7th International Masonry Conference 2006

IMPROVEMENT OF ENGINEERING PROPERTIES OF FIRED CLAY BRICKS THROUGH THE ADDITION OF CALCITE

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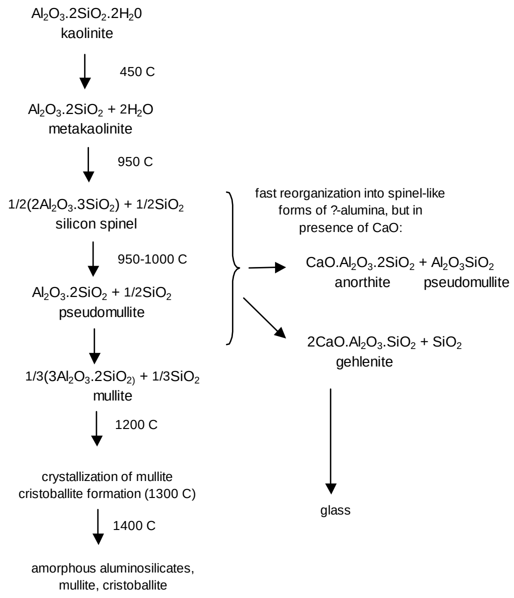
AIM OF THE WORK

To lower the firing temprature as a means to redce energy consumption in fired clay bricks production

To increase compresive strength of the bricks in order to improve mechanical properties and manufacture lighter bricks (thinner walls)

CALCITE AS FLUXING AGENT

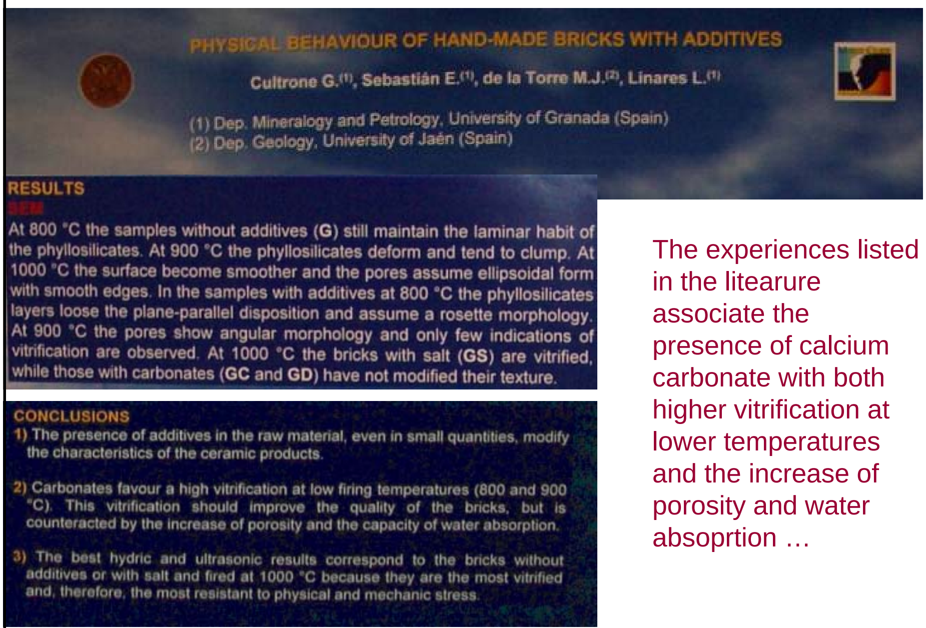


MECHANISM OF ACTION

The fluxing action of calcite on clay minerals is described in the paper presented by Mayoral et al at "Thermochimica Acta"[1]. The paper is based on the study of the mechanisms of decomposition of kaolinite and the ternary system CaO.Al2O3.2SiO2. The research was conducted on fly ash resulting from coal combustion, whose chemical composition is very similar to clay minerals, mainly aimed at studying the influence of calcite and sintering time over the reactions of aluminosilicates in solid state.

[1] M.C Mayoral et al: Aluminosilicates transformations in combustión followed by DSC", Thermochimica Acta 373 (2001), pp 173-180

PREVIOUS EXPERIENCES



The experiences listed in the litearure associate the presence of calcium carbonate with both higher vitrification at lower temperatures and the increase of porosity and water absoprtion …

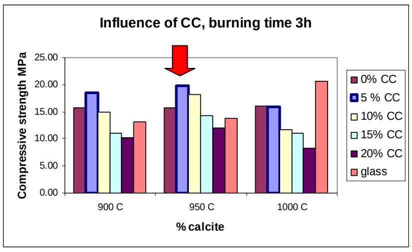
SPECIMEN PREPARATION

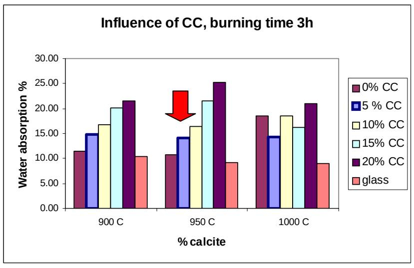
Cylinders with 3.5 mm diameter were cast in molds; Moulding pressure was 7 MPa. The cylinders were dried for 3-5 days and then fired in an electric oven. Firing was done in two stages: a) removing combined water up to 500 C, and b) Elevated temperature firing. Real bricks were also cast and fired in the same conditions

Testing procedure

-Compressive strength
-Water absorption
-Density
-Shrinkage
-Dimension changes
-Twisting
--Microstructural analysis

EXPERIMENTAL WORK: CYLINDERS





FIRST SET OF TESTS

Proportions admixture/clay: 0:100, 5/95, 10/90, 15/85, and 20/80

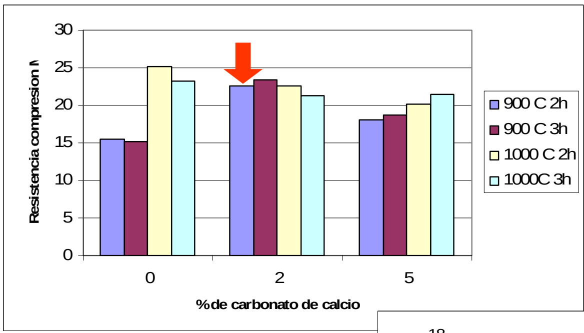
Burning time: 3 h

Burning temperature: 900 C, 950 C, 1000 C

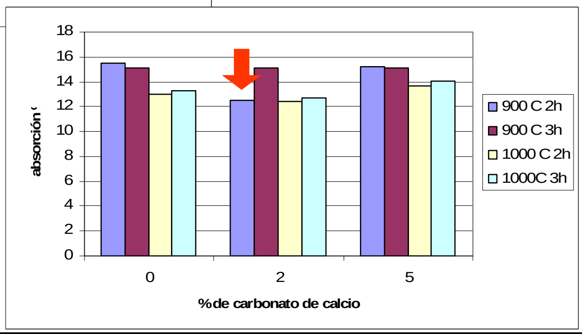
These tests showed: (a) That calcite appears to modify the mineralogical properties of the bricks, (b) The lower the amount of calcite, the better the impact...

We decided to lower the amount of calcite

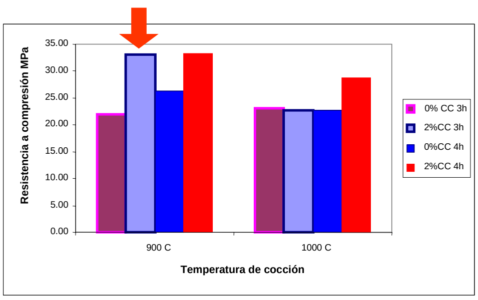
EXPERIMENTAL WORK: CYLINDERS

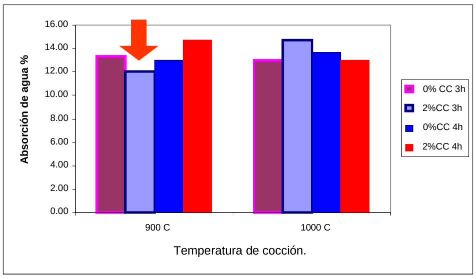


900 °C / 1000 °C were chosen as the most relevant temperatures. The best results were accomplished in bricks fired at 900 C with 2% calcium carbonate. Water absorption was improved. Firing temperature does not seem to influence in the range evaluated (2-3 hours)



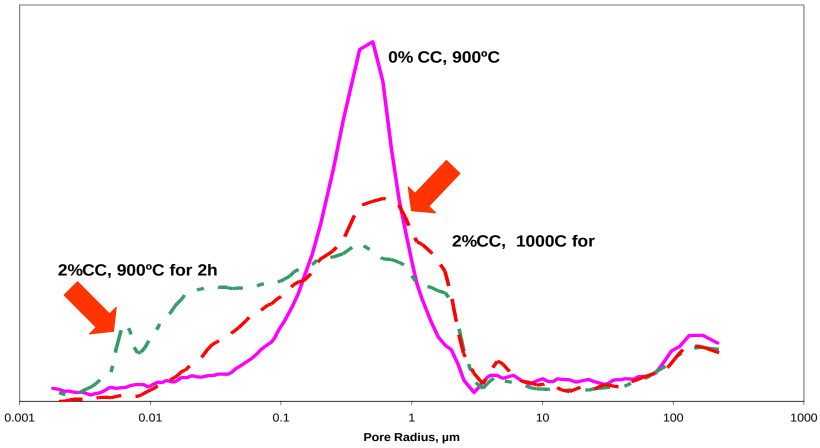
EXPERIMENTAL WORK: REAL BRICKS





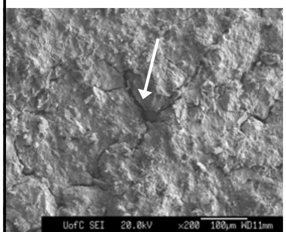
The experimental results obtained in cylinders were replicated in real bricks. The bricks fired at 900 C attained a higher compressive strength and a lower water absorption. No influence of firing temperature

MICROSTRUCTURAL ANALYSIS: MIP

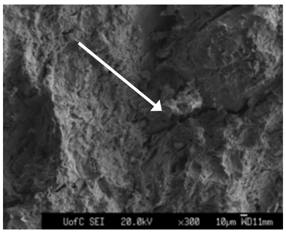


MIP tests showed no major differences in porosity between all the samples tested. Smaller pores (0.05-0.08) formed again in samples made with calcium carbonate admixture.

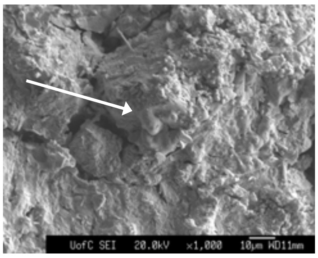
MICROSTRUCTURAL ANALYSIS: MIP



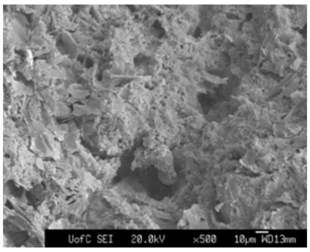
In sample M3 (1000 C, 2% CC), mayor cracks were observed, probably caused by the transition from CaO to $Ca(OH)_2$



Similar cracks were observed at sample M6 (900 C, 5% CC), also some stretched pores, as described in the literature*



SEM picture of sample M3 shows evident signs of glass melting

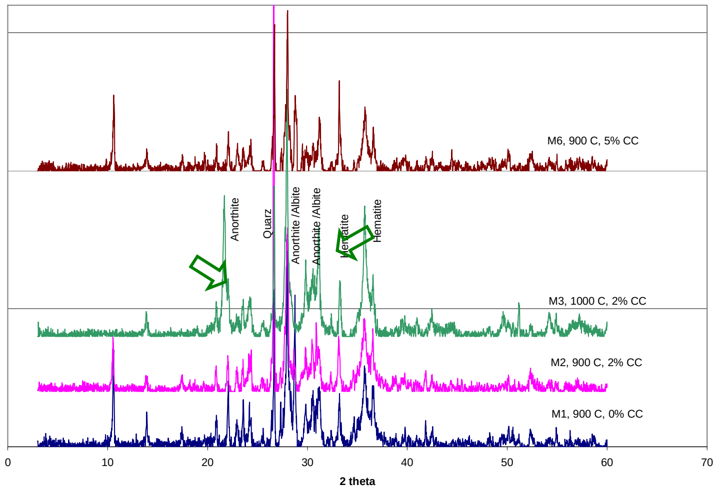


SEM picture of sample M2 shows typical phylosilicates structures densely organized

* Cultrone G. et al, Behaviour of brick samples in aggressive environments. Water, air and soil pollution 119: 191-207, 2000

Samp. ID	Burning temp.	% of C. Carbon.	Burning time
M-1 (bricks made in Cuba)	900 C	0	2h
M-2(bricks made in Cuba)	900 C	2%	2h
M-3(bricks made in Cuba)	1000 C	2%	2h
M-4(bricks made in Cuba)	900 C	0%	3h
M-5(bricks made in Cuba)	900 C	2%	3h
M-6(bricks made in Cuba)	900 C	5%	3h
M-7(FA bricks made in Canada)	900 C		

MINERALOGICAL TRANSFORMATIONS: XRD



Anorthite only appears in specimens made with calcium carbonate and fired at 1000 C.

DURABILITY TESTING

ID	% clayi	% cc	Temp	T (h)
MP1	100	0	900 C	3h
D1(M2)	95	5	900 C	3h
MP2	100	0	900 C	4h
D2(M6)	95	5	900 C	4h
MP3	100	0	1000 C	3h
D3(M4)	95	5	1000 C	3h
MP4	100	0	1000 C	4h
D4(M8)	95	5	1000 C	4h
MP5	100	0	900 C	3h
D5(M3-1)	95	2	900 C	3h
MP6	100	0	900 C	4h
D6(M3-2)	95	2	900 C	4h
MP7	100	0	1000 C	3h
D7(M3-3)	95	2	1000 C	3h
MP8	100	0	1000 C	4h
D8(M3-4)	95	2	1000 C	4h

These tests could be conclusive for the final application of the results in practice

Testing procedure

Wet/Dry cycles: (24 hours) in three phases: immersion in water for 16 hours at room temperature (20 C), forced dessication in an oven at 100 C for 6 hours and cooling at room temperature (20 C) for 2 hours.

Crystallization: (24 hours) in three phases: immersion in se NaSO4 x 10H2O (14%) (20ºC) for 4 hours, oven drying at 100 C for 16 hours, and cooling at room temperature (20 C) for 4 hours.

DURABILITY TESTING: WET & DRY CYCLES

T: 900 C, 3 h burning, control series (right) and sample made wit 5% calcium carbonate

T: 900 C, 4 h burning, control series (right) and sample made wit 5% calcium carbonate

T: 1000 C, 3 h burning, control series (right) and sample made wit 5% calcium carbonate

The **wet-dry cycles** did not give significant differences between the control series and the bricks manufactured with different amounts of calcium carbonate

DURABILITY TESTING: SALT CRYSTALLIZATION

T: 900 C, 3 h burning, control series (right) and sample made wit 5% calcium carbonate

T: 900 C, 4 h burning, control series (right) and sample made wit 5% calcium carbonate

T: 1000 C, 4 h burning, control series (right) and sample made wit 5% calcium carbonate

The **crystallization tests** did also not give significant differences between the control series and the bricks manufactured with different amounts of calcium carbonate

PRACTICAL APPLICATIONS: BRICK YARD

The trials were done in a typical brick yard in Cuba…

PRACTICAL APPLICATIONS: BRICK YARD

	Compressive strength MPa	Firing time	Firewood savings kg
Without calcium carbonate	14.6	10 h	-
With calcium carbonate	17.0	5 h	3200

The trials showed that there is a tremendous potential to optimize the production of bricks in the developing world…

PRACTICAL APPLICATIONS: INDUSTRY

1

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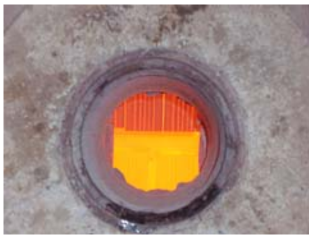

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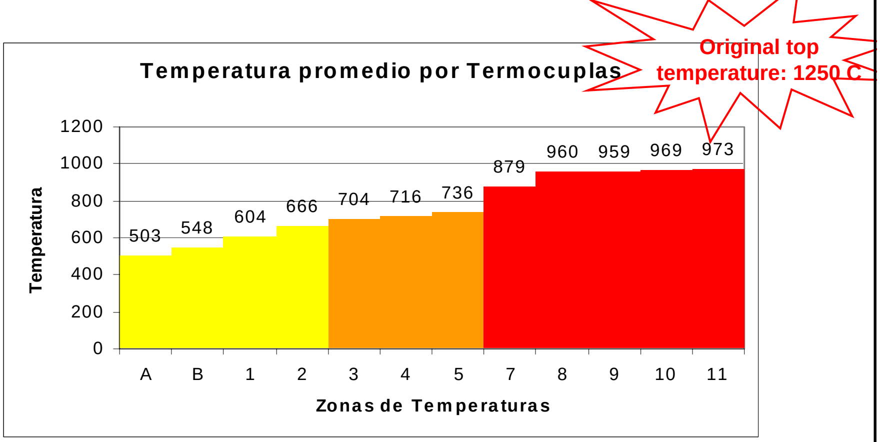
4

We decided to prove this idea further in the modern brick industry…

PRACTICAL APPLICATIONS: INDUSTRY



Cost difference	Fuel saved per hour of operation	Compressive strength sample with admixture	Compressive strength sample without admixture
18%	270 liters/h	2.6 MPa.	2.0 MPa.

CONCLUDING REMARKS

The addition of calcium carbonate (under 5%) to the clay used to manufacture fired clay bricks increases their compressive strength in the range of 30-50% when the bricks are fired at 900ºC.

Adding CC brings about an increase of the amount of small pores (pores having radius under 1 µm) in all bricks where CC is added. These pores result from the formation of CaO, and the microcracks produced during the expansion caused by the hydration of CaO.

The main new phase formed as a result of firing is anorthite, which is a component in bricks fired at 1000ºC.

The durability tests performed on real bricks made with CC proportion less than 5% appear to indicate that adding CC does not contribute to weakening of the brick matrix during exposure to an aggressive environment.

The idea was implemented at full scale production with outstanding results