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Research Article

"A Review on the Mechanical Properties and Environmental Benefits of Hempcrete"

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ARTICLE INFO	ABSTRACT

This review explores the comprehensive comparative analysis of the strength and durability properties between hempcrete and conventional concrete, aiming to provide detailed insights into their performance characteristics. Hempcrete, an innovative bio-composite material composed of hemp hurds, lime, and water, has emerged as a promising sustainable alternative to conventional concrete due to its renewable nature, low carbon footprint, and potential environmental benefits. This paper discusses various properties and applications of hemp and hempcrete such as mechanical performance and durability, with a focus on its carbon sequestration ability and carbon negativity, and the current research interest as well as its possible contribution towards solution of climate change problems.

Keywords: hemp, hempcrete, lime, durability, sustainability, carbonation, carbon-negative, water absorption, compressive strength.

I. Introduction

In construction, hemp refers to a variety of Cannabis sativa, primarily used as hempcrete—a bio-composite material made from the inner woody core of the hemp plant (hemp hurds) mixed with lime and water. Hempcrete is energy-efficient and low-carbon, as it doesn't require heating during production. It is environmentally sustainable and offers thermal insulation, fire resistance, acoustic absorption, and strong mechanical properties. Buildings and construction account for 40% of global CO_2 emissions, so reducing carbon footprints in this sector is crucial.

Bio-based materials are gaining attention in various industries, including construction, for their potential to reduce greenhouse gas emissions. These materials, derived from sources like wood, straw, hemp, flax, wool, and mycelium, are seen as sustainable alternatives [9]. Hemp, in particular, is notable for absorbing carbon dioxide, growing rapidly in 3-4 months, and serving as a carbon-negative building material. Hempcrete, made from hemp hurds, lime, and water, is sustainable and eco-friendly, aligning with goals for reducing carbon emissions in construction [10].

The proportion of hemp in hempcrete significantly affects its density, thermal conductivity, and mechanical properties [8]. By measuring these properties, we can evaluate the future potential of hempcrete as a building material. Hempcrete's success lies in its carbon-negative status, thanks to its agricultural origin and lime binder. It reduces energy consumption in buildings, leading to lower cooling and heating costs over the building's life cycle. Increased hemp availability is expected to reduce hempcrete costs, making it more appealing for builders and homeowners. This paper aims to compare hempcrete with conventional concrete, focusing on hempcrete's density, durability, thermal and mechanical properties, and environmental sustainability.

II. Literature Review

A. Hemp

Hemp is developed within the tropical locales of the world. It is one of the prevalent crops in those locales. The organic scientific name of this plant is Cannabis Sativa. The filaments produced from the hemp stack is used as a building item along with lime and cement [3]. Hemp may be a quickly developing annually abdicated (1.5 - 4 m height). The most part created for its tall inflexibility common fiber which is being created within the shoot , adjacent to the timbered center of the plant [4]. Hemp is cultivated for different purposes, majorly for the stem's bast fiber. The stem comprises two parts: a fiber sheath wrapped around a woody center known as shive, Hurd, or shive, and the stem itself [5].

Fig 1: Hemp Plant & Hemp Hurd

B. Hempcrete

Hempcrete (a composite) is made from hemp shive and a lime-based binder. It is significantly influenced by its components. Cellulose in hemp shive provides flexibility and insulation because of its porosity, hemi-cellulose binds the fibers and controls moisture. Also, lignin adds compressive strength and decay resistance. Extractives affect color, odor and durability. The strength and longevity of hempcrete are directly related to the concentration of cellulose and lignin in the hemp shive, with higher amounts that enhance its quality and lifespan [6].Cellulose and hemi-cellulose in hemp shive provide inherent porosity which enhances thermal insulation by blocking the transfer of heat and cold. These fibers also bestow to sound dampening, with higher levels improving hempcrete's sound absorption capabilities. Hemicellulose's ability to manage moisture absorption and release helps in maintaining optimal indoor humidity. In addition to, the presence of lignin in hempcrete enhances its fire resistance because lignin is a natural fire retardant [2],[7]. Hempcrete is made by mixing the inner woody core of the hemp plant (hurd/shive) with lime, water and a little amount of concrete [1]. This paper introduces hempcrete as a reliable construction composite material, focusing on its mechanical properties. It explores hempcrete's practical applications and uses , advantages, limitationsand highlighting its viability as a sustainable and eco-friendly building material.

III. Properties of Hempcrete

A. Compressive Strength

The ability of a material to withstand compressive loads without failing or changing its shape, characterizes the compressive strength of that material. There is slight variation in compression property of hempcrete since it is made up of hemp which is a natural product. Comparatively, hempcrete has remarkably lower compressive strength than concrete. Moreover, it can’t be used as a load bearing material on its own.

Many factors are responsible for the limited compressive strength of the material such as the arrangement of the shives, the high flexibility of the aggregate, the nature of the binder and the high porosity of the end product. Hempcrete’s compression strength can be affected by numerous factors as the type of the binder, the shiv/binder ration (S/B), the water/binder ratio (W/B), the curing and molding conditions and the production method. Studies have evaluated about how the different curing conditions (30%,75% and 90%), the binder content and the particle size affect the setting and hardening of the material along with some critical mechanical properties as the compressive strength and the modulus of elasticity [12].

By Increasing the binder proportions and increasing the density of the mixture with compaction, the performance of hempcrete in compression can be improved. Moreover, studies have shown that replacing an amount of lime with clay results to the creation of hydraulic compounds which can also affect the compressive strength in a affirmative manner. [14].

B. Thermal Behaviour

One of the tempting properties of hempcrete is its high-temperature resistance. Due to the cellular composition of hemp hurd, it shows eminent warm resistance, subsequently, advancing vitality effectiveness [15]. In situ monitoring and laboratory experimental studies havedisclosedhempcrete's favorable thermal properties. Depending on the mixture, hempcrete'sthermal conductivity (λ) can range between 0.06-0.18 W/(mK) for dry densities between 200 and 800 kg/m3 [13]. Hempcrete combines both micro and macro pore scales.
There is interconnection between Micro pores found within the hemp hurd and macro pores found within the hempcrete. According to studies, the porosity of hempcrete can range between 71.1% and 84.3% by volume. The level of porosity can affect the thermal properties of the hempcrete product because the conductivity is closely related to the density of a material and increases with a quasilinear relation. Other studies, have revealed that an increase of 50 kg/m3 in the density of the material can result to a rise of 0.005 W/mK in the thermal conductivity of the material. Unusual thermal conductivity values that range between 0.07-0.09 W/mK have been reported [11].

Additionally, hempcrete's thermal conductivity increases with an increase in the relative humidity levels. Besides of its ability to store heat, the hygro-thermal properties of hempcrete also affects the material's thermal conductivity. Water is considered as a significant heat conductor ascompared to dry air, which is reflected on the difference between their thermal conductivity values (λwater =0.6 W/(mK) and λai r =0.026 W/(mK) respectively). Studies have revealed that the thermal conductivity of hempcrete can increase even by 30% in humid environments, as the capillary condensation of water into the pores of the material is unfavorable for the thermal insulating performances [16].

C. Moisture Regulation

Hempcrete's high levels of permeability and hygroscopicity are related to the high porosity of the aerogel structure of the shiv. When an ample binder is selected (e.g. binders with high amounts of calcium lime) these properties can be further enhanced. Hempcrete shows high performances in indoor moisture regulation. High indoor humidity concentrations allows the condensation of the water vapour inside the material and thus the developed concentrations be avoided.
In contrast, in indoor air-dry conditions, hempcrete releases the moisture which is concentrated in the interior of the material back to the environment [11]. Tests have been performed on walls made of precast hempcrete blocks to monitor the hygro-thermal response of the material in different temperature and RH conditions for both coated as well as uncoated hempcrete walls. According to the results, the uncoated wall has a short response to temperature and RH, which were influenced by the setpoints of the experiment. On the contrary, in the case of a constant vapour pressure with a reduction on the temperature, the variations of the ambient temperature increased remarkably. In the case of the coated wall, the additional vapour resistance that is present to the assembly due to the coating, had led to a reduction in the vapour pressure through the wall and a delay in the vapour diffusion. Nonetheless, it did not stop the sorption-desorption and/or evaporation-condensation phenomena.

D. Durability

According to studies, in general hempcrete is a durable material that can endure the majority of factors which often cause the degradation of the usual building materials. Hempcrete constructions are not prone to degradation caused by salt exposure, as the size of the pores is relatively large and hinders crystallization. The alkalinity of the lime creates an unfavorable environment for mold and insects as well as the absence of nutrients hinders the growth of microorganisms [13]. The high levels of permeability and hygroscopicity allows hempcrete to undergo repeated absorption and desorption of moisture for an almost unlimited period of time. However, attention must be paid to the selection of external coverings, where moisture can be trapped which can affect the durability of hempcrete [11]. Due to the high levels of hempcrete's water permeability, the selection of appropriate coating is of major importance so as to avoid the entrapment of moisture inside the material that could lead to its degradation. Experiments have been performed to assess and gauge the behavior of hempcrete and the influence of different coatings in climate conditions.

E. Sustainability

Sustainable materials plays an important part in the creation of energy efficient constructions ensuring that no compromises are made at the expense of the environment, the society or the users. Nowadays, various parameters defines the level of sustainability that characterizes a material . Some of these parameters are the number of emissions that are created during the lifetime of the material as well as its embodied energy, the level of intervention in the nature and the landscape, the circularity re-usability and recyclability potential, the durability of the material, the type and use of resources and its efficiency in reducing energy consumption and

creating comfortable indoor environments. Hempcrete is a bio-based carbon negative material (-0.15 kg CO_2/kg). The higher environmental impact is displayed during the production of the binder. Its primary material hemp absorbs significant amounts of CO_2 during its cultivation. According to studies, hemp has been found to sequester 1.84 kg of CO_2 per kg of dry hemp through photosynthesis during its growth.
Additionally, after its manufacture hempcrete continues to absorb CO_2 from the atmosphere via carbonization. The total amount of sequestered CO_2 has been estimated to compensate for the production of lime and even result in negative levels of embodied carbon. Additionally, hempcrete is a durable and long-life material. Carbonization takes place in the operational phase of the material and results in the increase of its mechanical strength over time. As a result, the need for any alternative of the material is extremely rare. The recycling of hempcrete is possible, as it can be crushed and re-used in new hempcrete mixtures or insulation fillers . However such procedure is suggested to be avoided as it results in a down-cycling of the material [17].

IV. Conclusion

Hempcrete, a sustainable building material made from the hemp plant, lime, and water, offers significant environmental benefits, including energy efficiency, carbon sequestration, and reduced CO_2 emissions. Its thermal insulation, fire resistance, and durability make it a viable alternative to conventional concrete. As the construction industry increasingly adopts bio-based materials, hempcrete stands out for its potential to create energy-efficient, cost-effective, and environmentally friendly buildings. The material's rapid growth cycle and carbon-negative properties further enhance its appeal, positioning hempcrete as a key player in advancing sustainable construction practices.

References

1. R. Brencis, S. Pleiksnis, J. Skujans, A. Adamovics, U. Gross (2017), Lightweight composite building materials with hemp (Cannabis sativa L.) additives, Chem. Eng. Trans. 57 1375-1380.
2. Ahmed, J.S.; Sudarsan, S.; Parthiban, E.; Trofimov, E.; Sridhar, B. Exploration of mechanical properties of hemp fiber/flax fiber reinforced composites based on biopolymer and epoxy resin. Mater. Today Proc. 2023.
3. J.C. van Empelen (2018), A study into more sustain able, alternative building materials as a substitute for concrete in tropical climates, 1-26.
4. Sutton, D. Black, P. Walker (2011), BRE, IME An introduction to low-impact building materials, BRE. 1-6.
5. T. Woolley, "Hemp lime construction: A guide to building with hemp lime composites," 2008.
6. TG, Y.G.; Ballupete Nagaraju, S.; Puttegowda, M.; Verma, A.; Rangappa, S.M.; Siengchin, S. Biopolymer-Based Composites: An Eco-Friendly Alternative from Agricultural Waste Biomass. J. Compos. Sci. 2023, 7, 242.
7. Phiri, R.; Rangappa, S.M.; Siengchin, S.; Oladijo, O.P.; Dhakal, H.N. Development of sustainable biopolymer-based composites for lightweight applications from agricultural waste biomass: A review. Adv. Ind. Eng. Polym. Res. 2023, 6, 436–450.
8. Barbhuiya, S.; Das, B.B. A comprehensive review on the use of hemp in concrete. Constr. Build. Mater. 2022, 341, 127857.
9. Ortega, F.; Versino, F.; López, O.V.; García, M.A. Biobased composites from agro-industrial wastes and by-products. Emergent Mater. 2022, 5, 873–921.
10. Kumar, V.; Ramadoss, R.; Rampradheep, G. A study report on carbon sequestration by using Hempcrete. Mater. Today Proc. 2021, 45, 6369–6371.
11. Sutton, D. Black, P. Walker (2011), BRE, IME An introduction to low-impact building materials, BRE. 1-6.
12. Barbhuiya, S.; Das, B.B. A comprehensive review on the use of hemp in concrete. Constr. Build. Mater. 2022, 341, 127857.
13. Sawpan, M.A.; Pickering, K.L.; Fernyhough, A. Flexural properties of hemp fibre reinforced polylactide and unsaturated polyester composites. Compos. Part A Appl. Sci. Manuf. 2012, 43, 519–526.
14. TG, Y.G.; BallupeteNagaraju, S.; Puttegowda, M.; Verma, A.; Rangappa, S.M.; Siengchin, S. Biopolymer-Based Composites: An Eco-Friendly Alternative from Agricultural Waste Biomass. J. Compos. Sci. 2023, 7, 242.
15. Abdellatef, Y.; Khan, M.A.; Khan, A.; Alam, M.I.; Kavgic, M. Mechanical, thermal, and moisture buffering properties of novel insulating hemp-lime composite building materials. Materials 2020, 13, 5000.
16. Kumar, V.; Ramadoss, R.; Rampradheep, G. A study report on carbon sequestration by using Hempcrete. Mater. Today Proc. 2021, 45, 6369–6371.
17. Wagner, C. (2015). Basics of Industrial Hemp - an open textbook (Large print ed.). Open Hemp University. https://doi.org/10.13140/ RG.2.1.2795.2165