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U SUSRET OBNOVLJIVIM IZVORIMA ENERGIJE UZ UPOTREBU KONOPLJE - HEMPKRIT

TOWARDS SUSTAINABLE ENERGY SOURCES USING HEMP - HEMPCRETE

Mihailo SIMIĆ, Vladimir GRUŠKA, Dragan VUCICEVIC, Dražen POŽAR, Aleksandar SAVIĆ
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Ovaj rad ima za cilj da utvrdi prednosti korišćenja industrijske konoplje kao konstruktivnog materijala u savremenoj građevinskoj industriji, sa naglaskom na Hempkrit kao zamenu za glavne konvencionalne građevinske materijale. U ovom radu se takođe razmatra aktuelna globalna ekološka situacija kao ozbiljan problem čiji je jedan od glavnih uzročnika savremena građevinska industrija, kao i mogućnosti korišćenja Hempkrita kao građevinskog materijala, čiji je glavni sastojak industrijska konoplja. Takođe, u ovom radu se analizira metodologija izrade ovog kompozitnog materijala, njegove mogućnosti u konstrukciji i moguća konstruktivna rešenja.

Ključne reči: *održivi materijali; kompoziti; konoplja*

This paper has the intention to determine the benefits of using industrial hemp as a constructive material in the modern construction industry, with emphasis on Hempcrete as a substitute for conventional building materials. This paper also reviews the current global environmental situation as a serious problem, which one of the main creators is the modern construction industry, and the possibilities of using Hempcrete as a building material, whose main ingredient is industrial hemp. Also, this paper analyzes the methodology of creating this composite material and its possibilities in construction, and the possible construction methods.

Key words: *sustainable materials: composites; hemp*

1 Introduction

Modern society, as a logical extension of the antique society, aspires towards the progress of technologies, thereby leaving their architectural heritage for the future generations. This has been an ongoing process, since the creation of the first man's shelters, made from the natural materials known as: earth, wood, straw, moss, etc. Humankind has tended to progress in terms of such development, where one of the dominant aspects is building larger and more complex structures. This concept has led to the creation of the most significant construction material, concrete - more precisely, a special type of concrete, known as Roman concrete, which contained volcanic ash and crushed shells. Over time and with the development of civilization, humankind has significantly improved the idea of concrete as the main constructive material, so today we have concrete of high strength that gives us the possibility of designing and building the most complex structures.

Currently, in a world where there is a global campaign to raise public awareness of the importance of ecology and green building, our society, relying on concrete as the primary building material, has brought itself to a point where the production of concrete alone is the third largest emitter of CO_2 on the planet, with the current production rate of 10-20 billion tons per year [1]. Although there are projects that envisage the recycling of concrete, this process itself also contributes to pollution, by the opinion of the people in and outside the industry [2].

The general vision of the EASC (Ecological Association of Sustainable Construction) is regarding the future development of building materials and their application in architecture and construction sectors. This vision is based on the main goal - the use of natural biodegradable materials, the materials that have to undergo serious research, made with the natural bio-materials:

- Hemp;
- Straw;
- Clay.

Noticing the problem faced by the construction industry and the pollution this industry produces, it would make sense to incorporate the old materials for building houses, all with the intention of raising society's awareness of the advantages of bio-composites over conventional materials.

Everyone who lives in buildings made of conventional building materials is familiar with the problem of energy efficiency and, above all, thermal insulation of buildings. While during the cold period, an additional amount of energy is required (heating with electricity, gas or wood) in order to keep the building warm, in the summer, the use of electricity increases in order to cool the building. The reason for this is that in order to achieve the desired temperature comfort and reach the level of an energy efficient house, a large amount of investment in conventional thermal insulation materials is required to obtain desired temperature comfort, and thus reaching a certain level of energy passivity of the house.

This leads to the subject of natural biodegradable materials, in this case with industrial hemp, which derives its basic advantages from the cellulose part of the plant, which is called pozder. When it is crushed and mixed with a binder (hydrated lime) and water, natural composite material is created, called Hempcrete [3].

The reasons for using industrial hemp to make building materials are the benefits it provides both as a raw plant and as a processed product. For these reasons, it is logical to popularize the use of composite based on hemp – Hempcrete – in construction [4].

The benefits it provides are present both when hemp is used as a raw plant and when it is used as a processed product. For these reasons, it is logical to popularize the use of Hempcrete in construction.

2 What is Hempcrete

Hemp, as one of the earliest cultivated plants (10,000 years ago), which had a wide range of applications for people throughout history. Hemp was found in everyday life and was used for the production of textiles, ropes, firewood and even building materials, but over time it came to the point that it was almost forgotten. Today, with the rising awareness in society of the importance of ecology and energy efficiency in the construction industry, hemp again became essential for the materials with which we build our buildings [5].

Industrial hemp during the lifetime, absorbs twice as much CO_2 as 100 trees daily, and one hectare of industrial hemp can absorb 22 tons of CO_2 per hectare [6].

Regarding the thermal conductivity value (R value of the material, the higher the R, the better the material is an insulator), the use of hemp leads to the reduction of energy needed for heating and cooling, which means that it is a good insulating material.

Also, in terms of sound protection according to EN ISO 11654 (evaluation of sound absorption of materials for use in buildings), this material has a value of C [7], which means that it is suitable for use in housing. With the increasing number of researches on this material, there is a high potential for its use.

The basic building material that can be produced with hemp (industrial hemp) is hemp concrete, i.e. Hempcrete. This is completely biodegradable, hemp-based composite, and has three ingredients like classic concrete: aggregate, binder and water [8]. Hemp hurd (shiv) of different granulations is used as an aggregate, where the size of the hemp hurd granulation can vary depending on the needed aggregate size (Figure 1). Most often, hydrated lime is used as a binder without additional materials. After mixing and with time, two important chemical processes take place in the Hempcrete: petrification and calcification, which contribute to the final properties of the Hempcrete. Petrification (solidification of the material) occurs by absorption of carbon dioxide, which is needed by calcium (hydrated lime) to return to its basic form, i.e. calcite $CaCO_3$ [9]. While the calcification process takes place during the material mixing phase, where the hydrated lime binds to the pods itself due to the low silicate content in the pods.

Figure 1. Hemp aggregate sizes

These processes, as well as the ability of the plant to absorb CO_2 during its life, define Hempcrete as ecological material.

In addition to being completely organic, this material directly affects the reduction of the use of electrical energy for cooling and heating of buildings. Due to the large thermal mass (usually 0.06-0.07 W/mK) that this material possesses, it is able to absorb and release heat, which reduces the need for cooling and heating buildings through air conditioning. Bur for most common thickness of Hempcrete walls d=35 cm) thermal mass of that wall is 0.17 W/m2K.

Hempcrete as a material is resistant to mold and moisture, which is one of the main causes of deterioration of buildings today.

3 Construction methods and benefits of Hempcrete in buildings

The construction system of buildings made of composite biodegradable materials is similar to those of conventional ones, but the most common two are: cast in situ and the system with pre-made blocks.

3.1 Cast in situ

As with the standard Cast in Situ system, the main building material is prepared directly on the construction site and installed in the intended space for the future wall, where the wall formwork can be made of classic wooden boards which are forged together and form the stiff formwork. Alternative to the stiff formwork are larger panels made of moisture-resistant plywood, which speed up the time of production of the wall formwork. With both methods of performing the formwork, an interesting final texture of the wall can be obtained, which does not have to be additionally processed afterwards. Strictly spoken, Hempcrete cannot currently be considered as a structural material but as an infill. It is necessary to make a supporting structure; most often, it is a skeletal wooden structure that has the role of transferring the loads but also of holding Hempcrete fill. The material is poured in 50 cm or thinner layers [10]. The layer thickness is restricted because the applied layer would have time to dry so that after removing the formwork, it can support itself and the next layer of the wall. The drying time of this building system varies depending on the weather and the construction place. The Cast in Situ masonry method is most often used in the summer, where one layer of the wall usually has 1-2 days to reach the required strength before applying the next layer. If the wall was fully executed, it would take up to a month for complete drying and hardening.

Advantages of the Cast in Situ method with Hempcrete are:

1. Technologically simple wall construction technique
2. A lower chance of thermal bridges occurrence in comparison to the masonry brick wall, due to the compaction of the mass that forms a single unit, without breaks in the masonry that can lead to the appearance of thermal bridges.
3. Good thermal insulation of the building, due to "trapped" air inside the wall. The nature of Hempcrete material is to entrain a large amount of air, which contributes to the insulation of the wall.

4. It does not require great expertise of the workforce to carry out this method, workers don't need high expertise knowledges
5. Possibilities of modification and obtaining different forms of walls and slabs are vast in the case when Cast in Situ method is used.

Disadvantages of Cast in Situ methods include:

1. A relatively long period of drying and final hardening of the material, which depends on external ambient conditions and the environment where the building is constructed.
2. The use of a large workforce, i.e. the number of workers for execution.

3.2 Hempcrete block construction system

Another represented system of construction with Hempcrete is the use of prefabricated blocks. As with conventional blocks, Hempcrete blocks are produced in special factories and brought to the construction site where they are installed [10]. The way blocks are produced varies depending on the assembling system; they can be full blocks, with side grooves for installation, with openings on the lower sides of the block, etc. Variations in the method of installation and mutual strengthening of the blocks are large, which contributes to the variety of system solutions. Nevertheless, the manufacturing principle is the same, mould and a press are needed to make the blocks, which will form the final appearance and give it the strength needed to be installed. This way a large amount of Hempcrete can be placed on the construction site without additional waiting for the material to dry and harden. Also, this system requires a pre-made structure into which the blocks will be built. The advantage of pre-fabricated Hempcrete blocks compared to conventional blocks in terms of construction is that they can be cut to the appropriate size on the construction site and installed. Blocks can be connected to each other, in addition to the mechanical connection, by using lime-based mortar.

Advantages of the Hempcrete block construction system:

1. More massive production of blocks can be produced at the industrial level that the market demands;
2. Faster construction of buildings without additional waiting for the material to harden;
3. It can be used for building not only in the summer period, i.e. it can be built with them throughout the year because the blocks have already hardened and dried in the factory;
4. Achieving higher compressive strength, adding additives or less binding material. This also reduces its insulating power;
5. Use for larger projects where a higher building height is required.

Disadvantages of the Hempcrete block system are:

1. Higher density and compressive strength reduce its insulating capabilities;
2. The possibility of the existence of thermal bridges, due to the greater number of breaks in the wall;
3. More energy is spent on the production of blocks.

3.3 The possibility of using prefabricated walls

Prefabrication is a construction process that involves making previously designed modules (e.g. walls) in factories. After the materials have dried and hardened, they are taken to the construction site to assemble them as a whole. This principle of construction, especially in residential buildings in our region (former Yugoslavia), was the most prevalent in the 20th century, when the construction time was extremely shorted.

In terms of Hempcrete, it would require an already designed building, divided into separated modules that would be made in factories in special molds that would later be taken to the construction site. This type of construction combines the two basic principles of Hempcrete (Cast in Situ and the Block system) because the mass itself would be poured into molds that would wait the necessary time until the material solidifies. This also requires that all the necessary installations be set up before the actual pouring of the material.

Advantages of using prefabricated walls:

1. The speed of building objects;
2. Fewer workers are needed;
3. Independence from weather conditions and seasons for the needs of construction;
4. Possibility of a larger production of typical objects
5. Good environmental impact [11].

Disadvantages of using prefabricated walls:

1. The complexity of the project;
2. Transportation of elements - the problem of transporting large prefabricated elements;
3. The possible occurrence of thermal bridges at the joints of elements;
4. Fixed installations - the problem of subsequent installation or relocation of installations.

4 Conclusion

During the period of massive development of building materials and systems, society failed to pay attention to the key benefits of conventional materials, without excessively considering the impact of the building materials production and application on the environment, without realizing how the production process and the lifespan of a material affect the world around us. This has led to the fact that the construction industry is one of the main carriers of global pollution that we are all currently witnessing.

Besides making the construction industry more sustainable, we should find new ways to reduce the present pollution as much as possible. Currently, where the global trend of society is ecology and energy efficiency, Hempcrete is becoming an increasingly popular and logical choice for one of the main building materials. Despite the global decision to remove industrial hemp (the main ingredient of Hempcrete) from usage, evidence remains that in the past, this material was the basis of our society, and not only in the construction industry. Today, we rediscover its possibilities and strive to improve this material through building composites and expand its use in construction.

The paper illustrated the Hempcrete capabilities to correspond to the principles of green construction. The “greening” of the energy industry sector is already taking place fast, providing a good place to practice advanced ecological and sustainable building materials and building systems in this sector. When critically evaluated, many of the support and temporary structures in the sustainable energy sources industry can be built from Hempcrete.

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