DETAILING THE EFFECTIVE USE OF RAINSCREEN CLADDING TO PROTECT STRAW BALE WALLS IN COMBINATION WITH HYGROSCOPIC, BREATHABLE FINISHES

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ABSTRACT
Straw bale buildings are still a relatively unfamiliar sight within the UK's building stock. However, the drivers of sustainable construction combined with a rising profile as a construction technique have increased the general awareness of this form of construction in the UK. This has led to an increasing number of buildings of this type being planned and constructed in the UK. However, the effects of moisture on these materials, particularly in a temperate maritime climate, are of some concern. Research being undertaken at the universities of Plymouth and Bath has produced interesting evidence of the efficacy of simple timber rain-screens as additional protection to these potentially vulnerable materials, particularly when compared to the traditional lime based finishes currently advocated for this type of construction. The use of a permeable, hygroscopic finishes such as lime renders are considered essential as this allows vapour dispersal from the wall. However, the traditional render only system can allow ingress of moisture to the interior of the wall if subjected to adverse weather conditions, such as driving rain. This paper discusses the detailing of exterior wall constructions that combine the use of rain-screens with a vapour permeable finish to form an outer layer that can resist the weather while still allowing for the dispersal of any moisture. It also summarises findings of a PhD research project at the University of Plymouth, which is investigating the moisture performance of straw bale construction in a temperate maritime climate. This paper will be useful to Architects, Designers and Contractors involved in the design and construction of straw-bale buildings in temperate climates.

KEYWORDS: Moisture, Monitoring, Rainscreen, Straw-bale, Construction.

INTRODUCTION
Architects, engineers and clients are increasingly interested in energy efficient dwellings and, in more general terms, structures that are benign to the environment. Depending on the specific properties of the design; the resulting buildings might be named Zero Energy Houses, Low or Carbon Neutral Homes, Passive Houses or, more generally, Eco Houses [1]. Eco Houses now often take account of the setting, rural or urban, the level of technology used to drive the comfort and communication related built-in devices. The locality of materials and their embodied energy are also used to potentially place the design in a hierarchy of 'greenness'. Modern methods of construction including the use of

Structural Insulated Panels (SIPS), refined heat recovery and low energy lighting can help the designer to achieve level 6 of the UK's Code for Sustainable homes. Although general guidelines for the design and reviews of case study eco houses are available, (for instance Eco House: a design guide by Roaf *et al* [2]), the actual in-depth design decisions that lead to the development of an Eco House design can be confusing to both client and architect. It is therefore of particular importance that emphasis is placed on the fundamental issues of Eco design, namely the embodied energy of the materials used and the primary energy needed to operate the building [3], before considering some of the more debatable additional technologies that are sometimes used, which has led to the term 'Greenwash'.

The use of straw bales in the construction of an Eco House contributes to both a low embodied energy and primary energy need. The low embodied energy stems from the fact that straw bales are a by-product of an existing industry, and that they have absorbed carbon dioxide whilst growing [4]. This makes straw bales not just carbon neutral, but carbon negative. The low U-value achieved by a straw bale wall (typically 0.16 W/m^2K from a thickness of 450-500 mm) contributes to a low primary heat energy need. Having outlined the positive credentials of straw bales, it has to be acknowledged that there are questions to be asked about their suitability in a temperate maritime climate such as in most of the UK; hence the research being undertaken by the first author into the moisture performance of straw bale construction.

VAPOUR PERMEABLE CONSTRUCTION

In modern methods of construction there are essentially two approaches to the way that an exterior wall handles moisture. The first method is to use finishes on both sides of the wall that are impervious, therefore, keeping the interior of the wall completely sealed against the ingress of water. The problem with this is that it is virtually impossible to completely seal a wall, and once moisture has entered, it is hard for it to escape, which can degrade the wall. The alternative is to use a form of construction known as a 'breathing' wall [5]. The finishes used on the wall should be airtight but vapour permeable, which will allow the water vapour that is created inside the building to migrate to the outside without becoming trapped inside the wall. This has benefits for the indoor air quality, but more importantly, it is generally recognised that a vapour permeable finish is important in protecting organic materials such as wood and straw, in that it mitigates against any build up of moisture and the potential for damage that would ensue [6].

When detailing a wall build up of this kind, it is important that the degree of permeability of the different finishes on each side of the wall is balanced. In a temperate climate, the warm interior air will almost always contain more moisture, with a higher vapour pressure than the cooler air outside. The moisture from the inside will travel through the wall to the lower pressure on the exterior face of a building. So to avoid the water vapour building up to the point where it can condense into water droplets (known as interstitial condensation), it is important that the inside face of the wall should be less permeable than the outer, always encouraging the flow of vapour to the outside.

OBJECTIVE

In straw bale building this vapour permeability is created by the use of lime based renders. The problem with such a hygroscopic material is that there is the potential for moisture from driving rain to enter the wall, and although it would normally evaporate from the wall surface, if the rain is constant then there can be a dangerous build up of moisture in the straw. This paper will firstly look at the results from the monitoring of structures that use both lime render and a vented rainscreen cladding, and then discuss the detailing of a straw bale wall build up that incorporates additional elements to facilitate the easy attachment of rainscreen cladding.

METHODOLOGY

The level to which simple rainscreen cladding can protect a straw bale wall has been explored through the monitoring of a house in Totnes, South Devon, that has walls on all elevations using both a plain rendered finish and timber rainscreen cladding, enabling moisture content to be compared by taking measurements from the different sections of the same wall, see Figure 1.

Fig 1(Right). External wall of Totnes house showing use of a vented timber rainscreen and plain render on the same elevation Fig 2(Left). Straw bale panels protected with different renders including, on far right, panel finished with timber rainscreen

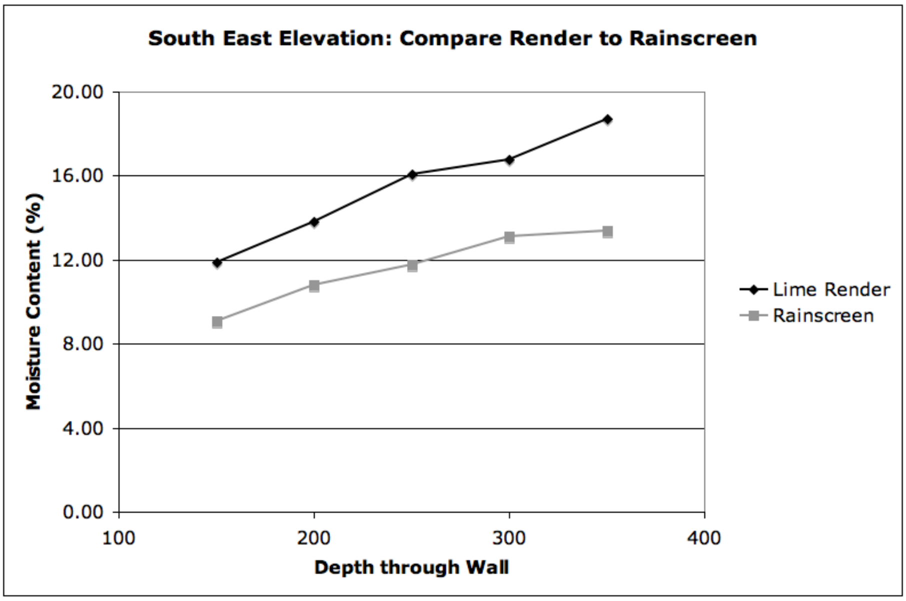
The readings from the Totnes house can be compared with the results of an experiment set up by the University of Bath to compare the efficacy of different mixtures of lime render on a series of straw bale filled panels constructed in a field near Liskeard, Cornwall in 2007. It was decided to add timber rainscreen cladding to one of the panels, allowing a comparison to be made between two of the panels that were the same in all respects apart from the addition of the rainscreen cladding to one of them, see Figure 2.

RESULTS

Totnes House

The Totnes house was finished in 2005, and has been continuously monitored since then, giving a unique insight into the moisture performance of a residential straw bale house over a time period approaching four years. On two of the elevations, Northwest and Southeast, moisture readings were taken in the same position on both floors, allowing a comparison to be made. All the exterior walls are constructed with straw bales on their edge with a thickness of 390mm, including three coats of 'fat' lime render on the inside. The outside of the straw bale wall on the first floor has a single 10mm coat of render, an air gap of 25 mm, a breather membrane, another air gap of 25 mm and finally the cedar rainscreen which is 18 mm thick; leading to an overall exterior wall thickness of 468mm. On the ground floor the straw is finished with the same three coats of fat lime render on both sides.

The straw in two of these walls was measured at 50mm intervals through the wall, starting at a depth into the wall of 150mm. The two sets of results for the Southeast and Northwest elevations, taken on the same day, are shown in Figure 3,



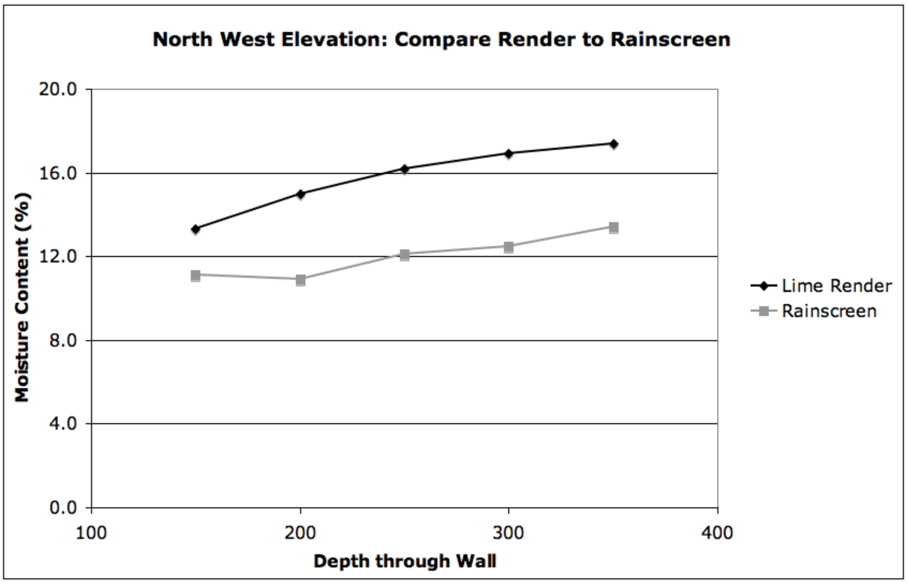


Fig 3. Readings of moisture content from the same position on the ground floor (lime render) and first floor (timber rainscreen) on the Southeast and Northwest elevations of the Totnes house taken on the 8th of November 2008

The graphs in Figure 3 above show similarities, with the average difference in moisture content between the render and the rainscreen cladding being 3.8% on both elevations. There are other factors influencing the readings, such as distance from the ground, and the fact that the water running off the rainscreen cladding is likely to be falling on the render below, but in the first authors experience they are a fair representation of the reduction in moisture afforded by the use of rainscreen cladding.

LISKEARD PANELS

The method used to measure the moisture content of the straw bale panels at Liskeard differs from that used at the Totnes house. In this case the moisture content was recorded by using relative humidity sensors placed at various locations in each panel. The graph in Figure 4 below shows a combined average reading from the same four sensors placed at the bottom front and middle, middle front and middle of the middle in both the rendered and rainscreen panel.

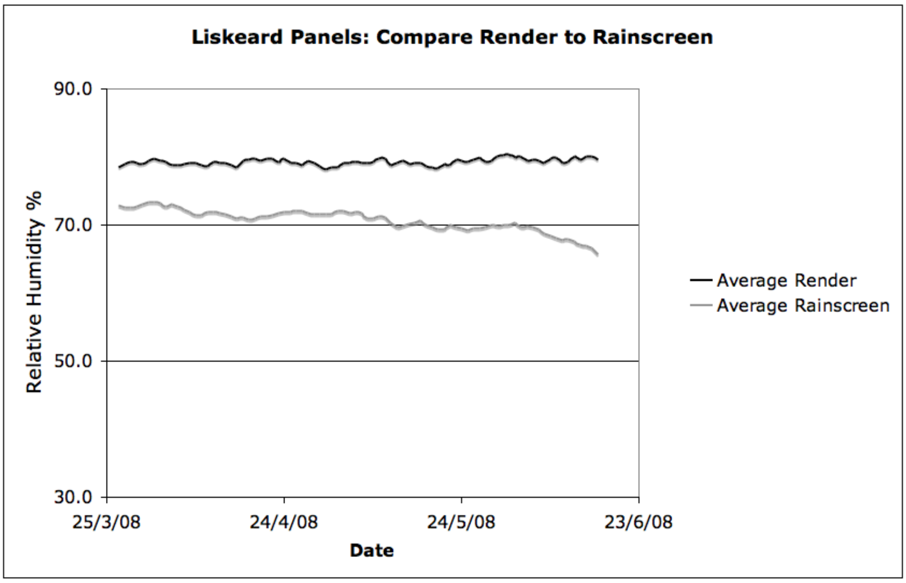


Fig 4.Average readings of relative humidity for two of the panels shown in Figure 2 during April, May and June 2008. The higher trace being from the rendered panel, the lower is from the panel protected by a rainscreen.

The other difference is that the Liskeard graph in Figure 4 above shows a series of readings taken over three months, rather than a snapshot of a single day, as in the Totnes house graphs in Figure 3 above. It can be seen that the rendered panel has remained fairly constant at around 80% relative humidity (RH), while the rainscreen cladding protected panel is gradually drying out.

Using Sorption Isotherms created in the laboratory at Plymouth University [7], it is possible to translate the RH values into moisture content (written as a percentage of the weight of water to the dry weight of straw). When observing the RH of the two panels at the end of the time period, it is seen that the rendered panel has an average of 79.5% compared to the rainscreen cladding panel at 65.7%. This translates to moisture contents respectively of 16.8% and 13.6% with a difference of 3.2%. At the Totnes house the difference was 3.8%, showing that a rainscreen cladding panel has had a consistent effect in these different applications.

SUMMING UP THE MOISTURE PERFORMANCE OF A VENTED RAINSCREEN CLADDING

It is generally acknowledged that a safe upper limit for the moisture content of the straw in a wall is 25% [8], and the research at Plymouth University has shown that to be a sensible limit. Although none of the walls in the above graphs (Figures 3 and 4), are showing dangerous levels of moisture and it could be argued that render on its own is providing an adequate protection against moisture ingress, what is not shown is what happens when moisture ingress becomes problematic. The rainscreen cladding will always have an ameliorating affect on the ingress of water. The maximum readings on the outside of all the walls behind the rainscreen cladding panels are remarkably similar, with the two Totnes walls both at 13.4%, whilst the Liskeard panel had dried to 13.6%. This is the level of moisture that could be expected in an organic material open to the outdoor atmosphere, but protected from the rain and it is unlikely that these readings will get any higher, whereas measurements of plain rendered walls have been recorded in excess of 30% [9]. This makes the use of vented rainscreen cladding to be the best insurance against straw decay, especially on the most severely exposed walls.

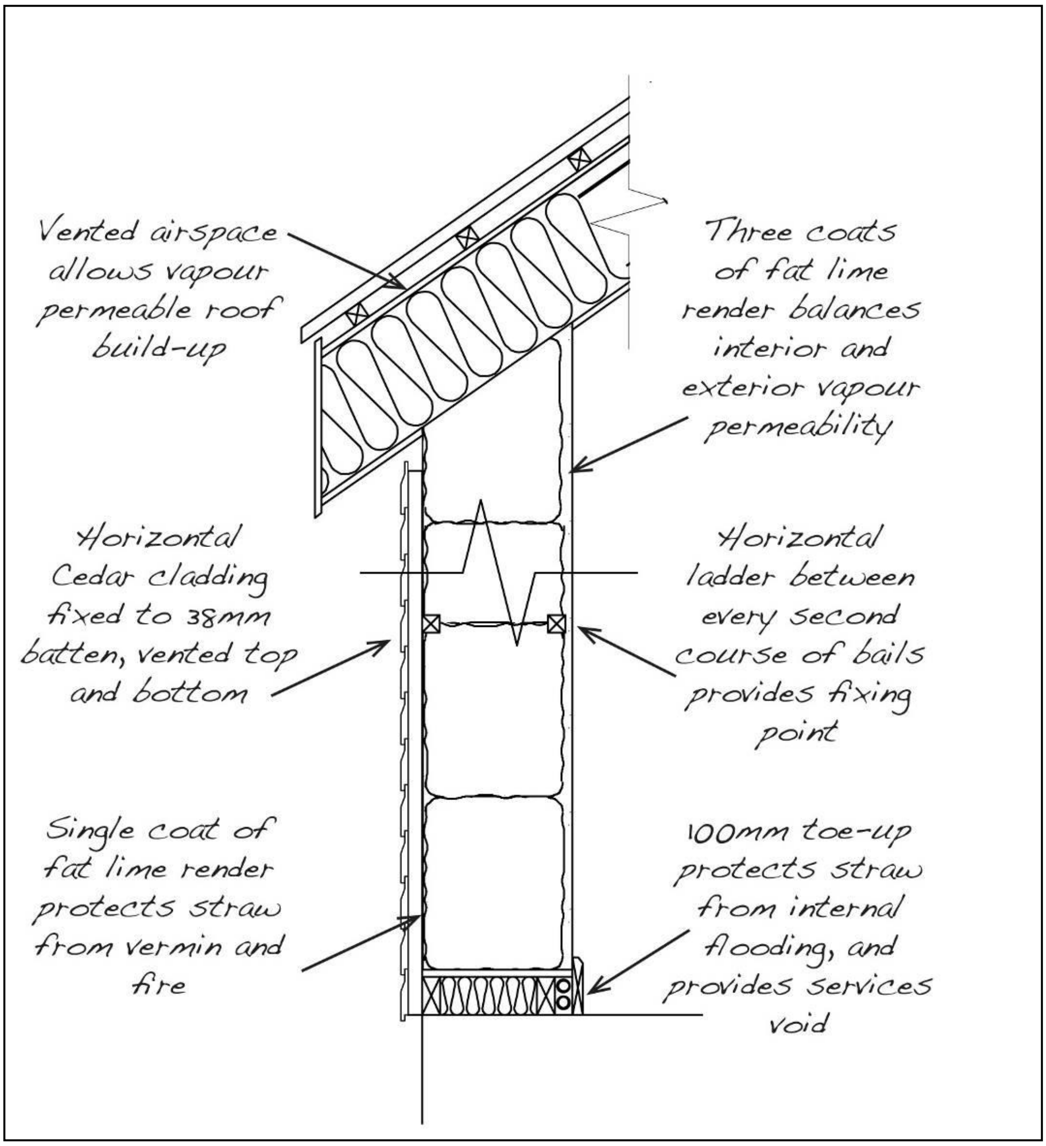


Fig 5. Simplified section through a straw bale wall with a vented timber rainscreen cladding pane

DETAILS FOR THE DESIGN OF A RAINSCREEN CLADDING PANEL

One of the problems in straw bale building is the difficulty in providing fixing points within the straw wall. A solution that was pioneered in the Totnes house is to lay a simple timber 'ladder' on every second course of bales, see Figure 6. This 'ladder' provides a mid point fixing for the battens that support the rainscreen cladding panel. Because the rainscreen cladding panel is the impervious outer layer of the wall build up, the lime render on the bales does not have to be watertight, so one coat of lime render is enough to protect the straw against vermin and the surface spread of flame, see Figure 7 below. This single coat of render balances the lower permeability of the three coats on the interior of the wall as discussed in section 2 of this paper above.

Fig 6.'Ladder' made from 38x38mm batten, laid on the second course of bales, provides a valuable fixing point both on the inside and outside of the finished wall.

The Battens allow the rainscreen to 'stand off' the surface of the rendered straw bales and provide the airflow behind the rainscreen, which is essential to remove the water vapour that has worked its way out from the interior of the house.

Fig 7. Battens fixed to the horizontal 'ladder' and single coat of lime render applied.

The Totnes house was designed with a rainscreen cladding panel of vertically hung rough sawn cedar planks on the first floor, see Figure 8 below.

Fig 8.Rainscreen of rough sawn cedar planks on the Totnes house.

It was not intended that this rainscreen cladding panel should be watertight (there are gaps of up to 10mm between the timber planks), so it was decided to place a vapour permeable breather membrane behind these timber planks. It would be simpler to make the rainscreen cladding panel impervious, which would mean that the breather membrane is not needed, as shown in the sectional drawing in Figure 5 above.

CONCLUSION

This paper has discussed the detailing of the effective use of rainscreen cladding to protect straw bale walls in combination with hygroscopic, breathable finishes.

The findings from the methodology clearly show the effectiveness of rainscreen claddings, and the results have demonstrated that although a properly detailed and applied finish of fat lime render is considered adequate protection for most straw bale walls, where a building can be exposed to prolonged periods of driving rain there is no doubt that a vented timber rainscreen can significantly improve the performance of this form of low energy wall construction, thereby increasing its viability in the temperate maritime climate of the United Kingdom.

Acknowledgement

This research is partly supported by Great Western Research, The Ecology Building Society and The National Non-Food Crop Centre. The tests undertaken by the University of Bath were sponsored by the Technology Strategy Board. The contribution of Dr Mike Lawrence (University of Bath) is also acknowledged.

References

1. Vale, B. and Vale R. (1975). The autonomous house : design and planning for self-sufficiency. Thames and Hudson, London, UK.

2. Roaf, S., Fuentes, M. Thomas, S. (2007) *Ecohouse 3: A Design Guide.* Architectural Press, London, UK

3. Halliday, S. (2008) *Sustainable Construction* Butterworth Heinemann, London,

4. Jones, B (2002) *Building with Straw Bales.* Green Books, Totnes, UK

5. Harris, C., Borer, P. *The Whole House Book.* 2nd Edition (2005) Centre for Alternative Technology, Powys, UK

6. Straube J.F. (2000) Moisture Properties of Plaster and Stucco for Strawbale Buildings Report for Canada Mortgage and Housing Corporation.

7. BS EN ISO 12571:2000 Hygrothermal performance of building materials and products. 8. Summers, M. (2006). Moisture and decomposition in straw. In: King, B. (Ed). *Design of straw bale buildings.* Green Building Press, San Rafael. pp. 161-172.

9. Goodhew, S, Griffiths, R. & Woolley, T. 2004. An investigation of the moisture content in the walls of a straw-bale building. Building and Environment, Elsevier, 2004. Vol 39/12 pp. 1443.