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Experimental Study on Hempcrete as A Sustainable Green Building Material

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----------ABSTRACT----------
Hempcrete is a sustainable, carbon negative and bio composite material prepared from mixing hemp hurds, lime binder and water. Due to the rise of greenhouse gas emission, there is need for developing and using of sustainable alternatives for better future practices. In these modern days, Hempcrete plays an important role in maintaining sustainable alternatives for better sustainable building practices. This study shows how hempcrete as a sustainable bio composite helps in modern building practices and act as an ecofriendly alternative for non-load bearing applications. Because of its low compressive strength which limits its purpose of using in building material. These studies involved preparation of hempcrete cubes which consists three samples of samples of different mix ratios and test it on laboratory for evaluating compressive strength, specific gravity and water absorption at different curing duration. Results showing hempcrete uses a light weight, energy efficient, and sustainable material fulfilling the need for further studies to enhance the properties of hempcrete and durability for higher applications in the building process.

Keywords: *Hempcrete, Carbon negative, non load bearing, Hemp hurds, Lime binder.*

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I. INTRODUCTION

In modern days, construction industries are challenged to minimize their energy use and carbon footprint. Both commercial and residential structures consume a high amount of energy for operating and developing. Process of building construction and operations are directly related to a large amount greenhouse gas emission, especially carbon dioxide. The past few years have faced an increasing awareness of our limited resources and this has prompted the industry to rethink its present construction approaches and utilization of traditional construction materials such as concrete, wood and structural metals (mostly steel and aluminum). The concerns surrounding sustainability of modern construction processes have resulted in research and development of alternative construction materials/building systems. One such possible building material that is being examined nowadays by the construction industry is hemp. Hempcrete is a sustainable, carbon negative and bio composite material prepared from mixing hemp hurds, lime binder and water. It is a plant-based building material made with less impact on environment which decrease both energy and natural resources consumption. Hempcrete is also a cost effective and has a sustainable property leading to a promising material for renovation and new projects for building process. Mechanical, acoustic and thermal property of hempcrete have been widely studied. But its modulus of elasticity and compressive strength are low as well. So, hempcrete can be used as an infill in timber stud walls, but it cannot be used as a direct load bearing material.

II. LITERATURE REVIEW

The paper discusses the principal constituents of hempcrete and then considers the prospects and limitations of the material. This study provides an in-depth analysis of the present research on the use of hempcrete as a sustainable building material. In addition, the study discusses different building processes and practical applications, binders, mix designs, and the features of hempcrete from fresh-state properties to the mechanical, durability, thermal and acoustic properties of the material.[1] This study is devoted to the usage of hempcrete as an eco-friendly alternative to the conventional building materials. Hempcrete is a mixture of hemp shiv, lime-based binders and water. It is a lightweight, non-load-bearing material with good thermal insulation and moisture management capabilities. The review shows low density, moderate compressive strength (0.2-3.5 MPa) and poor

thermal conductivity which can be employed for energy efficient buildings.[2] Industrial hemp and its applications in different sectors focusing on sustainable building materials. The review deals with the processing of hemp stalks by retting and fiber extraction methods for manufacture of hemp fiber and hemp hurds for industrial purposes. The paper also says that hemp hurd is used to make hempcrete, a light-weight bio-composite of hemp hurds, lime binder and water.[3] Lime hemp concrete (LHC), commonly termed hempcrete, is a sustainable bio-based construction material obtained by blending hemp shiv and lime binder. It is intensively researched due to its low density, thermal insulation capabilities and lesser environmental effect compared to traditional concrete. However, earlier research have revealed low compressive strength of hempcrete (usually less than 2 MPa) which limits its structural usage. Nguyen's research found that compaction during casting improved the strength and stiffness of hempcrete by reducing internal voids.[4] The eco-friendly bio-composite material named Hempcrete is created from industrial hemp shiv, lime binder and water. Research has shown that hempcrete is a sustainable alternative to standard concrete owing to its low carbon impact and regenerative nature. Industrial hemp (Cannabis sativa L.) is fast growing, requires little water and fertilisers and takes up high amounts of carbon dioxide during production. Several studies show that hempcrete, because of its porous nature provides thermal insulation, acoustic performance and moisture control.[5] Hempcrete is a green building material composed of hemp shiv, a lime and water. The porous nature of hempcrete gives high thermal insulation, sound absorption, moisture control and fire protection. Researchers say hempcrete is lightweight and sustainable, absorbing carbon dioxide as the hemp grows and reabsorbing CO2 when the lime binder cures. Different binders and mixing ratios have been investigated to increase the strength and durability of hempcrete. Previous studies have shown that hempcrete is a promising sustainable building material for green buildings in general.[6] Hempcrete is a bio-based building material composed of hemp shives, lime binder and water. The authors have shown that hempcrete is a material with good thermal insulation, moisture control and sound absorption capabilities and can be used in the construction of sustainable structures. Life Cycle Assessment (LCA) studies have shown that hempcrete is less damaging to the environment than traditional building materials. Hemp absorbs carbon dioxide as it grows and a lime binder also absorbs CO_2 during carbonation, meaning that hempcrete is a carbon negative material. [7]

III. MATERIALS AND METHODOLOGY

3.1 Materials

The following materials are used in this study

1. Hemp: Hemp (Cannabis sativa) is an agricultural crop, which can be used as a construction material combined with lime and cement. Hemp is a fast-growing annual crop (1.5-4m height) farmed largely for its high tensile force natural fibre which grows in the stem surrounding the woody core of the plant. The woody core of the plant is cut into small sizes (5-25mm) (hurd/shive) and then mixed with water and lime (to decrease the setting time) to make a bio-composite mix called hempcrete..
2. Hydrated lime: The primary component of non-hydraulic lime is often more than 95% calcium hydroxide, or Ca (OH)2. Quicklime (calcium oxide) is created by heating sufficiently pure calcium carbonate to between 954° and 1066°C in order to drive off the carbon dioxide and create non-hydraulic lime. This is carried out in a kiln for lime. After that, the quicklime is slaked, or hydrated, by thoroughly mixing it with enough water to make a slurry (lime putty) or with less water to make a dry powder (hydrated lime; calcium hydroxide). The complete process by which hydrated lime mix with the carbon dioxide in the atmosphere and spontaneously returns to calcium carbonate is known as the lime cycle.
3. Water: Water is an inorganic compound having the formula H2O. It is a chemical compound that is colourless, odourless, and virtually colourless. It is the major component of all known living species, streams, lakes and oceans of the Earth, where it serves as a solvent. Water is a polar molecule and has strong intermolecular hydrogen bonding which is a huge contribution to its physical and chemical features. It act as major role in hydration process in cement, which leads the binding of aggregates together to form a strong and durable material. The property and quantity of water can affect its workability, strength, durability and overall performance.

3.2 Mix Design

Three different types of samples were moulded using hempcrete. The samples were mixed at different mixing ratio. The mixing ratios are shown in Table 1. The 1st sample was moulded with a lower water ratio. The 2nd sample was moulded with high water ratio and 3rd sample was moulded with a little lower lime ratio than 2nd sample.

Table 1-Quantity of materials for sample 1

MATERIAL	RATIO	QUANTITY(Kg)
HEMP	1	0.337
WATER	1.5	0.506
LIME	1.5	0.506

Table 2-Quantity of materials for sample 2

MATERIAL	RATIO	QUANTITY(Kg)
HEMP	1	0.305
WATER	2.5	0.763
LIME	2	0.610

Table 3-Quantity of materials for sample 3

MATERIAL	RATIO	QUANTITY(Kg)
HEMP	1	0.336
WATER	2.5	0.840
LIME	1.5	0.504

IV. RESULTS AND DISCUSSION

4.1 Results

The results are given in table 4 and 5 for various mixes and average load and average compressive strength is found as in tables for 14 days and 28 days

Table-4: Compressive Strength Test for 14 days of curing.

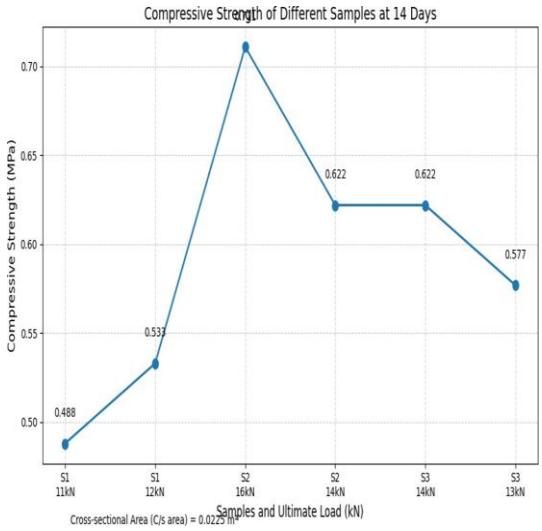
Sample	Ultimate load (kN)	C/s area (m2)	Compressive strength (Mpa)	Average
1	11	0.0225	0.488	0.592
	12		0.533	
2	16		0.711	
	14		0.622	
3	14		0.622	
	13		0.577	

Table-5: Compressive Strength Test for 28 days of curing

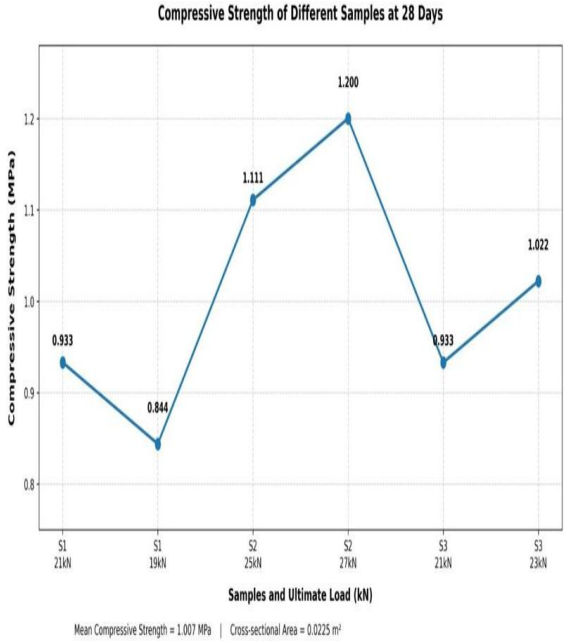
Sample	Ultimate load (kN)	C/s area (m2)	Compressive strength (Mpa)	Average
1	21	0.0225	0.933	1.007
	19		0.844	
2	25		1.111	
	27		1.2	
3	21		0.933	
	23		1.022	

4.2 Discussion

The compressive strength test result for both 14 and 28 days of curing are given below as a graph.



Hempcrete had a lower compressive strength than traditional concrete but was within the allowed limit for non-structural use. The maximum average compressive strength of 0.666 MPa was obtained for sample 2. Better strength was attributed to higher lime concentration as lime is the main binder. Mean Compressive Strengths: Sample 1-0.592 MPa , Sample 2-0,666 MPa , Sample 3-0.599 MPa. Sample 3 had less lime concentration, hence there was less bonding, less strength. The effect of water to binder ratio was more profound on strength development. Excess water increased porosity, and decreased density and compressive strength.



The results showed that all hempcrete samples had a considerable increase in compressive strength after 28 days of curing. The sustained hydration and carbonation of the lime binder was responsible for the improvement in strength. The maximum average compressive strength was obtained in sample 2, which is 1.156 MPa. Higher lime level boosted the bonding between hemp particles and also increased compactness of specimens. Higher lime level boosted the bonding between hemp particles and also increased compactness of specimens. Average crushing strengths: Sample 1- 1.007MPa, Sample 2-1.156 MPa, Sample 3-0.978 Mpa . It was proved that lime content was a crucial component affecting the mechanical performance of the hempcrete. All mixes demonstrated a significant strength improvement over the 14-day results. Lime also carbonates slowly over time, so hempcrete continues to get stronger. The obtained strength values are in the range of the typical hempcrete values of 0.2–3.5 MPa described in the literature.

4.3 Comparision of hempcrete and traditional concrete

The compressive strength of traditional concrete (20-40 MPa) is much stronger than that of hempcrete (0.592-1.156MPa) due to the dense cement-aggregate matrix of concrete and lightweight and porous structure of hempcrete. Therefore, hempcrete is not suited for structural load-bearing applications but it has various advantages such as reduced density, improved thermal and acoustic insulation, humidity regulation and improved indoor air quality. Hempcrete is an environmentally sustainable material due to its capacity to sequester carbon. Hemp plants take CO_2 in growth and the lime binder also absorbs CO_2 by carbonation. Hempcrete's carbon footprint is around 35 kg CO_2e/m^3 whereas normal concrete's carbon footprint is 240 kg CO_2e/m^3. This can have a huge impact on the environmental footprint of buildings. The study indicates that the strength of hempcrete rises with curing time, due to enhanced internal bonding and lime carbonation. Increasing lime content improves the compressive strength. Hempcrete with more water has less porosity and strength. Under compression it shows quasi-ductile behaviour and needs good curing for best results. Hempcrete is a lightweight, thermal efficient and sustainable material so can be used in non-load bearing applications such as partition walls, infill panels, insulation blocks and green building construction. Hempcrete is an interesting green material for ecological and energy efficient buildings, but cannot replace ordinary concrete for structural elements.

V. CONCLUSION

The specific gravity for hemp hurd achieved was 0.67, that is less than that of normal aggregates i.e. 2.4-2.7 and the achieved value says that hemp hurd is a lightweight material and it shows that the porous structure of hemp has high water absorption.The compressive strength test results were 0.592 Mpa and 1.007 Mpa at 14 days

and 28 days respectively, the values obtained are within the usual range of 0.2-3.5 Mpa for non-structural hempcrete applications. In comparison with the normal concrete, the strength were very less than that of normal concrete i.e. 20-40Mpa which confirm the application of hempcrete is limited to non-load bearing uses. Strength development was improved by increasing the lime concentration, and strength gain over time was achieved by longer curing times duration, which led to progressive hydration and carbonation.

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