INFLUENCE OF CORK POWDER GRAINSIZE IN THERMAL AND MECHANICAL PROPERTIES OF CORK-NHL MORTARS

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Abstract

Cork is a unique material, characterized by small closed cell structures, high insulating properties, very low density, high fire resistance and a very good durability after simple thermal treatment. The main use of cork in the production of stopper and insulating panels obtained with cork grains and a polymeric resin. Usually cork grains used in panel production have a grainsize around 1-2 mm. In this work cork grains have been used as aggregates for natural hydraulic lime mortars by reducing grainsize distribution.

Cork grainsize has been reduced by means of a knife mill and divided in three different distributions, i.e. 1, 0.5 and 0.25mm. Mortars have been prepared according to NHL to cork to natural sand volume ratio equal to 2:3:2.

Three point bending and compression tests showed that reducing cork grainsize leads to a slight increase in mechanical performance. On the other hand thermal conductivity showed to be independent from cork grainsize.

Scanning electron microscope investigation was also performed to better understand these results.

Keywords:
Cork, Sustainable mortar

1 INTRODUCTION

Most of the residential buildings in Italy were built between 1946 and 1961, immediately after the World War II, as a consequence of outdated design, 30% of buildings offer a poor energy efficiency [ISTAT 2014]. Moreover even mostly buildings built up to the early nineties have inadequate thermal effectiveness as poor materials have been often used and energy regulation wasn't applied. As a consequence of this situation almost 40% of buildings has the poorest energy certification [ENEA, 2012] according to Italian standards.

In such a poor condition for residential architecture the development of insulating materials to be applied as plasters and renders in existing buildings is a crucial application for energy saving politics [Adityia et al 2017, Al-Homoud, 2005].

The use of insulating plasters and renders is one of the most common strategy to increase the thermal properties of buildings. In insulating plasters several materials are used to reduce thermal conductivity of the mortars such as perlite, silica spheres etc. Cork is even used for this purpose as it is a natural high insulating material. Aim of this work is to study the influence of cork grainsize for the formulation of an insulating mortar to be used as plaster.

Cork is a natural, renewable, sustainable, biologically stable, insulating, with low Poisson ratio, soundproofing, slow burning material [Silva, 2005] and can be used to improve thermal performance of Natural Hydraulic Lime mortars. Moreover Cork has a high coefficient of friction, resilience, high energy absorption, near-zero Poisson coefficient, slow burn rate and shock absorption capacity [Schiavoni et al, 2016].

2 MATERIALS AND METHODS

Cork used in this work is supplied by *Sifar Srl*, a cork based products producer in east Sicily. During stopper production, a large amount of cork is not used because it is unsuitable or is discarded during production. This material is granulated and selled for other purposes.

Starting grainsize of cork was around 3mm, the common grainsize commercially available for production of cork panel and composites. As the aim of this work is to study the influence of grainsize in a mortar it was reduced to three maximum grainsize: coarse 1, medium 0.5 and fine 0.25mm, figure 2, by means of a knife mill Retsch SM100 operating at 1500rpm.

The cork grainsizes have been chosen according to observations of cork structures. As showed in figure 1 cork cells have an average size around 0,02 mm so that the minimum cork grainsize should guarantee the presence of a good number of unaltered cork cells in every grain.

Beside cork, a natural river silica sand was used to prepare mortars in order to increase its mechanical properties. River sand used in this work has a maximum grainsize equal to 3mm. Chosen binder is a 3.5 Natural Hydraulic Lime, Cepro I/60 classified according to European Standards [UNI EN 459-1]. Mixing of mortars' components have been made with demineralized water in a 0,5 weight ratio with respect to binder.

Tab. 1: Mortars' composition by volume.

Mortar	NHL	River sand	Cork 0.25mm	Cork 0.5mm	Cork 1mm
A	1	1	1.5		
B	1	1	0.75	0.75	
C	1	1		1.5	
D	1	1			1.5

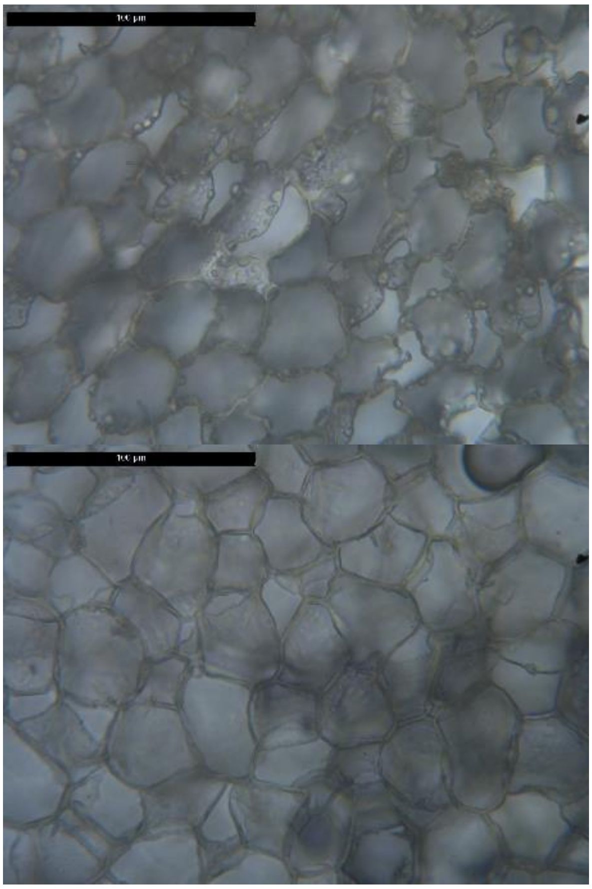

Fig. 1: Transverse, up, and tangential, down, section of cork observed with a transmitted light microscope.

Preliminary mixing tests have been performed to choose the proper binder to aggregate ratio. Four samples have been prepared with different proportion between binder and aggregate and between cork and river sand, see figure 2. According to the observation of these preliminary tests a volume binder to aggregate ratio equal to 1:2.5 was chosen, where aggregate consists of the 1.5 parts of cork and 1 part of river sand, sample B in lower figure 2.

Four different cork grainsizes were used and mortars were labeled with a letter indicating cork grainsize as in table 1. Water to binder weight ratio was kept constant and equal to 0.5.

Fig. 2: Up: Cork grainsize from left: 1, 0.5 e 0.25 mm. Down: Preliminary samples for mixing grainsize.

Three types of samples have been prepared in order to perform compression, three point bending and thermal conductivity tests. For every mortars' type, six samples have been prepared for both mechanical tests and 2 samples for thermal conductivity measurements.

Compression test samples consisted of cubes with 25mm edges, three-point bending samples were rectangular prisms with edges 80x30x25mm, and finally thermal conductivity specimens consisted of rectangular panels with 160x140x40mm edges.

Samples for mechanical characterization have been prepared using silicon rubber molds, see figure 3, while thermal conductivity samples have been prepared in steel molds. Mortars' setting occurred within the molds for four days and hardening took place in a box kept at 40°C and high relative humidity by the presence of demineralized water for 90 days.

Mechanical characterization was performed by means of a Zwick/Roell Z005 Universal Testing Machine, equipped with a 5KN load cell. Compression test has been performed at a constant speed of 0.2mm/min and a preload equal to 3N, in order to break the samples in a time between 1 and 2 minutes. Three-point bending test was performed at a constant speed of 0.1mm/min and a preload equal to 3N with a 54mm span.

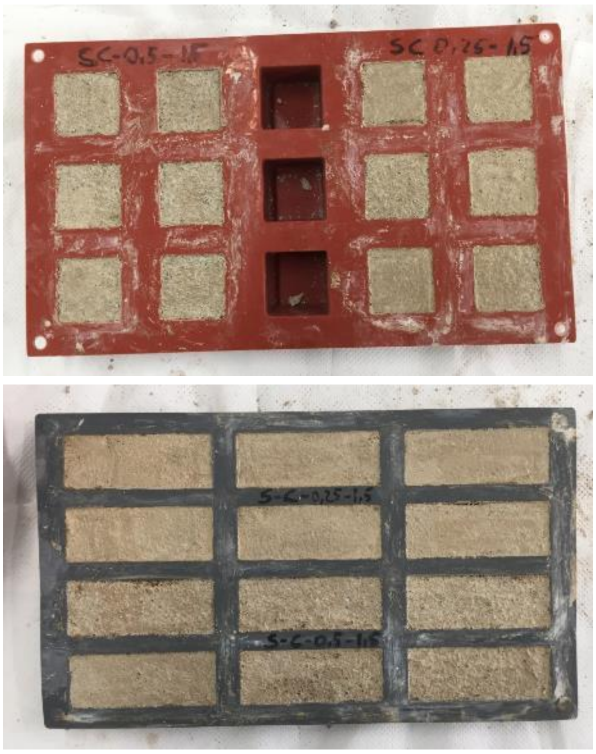

Fig. 3: Silicone rubber molds for compression, top, and three-point bending, bottom.

Fig. 4: Samples for thermal conductivity measurement, before and after insertion on guard ring.

Thermal conductivity measurements have been performed on a LaserComp FOX314 heat flow meter according to ASTM C518 e ISO 8301 standard. Samples surfaces have been polished prior every measurements, as shown in figure 4.

Scanning electron microscopy has been performed by means of a FEI Quanta 600, Environmental Scanning Microscope, equipped with a Field Emission Generator electron source, operating in low vacuum mode, at 0,5mbar of water vapour pressure in order to avoid gilding of the samples.

3 EXPERIMENTAL RESULTS

The samples have been tested in order to evaluate the influence of cork grainsize on mechanical and thermal properties of mortars.

3.1 Three point bending

Three-point bending have been performed on 6 sample for every mortar type. Results from such test are resumed in figure 5.

It can be easily noted that flexural strength is significantly higher only for A samples, the mortars obtained with lower cork grainsize, no significative difference can be noted with the other grainsizes.

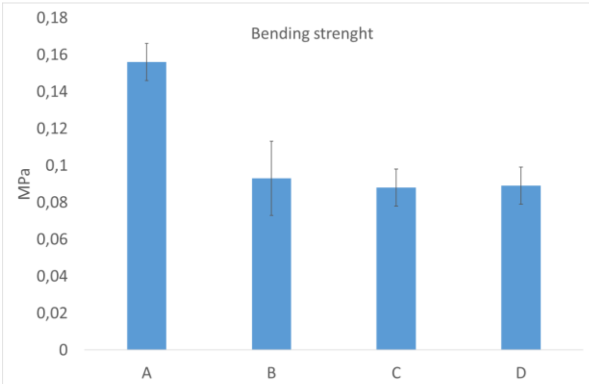

Fig. 5: Three-point bending results, cork grainsize increases from A to D.

3.2 Compression test

Compression tests have been performed on six samples for each formulation. The specimens were measured with a digital centesimal caliper before the test in order to achieve compression tension.

Results are shown in figure 6. It can be noted that compression strength slightly decrease with increasing cork grainsize. This is probably due to the fact that larger cork grains can be compressed more than small ones. Moreover larger cork grains induce a lower workability of the fresh mortar leading to a poorer component distribution within the mortar, as clearly shown by the measurement of apparent density that decreases with increasing cork grainsize.

Another interesting result is that compression failure occurs always at high deformation with large longitudinal cracks in the sample, as shown in figure 7.

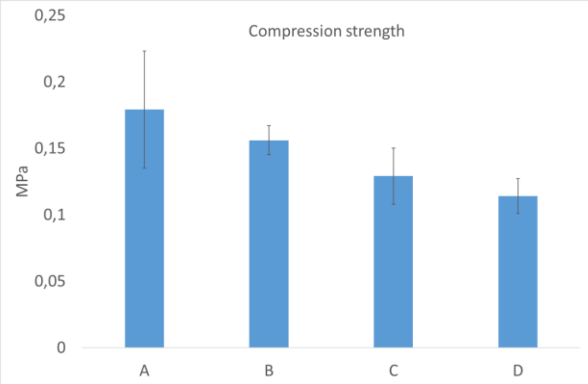

Fig. 6: Compression test results, cork grainsize increases from A to D.

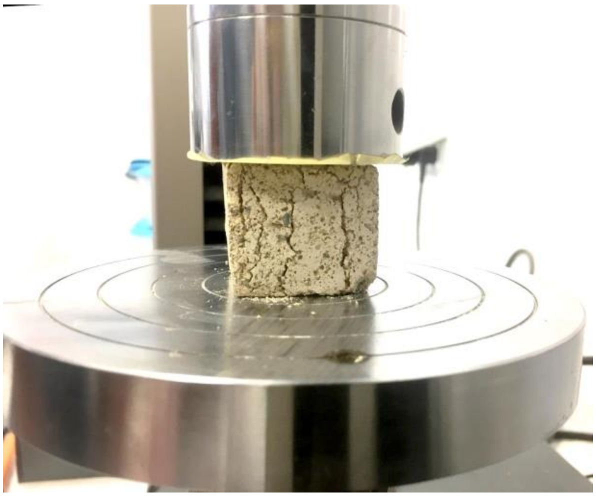

Fig. 7: Compression sample at the end of the test.

3.3 Thermal measurements

Prior to thermal conductivity measurements all samples have been weighed and measured in order to determine their apparent density, as this value can influence the thermal conductivity. Figure 8 shows density and thermal conductivity values for all mortar's types. It can be easily noted that cork grainsize has a negligible influence on both values. Particularly samples A have a slightly higher density, nevertheless have the same thermal conductivity than other mortars.

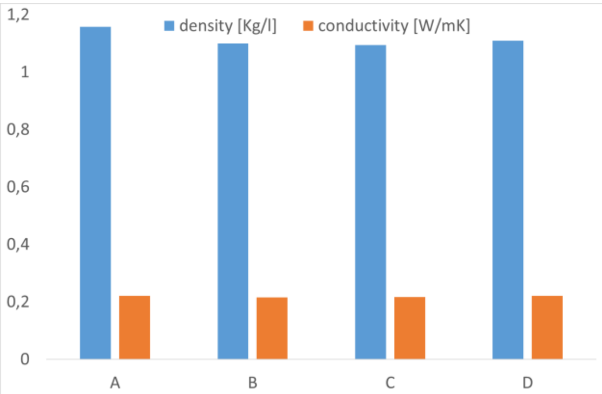

Fig. 8: Density and thermal conductivity values for all types of mortar.

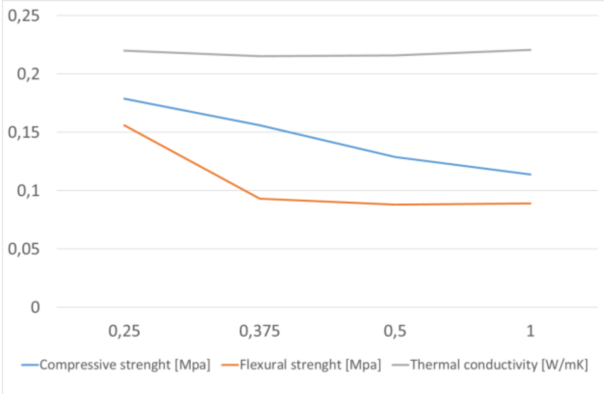

Fig. 9: Mechanical and thermal characteristics of mortar as a function of cork grainsize

3.4 Scanning electron microscopy

Finally, some samples have been observed in low vacuum mode in a scanning electron microscope in order to evaluate the adhesion between cork and mortar.

After compression test failure surfaces have been observed in order to verify the adhesion between cork and binder and the structures of cork's grains as good mechanical and insulation properties are strictly related to these parameters.

In figure 10 it can be easily noted that cork has a good adhesion to the mortar: the cork grains are perfectly adherent to the mortar even after compression tests. Particularly it has to be underlined that the mortar is present after failure along the cork grain, as visible in the left part of the picture.

Moreover, in figure 11 it is possible to observe that even at a grainsize equal to 0,25mm cork grains consist of a large number of cork cells. This is a central point as a lower grainsize ensures higher mechanical properties, while the presence of well preserved cork cell structure guarantees the insulating properties and low Poisson ratio of the cork.

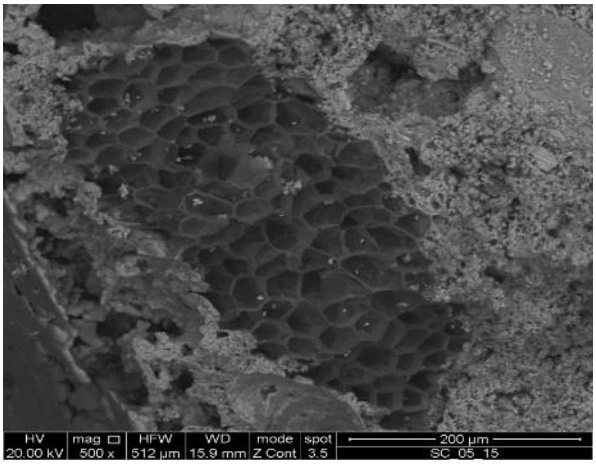

Fig. 10: Scanning electron image of a C mortar.

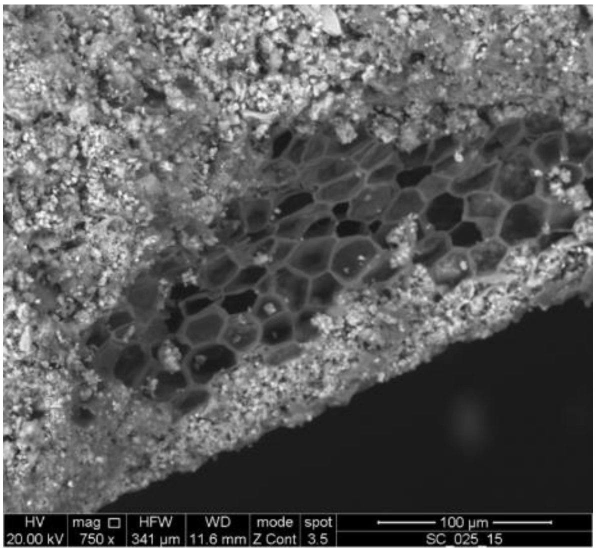

Fig. 11: Scanning electron image of a A mortar.

4 CONCLUSIONS

This paper deals with the properties of insulating mortars obtained by the use of cork powder as aggregate. Particularly the influence of cork grainsize on mechanical and thermal properties of mortars has been investigated by preparing samples with four different cork grainsize, i.e. 0.25, 0.5 and 1mm.

The experimental results suggest that cork grainsize has no significative influence on thermal conductivity of the mortars, that is probably affected by the total amount of cork. On the contrary cork grainsize can affect significantly mechanical properties as clearly shown by figure 9. Particularly compressive strength decreases with increasing cork grainsize while flexural strength is quite higher only for lower grainsize samples.

The density of proposed mortars after hardening is slightly influenced by cork grainsize, and lower grainsize leads to a higher value of apparent density, indicating a lower porosity of the sample

These results suggest that fresh properties of the mortars can be affected by cork grainsize, particularly mortars' workability, leading to a slightly higher mortar density due to lower porosity.

Scanning electron microscopy observation showed a good adhesion between cork and mortar in all investigated samples, regardless of grainsize. Moreover it was possible to confirm that even at lower grainsize a high number of cork cell is present in cork grains, ensuring a good insulating behaviour and the exploitation of cork properties.

Further investigations are ongoing in order to verify the minimum cork grainsize that ensures good insulating properties coupled with higher mechanical properties.

5 ACKNOWLEDGMENTS

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