

# Hemp-Lime Bio-Composites – Properties and Applications in Architectural Design

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**Abstract** – This paper discusses physical properties and applications of hemp-lime bio-composites in architectural design. Hempcrete is a new, innovative construction material with significant ecological benefits, which gains popularity all over the world. Research on this topic is being conducted in many areas: material science, civil engineering, agriculture, ecology and architecture. The aim of this work was to review the worldwide publications and systemize the knowledge about the issue to provide information designated mainly for architects.

Keywords – hempcrete, hemp-lime composite, sustainable construction materials

## I. Introduction

Construction is responsible for very high energy consumption and consequently significant share in GHG emission. Production of construction materials causes about 8 – 12 % of global CO<sub>2</sub> emission [1]. Materials, because of their physical properties, have also impact on energy efficiency of the buildings.

Energy efficiency policy, implemented in line with the widespread recognition of the need to protect the environment and the climate, led to development of an entire branch of „green” architecture. „High-tech” solutions, which include complex installations, control systems and superior insulation (often using synthetic or toxic, high embodied energy materials) are the mainstream, but at the same time, a „low-tech” approach exists and develops at the opposite pole. It focuses on using natural materials and natural physical phenomena in order to save energy and provide favourable living conditions, rather than invest in expensive technical infrastructure.

Hemp-lime composites are materials with properties that provide significant opportunities to exploit in design of „low-tech” sustainable architecture.

## II. Production process and physical properties

The composite is obtained by mixing the following ingredients: hemp shiv, lime-based binder, and water (sand may be also added to the mix).

Hemp shiv is an inner part (a core) of *Cannabis Sativa L* (industrial hemp) stem, obtained in decortication process and chopped into particles (diameter of 1 – 5 mm and length of 5 – 35 mm are dimensions desired for building purposes [2]). It constitutes about 70% of the plant mass – fibers (as well as flowers and seeds) are removed and used for other purposes in other industries. Cellulose represents 40,4 – 51,7% of the its chemical composition [2].

Cultivation of the plant has low negative impact on the environment (comparing to other crops) [3,4] and absorbs CO<sub>2</sub> from the atmosphere (approx. 2,5 tons per ha [2]). Processing of hemp involves no chemicals and produces no waste [2].

Lime-based binder is a mix of binding substances with the largest share of hydrated lime. Other ingredients often present in the mix are: cement, natural hydraulic lime, pozzolans and other additives (in different proportions, depending on the expected properties). Production of a binder consumes energy and causes considerable carbon dioxide emission. Carbonatation process which occurs in building partitions, lowers the final emission.

The material has low mechanical strength, quite low thermal conductivity and high vapor permeability [5]. It is fire resistant [5]. Lime content provides resistance against biological corrosion [5]. The properties can vary to a great extent depending on: characteristics of the organic infill, characteristics of the binder, proportions of the ingredients in a mix and construction technique (associated technological process of manufacturing the material may result in different density and other properties). An example of properties of the material provided by an European producer [6] are shown in table 1. These values fall within the ranges found in the publications. Table 2 shows other parameters based on the publication review.

Properties of the material provide environmental benefits. Low thermal conductivity, medium density and quite high specific heat results not only in a good insulation but also in a considerable „thermal mass” of the building elements. The overall carbon dioxide emission is an important factor as well – the material is considered to have low, zero or negative carbon footprint (depending on properties and methodologies used for calculations). Overall CO<sub>2</sub> emission in *cradle to grave* approach can be negative (-3,5 kg/m<sup>3</sup> in the most probable variant in [7]).

TABLE 1

PROPERTIES OF THE MATERIAL ACCORDING TO EUROPEAN PRODUCER

Density	280 – 320 kg/m <sup>3</sup>
Compressive strength at 90 days	0,7 – 0,9 Mpa
Thermal conductivity	$\lambda = 0,076 - 0,085 \text{ W/mK}$

TABLE 2

OTHER PROPERTIES OF THE MATERIAL ACCORDING TO SELECTED PUBLICATIONS

Specific heat	1000 – 1560 [8] J/kgK, generally about 1300 J/kgK
Vapor diffusion coefficient	4,61 – 5,72 [8,9] generally about 5
Carbon capture (cradle to gate)	-358 – 62 kg/m <sup>3</sup> generally about -100 kg/m <sup>3</sup> [5]

### III. Construction techniques and architectural applications

The material can be used in construction in the form of: monolithic walls manually compacted in a 2-sided formwork with structural (timber or steel) frame inside; monolithic walls or vertical insulation layers manufactured by projection (spraying) the mix on a one-sided formwork; precast blocks or bricks ready for bricklaying; prefabricated entire building elements or horizontal insulation layers (less dense, only slightly compact).

Modern history of the material began in late 1980s, when it was invented specifically for renovation of historical wattle and daub buildings in southern France. Fig.1 shows the first building where the material was used. Properties of the material, allowing resistance in damp environment and providing good „cooperation” with wood, brought success in the renovation works. Later, the material was improved and used in new buildings world-wide (most of them were built in France and UK where the technology has developed to the highest extent).



Fig.1 [10] Maison de la Turquie – Nogent-sur-Seine France. Renovation in 1986.

Experimental buildings with partitions made of hempcrete revealed excellent thermal and moisture performance [11]. Application techniques allow to minimise thermal bridging and increase air-tightness. Low thermal diffusivity may result in lower heat loss than expected from  $\lambda$  value [9]. Hempcrete partitions provide high inertia against temperature fluctuations and stabilize temperature in the rooms [12]. „Breathability” of the partitions helps to regulate humidity of the interiors and creates favourable microclimatic conditions [13].

### Conclusion

An analysis of the properties and applications of hempcrete, as well as laboratory tests and experiments conducted in the existing buildings confirm usefulness of the discussed material in architectural design and its high potential for development of environment- and user-friendly architecture.

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