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Assessment of moisture and mould of hempcrete and straw panels

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Abstract. At present buildings contribute a third of total greenhouse gas emissions. There is a need for sustainable solutions and natural materials, which offer low-embodied energy and their low impact has a promising potential as construction alternatives. Hempcrete is a lightweight insulation material, which provides natural, airtight, and vapor-permeable insulation. Straw panels are also natural construction materials and they consist of extruded wheat straw and are surrounded with recycled paper on all sides. There are some risks, which can be associated with the use of such materials - infestation, biological degradation, presence of moisture, and structural degradation. The aim of the study is to determine the critical moisture level and mould resistance of hempcrete and straw panels. The results of this study are valuable to both scientists and structural engineers.

1. Introduction

The impacts of climate change are visible worldwide [1], but global greenhouse gas emissions (GHG) from buildings continue to increase, and at present buildings contribute a third of total greenhouse gas emissions [2]. There is an urgent need for sustainable materials and technologies, which can be used as construction alternatives, to slow down the rate of climate change [3, 4].

The European Union produces a total of 700 million tonnes of waste in the form of agricultural post-harvest residues every year [5]. Hemp shives and straw are both residual, bio-based materials, and the use of renewable materials in the production of building compounds is increasing [6]. Both hemp and straw are carbon-negative materials because they absorb carbon dioxide from the atmosphere during growth [7, 8]. Also, they are both materials with a serious risk possibility of fungal contamination [9].

Hemp concrete or hempcrete is a mixture of hemp shives and a binder (lime or cement) [10] and it is a lightweight insulation material [11, 12]. Hempcrete blocks can be covered with finishing plasters or walls made from hempcrete can be left without any covering [7].

Piot et al found, that the humidity inside the hempcrete wall can lead to mould growth [10]. Bessette et al (2015) have found that although the binder is alkaline, it is not sufficient to stop microbial development and growth [13].

Straw panels are insulation materials made with multidirectional press technology [14]. The load-bearing structure of straw panels has made of wood, the surface is flat and homogeneous [15]. There are some risks which can be associated with the use of such materials - infestation, biological degradation, presence of moisture, and structural degradation [14].



On the materials used in building different genera of moulds occur together [16]. Moreover, if the conditions are favourable for microorganisms, they can multiply [17]. Aerobic microorganisms which colonize bio-based materials need nutrients, the availability of oxygen, suitable temperature, and the availability of free moisture in the material to grow [18].

Inside a building, relative humidity (RH) and temperature are the most investigated criteria for mould growth [19] and both criteria have important roles to play in the comfort and health of users [20]. It is known that for mould growth the critical range of relative humidity is between 75-95% [19]. Mould can grow in temperatures between 0 and 50°C but the most suitable temperature range varies from 20-35°C [20]. It is also very important that the growth conditions are available for a certain period [19, 20].

The aim of this research was to determine the critical moisture level and mould resistance of hempcrete and straw panels, which use is gaining popularity as building materials.

2. Materials and Methods

For the experiments, hempcrete (8 specimens) and straw panel (8 specimens) specimens were chosen. To simulate moisture conditions enough to induce the growth of microorganisms the test chamber was built according to ASTM standard method D3273-00 “Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber” [21]. In the bottom of the test chamber instead of soil a vessel with distilled water was used to maintain the relative humidity level inside the chamber. The experiment started with the humidity level of 75%, raised by 5% by adding more water to the vessel every week. At the end, in the fourth week of the experiment the relative humidity level in the chamber was 95%. The chamber was kept in a room with an indoor temperature of $22 \pm 0.2^\circ\text{C}$.

The samples were hung with hooks made of stainless-steel wire. For the experiments, only vertical placement was used. The test chamber was equipped with data loggers (Hobo UX100-023 data loggers (measuring range from -20°C to $+70^\circ\text{C}$, 5% to 95% RH, accuracy $\pm 0.35^\circ\text{C}$ and $\pm 2.5\%$ RH, manufacturer Onset Computer Corporation, Bourne, United States)) which recorded temperature and moisture data in the upper and lower space of the chamber. After placing the samples, the test chamber was closed and insulated. No air circulation was used to prevent mould from spreading inside the chamber. The chamber was checked daily and in the appearance of visible mould the sample was removed from the chamber. The growth on the samples was detected visually and the identification of mould genera was performed with a microscope (model SP100, Brunel Microscopes LTD, Chippenham, United Kingdom) at the 100x magnification. For the disinfection of the test chamber, laboratory-grade ethanol (96.6) was used without further purification. Distilled water was prepared and readily used from the laboratory's distilled water system.

3. Results and Discussion

The experiment was carried out for 4 weeks in the critical range (75-90%) of relative humidity [19] and at average temperature $22 \pm 0.2^\circ\text{C}$. The internal climate reached 75% of RH during the first week and no signs of visible mould were detected. At the end of the second week (RH=80%), there were signs of mould development on both materials. The lowest RH at which mould growth appeared was 80% - two hempcrete specimens and four straw panel specimens were removed from the chamber and inspected visually and afterwards under the microscope. At the end of the third week (RH=85%), three hempcrete specimens and four other straw panel samples were found to have signs of mould development. At the end of the fourth week (RH=90%) all three hempcrete samples, which were left in the chamber, were covered with mould.

The moulds found from straw panel specimens were identified as the members of genera *Aspergillus*, *Alternaria*, *Cladosporium*, *Penicillium*. On the hempcrete specimens, members of genera *Aspergillus*, *Cladosporium*, *Fusarium*, and *Penicillium* were identified. Genera *Aspergillus*, *Alternaria*, *Cladosporium*, and *Penicillium* are well-known and commonly found environmental contaminant fungi [22]. All mentioned genera have found from straw producing crops

before [23]. Members from the genus *Fusarium*, which is a well-known pathogen causing foot rot on hemp [24], were also found from the specimens of hempcrete.

The critical moisture level for visible mould growth to occur for both materials according to our experiments was 80% RH. Pre-treatment with antifungal agents [25] or the use of clay or lime plaster, which have antibacterial properties could be potential measures to inhibit the microbial growth [26].

4. Conclusions

Biobased materials are potential substrates when the conditions are suitable for mould growth. Mould may result from the biodegradation of materials, spoilage of the surfaces, and eventually may also become health hazards for humans. Hempcrete and straw panels are both environmentally friendly materials, but they are particularly vulnerable to attacks by microorganisms. It is important to handle them with care and protect these materials from humidity to avoid mould growth on the surfaces of these materials. The results of the experiment have a practical value of providing information about the risks that can accompany the improper handling of moisture-sensitive materials.

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