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PROPERTIES OF A NEW BINDER BASED ON LIME

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Abstract

The purpose of this research is to investigate the physical, chemical and mechanical properties of an eco-friendly binder based on hydrated lime $Ca(OH)_2$ and optimized sugarcane bagasse ash (SCBA). It is a lightweight binder performed with low energy consumption and low CO_2 emission materials. The SCBA was sieved and the physical and chemical effects of removing the coarse particles present in this ash were analyzed. Experimental investigations revealed that sieving procedure improves both finesse and reactivity of the raw SCBA and increases by 30 % the compressive strength of the binder based on SCBA and Ca(OH)₂.

Keywords:

Sugar cane bagasse ash; Ca(OH)₂; Pozzolan; Pozzolanic reactions.

1 INTRODUCTION

Due to the worldwide development an increase in civil engineering construction is expected. In order to scale down the impact of these activities on the environment, mankind lean towards using a less carbon emission technology and a more suitable material in building construction. The use of industrial by-products as an alternative is a good solution to figure out that problem [Payá 2002]. Furthermore, it helps out the industrial wastes managements and valorizations.

The production of Portland cement (PC) involves high energy and raw material consumption [Koteng 2015]. In addition, high CO_2 emission occurs during its fabrication. Nowadays, industrial by-products such as silica fume and fly ash are used as a replacement or substitution of PC [Koteng 2015]. These minerals admixtures allow the production of high strength concrete with an improved rheology, mechanical behavior and durability [Cordeiro 2009].

Sugarcane bagasse ash (SCBA) is another by-product obtained after the calcination of sugarcane bagasse for energy production. SCBA is an available by-product in tropical countries (Brazil, India, Guadeloupe...) [Cordeiro 2009(1)]. SCBA is a material mainly composed with silicon dioxide, aluminum and iron oxide. This ash has a low density and its storage outside induce the pollution of soil, air and water [OCSB 2007]. The pozzolanic reaction in presence of SCBA is obtained from the reaction of its silicon and aluminum amorphous phases with calcium hydroxide (Ca(OH)₂). This reaction forms calcium silicate, calcium aluminate and calcium alumino silicate hydrates [Souza 2012] responsible of the paste hardening. SCBA can be mixed directly with $Ca(OH)_2$ or used with PC and hydraulic lime due to the production of $Ca(OH)_2$ during their hydration.

However, many studies have underlined the use of SCBA as a pozzolanic material but the uncontrolled calcination temperature of bagasse and the contamination with other materials reduce the pozzolanicity of this ash [Martirena Hernández 1998, Morales 2009, Payá 2002]. In order to improve the quality of the SCBA, they have chosen either grinding the SCBA to increase the specific area [Cordeiro 2009(1), Payá 2002, Frías 2011, Rukzon 2012, Rodier 2014] and/or optimising the calcination temperature to increase the reactivity of the ash and reduce the amount of organic material [Morales 2009, Ganesan 2007, Frías 2011, Rodier 2014].

In this study, we will optimise the pozzolanicity of the SCBA with a controlled temperature of calcination and the screening of the granulometry. The SCBA will be used with hydrated lime. The amount of SCBA in PC and SCBA paste is around 30% of the total binder weight [Rukzon 2012]. Adding SCBA to hydrated lime allows the use of around 70% of this ash and contributes to its valorisation [Martirena Hernández 1998]. In addition, compared to PC binder, lime with pozzolanic materials produces a lightweight paste and a more suitable material for the environment (energy consumption and CO_2 emission) [Koteng 2015].

The objectives of the present work are to study (1) the effect of removing the coarse particles (more than 45μ m) present in the SCBA and (2) the influence of calcium hydroxide and SCBA contents on physical, chemical and mechanical properties of the binder. For

this purpose, the SCBA will be previously sifted and characterized.

2 MATERIALS

2.1 Hydrated Lime

The hydrated lime used in this study was a commercial calcium hydroxide with more than 95 % of Ca(OH)₂ content (VETEC / SIGMA-ALDRICH Brazil).

2.2 Bagasse ashes

The sugarcane bagasse was provided by a bio-energy company, which supplies electricity for the surrounding area in Pirassununga (Brazil – SP). The bagasse ash was obtained after 2 steps of calcination of sugarcane bagasse in the laboratory (400 °C for 1 hour + 600 °C for 2 hours). The yields of calcination for sugarcane bagasse at 400 °C and 600 °C, after each process of are shown in *Tab.* **8**.

Tab. 8: Yield of calcination of sugarcane bagasse at 400 °C and 600 °C.

Calcination at 400 °C	Calcination at 600 °C
(%)	(%)
10.8 ± 0.8	4.1 ± 0.2

The calcined bagasse ash was sifted at 45 $\mu m.$ We have noticed 3 kinds of particles:

- The raw bagasse ash obtained after the calcination at 600 °C (SCBA-raw);
- The particles retained in the 45 μm sieve: (SCBA-ø>45μm);
- The ash particles, which have passed through the 45 µm sieve (SCBA-ø<45µm).

During the sieving process some fine particles were blown away by the wind. Besides, a few amount of particles less than 45 μm remained in the SCBA-ø>45 $\mu m.$

2.3 Superplasticizer

The superplasticizer (SPP) used in this study was a free-flowing spray dried powder of a modified polycarboxylic ether (Melflux® 2651 F). It is a high performance superplasticizer for cement based construction materials.

2.4 Binder formulation

The formulations of the binders are shown respectively for the matrix based on SCBA-ø<45 µm and SCBAraw in *Tab.* **9** and *Tab.* **10**. In order to analyse the influence of ashes content in the binder, the mass ratios (SCBA-ø<45 µm/Ca(OH)₂) 1, 1.5, 2.33 and 4 were chosen. The proportions of lime for the SCBAraw pastes were calculated from the amount of SCBAø<45 µm present in the SCBA-raw.

Tab. 9: Formulation of SCBA-ø<45 μm and hydrated lime (CH) binders.

Designation	SCBA-ø<45 µm (g)	CH (g)	Water (g)	SPP (g)
SCBA-ø<45 µm/50-50	50	50	52	2
SCBA-ø<45 µm/60-40	60	40	52	2
SCBA-ø<45 µm/70-30	70	30	52	2
SCBA-ø<45 µm/80-20	80	20	52	2

3 METHODS OF CHARACTERIZATION

3.1 SCBA characterization

Scanning Electron Microscopy (SEM)

The morphology of SCBA particles was investigated using Scanning Electron Microscope - HITACHI TM3000, the acceleration voltage used for the SEM analysis was 15 kV. Elemental analysis was performed using the SEM TM3000 with SwiftED 3000 Energy dispersive X-ray spectrometry (SEM-EDS).

Tab.	10: Formulation of SCBA-raw and hydrated lime
	(CH) binders.

	SCBA-raw (g)				
Designation	SCBA- ø<45 µm	SCBA- ø>45 µm	CH (g)	Water (g)	SPP (g)
SCBA-raw/50-50	24	52	24	23	1,46
SCBA-raw/60-40	26	56	18	22	1,32
SCBA-raw/70-30	28	60	12	22	1,21
SCBA-raw/80-20	30	63	7	21	1,11

Fluorescence X

The chemical composition was determined by X-ray fluorescence analysis (XRF, S8 Tiger, Bruker AXS).

X-Ray diffraction (XRD)

X-ray diffraction of the ashes was performed with an X-ray diffractometer Horiba LA-960 - CuK α radiation, which generated a 40 kV voltage and a current of 30 mA. The range of the scanning angle was 5° to 60° 20 at 3 °/min. The sample was grinded with an agate mortar and sifted with a 45 µm sieve.

Particle size analyzer

Particle size distribution of bagasse ash and lime was performed using a laser diffraction particle size analyzer (SALD-201V, SHIMADZU, Japan).

Blaine permeability and Helium pycnometry

The specific area was determined by a CONTROLAB automatic Blaine air permeability apparatus, and the specific density with a Helium pycnomatic ATC (Thermo Scientific, USA).

Ionic conductivity test

In order to evaluate the pozzolanicity of bagasse ashes, electrical conductivity measurement of lime-SCBA-water suspension was performed according to Luxàn et al. methods [Luxán 1989] improved by Payá et al. [Payá 2001]. The purpose of this test is to find out the electrical conductivity evolution at 40 °C of 250 mL of saturated Ca(OH)₂ solution with 5 g of pozzolan material. The ionic conductivity reduction of the solution is due to the fixation of dissolved Ca(OH)₂ by the pozzolan particles. The effect of the soluble ions in pozzolanic materials on the conductivity value was determined with a mixture of 250 mL of deionized water and 5 g of pozzolan [Payá 2001]. The final subtracted pozzolanic activity (P₀) was obtained after deducing the soluble ions effect (P1) from the saturated lime solution conductivity value (P2). In our study, the lime solution was obtained after the dissolution of Ca(OH)₂ in a deionized water with a concentration of 2 g/L. Afterwards, the over saturated solution was stirred for 20 minutes then sifted in 5 µm paper filter to eliminate the extra Ca(OH)2. This method allows us to prepare the solution in 30 minutes and reduces the problem of carbonation. The conductivity of the lime solution at 40 $^{\circ}$ C was around 11 mS/cm and the pH value about 12. The ionic conductivity of rice husk ash (RHA) composed of more than 95 % of silicon dioxide, was done with the same procedure to analyze the SCBA results.

3.2 SCBA-lime binder characterization

Compressive strength

The compressive tests were measured on cylindrical specimens of 25 mm diameter and 50 mm high using 6 replications (inspired from ASTM C780-14, 2014). The samples were cured in water at around 25 °C and the test was done with an EMIC DL 30000 universal testing machine, a 50 kN cell load, a constant deformation rate of 0.3 mm/min, and a swivel device to enable a uniform approach to the upper side of the samples [Mármol 2016].

Wet bulk density

The wet bulk density was determined according to the ASTM C948-81 standard on the same 6 samples [ASTM C948-81 2016]. The test was done with an analytical balance sensitive to 0.01 g suitable for determining the mass of the specimen in water as well as in air.

X-ray diffraction and thermogravimetry

In order to stop the hydration, the samples were crushed in acetone, diluted in acetone, stirred for 15 minutes, filtered with a 5 μ m paper filter, dried, crushed and then sifted until the particles diameters are less than 45 μ m.

X-ray diffraction analysis was performed using the same equipment as for SCBA (paragraph 3.1).

Thermogravimetric analysis was performed on powder sample using a Simultaneous Thermal Analyzer (STA-6000), under N₂ at 20 mL/min, and heated from 50 °C to 950 °C at 10 °C/min).

4 RESULTS

4.1 SCBA characterization

Morphology observation and particle size distribution

As SCBA-ø<45 µm constitutes 32.0±2.3 % of the raw SCBA, the SEM observation (Fig. 1) was made on SCBA-raw (a).



Fig. 1: SEM observations of (a) SCBA-raw, (b) ashes from the fibers, (c) spongious particles, (d) spherical silica particles, (e) prismatic silica particles.

The SEM images confirm the presence of 4 kinds of particles:

- Calcined fibers particles with a diameter around 4 μm from the bagasse fiber (b);
- Calcined spongious particles with a diameter less than 1 μm (c) and similar to the air-bubbles containing particles detected by Paya et al. [Payá 2002];
- Spherical silica particles with around 8 µm of diameter (d);
- Prismatic silica particles that can reach a diameter of 500 µm (e).

The EDS shows that (b) and (c) are made of silicon, aluminum, iron, potassium, phosphorus, calcium and oxygen. Particles (d) and (e) are mainly composed of silicon dioxide.



Fig. 2: Particle size distribution of the SCBA and the Ca(OH)₂.

The particle size distribution of the ashes and the calcium hydroxide are shown in the Fig. 2. It can be noticed that the lime and the SCBA-ø<45 μ m have a similar particle size distribution. Their means diameters are respectively 8 and 10 μ m. The SCBA-raw have a mean diameter of 86.2 μ m and the manual sieving at 45 μ m allows the separation of: the fine particles of ashes SCBA-ø<45 μ m mainly composed of (b) - (c) and (d) and the coarse ash particles (SCBA-ø>45 μ m) mainly composed of (e).

Chemical composition

The chemical composition of the SCBA-raw and the SCBA-ø<45 µm was determined by X-ray fluorescence (*Tab.* **11**).

Tab.	11: Chemical composition of the SCBA-raw	and
	SCBA-ø<45 μm.	

Flowente	Weight %		
Elements	SCBA-raw	SCBA-ø<45 µm	
SiO ₂	40.07	38.90	
Al ₂ O ₃	7.40	8.27	
Fe ₂ O ₃	10.60	9.42	
CaO	10.10	9.50	
K ₂ O	13.60	13.60	
P ₂ O ₅	4.39	4.47	
MgO	2.95	3.41	
TiO ₂	2.94	2.37	
SO3	3.27	3.37	
Na ₂ O	< 0.001	0.05	
CI	0.33	0.32	
MnO	0.37	0.42	
CuO	0.07	0.05	
ZnO	0.10	0.10	
BaO	0.13	< 0.001	
Loss of ignition	2.96	5 69	

The chemical composition of SCBA-raw and SCBA- \emptyset <45 µm is almost the same. These bagasse ashes are mainly composed of silicon dioxide, aluminum oxide and iron oxide. The main difference lies in the coarse crystalline phases of quartz in the SCBA-raw. We can also highlight the high amount of salt (K₂O and P₂O₅) in these ashes.

The XRD spectra confirm the presence of crystalline phase of silicon dioxide quartz (Q) especially in the SCBA-raw and the SCBA- ϕ >45 µm (Fig. 3 and Fig. 4) On the other hand the amorphous phase, represented by the large signal from 15° to 40° (20), is responsible of the reactivity of the bagasse ashes (Fig. 4) [Cordeiro 2009(1)].

This amorphous phase reacts with calcium hydroxide $(Ca(OH)_2)$ to form calcium silicate hydrate (C-S-H), calcium aluminate hydrate (C_4AH_{13}) and calcium alumino-silicate hydrate $(C_2ASH_8 \text{ and } C_3ASH_{13})$ [Souza 2012]. Ubbríaco and Tasselli [Ubbríaco 1998] in their study also stated the formation of calcium monocarboaluminate hydrate $(C_3A.CaCO_3.11H_20)$ in SCBA-lime paste.

The SCBA-ø<45 μ m is more amorphous than the SCBA-raw because the SCBA-ø>45 μ m removed with the sieving process are mainly crystalline phases.



- D2 : Diffractogram of SCBA-Ø>45 µm
- Fig. 3: XRD of SCBA-raw, SCBA-ø<45 µm and SCBA-

ø>45 μm.



D2 : Diffractogram of SCBA-ø>45µm

D3 : Diffractogram of SCBA-ø<45µm

Fig. 4: XRD of SCBA: detail of the amorphous phases.

The XRD of SCBA-ø<45 µm (Fig. 5) shows that apart from quartz, crystalline phases of anhydrite, leucite, calcium oxide and calcite are present in the SCBA.

The specific area of SCBA-ø<45 μm is almost the double of SCBA-raw, due to the coarse particles

exclusion. Compared to Cordeiro [Cordeiro 2009(1)] and Rukson [Rukzon 2012] samples, SCBA-ø<45 μ m is twice higher than literature results for grinded SCBA. Fine particles can reduce the porosity of the final paste but it will increase the water demand of the binder [Ganesan 2007].

Specific area and specific density

The specific density and the specific area of the SCBA-raw, SCBA-ø<45 μ m and the calcium hydroxide are summarized in *Tab.* **12**.

Tab. 12: Helium pycnometer density and specific area
of the SCBA-raw, SCBA-ø<45 µm and the calcium
hydroxide (Ca(OH)2).

Designation	Helium pycnometer density (kg/m ³)	Specific area (m²/kg)	Sources
SCBA-raw	2 580 ± 13	994 ± 4	Present study
SCBA-ø<45 µm	2 345 ± 30	2 520 ± 2	Present study
Ca(OH) ₂	2 161 ± 19	1 007 ± 1	Present study
SCBA 2	2 530	1 197	[Cordeiro 2009(1)]
SCBA 3	2 240	1 250	[Rukzon 2012]

Pozzolanic activity by ionic conductivity test

The results of the pozzolanic activity are shown in the Fig. 6 and Fig. 7.



Fig. 6: Pozzolanic activity of SCBA by ionic conductivity test.

After 50h in the deionized water solution, SCBA-ø<45 µm and SCBA-raw reach respectively 4 mS/cm and 1.5 mS/cm (P₁ curves in the Fig. 6). This difference is due to the higher amount of soluble salts in SCBA-ø<45µm (Na₂O and P₂O₅) than in SCBA-raw and the absence of coarse and inert particles of quartz.



Fig. 7: Pozzolanic activity of SCBA by ionic conductivity test, P_0 curves { $(P_0)=(P_2)-(P_1)$ }.



Fig. 5: XRD of SCBA-ø<45 μm.

SCBA-ø<45 μ m is more reactive than SCBA-raw because it has a lower ionic conductivity at the end of the test. In both SCBA P₀ final subtracted curves (Fig. 7), there is a first zone from 0 to 6 hours, then in the second zone, the ionic conductivity drops.



Fig. 8: RHA with different amount of calcium oxide.

This is probably the effect of the calcium oxide (CaO) present in the SCBA. In order to confirm this fact, the pozzolanic activity by ionic conductivity test of rice husk ash composed of more than 95 % of silica (RHA) with different amount of CaO (0% - 2% - 5% and 10% of mass) was measured and similar behavior was observed when the mixture contains a higher amount of CaO (Fig. 8).

4.2 SCBA-lime binder characterization

Compressive tests

The results of compressive strength tests are shown in the Fig. 9 for SCBA-ø<45 μ m and Ca(OH)₂ pastes and Fig. 10 for SCBA-raw and Ca(OH)₂ pastes. These tests show that a higher mechanical performance can be reach for SCBA-ø<45 μ m-lime binder. A maximum modulus of rupture (MOR) in compression of 39 MPa was reached with the SCBA-ø<45 μ m at 56 days. For the SCBA-raw a maximum of 30.5 MPa was reached with 18 % of lime at 56 days. According to the MOR of the paste, the optimum proportions of binder are: 60% of SCBA-ø<45 μ m and 40% of Ca(OH)₂ and 82% of SCBA-raw and 18% of Ca(OH)₂.

The result of the compressive tests of SCBA-lime binder, cured in water at room temperature, is higher than the value found for pozzolan-lime paste in the literature:

- Martirena Hernández et al. have done pastes with 70 % of SCBA, 30 % of Ca(OH)₂ and 0.5 of water to binder ratio. They have obtained a maximal stress of 7.7 MPa at 28 days [Martirena Hernández 1998].
- Ratiarisoa et al. have found a maximal stress of 18.8 MPa (28 days) with a mixture of 70 % metakaolin and 30 % Ca(OH)₂, and a water to binder ratio of 0.55 [Ratiarisoa 2016],
- Koteng and Chen have reached a maximal stress of 21 MPa (28 days) for 70 % of fly ash and 30 % of Ca(OH)₂ [Koteng 2015].



Fig. 9: Compressive strength of SCBA-ø<45 μm-lime binder.



Fig. 10: Compressive strength of SCBA-raw-lime binder.

This mechanical behavior is probably due to the low water binder ratio of the paste. For the SCBA-raw, the water to binder ratio of 0.23 is reached because of the non-grounded bagasse ash.

In order to show the effect of grinding the SCBA, particles retained in the 45 μ m sieve was crushed manually (SCBA-a>45 μ m). We observe that grinding

SCBA pulverizes the coarse crystalline particles (a) and forms a fine inert particle (b) (Fig. 11). This procedure increases the specific area of the SCBA and brings to a higher water demand without increasing the reactivity of the ashes. Maybe the ashes obtained with this method will be less reactive than SCBA obtained after a sieving without a grinding process (c).



Fig. 11: Observation of SCBA-raw, SCBA after grinding and SCBA after sieving particles.

Furthermore, the total water to binder ratio (0.52) of SCBA-ø<45 μ m is around 2.25 times higher than SCBA-raw paste (0.23), this extra water didn't induce a decrease of compressive strength due to the finesse, the reactivity and the absence of coarse inert particles in the SCBA-ø<45 μ m ashes.

The second reason of this mechanical behavior is the presence of salts in the initial SCBA as using salts in a pozzolan-lime binder increases the mechanical properties of the paste [Shi 1993, Allahverdi 2006, Saldanha 2016].

The wet bulk density of SCBA-ø<45 μ m-lime paste is around 1 700 kg/m³ and 2 000 kg/m³ for SCBA-rawlime one (*Tab.* **13**). Samples with SCBA-raw present higher density than the specimens with SCBA-ø<45 μ m because of the lower water demand and the presence of dense quartz particles.

Tab.	13: Wet bulk densities of SCBA with different
	amount of Ca(OH)₂.

Designation	Wet bulk density (kg/m ³)
SCBA-ø<45 µm/50-50	1 659 ±10
SCBA-ø<45 µm/60-40	1 680 ±16
SCBA-ø<45 µm/70-30	1 676 ±13
SCBA-ø<45 µm/80-20	1 653 ±9
SCBA-raw/50-50	1 906 ±5
SCBA-raw/60-40	1 973 ±11
SCBA-raw/70-30	1 977 ±8
SCBA-raw/80-20	2 009 ±9

Chemical analysis of hydration products

The chemical compositions of SCBA- ϕ <45 µm-lime binder were analyzed after 28 days thanks to XRD spectra (Fig. 12) and DTG spectra (Fig. 13). Thermogravimetric analysis was performed with these pastes before (Fig. 14), and after hydration (Fig. 15), at 7 days, to follow hydrates formation.

The following notation is used to identify the samples with different amount of SCBA-ø<45 μ m and lime: SCBA-P - Xd with P% of SCBA-ø<45 μ m + (100-P)% of Ca(OH)₂ at 'X' days of curing.

The XRD spectrum of SCBA- ϕ <45 µm-lime binder (Fig. 12) shows a large signal from the range of 15° to 40° which is attributed to the formation of amorphous phases of calcium silicate and calcium alumino silicate hydrates.



Fig. 13: DTG curves of SCBA-P-28d binders after 28 days of hydration.

The diffractogram confirms the presence of calcium monocarboaluminate (Mc) and calcium hemicarboaluminate (Hc) hydrates as hydration products. The presence of sulphate ions in the initial SCBA brought to the formation of ettringite (E) during the hydration. This ettringite formed at room temperature increased the mechanical property of the paste [Dermatas 2003, Žemlička 2015]. At 28 days, Ca(OH)₂ is totally consumed in SCBA-80-28d and in SCBA-70-28d but still present, in relative proportions of input materials, in the two other formulations.

The Fig. 14 shows the DTG spectra of SCBA-P-Xd binders before hydration:

- at around 100 °C, a peak assigned to the loss of a small amount of water [Souza 2012];
- at around 420 °C a large peak attributed to the dehydroxylation of portlandite [Souza 2012];
- at around 600 °C, peaks attributed to the decomposition of calcium carbonate [Souza 2012].

After hydration (Fig. 13 and Fig. 15):

- at around 100 °C, a peak attributed to the dehydration of calcium silicate hydrates [Ratiarisoa 2016, Magniont 2010];
- at around 150 °C, a peak attributed to the dehydration of ettringite [Fraire-Luna 2006];
- at around 220 °C, peaks attributed to the dehydration of calcium monocarboaluminate and calcium hemicarboaluminate hydrates [Ratiarisoa 2016, Magniont 2010];
- at around 330 °C, a peak attributed to the dehydration of hydrogarnet [Magniont 2010].
- at around 420 °C, a peak attributed to the dehydroxylation of portlandite, its quantity depends on the initial amount of the component and the age of curing [Souza 2012];
- at around 700 °C, peaks attributed to the decomposition of calcium carbonate [Souza 2012].



Fig. 12: XRD spectrum of SCBA-P-28d binder at 28days.

At 7 days of hydration (Fig. 15 and Tab. 7), $Ca(OH)_2$ is consumed for SCBA-70-7d and SCBA-80-7d but still present in the two other samples.







Fig. 15: DTG curves of SCBA-P-7d binders at 7 days of hydration.

Apart from that, we can deduce that SCBA-70-7d is the one with the highest amount of hydrates followed by SCBA-60-7d and almost the same quantity in the SCBA-50-7d and SCBA-80-7d (based on of the hydrates peaks areas from 50 °C to 400 °C).

Tab. 14: Remaining amount of lime (weight %) at 0, 7 and 28 days of hydration.

Designation	0 day	7 days	28 days
SCBA-80-Xd	100	0	0
SCBA-70-Xd	100	0	0
SCBA-60-Xd	100	11	7
SCBA-50-Xd	100	28	19

At 28 days of hydration (Fig. 13 and Tab. 7), $Ca(OH)_2$ is consumed for SCBA-70-28d and SCBA-80-28d but still present in the two other samples. The sample SCBA-80-28d presents the lowest amount of hydrates, there are not enough calcium ions and the pozzolanic reaction is over. On the other hand, there is an excess of $Ca(OH)_2$ in SCBA-50-28d compared to the proportion of the ashes. These are the reasons why SCBA-50-28d and SCBA-80-28d have a lower mechanical property than SCBA-60-28d and SCBA-70-28d pastes.

5 SUMMARY

Removing the coarse particles present in the SCBA increases the specific area and the reactivity of the ashes. Despite the fact that the 45 μ m sifted SCBA has a high water demand, when it is mixed with Ca(OH)₂ the SCBA-Ca(OH)₂ paste reaches 39 MPa, which is 30 % higher than the performance of the binder made with raw SCBA. This is due to the higher reactivity of the SCBA-ø<45 μ m-lime binder. During the hydration of SCBA-lime binder, there are C-S-H, calcium monocarboaluminate and calcium hemicarboaluminate hydrates and also hydrogarnet formations.

Removing by sieving coarse inert particles of SCBA produces a good pozzolanic material for pozzolan-lime paste. It increases both reactivity and finesse of the ashes.

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