1

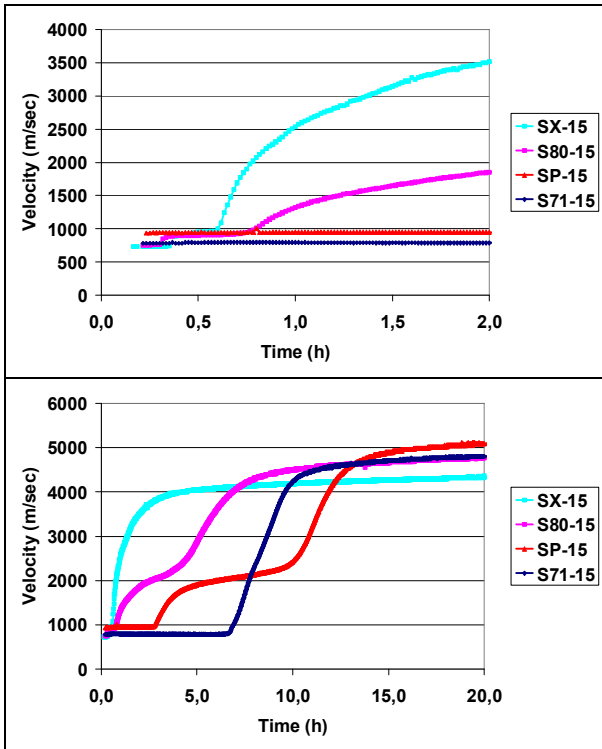


Fig. 7. Ultrasound profile of RC CAC-15 with different calcium aluminates

The impact on porosity achieved with the different CAC can be seen in Fig. 10. The apparent porosity can be reduced by about 4%-points by replacing 15% S71 by 15% SP. While the formulation with 15% S71 creates the typical strength profile of a RC with decreasing CCS along with increasing temperature this trend can be turned around when a dosage of 8% SP is chosen (Fig. 11). In that case, although strength is lower after drying, it starts to increase above 800°C and reaches 50 to 100% higher strength after firing at 1350 and 1500°C respectively. Here the strength evolution is now closer to what is known from microsilica-free low cement castables and indeed with an addition of 8% SP, the CaO content is at 1.4% as in a classical LCC. But in case of RC SP-8 the castable maintains a high formulation simplicity and is made without addition of supplementary filler or deflocculants.

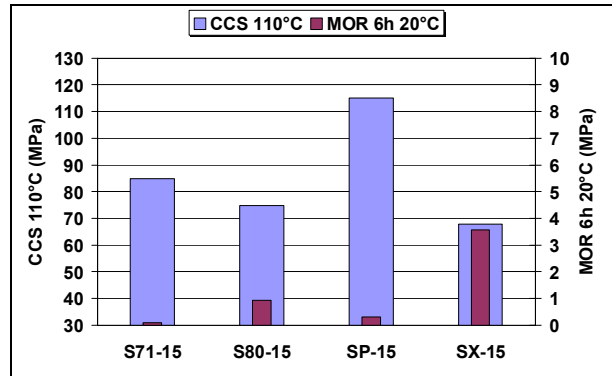


Fig. 8. Green MOR after 6h (20°C) and CCS 110°C

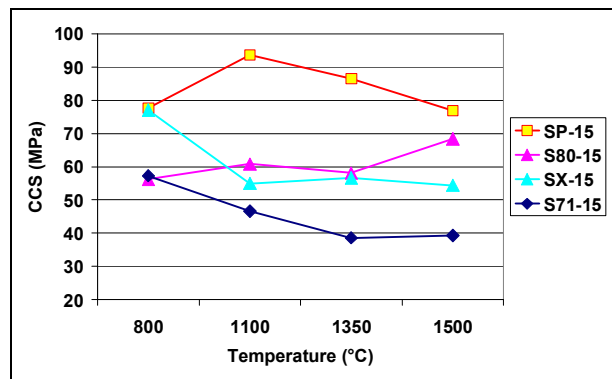


Fig. 9. CCS evolution of RC CAC-15 with different Calcium Aluminates

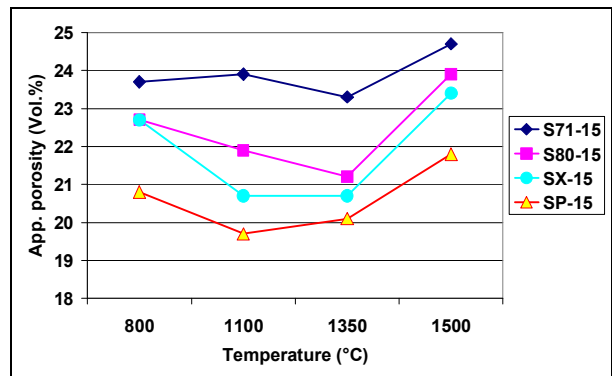


Fig. 10. Apparent porosity of RC CAC-15 with different calcium aluminates

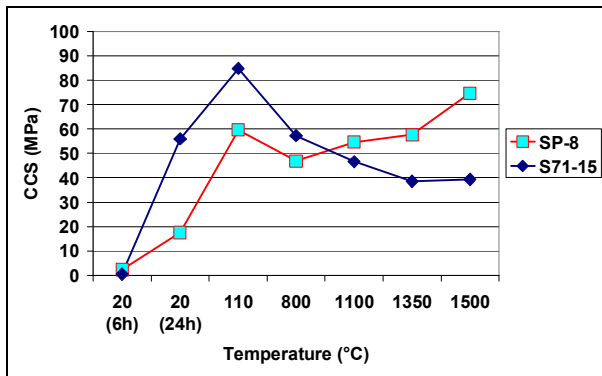


Fig. 11. CCS of RC SP-8 in comparison to RC S71-15

3 Summary and Conclusion

The implementation of the latest CAC-technology into regular castables boosts their performance to a level which was not achievable so far by classical 70% and 80% Al₂O₃-containing CAC. With SECAR Xeniom™ a similar strength level can be achieved as with a SECAR® 80 based RC but at a lower amount of CaO in the castable so that the hot properties are expected to improve further. The fast strength development of SECAR Xeniom™ makes it an ideal choice for efficient precast production. With SECAR® Plenium high strength RC can be easily designed without the need to add filler and deflocculants, although this is a possible route for further improved properties where necessary. A strength increase by 50-100% compared to Secar®71 can be achieved with SP throughout the whole temperature profile from 800 to 1500°C at equivalent amount of binder. Excellent abrasion resistance can be expected in particular in the temperature range of 800 to 1100°C for example in petrochemistry applications. Both, SECAR Xeniom™ and SECAR® Plenium build a microstructure with a low porosity and small pore diameters which make them less sensitive to infiltration of liquid metals and slags. Known already for their high performance in Microsilica-free (SP) and Microsilica-containing LCC's (SX) these state-of-the-art calcium aluminate cements

represent in fact all-round binder from which as well regular castables can profit to a high extent.

4 Acknowledgements

The authors would like to thank J.M. Auvray and V. Guillaumin from Kerneos Research Center for their excellent support during this study.

5 References

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