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REED-BASED ECO-FRIENDLY THERMAL INSULATORS

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Abstract: *This paper is part of an extensive project aimed at promoting traditional and eco-friendly materials. One such material is reed, which, mixed with organic and inorganic binders, can form new thermally insulating materials with similar properties to the ones of the materials currently used in construction. This study falls in the "New materials and technologies in the building industry" category and is aimed at contributing new ideas to the field of natural, environmentally friendly building materials with reduced energy consumption and negative carbon dioxide emissions.*

Key words: *reed, ecology, thermal insulation, thermal conductivity*

1. Introduction

Climate change is the phrase used to describe the negative impact of global warming on our Planet. The accumulation of greenhouse gases in the atmosphere – mainly due to the burning of fossil fuel – has led to an increase in temperatures, which dramatically alters the Planet's weather patterns.[1]

Contrary to popular belief, global warming and climate change are not improving our way of life, but have an undeniably negative effect! Urgent measures need to be taken and unless we take them, our future becomes insecure. Climate change is probably the greatest threat humanity has ever faced.[1]

Buildings constitute the biggest energy consumer, using 40% of the total energy consumed, more than transport (32%) and industry (28%). Insulating buildings can substantially reduce energy consumption and the costs associated with it. [3]

The energy consumption of any building can be reduced by insulation. Thermally insulating materials are easy to apply and will last throughout the building's lifetime without requiring maintenance.

Researchers' desire to reduce both pollution and costs has led them to turn their attention to unconventional building materials with similar properties to those of traditional materials used in civil engineering. These materials would contribute to reducing pollution, as well as the housing shortage and could cause housing costs to drop, thus making it easier for people to have a home of their own. [2]

This paper is part of an ample project that seeks to promote eco-friendly traditional materials such as reed, which, mixed with organic or inorganic binders, can lead to the creation of new thermally insulating materials, which can act as good temperature and humidity regulators,

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ensuring a pleasant environment and having a positive impact on human health.

Even though the main purpose of thermal insulation is related to the reduction of energy consumption, one must not forget that the materials employed impact the environment throughout the building's lifetime.

When evaluating the impact of thermally insulating materials on the environment, several aspects must be taken into consideration: the necessary resources for production and fabrication, the pollutants emitted during their life cycle and during recycling, as well as the impact on the quality of the air [3].

This study aims to obtain a new thermally insulating material by using its own recipe, which contains ground reed mixed with a traditional binder, resulting in a type of mortar with thermally insulating qualities.

Reed makes for one of the vastest compact surfaces in the Danube Delta, covering over 1,500 km² of its total surface, but it can also grow in other parts of the country, such as the marshlands in the Romanian Plain, the Jijia Plain, the Tisa Plain and the Transylvanian Plain. (Fig. 1)

Fig. 1 *Reed near Geaca commune, at the centre of the Transylvanian Plain*

Its physical characteristics make reed the ideal building material: it is light, yet stable. The air inside and in between reed straws ensures remarkable thermal and acoustic insulation, thus generating high comfort. It can also be easily combined with other building materials such as cement, polyvinyl alcohol, lime and plaster. [4]

These qualities have earned appreciation for it in modern architecture as well. In this context reed-based materials – prefabricated and otherwise – have proven their efficacy by combining physical and ecological qualities. Producing these materials requires reduced energy consumption and can be done without the use of chemical components and with no carbon dioxide emissions or residues.

On a global scale, the field of ecological, energy efficient building is on the rise. The governments of many countries encourage the use of natural building materials, the main beneficiaries thereof being public institutions themselves. In Romania, eco-friendly houses with natural thermal insulation systems are becoming more and more known and ever more specialists are becoming interested in this type of building.[7]

2. Materials and Methods

2.1. Materials

The main aim of this study is to obtain new types of thermally insulating materials by using ground reed mixed with various organic and inorganic binders.

In an attempt to improve the thermal characteristics of the new material, the influence of ground reed as a thermal insulator that is a component of new mortars made with traditional binders – cement, plaster, lime and polyvinyl alcohol – is being studied.

2.2. Preparing the composites

The reed used in the experimental programme was harvested in Cluj county, near Geaca commune, which is located at the centre of the Transylvanian Plain and harbors part of the chain of lakes that make up the "Fizeș Valley Lake Complex".

After harvesting, those parts of the reed which were not in optimal condition, exhibited traces of mould, rot or any other imperfections caused by various insects or by storage was removed. Then the reed was cut into 20 and 40 cm pieces in order to fit in the MC22 hammer mill, the productivity of which is 1-1.8 t/h for reed.

Four original mortar recipes were created. In each case, the fibres consisting in ground reed remained constant, while the binder in each recipe was different. Thus, the first mortar contains cement, water and ground reed, the second plaster, water and ground reed, the third lime, water and ground reed and the fourth polyvinyl alcohol and ground reed (table 1). The fresh material was poured into original 150x150x30 mm molds sized to fit the dimensions of the machine for the determination of the thermal conductivity coefficient (λ).

The fresh paste was poured into 40x40x160 mm prisms, 3 for each recipe, in order to determine flexural strength and compressive strength.

The components of the four original recipes Table 1

TEST	BINDER				WATER	GROUND REED
	LIME [g]	CEMENT [g]	POLYVINYL ALCOHOL [g]	PLASTER [g]	[ml]	[g]
A1		1000			380	130
A2				1000	550	130
A3	1000				710	130
A4			300			130

3. Test Methods

Since the proposed thermally insulating material comes in the form of a mortar, the first stage of the experimental programme is to determine its physico-mechanical characteristics in accordance with SR EN 196, SR EN 459-1: 2003, STAS 10275-4-91. The mortars obtained were submitted to the determination of bulk density, flexural tensile strength and compressive strength. First, the flexural strength of the samples was tested, then the resulting halves were submitted to compressive strength tests. Mechanical strengths were determined 28 days after preparation.

Determination of bulk density

The prisms made according to original recipes (A1, A2, A3, A4) sized 40x40x160 mm were weighed, measured for L, l and h, then their bulk volume and subsequently their bulk density were calculated. Table 2 features the average values obtained for each recipe [5]:

Bulk density Table 2

Recipe	A1	A2	A3	A4
ρ_a avg [g/ cm^3]	1.666	1.516	1.071	0.780

Determination of flexural tensile strength

Flexural tensile strength is determined according to SR EN 1015-11: Methods of test for mortar for masonry. Part 11: Determination of flexural and compressive strength of hardened mortar.

Fig. 2 *The machine used for the determination of flexural tensile strength, the Building Materials Laboratory of the Faculty of Civil Engineering*

Fig. 3 *The prism ends of a 40x40x160 mm test sample resulted from the flexural tensile strength test.*

This test is performed with the aid of the flexural testing machine (Fig. 2) on prisms sized 40 x 40 x 160 mm. A shock-free load is applied at an even rate between 10 N/s and 50 N/s so that the fracture should be produced within 30 to 90 seconds (Fig. 3). The maximum applied load is registered in Newtons. The mechanical flexural strength is calculated according to the following formula:

$$f = \frac{1.5Fl}{bh^2}\ , [\text{N/ mm}^2] \qquad [6]$$

Where: F is the maximum applied load;
l is the span length between bearing blocks;
b and h are the dimensions of the cross-section.

Table 3 features the average flexural strength for the 3 prismatic specimens of each of the four recipes.

Average flexural strength for the 4 types of mortar

Recipe	**Average flexural strength after 28 days** $\overline{R_{fl}^{28}}$ **[N/ mm2]**
A1	4.08
A2	3.63
A3	0.48
A4	2.22

Determination of Compressive Strength

The determination of compressive strength is performed in accordance with SR EN 1015-11: Methods of test for mortar for masonry. Part 11: Determination of flexural and compressive strength of hardened mortar.

The test is performed on the leftover prism pieces resulted from the flexural test, by using a hydraulic press (Fig. 4). The test is always applied perpendicularly to the direction of casting of the prisms, as strength is lower on this direction due to the possibility of mortar segregation. A progressively increasing shock-free load is applied at a load increase rate of 50 N/s to 500 N/s, so that the fracture should be produced within 30 to 90 seconds.

Fig. 4 *The hydraulic press of the Building Materials Laboratory of the Faculty of Civil Engineering*

The maximum applied load is registered in newtons. The following calculation formula is used [6]:

$$f_c = \frac{P}{A}, \text{ [N/mm2]}$$

Where: P is the breakage force;

A is the surface area of the section.

Figure 5 features the two ends of the prism of mortar A2 tested for compression, while the average results obtained following the compression test can be seen in table 4.

Fig. 5a *Compression test for mortar A2*

Fig. 5b *Compression test for mortar A2*

Average compressive strength of the four types of mortar Table 4

Recipe	**Average compressive strength after 28 days** $f_c^{avg} = \frac{\sum_1^n f_c}{n}$ **[N/ mm2]**
A1	8.62
A2	6.25
A3	0.80
A4	2.75

Determination of thermal conductivity through the heat flow meter method

The determination of thermal conductivity through the heat flow meter method was performed in accordance with SR EN 12667.

Fox 200/300 (figure 6) is an accurate, easy-to-use instrument for the determination of thermal conductivity in accordance with ISO 8301. It provides quick and precise results, which are shown in table 6. The FOX 200/300 instrument consists of two basic parts: the upper part and the base. The upper part of the instrument is the actual test chamber. Once the door has been opened, the sample can be placed between the two plates, in the test stack. The upper plate is stationary. The lower plate can move up and down. The upper side of the sample will have a temperature of 20 $^{\circ}$C, while the temperature of the lower side will be of 0 $^{\circ}$C.

Fig. 6 *The thermal conductivity measuring instrument*

Thermal conductivity of the four types of mortar Table 5

Recipe	**Thermal conductivity λ [w/mk]**
A1	0.355
A2	0.315
A3	0.236
A4	0.075

3. Results and Discussion

The original contribution of this paper refers to the new types of thermally insulating materials based on ground reed. The original recipes were tested by means of standardised methods in order to determine their physical characteristics and their mechanical strengths.

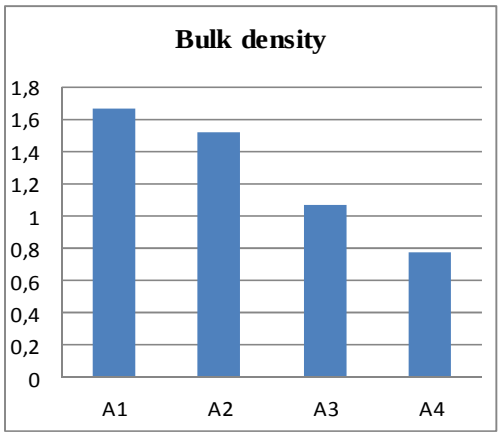

Fig. 7 *Bulk density*

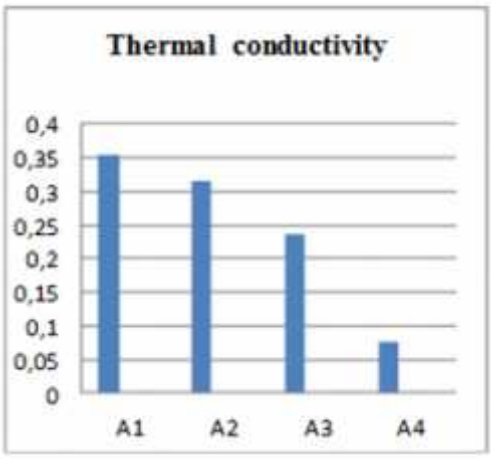

Fig. 8 *Thermal conductivity*

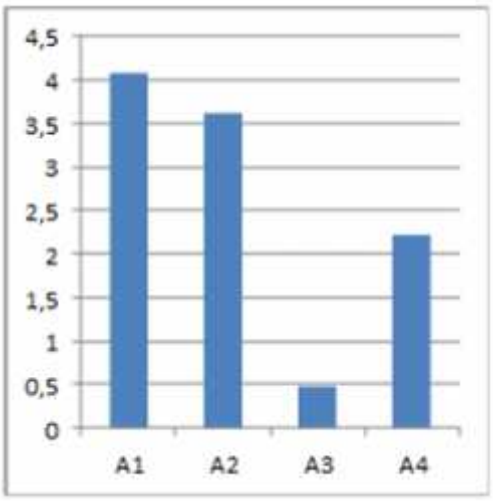

Fig. 9 *Flexural strength* $R_{ti}[N/mm^2]$

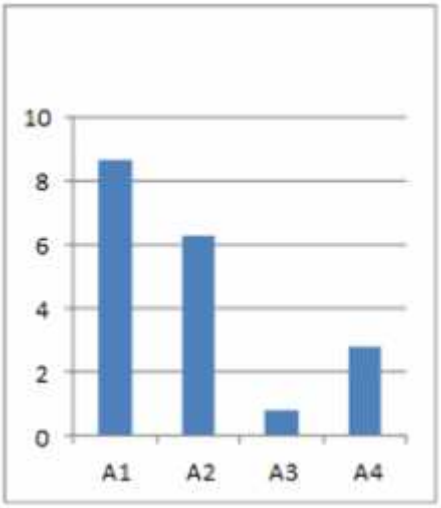

Fig. 10 *Compressive strength $R_C[N/mm^2]$*

The evolution in time of the mechanical strengths of mortars made of binders and reed was observed - figure 9, figure 10. A comparative study was conducted for the four types of mortar, which analysed the influence of the type of binder which was mixed with the reed.

Upon analysis of the average values of flexural strength – figure 9 – and of compressive strength – figure 10, a similar behaviour is noted, with the cement-based mortar registering the highest values, followed by the plaster-based one, the polyvinyl alcohol-based one and the lowest values being registered by the lime-based samples.

Following the determination of thermal conductivity – figure 8 – by means of the heat flow meter method, it has been noted that the results of bulk density measurements - figure 7 – are proportional to those of thermal conductivity measurements – figure 8 – in the case of each mortar. As far as the thermal resistance determined with the aid of the Fox 200/300 machine available in the Building Materials Laboratory of the Faculty of Civil Engineering is concerned, the 4 samples yielded promising results, with sample no 4, an original recipe consisting of polyvinyl alcohol and ground reed, registering the lowest thermal conductivity of 0.075 [w/mk].

As we know, a material is considered to be thermally insulating if its thermal conductivity is below 0.1 [w/mk], so, according to the results of the determination of thermal conductivity (0.075 [w/mk]), sample no 4, made of polyvinyl alcohol and ground reed, can be included in the category of thermally insulating materials. We believe that the purpose of the first batch of samples has been achieved, namely that of obtaining a thermally insulating material. The recipes will be subsequently optimised by increasing the amount of reed in an attempt to reduce conductivity as much as possible and obtain a good thermal insulator. However, at the same time the evolution of the strengths of the new types of mortars must be monitored carefully. In the next stage of the experimental programme, the adhesion to the support layer will also be monitored for the proposed mortars. [8]

4. Conclusions

This paper fits into the ‘New materials and technologies in the building industry’ category and seeks to make an innovative contribution to the field of eco-friendly building materials with low energy consumption and negative carbon dioxide emissions.

The tests performed on mortars prove that there are new possibilities for using reed in construction.

It has been concluded that, by using reed, one can create new building materials which have similar characteristics to those of classic materials, but which are natural, eco-friendly and can be used for insulation and finishing (thermally insulating mortar). Meanwhile, the eco-friendly construction market is on the rise and more and more

specialists are becoming interested in such constructions.

The conclusions of this paper are encouraging and we will move on to the next stage, in which the recipes will be optimised in order to yield a mortar with thermally insulating characteristics, minimal mechanical strengths and adhesion to the support layer, by using the largest volume of reed possible and the most advantageous binder.

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