USE OF WOOL IN THE COMPOSITION OF BUILDING MATERIALS – SUSTAINABLE SOLUTION FOR IMPROVING THERMAL, ACOUSTIC PERFORMANCE AND INDOOR AIR QUALITY

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ABSTRACT

The article presents a synthesis of international research aimed at studying the use of natural and renewable resources such as sheep's wool with / without plant waste in order to improve the thermal and acoustic performance of construction materials in which it is incorporated. During the research programs, samples were made from the mixture of wool with mortars, concretes or clay; these were tested to determine the mechanical, thermal and acoustic properties and to highlight the positive contribution of wool.

Keywords: wool, hemp, mortar, clay, concrete

REZUMAT

În cadrul articolului se prezintă o sinteză a cercetărilor la nivel internațional ce au avut ca obiect studiul utilizării resursei naturale și regenerabile precum lâna de oaie cu / fără deșeuri de plante cu scopul îmbunătățirii performanțelor termice și acustice ale materialelor de construcție în care este înglobată. În cadrul programelor de cercetare s-au confecționat epruvete rezultate din amestecul lânii cu mortare, betoane sau argilă, acestea fiind testate pentru determinarea proprietăților mecanice, termice și acustice și pentru evidențierea aportului pozitiv al lânii.

Cuvinte cheie: lână, cânepă, mortar, argilă, beton

1. INTRODUCTION

The construction sector has a considerable impact on the environment: in the building stage, by using resources from the natural environment; during the operation period by consuming resources for heating or cooling and related gas emissions, respectively at the end of the operation period by integrating the resulting waste into the natural environment.

Wool can be considered a renewable resource, as a sheep produces an average of 2.3 to 3.6 kg of wool per year, which must be removed to maintain the animal's health. It is estimated that about 75% of the wool (approximately 150 million tones per year) produced by sheep farms in Europe cannot be used in the textile industry. As for its storage it is necessary to carry out a sterilization treatment at 130ºC, the wool, mostly stored in improper conditions, is burned; this causes a negative impact on the soil and air pollution (Cardinale et al., 2017).

1.1. The need to use natural fibers for good thermal insulation materials

The durability and energy efficiency of buildings are currently assessed not only on the basis of thermal insulation parameters and heating demand, but also on the basis of primary energy demand, CO_2 reductions and ecological properties of building materials.

The new regulations and the growing demand for sustainable materials have led to the development of materials that can provide both thermal and sound insulation and that incorporate or are made entirely of renewable natural resources that do not cause noxious effects on the human health.

1.2. The need to use natural fibers for good sound insulation materials

Sound absorption panels for home acoustic applications are generally made of porous synthetic materials, such as rock wool, glass wool, polyurethane or polyester; these have an expensive production process and are generally based on petrochemicals. Fiberglass materials have been shown to have carcinogenic effects, (Papadopoulos, 2005). Taking into account these criteria for choosing the materials suitable to be used for sound insulation in recent research, the possibility of using materials with inserts, or entirely made of vegetable fibers due to their cellulosic structure, has been studied.

The use of these natural materials in addition to the advantages of mechanical behavior of construction materials in which they are incorporated, bring a great advantage on healthier indoor conditions but also reduce the impact on the environment by reducing the amount of waste to be stored or incinerated.

2. RESULTS AND DISCUSSIONS

Cardinal T. et al. (2017), at the University of Turin (Italy), conducted a study on the mechanical and thermal characteristics of mortars whose composition has been improved by introducing wool from waste from an old duvet.

The materials used were: cement - CEM II / A RCK 42.5 N; sand - 0.63 mm; lime - for the sample without wool, a water / cement ratio of 0.4 was computed, and for the samples with wool additional water was added to ensure the necessary workability, and wool (10mm) - in percentages of 2%, 5% and 7%, respectively. The use of 2% sheep wool together with cement, sand, lime and water for making mortars resulted in a 24% decrease in the thermal conductivity, while maintaining mechanical strength.

Fantili et al. (2017), at the University of Turin (Italy), conducted a study on the mechanical properties of mortars whose composition has been improved by the introduction of wool and hemp. Treated and untreated wool and hemp were introduced into the mortar compositions. The treated wool was introduced as a bed of yarn at a rate of 5 kg / hour, in a device with a plasma electrode that achieved a relevant penetration of the plasma over the entire height of the wool bed. Three-point bending tests were performed, according to EN 196-1, on samples with dimensions of 160x40x40 mm, made of 5 types of mortar compositions.

The introduction of 1% of the mass of the composition of the mortar (10 g) of wool fibers, determined the increase by 18% (untreated) and 23.31% (treated) of the resistance to bending, and by 151% (from 0.056 to 0.141 N/mm) (untreated) and by 166% (from 0.056 to 0.149 N/mm) (treated) of the fracture hardness, G_f. The introduction of 1% of the mass of the composition of the mortar (10g) of hemp fibers, causes the increase by 8% (untreated) and 11.69% (treated), at bending, and by 251% (from 0.056 to 0.197 N / mm) (untreated) and by 276% (from 0.056 to 0.211 N / mm) (treated), at Gf. The application of plasma treatment results in superior mechanical properties for both fibers.

Pennacchio R. et al. (2017), at the University of Turin (Italy), conducted a study on the mechanical and thermal characteristics of mortars, of which they made panels measuring 90 x 52 x 4.5 mm; in the composition of the panels, wool and hemp were introduced.

Wool of inferior quality was used; this is not accepted in the textile industry because it is black, fibers that are too thin and have irregular length. The treatment was minimal, in order to reduce the amount of consumed energy, the wool being washed and dried, but still showing plant residues. *The hemp* used was kept soaked for 4 months. Hemp patches were crushed into fibers measuring 0.2 to 5 cm long and 0.05 to 1 cm thick.

The thermal transmittance was determined, in-situ, according to ISO 9869, for 10 days in winter, with sensors arranged inside / outside a test box of dimensions 4x2,5x3 m, with the northern facade insulated with 2 layers of panels.

To determine the sound absorption coefficient, the reverberation chamber method was used, in the frequency range 100-5000 Hz in the 3-octave frequency band; the panels were free or covered with textile material arranged according to the practical applications, for the protection of the panels and with an aesthetic role. A uniform distribution of acoustic energy and random direction of the incident sound on the panel were obtained.

The values determined for the thermal transmittance U =0.41 W/m^{2}K are comparable to other fibrous insulating materials such as glass wool or mineral wool, compared with 0.21 W/mK of 1.2 cm gypsum boards and with 0.35 W/mK of 1.5 cm concrete panels. From an acoustic point of view, the panels performed well for medium and high frequency sounds, typical for other fibrous materials with the same density, thus can be used inside buildings.

Alyousef et al. (2020), carried out a study on improving the mechanical properties of concrete by adding in the composition 0.5%, 1%, 1.5%, 2%, 3%, 4% and 6% wool, respectively.

The treatment of wool fibers was performed by immersing the fibers in a container filled with salt water (with a concentration of 35%) for 24 hours at an ambient temperature of 22 ÷ 28 ºC, in order to increase the friction surface of the fibers, to ensure good bonding and increase strength. From the achieved compositions a series of 3 samples: cylinders were made, with a diameter of 150 mm and a length of 300 mm - for compression and stretching and prisms of 150 x 150 x 700 mm - for bending.

The workability was determined on the wet samples immediately after the preparation of the compositions; this decreased with the increase of the fiber content, from 55 mm (without fibers) to 0 mm (with 6% fibers), making the concrete denser and of lower workability.

The compressive strength was determined on dry samples for 7, 14, 28, 90 and 180 days. The decrease of the resulted values, as compared to the reference concrete with the strength of 20.94 MPa was observed, as well as the increase of the weight of untreated wool fibers with weight (0 ÷ 6%) as follows: 7-day samples: 5.5 ÷ 79.7%, 14-day samples: 12.5 ÷ 75.2%; samples at 28 days: 9.8 ÷ 64.3%; 90-day samples: 7.7 ÷ 46.9%; 180-day samples: 5.1 ÷ 61.5%, The smallest difference was recorded for the 180-day samples, which means that an increase in drying time causes an increase in the strength of the concrete.

The bending strength was determined on 28-day-old samples. It was observed that the highest strength values were obtained for the samples with a content of 0.5 ÷ 3% of untreated wool, determining a increase, compared to the reference sample, by: 10.86% (0.5%), by 11.22% (1%), by 15.96% (1.5%), 16.46% (2%) and 15.01% (3%) and a decrease of 0.55% (4%).

The microstructural examination of the compositions was done with an electronic scanner in order to identify the defects along the transition interface areas. Due to the chemical reaction between wool fibers and cement microstructure, gels form in the concrete composition that reduce porosity and penetrability, with favorable effects on durability, but increase the weight of fibers to 4%, cause agglomeration of wool fibers and creates gaps around them, being defective in the concrete matrix in the transition zones at the interfaces, losing the connection with the cement, and yielding to lower strengths than the reference samples.

Mounir et al. (2015), in a research program, made soil mixtures in which they added wool fibers in proportions of 3% and 5% and water in proportions of 0.3 (w/g = 0.3). From the created compositions they made samples with dimensions of 10x10x2 cm. For clay-wool composites, the thermal conductivity decreased by 53% for 3% wool compositions and by 63% for 5% wool, this having the role of slowing down the penetration of heat from the outside, because it creates porosity inside the material.

Bosia et al. (2015), at the University of Turin (Italy), performed in-situ measurements on the interaction of formaldehyde with panels made entirely of wool.

To carry out the experiments, panels with dimensions of 600x600x45 mm were made in three density variants. Taking into account the composition of wool fibers (82% keratin, 17% non-keratinous proteins and 1% lipids and polysaccharides), the high protein content offers the possibility of absorption and neutralization of heavy metals and hazardous gases such as nitrogen oxides, sulfur or formaldehyde. Wool panels can reduce the concentration of formaldehyde in the indoor environment by 89.3% in 3 days.

Enache et al. (2018), at INCD "URBAN-INCERC", Timisoara Branch, conducted research on improving the physical properties of earth mortars by introducing 1.5% of sheep wool fibers and sunflower oil.

The use of sheep wool for clay compositions aimed to increase the mechanical properties and to prevent the propagation of cracks during clay drying; due to the anchoring effect of the fibers, the adhesion between clay and fibers increases. The value of the axial contraction decreased by 66% at 28 days after the achievement, the compression strength increased with 108%, the bending strength with 14.36% (Fig. 1) and the adhesion to the support by 87.69% (Fig. 2).

3. CONCLUSIONS

The use of the above materials makes it possible to produce ecological houses from local, natural materials and to obtain superior mechanical, thermal and acoustic properties.

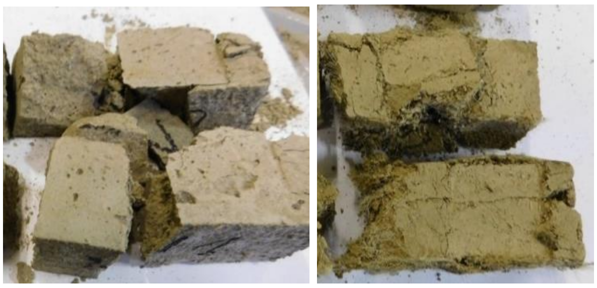

Fig. 1. Aspect of samples of mortar without / with wool after bending and compression

Fig. 2. Aspect of samples of mortar without / with wool

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