Figure 6. Desiccated *platanus acerifolia* fruits

The *platanus acerifolia* fruits were naturally desiccated and manually mashed (Figure 7), the cork plugs were all triturated (Figure 8) to form particles having a diameter smaller than 2 mm, while the cardboard was cut into pieces and soaked into water.

The used binder is hydraulic lime NHL 3.5, selected for being a natural material (it is produced by heating –calcining-limestone that naturally contains clay and other impurities), for its quite fast set and for its high compressive strength.

The weight composition of the mixture constituting each sample is reported in Table 1, whereas in Figure 9 the weight shares are depicted.

With regards to this aspect, it must be highlighted that in the aim to construct sample C, the cardboard was preliminary dampened, in order to allow it to be blended with the mixture. The water content of the mixture reported in Figure 9 is only referred to the quantity needed to blend the hydraulic lime and does not take into account the water used to damp the cardboard. On the contrary, the weight of the inert is referred to the wet cardboard and, therefore, it comprises the weight of the water used to damp the material.

Every mixture has been used to structure the correspondent sample, exploiting the formerly described formworks. The obtained dimensions, which do not usually employ the global amount of mixture, are reported in Table 2.

Figure 7. Crumbled desiccated *platanus acerifolia* fruits

Figure 8. Triturated cork plugs

Table 1. Weight composition of the samples

Sample	Inert material	Weight (g)			
		hydraulic lime	inert material	water	TOTAL
A	*platanus acerifolia* fruits	2700	600	2140	5440
B	cork plug	766	340	810	1916
C	Wet cardboard	911	2734	2500	6145

After the construction, the samples were made rest into the formworks for a few days in order not to alter the homogeneity of the mixture with movement and, hence, at the end of this period they were weighted for the first time.

Table 2. Structure of the samples

Sample	Inert material	Dimensions (cm)		
		length	width	thickness
A	*platanus acerifolia* fruits	30	30	4.6
B	cork plug	30	30	2.9
C	cardboard	30	30	4.4

All the samples underwent a natural drying process during which they were progressively weighted; as a result, the weight loss is reported in Figure 10.

It is worth noting that the weight of sample C reached a steady state more slowly than the other two, even though the global weight loss at the end of the drying process was higher.

This phenomenon is due to the mixture composition of sample C, which has a smaller content of binder, and to the behavior of the cardboard which absorbs a great deal of water at the beginning, but slowly releases it during the drying process.

However, the sample will be further investigated, to verify the evolution of dry process and the achievement of stability conditions.

In Figure 11 the density of the three samples, at the end of the drying process, is reported. As expected, sample C has the lowest density, owing to the higher weight loss.

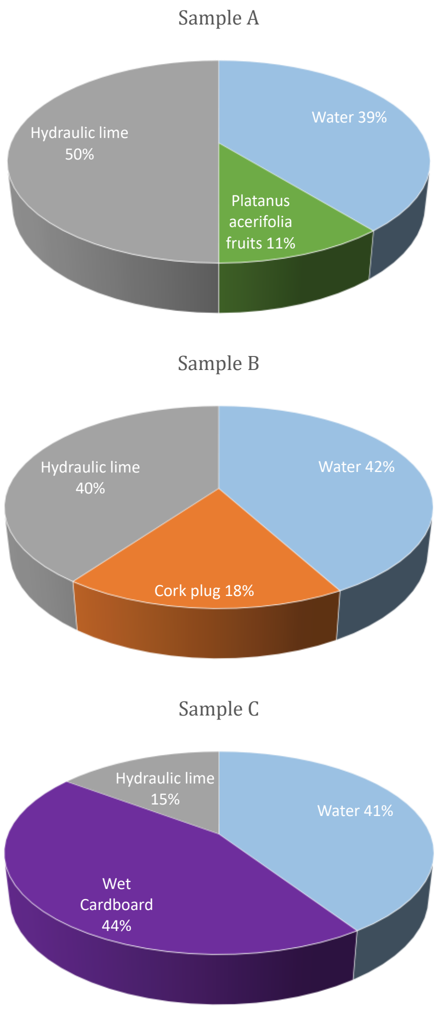

Figure 9. Weight shares of the studied samples

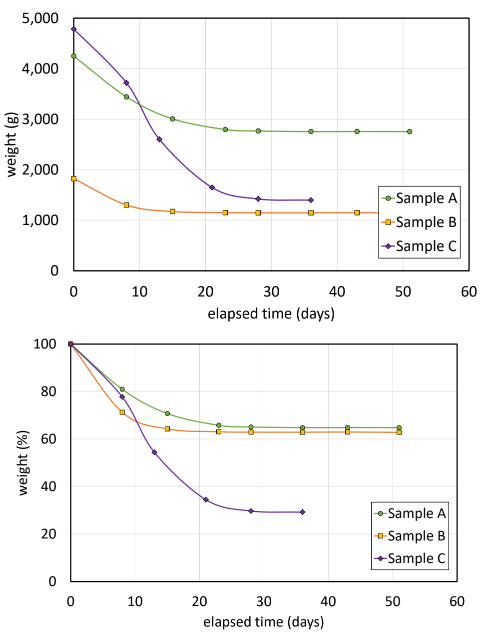

Figure 10. Weight loss of the studied samples

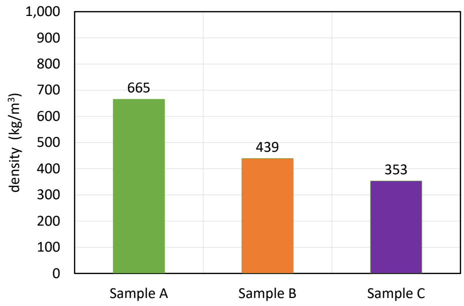

Figure 11. Density of the studied samples

3. MEASUREMENT RESULTS

The measurements involved several temperature gradients, in order to investigate the variation of the sample thermal conductivity with the temperature in the range between 0°C and 40°C.

The ranges used were the ones reported in Table 3, where the lower limit, t_{low}, namely the set-point value for the lower plate of the instrument, the higher limit, t_{up}, that is the set-point value fixed for the upper plate, and the average temperature, t_{avg}, are specified.

Table 3. Temperature ranges

Range ID	t_{low} (°C)	t_{up} (°C)	t_{avg} (°C)
1	0	20	10
2	5	25	15
3	10	30	20
4	15	35	25
5	20	40	30

The results of the thermal conductivity measurements are reported in Figure 12, which depicts their trend with temperature, and Table 4, which specifies the average values and the standard deviations.

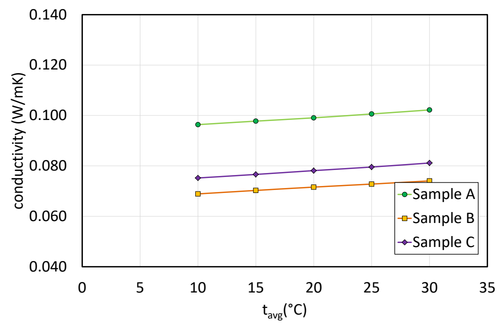

Figure 12. Measurement results

Table 4. Experimental results

Sample	Inert material	k ($W\ m^{-1}\ K^{-1}$)	Standard Deviation ($W\ m^{-1}\ K^{-1}$)
A	*platanus acerifolia* fruits	0.0992	0.00205
B	cork plug	0.0715	0.00182
C	cardboard	0.0781	0.00209

It can be noted that, in the studied ranges, the variation of the measured parameter with temperature is small.

Furthermore,

Figure **13** shows the variability of the thermal conductivity with the density of the material. Albeit the few available results do not allow a definitive statement on this topic, it could be highlighted that, as it is usually expected, the lowest density values allow the lowest thermal conductivity values to be reached.

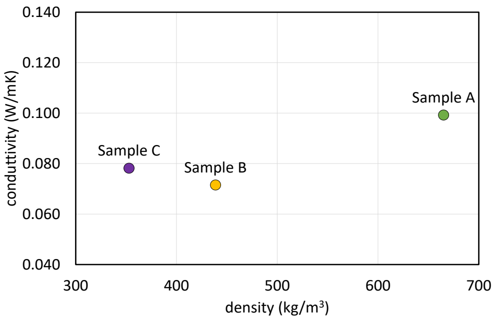

Figure 13. Thermal conductivity versus density

4. CONCLUSIONS

Nowadays, the demand for green building materials, especially insulating materials from renewable resources, is sharply rising. Natural material are emerging as low cost, lightweight and apparently environmentally superior alternatives to traditional matters in composites used in building constructions.

In this context, this paper reports the preliminary results of a research activity aimed at the assessment of the insulation features of various structures made up of totally natural and biocompatible materials, in order to try to single out the optimal configurations.

The studied mixtures, in fact, consist of a natural binder (such as hydraulic lime NHL 3.5) and a biocompatible inert material (such as *platanus acerifolia* fruits, natural cork and cardboard).

The results demonstrate that the thermal conductivities of the studied structures are lower than 0.1 W/mK, confirming that, albeit further improvement are possible by modifying the texture and composition of the compounds, these elements can be considered a good alternative to the most used insulating materials. Furthermore, being constructed using waste materials, they are a contribution to the recycling processes which can make the building industry more sustainable.

On the other hand, notwithstanding the encouraging results, additional analysis are needed for a complete assessment of the studied structures: mechanical resistance, impact of moisture content and the influence of the drying process on the thermal and mechanical properties should be furtherly investigated.

In this direction the prosecution of the research activity has been planned.

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NOMENCLATURE

k	thermal conductivity, W m^{-1} K^{-1}
q	heat flux, W/m^2
Q	electric signal from the transducer, μV
S	calibration factor, W m^{-2} μV^{-1}
t	temperature, °C

Apex

up	referred to the upper plate of the instrument
low	referred to the lowest plate of the instrument

Subscript

cal	referred to the calibration run
test	referred to the actual measurement run