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An investigation of the moisture content in the walls of a straw-bale building

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Abstract

This paper examines the use and accuracy of a moisture probe used in the walls of a straw-bale building. The performance of the moisture probe is assessed against laboratory-based measurements. The measurements from a number of moisture probes placed in the walls of a case study straw-bale building over a 2-year period are presented. The moisture content measurements from the building are discussed in the light of laboratory findings and the condition of the straw in the lower part of the most exposed wall. Potential influences upon the readings obtained from the moisture probes along with possible alternative assessment methods are discussed.

Keywords: Straw-bale; In situ moisture measurement; Thermal properties; Sustainable building techniques

1. Introduction

Buildings made wholly or partly from straw have been constructed in the UK using techniques similar to contemporary designs in the Northern United States of America. The resurgence of this building technique has been prompted by a range of issues but most stem from the inherent sustainability of the structure of such buildings. In this sense, sustainability is defined not only in terms of energy efficiency but also the use of local and renewable materials. Such materials reduce carbon emissions and energy used in transport and manufacturing. Also from a life cycle point of view natural materials can degrade at the end of life and do not cause pollution or hazards. The UK department of Trade and Industry has recently recognised this by funding a study into construction materials from crops [1].

The straw-bales offer good insulation values, according to Christian et al. [2]. The measured steady-state *R*-value, (thermal resistance) for a straw-bale wall, built according to the Tucson, Arizona, structural code, was 2.8 m^2 K/W, equivalent to a thermal transmission value of 0.35 W/m^2 K. This is complemented by other factors such as straw is normally a waste product and the ease of disposal of any straw after its use as a building material.

However, straw-bale buildings, by their very nature are organic and are liable to suffer degeneration due to certain combinations of moisture and temperature. It has been suggested that the ideal moisture content of a straw-bale wall is 14%, as this is below the level that is believed to allow biological activity to begin [3]. This is echoed by Still '*At 20% moisture content most organic material starts to degrade such as grains, wood and straw.*' [4]. Degradation of rice straw has been found to be reliant on a function of moisture content and humidity of stored bales [5]. However, moisture content and temperature are only part of a range of factors influence the degradation that will occur within straw-bale walls. These wider factors, include the building design and detailing used, but also rely heavily upon the buildings siting, orientation and the regional climate of the site. It was therefore proposed that a moisture study should be carried out to establish the moisture content of a straw-bale wall in a particular geographical region.

Relative humidity and temperature measurements have been taken from the upper, middle and lower sections of a California winery built from straw-bales [6]. The measurements were taken using combined relative humidity and temperature sensors. The results from these measurements, although comprehensive, focused on the relative humidity

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in the straw-bale walls and did not relate these figures to the actual moisture content of the straw.

The most common method used to measure the moisture content of straw-bale wall is the wood-disc sensor [7]. This is mainly because they are cheap, easy to read and are viewed as being reasonably accurate. Fugler's paper compares several series of laboratory-based moisture studies in an attempt to calibrate the most commonly used design. The paper's analysis of field studies carried out upon three Quebec straw-bale houses in 1997 concluded that most straw-bales were usually dry enough to avoid rot, but also stated that there '.....*are not enough monitored houses to make conclusions*'.

This study will investigate the performance of a wood-disc moisture probe using laboratory measurements and presents the results from a number of probes placed in the external straw-bale walls of a case study building.

2. The wood-disc moisture probe

The wood-disc moisture probe chosen is based upon the work carried out by Canada Mortgage and Housing Corporation and is advocated by Gonzalez of the University of British Columbia [8] and Woolley of Queens University Belfast [9] (Fig. 1).

The wood-disc moisture probes, of area 25 mm^2 were constructed of wood 5-mm thick. The block is drilled in 2 places to make holes 5 mm apart, although the exact distance is unimportant [10]. Two stainless-steel screws are then inserted with a stripped end of a piece of wire wrapped around the head of each screw. The wood-disc is then placed at the end of a PVC tube with ventilation holes made around it. The tube can vary in length depending upon how deep into the wall it is being placed. The two wires are then run the length of the tube and left protruding out of the end. These will be outside the building, ready for readings to be taken. Readings are taken using a '*Protimeter*' Wood Moisture Meter calibrated for wood. The moisture content of the wood-disc within the probe is influenced by the relative humidity of the bale via the vent holes in the PVC tube. In this way the moisture content of the bales may be assessed.

Fig. 1. Illustration of a typical wood-disc moisture probe (drawn by Neill Hughes).

The reaction times and the operation of the probes at different temperatures is an issue. Fugler measured the response of several wood-disc moisture probes (as opposed to the discs used here, using two varieties of timber, Balsa and White Pine, and found that a time lag existed for any probe measuring Relative Humidity. However, when the wood-disc moisture probes were used to monitor straw-bale buildings, the slow reaction of the probes matched the slow reaction of the straw to the uptake of moisture. As part of the same measurements Fugler also investigated the wood-disc moisture probe's response at different temperatures. It was found that there may be some influence of temperature on response, but for the range of temperatures studied (13°C to about 28°C) the influence was small and difficult to determine. However, Fugler does state that for measurements in winter, in cold climates, a temperature correction would be necessary. This correction is further investigated within the calibration section of this paper.

A further concern maybe the electrical effects of the length of connecting wire used between the wood-disc and the connection with the electrical moisture meter. Lacinski investigated this aspect and found that using identical wood samples and wires that ranged in length from 3 to 21 m, all the moisture readings were within 1% of each other [10].

3. Calibration of the wood-disc sensors

An initial study to calibrate and assess the validity of measurements taken using the moisture probe was carried out in the laboratory. One bale of the straw, from the batch used in the case study building, was placed in an exterior storeroom with three wood-disc sensors placed inside the bale. Two pieces of timber, identical to those inside the sensors, were also placed in the bale. The relative humidity and temperature conditions around the bale were monitored. The bale was allowed a week to stabilise and then readings were taken twice weekly from the wood-disc sensors, the hygrometer and the thermometer. Further to this, straw samples were taken from the bale at the same time and (1) oven dried and (2) measured using a moisture balance to find the exact moisture content. The results of this calibration are shown in Table 1.

The oven dried moisture content was calculated using

$$\frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

$$= \text{percentage moisture content, referred to as mc\%.}$$

To ensure that the readings that were being gathered from the wood-disc probes gave a valid measurement of the moisture content of the straw-bale walls of the case study building, a laboratory calibration exercise was carried out.