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INSULATION BOARDS MADE OF SHEEP WOOL AND MINERAL CEMENT

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Abstract: *People always tried to evolve and discover new paths to improve their life. This fact can be seen everywhere in nature: plants, animals, materials, etc. Well, since humans are part of the nature we also follow those rules. Today technologies are anyway more advanced than 100 years ago technologies, and the trend show us that further we go, faster we "brake the laws of physics", but actually this means we discover new areas of the general science. Now, the physics may offer us new things every day, but humans are limited in terms of resources, and this means the best way to evolve is to limit resources usage and recover, where possible, as much as possible. In our study we focused on the limitation of the resources used to create climate conditions for general buildings by using at the same time only natural materials with very low impact on the environment.*
Keywords*: nature, thermal insulation, sustainability, wool*

1. INTRODUCTION

The idea started when we understood that it is a general problem on global scale about the way people are heating their buildings today. It is well known that resources are limited and nowadays we see the keyword *sustainability* on every book, wall, news, etc. What sustainability actually means? Well, it comes about 90% from: SUSTAIN + ABILITY. So the direction where people are trying to go seems to be called exactly sustainability, or in other words, to keep this planet in living conditions also for our children and their children, and so on. Even if still we have a very long way until there, there are a lot of people concerned about this. Also many countries adopt laws to direct us towards the right path [1].

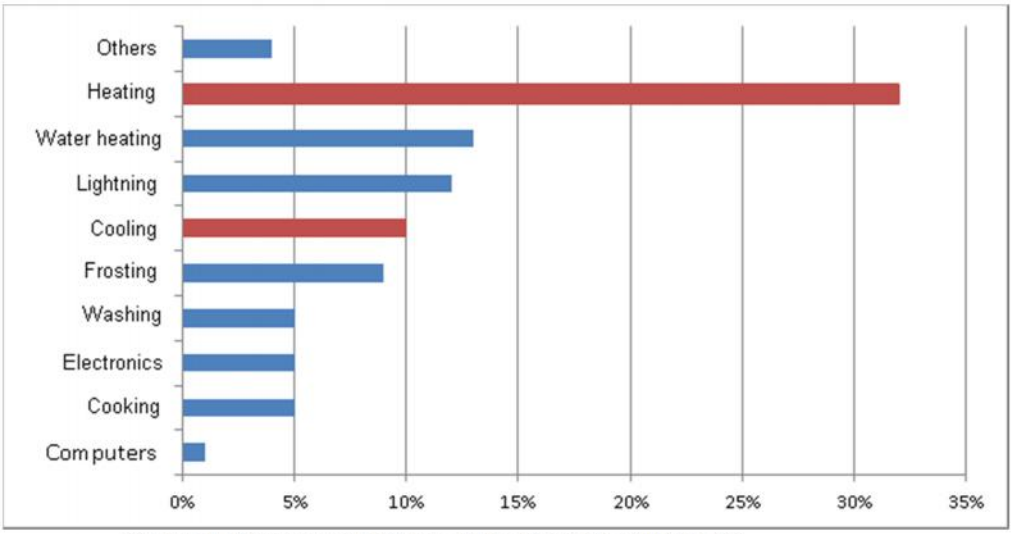

Figure 1: Energy consumption in residential buildings [2]

Recently, a team from the Department of Mechanical Engineering ~~at~~ from "Transilvania" University of Brasov started to study this sector of buildings insulation. We were also interested in improving life quality by using natural materials. Insulations industry is widely spread on the globe because every single person would need

proper climate conditions to live. This means that also here goes a big part of the resources, we have got. Everyone heard about the waste of the energy used to condition our houses, and also everyone heard about the constant care of the resources we use in this domain. Other main idea is: "The most effective development strategy is based on saving as much resources as we can" So the first step was to find some information about the actual cost of energy needed and we found plenty of studies showing that in building insulation there are many things to improve. For example, one study from United States of America shows us that the energy used by a building splits into different sectors as heating and cooling, water heating, lighting, washing, electronics etc. [2]
As we clearly can see in Figure 1, the energy used for heating and cooling a residential building represents almost half of the entire energy used by that building. Obviously, this study represents a case from United States of America, but the heating energy is more than twice as big as the next ~~most~~ energy consumer in the building (energy spent for water heating).
The next Figure (2) represents the energy consumption in a commercial building, but you will notice that there is no significant difference, except the lightning usage.

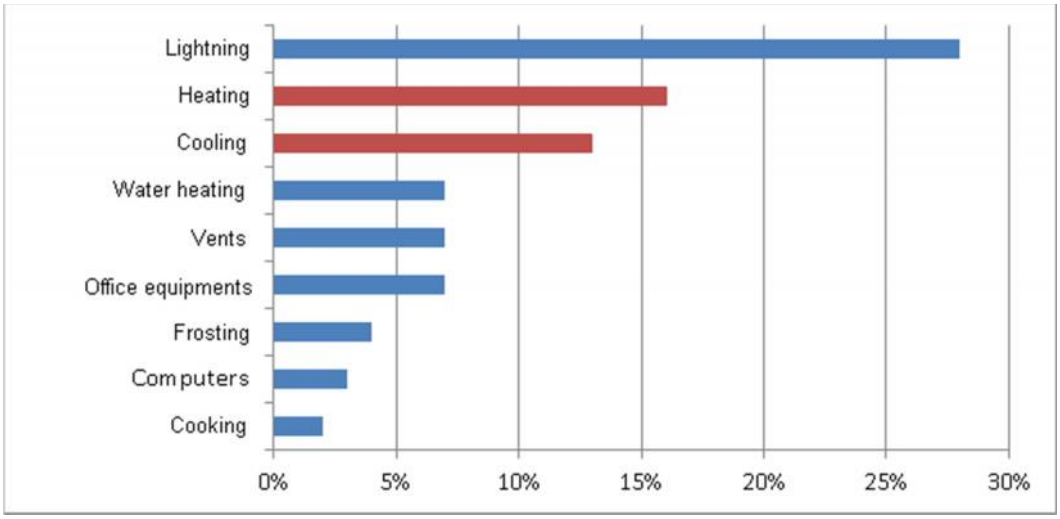

Figure 2: Energy consumption in commercial buildings [2]

So, as this study shows, the energy used to condition the climate in a building, either a commercial or a residential one, needs to be taken in consideration. Actually, we clearly can see that the energy used for heating and cooling a building represents the biggest percent of the total energy used by that building. There are anyway more studies showing the same thing, some from United States of America and some from other countries.
In the last period, Romanians started to pay great attention to the buildings thermal insulation because of more factors. People living in Romania showed some interest in insulating their private homes, while most of the companies and state institutions are already insulating most of their buildings.
Now, the biggest issue we had was regarding the materials used to insulate the building. One of the most used materials in buildings thermal insulation is polystyrene and this is not only in Romania, but in the most countries of the European Union and some other countries. The problem with the polystyrene is not about its insulation properties, because its thermal conductivity is low enough (λ=0.04 W/mK), but this material is not natural and its decomposition takes a lot of time to end [3] and it is very flammable.
Finally, we started to look attentively for natural materials with thermal insulation properties and in the next chapter you will see how we tried to find a solution for this issue.

2. MATERIALS, EXECUTION AND RESULTS

The very first condition was: ***The material we use has to be natural***. We started to search for natural materials to be used in our experiment, materials to correspond to some of our criteria. Other criteria were: very good thermal insulation properties, biodegradation and sustainability. So, among other important properties we have selected few materials to try, that comply with our criteria. Most relevant materials were sawdust, wheat straws, hemp and sheep wool. The reason we finally chose sheep wool was that is less flammable than the previous materials. Also, this represents a chance to use the wool from our region, which usually is no more used today by the shepherds. The first idea was to clean the wool by means of some distinctive processes and afterwards to roll it for the interior usage in buildings. Other idea, the one we tested, was to incorporate the wool in cement and to form insulation panels for outdoor conditions. Because plaster has a very quick cementing time and it is also a very good binder, it was chosen for our experiments. So, we have managed to create a 250x250x40mm frame

made out of wood. This served as a mold for our mixture. We produced many samples, but the most relevant ones were the panels made out of plaster, wool layer and the reinforcement of PVC fiber and plaster, the last ones being made only from one wool layer. All the samples were dimensioned to 250x250x22mm. The quantity of material was quite similar: 1200g of plaster, 1L of water for the cement. For the samples containing wool and PVC fiber, the weight has grown with 30g for the wool layer and 10g for the PVC reinforcing fiber [1].
Below you can see the samples made only from cement (Fig.3), the samples made from plaster, wool layer and PVC reinforcement fiber (Fig.4), the sample made only from wool layer (Fig.5) and the matrix (Fig.6).

Figure 3: Sample nr.1

Figure 4: Sample nr.3

Figure 5: Sample nr.5

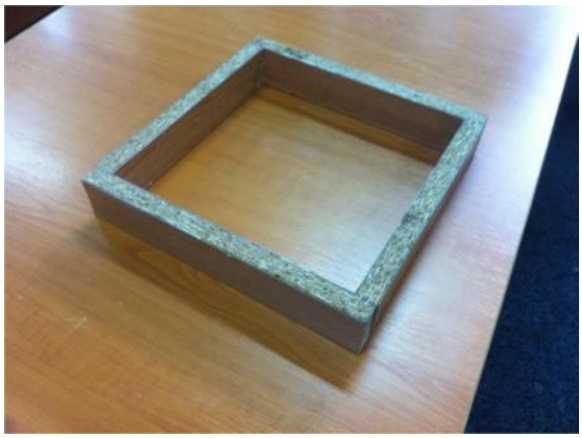

Figure 6: Matrix

The process of making the frame and also the panels took place in Brasov, using some of the University materials, resources and locations. The period of time for the samples to dry was of 10 days, losing most of the water due to evaporation. The weight of the samples at the beginning of their construction were almost 2200g, while after 10 days same sample were almost 1200g heavy.
One of the most difficult issues we had was the short time of cement solidification; in 5 minutes the panels were already solidified [1].
The measurements done tried to determine the thermal insulation properties of those samples. We managed to obtain results for our samples using the University equipment based on the guarded hot plate method [4], [5
In order to determine the coefficient of thermal conductivity we used Fourier's relation:

$$q = \frac{\lambda}{\delta} \cdot \Delta_t \quad (1)$$

where, λ is the coefficient of thermal conductivity; δ is the board thickness, $\Delta t = t_1 - t_2$ is the temperature difference between the two surfaces of the sample and q is the heat flow.

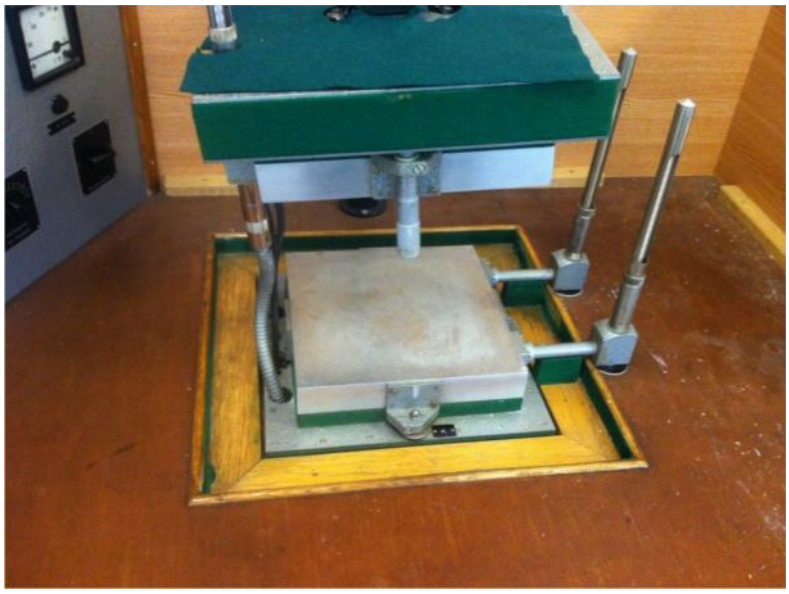

Figure 7: Equipment used to determine the λ coefficient

The quantities Δt, δ and q were obtained by measurements and afterwards we have calculated the coefficient of thermal conductivity.
This equipment we used can measure the coefficient of thermal conductivity λ from 0.025 up to 1.7 kcal/mhgrd.
The dimensions of the boards that can be tested are between 200 and 250mm for the length of the squared area and between 3 and 70mm for the thickness. The ambient temperature needs to be between 18 and 25°C and the relative humidity between 55 and 65%. The measurements lasted for about 3 hours for each sample. Also this equipment had different steps of heating depending on the sample that is to be tested. The k constant and also the w constant of the experimental equipment for each step are represented in Table 1.

Table 1: k and w constants values for each step [5]

Heating step	K [kcal/m^{2}kWh]	W[m^{2}h·grd/kcal]
1	105.3	
2	151.7	
3	218.2	
4	317.6	
5	464.8	
6	680.2	$1.3 \cdot 10^{-3}$
7	1008.0	
8	1491.0	
9	2179.0	
10	3170.0	
11	4582.0	
12	6549.0	

but also we can determine the value of w constant by using next relations:

$$w = \frac{q_2 \cdot \delta_2 \cdot \Delta t_1 - q_1 \cdot \delta_1 \cdot \Delta t_2}{q_1 \cdot q_2 \cdot (\delta_2 - \delta_1)} \quad (2)$$

We have also determined the density of our material by using next relation:

$$\rho = \frac{m}{V} \quad (3)$$

where, V - sample volume and m –sample mass.

To determine the equivalent thermal coefficient λ_{ech} ~~value~~ in order to establish the heating step of the equipment we used the ~~nest~~ following relation:

$$\lambda_{ech} = \frac{\delta_t}{\frac{2\delta_i}{\lambda_i} + \frac{\delta_l}{\lambda_l}} \quad (4)$$

where, λ_l is the coefficient of thermal conductivity for wool, λ_i is the coefficient of thermal conductivity for the cement used.

We also had to consider the accuracy of the four thermometers of the equipment. Since any measurement cannot be ideal, we had to consider the next temperature correction coefficient values read at the four thermometers:

Table 2: Temperature correction coefficient values for the four thermometers of the equipment [5]

Temperature °C	t_{w1}	t_{w2}	t_{k1}	t_{k2}
20	+0.05	+0.08	+0.07	+0.11
25	-0.02	+0.05	+0.09	+0.08
30	+0.07	+0.06	+0.05	+0.08
35	+0.01	+0.05	+0.02	+0.02

In Figure 8 the most relevant results we had are represented. As we can see, the differences are very important. For the first sample the λ coefficient was approximate 0.26 W/m·K, while for the sample with 2 mm layer of wool and a stiffening PVC fiber, the λ coefficient was approximate ~~to~~ 0.23 W/m·K. The most effective, as it was expected to be, was the sample 5 made only from a wool layer, uncompressed, where λ=0.045 W/m·K, almost the same as polystyrene, but for a natural material.

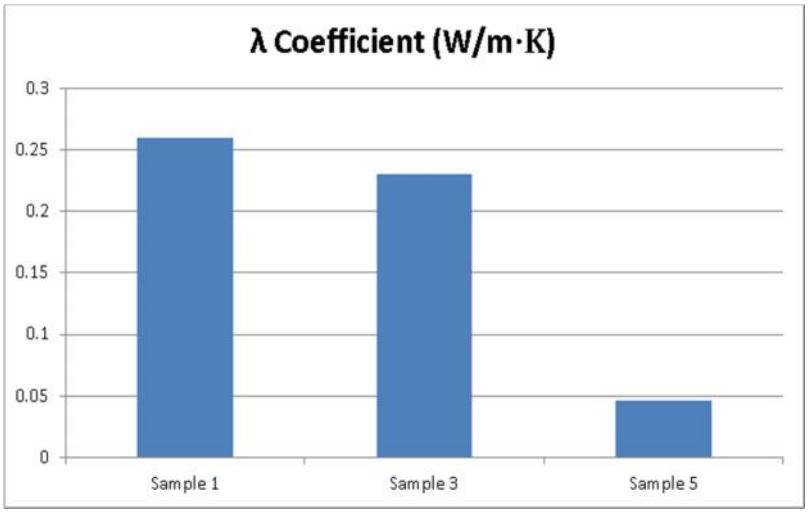

Figure 8: λ Coefficient for different samples

3. CONCLUSION

Wool by its natural form is an insulation material, perfected by nature itself, and also used since thousands years ago, but only recently disregarded for other usage like building insulation.

The principal purpose of this study was to find a sustainable solution for the building insulation issue, an issue that wastes a really big amount of Earth resources. Also, since pollution is growing and became one of the biggest issues of nowadays population, we tried to find a natural way to fix the problem. The question we asked was: *Why should we waste more energy and materials to create something when we already have something which is better than anything we would ever create?* Because, to be honest, humans are just a tiny part of the

entire system and since the very beginning we are just trying to copy what we see, and its original made by nature.
Research will continue, since we verified our hypotheses which assumed wool will face off and win this competition against other insulation materials for buildings, especially polystyrene. We intend to study more detailed how the percent of wool in the boards influences its properties, since we managed to obtain almost 10% improvement in conductivity for only 2mm layer of wool, where 2mm of wool layer means only 10% of the whole thickness of the sample. For the future, our plan is to modify the amount of wool in other samples.
We hope our results show that wool represents an alternative to replace "conventional" materials, and this could represent a way to improve the general situation concerning pollution and sustainability since it could save a lot of wasted resources to heat buildings and also considering the costs of producing wool insulation.
This article presents only a part of the main idea and how we were producing samples for the study.

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