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EMBODIED CARBON IN CONSTRUCTION MATERIALS: THE POTENTIAL ROLE OF HEMPCRETE

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by **Australian Institute of Quantity Surveyors**

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from cement-based materials used in construction. Due to the significant impact of the construction sector on the environment, creating new materials with lower environmental impact has become a crucial and pressing matter. One possible approach is to minimise the use of non-renewable resources. For example, in the context of structural concrete, using recycled aggregates from construction and demolition waste has been explored as a potential replacement for natural aggregates.

SOME CONSIDERATIONS MODEL...

At present, most constructed spaces utilise concrete, which mainly consists of cement (typically Portland cement), aggregates, and water. In order to produce cement, a binding agent is necessary, which is typically lime-based.

There are two major sources of GHGs during the manufacture of cement.

Firstly, carbonation happens during the heating of limestone to produce lime, wherein calcium carbonate is transformed into calcium oxide and CO2 is released in the process. This procedure is inevitable and accounts for approximately 55% of greenhouse gas emissions.

The second cause of GHG emissions is the energy required to heat the kiln for producing lime. Most of this energy comes from fossil fuels and accounts for 32% of the total GHG emissions. Together, these procedures contribute to 87% of the GHG emissions produced by the construction sector, which, as mentioned earlier, represents 18% of the total national GHG emissions. Substituting bio-based materials for concrete requires significantly less lime, typically only up to 21.4%, whereas concrete can contain more than 45% lime. Carbon sequestering materials and technology can be used as a decarbonising technique for the built environment. Bio-based materials improve energy performance in the built environment in comparison to using conventional materials. One such technology is the replacement of existing materials with bio-based alternatives.

Cast-in-place hempcrete production

Hempcrete is one of these materials. It is a bio-based constructive medium of a mix of hemp shivs, lime, sand, and water. The hemp plant sequesters CO2 during its growth through photosynthesis, and when harvested and processed into hemp shivs and hempcrete, it stores the biogenic carbon. According to the Australian Hemp Masonry Company, hempcrete has a lower carbon footprint than conventional materials, high sound absorption, high moisture buffer capacity, excellent thermal insulation properties and is fire resistant.

Hempcrete can be used in three different ways: pre-made bricks, a coarse mixture for packing, or a liquid mixture for spraying. Using pre-made bricks is a dry method for building with hempcrete while packing and spraying require mixing the raw materials into a liquid mixture that dries on site. The dry method is suitable for retrofitting existing structures since the blocks are made uniformly and can match traditional masonry techniques. On the other hand, the wet methods are more expensive and less efficient for retrofitting and are better suited for new structures since they are applied on-site and become part of the structure.

Pre-cast panel

However, this novel material is still incompletely researched, especially in the Australian context.

In Australia, most of the current Hempcrete projects use the method of mixing raw materials and tamping. This involves layering the mixed Hempcrete into a formwork and compressing it by hand with mallets. The process is repeated as the lower layers set and the formwork is moved up to add more Hempcrete layers until a wall is formed over several days.

Life cycle assessments (LCAs) are scientific evaluations that measure the environmental impact of products throughout their lifecycles. Previous LCAs have found that to reduce carbon emissions using hempcrete, it is necessary to transition away from lime binders, although research on alternative binders is currently insufficient. LCAs have shown that hempcrete has clear advantages in terms of embodied energy compared to traditional materials and similar thermal properties to concrete with similar densities. Hempcrete also has a net carbon-negative impact as it stores more carbon than it produces during manufacturing. However, due to the lack of industry standardisation, carbon storage levels in hempcrete vary depending on its composition during global production, with current estimates ranging from 35 to 87 kg of carbon per square metre of 250mm thick blocks.

Manufacturable blocks

Further carbon reduction can be achieved by improving the manufacturing process and reducing the amount of cement used. In-situ carbonation of hydraulic binders can lead to additional carbon sequestration of 13.15 kg of carbon dioxide per square metre of hempcrete. Hempcrete's ability to sequester carbon is impressive and can contribute to carbon-neutral construction by replacing carbon-intensive materials.

Additionally, the hygrothermal properties of hempcrete can potentially reduce building energy consumption. A study in Canada showed that the insulative properties of hempcrete could decrease heating and cooling energy consumption by 10% and 37%, respectively, compared to expanded polystyrene (EPS). This reduction in energy consumption is particularly attractive for the Australian domestic market, where heating and cooling homes account for 20% and 50% of energy consumption, respectively. Reducing electricity consumption for heating and cooling could have significant flow-on effects on the Australian carbon footprint, as the country relies heavily on coal-powered energy.

Hempcrete’s positive attributes contribute to low environmental impacts, healthy indoor living, and energy savings. The thermal regulating properties can reduce heating and cooling requirements, promoting the construction sector to shift to energy-efficient buildings. Limiting the use of energy resources contributes to healthier and more environmentally sustainable buildings throughout their life cycles by positively impacting human health and the environment.

Hempcrete’s positive attributes, as listed below.

Attribute and Degree

Carbon footprint

Negative carbon footprint due to biogenic CO2 uptake during hemp growth and to CO2 uptake by carbonation

Acoustic performance

Sound absorption coefficient of about 0.6

Moisture Buffer Value (MBV)

Good moisture buffer 'value (MBV) of 2 g/ (m^2.%RH)

Thermal capacity/Insulation

R-1.25 per inch to R-2.3 per inch for low (200 kg/ m^3) to medium (400 kg/m^3) density wall insulation mixes.

Fire resistance

Good reaction to fire (class “C - s2 - d0”) according to EN 13501-1

Similar to other new technologies, there is insufficient long-term information available regarding hempcrete and other bio-based materials. This poses a concern as the lifespan and robustness of in-situ hempcrete are not widely known. However, this is changing as we at UTS are evaluating the performance of hempcrete over time, providing long-term data where degradation owing to age is likely to become apparent.

This will involve conducting experiments to measure indoor environmental quality parameters of scaled-down structures: cast-in-situ hempcrete; and prefabricated hempcrete panels. This will aim to measure and compare the performance of hempcrete production alternatives in terms of indoor environmental quality, to demonstrate the importance of developing panels meeting the desired criteria.

To optimise the design considerations of hempcrete production alternatives, we are collecting information regarding the packaging, transportation logistics, installation, and disassembly at the end of the building use. This will contribute to scaling up the production of hempcrete which will promote the abundance of ‘green’ buildings, with the results combined aimed at decarbonising the built environment.

Scaled-down hempcrete structure built at UTS Tech Lab for air quality and thermal performance monitoring. This structure is the first of four to be built

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Dr Peter Irga is a Senior Lecturer researching the integration of hempcrete and green walls and green roofs into the built environment to maximise their combined effects. Holistically, his work aims to demonstrate that green infrastructure provides our cities with not only natural beauty, but also happier and healthier people.

Professor Sara Wilkinson is a chartered building surveyor and Australia’s first female Professor of Property. Her transdisciplinary research program sits at the intersection of sustainability, urban development and transformation, with a focus on green cities and preparing our urban environments for the challenges of climate change.

Flora Myrto Georgakopoulos is a PhD Candidate in the School of Built Environment at the University of Technology, Sydney. She is conducting research on sustainable construction, including prefabrication, modularity, and the use of renewable materials and greenery. She strives to develop ideas and solutions for healthy living spaces that form circular economy and carbon neutral patterns.

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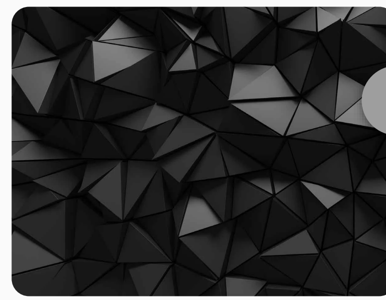

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