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Beat your head against the wall!

Seeking workable solutions to insulation and moisture control in traditional Welsh dwellings.

For the owners/occupiers of traditional dwellings moisture control is vital for comfort and health and similarly vital for longevity of the building fabric. Control of heat loss is crucial to reducing energy use, therefore expense, of continued use of these dwellings. As a design -build contractor, lifespacedesign was asked to inspect a traditional dwelling in the Snowdonia National Park with a view to remedial damp prevention and energy saving (Fig.1). The outcome of this study and examination of possible solutions may have implications for other buildings of this type. Control of moisture within the conditioned space of a dwelling is the core issue of the lecture "Condensation and Breathing Walls" and is closely related to the lectures on ventilation and on cooling. A web based literature search revealed a number of papers studying specific types of stone (none slate) and work on *cement* mortars. Many papers were found attempting to define a framework for modelling Heat, Air and Moisture (HAM) properties of modern building types and a small number reaching to the historic built environment.

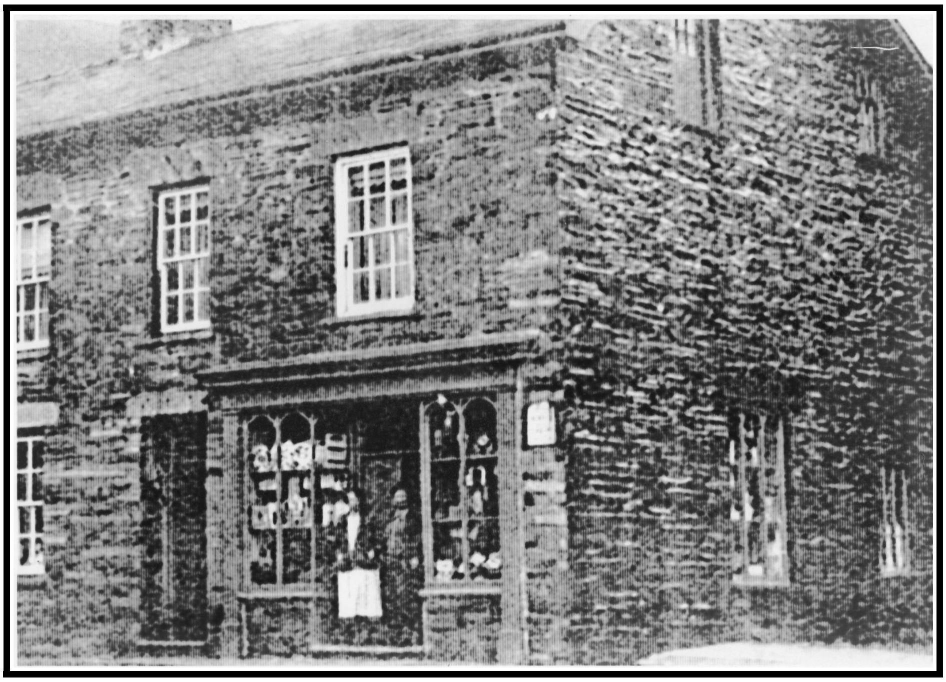

Fig.1 *Victorian image of Tan–y–bryn* (*from the owner's collection*)

The property examined is an end of terrace early/mid 19th C former shop built of slab slate with lime mortar. (For more details see Appendix A). Site is the base of a north facing slope in a classic glacial valley aligned SW/NE. In addition to falling under the National Park conservation regime, the terrace is itself a grade 2 listed building.

As the sole permanent occupant, the owner reports the house as impossible to thoroughly heat and always feeling damp. Only in late summer is the interior described as comfortable. Heating and drying effort is concentrated on a few smaller rooms using electric heaters. Whilst the owner reported no problems of mould growth the survey revealed mould on interior walls and on soft furnishings. The design brief is to provide solutions which control internal moisture, aiming to remove damp from fabric, and to insulate to 2006 Part L standard. Consulting advisory publications yields the following

> "*In converting or retrofitting existing buildings, care must be taken to prevent loss of thermal mass. This often occurs when buildings are insulated on the inside face of masonry walls and floors.*"

and in relation to windows referring to 2006 part L compliant systems;

> *"However, installing such windows may be inadvisable in historic properties or in Conservation Areas. In such circumstances, the use of insulated shutters, coupled with secondary glazing may be advisable."*

Forster et al. 2009 *Guidance for Sustainable Design in the National Parks of Wales*

It must be noted that the client reports vigorous opposition even to these solutions from the SNPPA (Snowdonia National Park Planning Authority). Essentially the advisory materials have nothing to offer the owners of existing buildings seeking to achieve modern insulation standards. Compare this with advice available from BRE in relation to the internal insulation of solid masonry walls;-

> **Associated technical risks**
> 3.8 *Increased heat loss due to air movement*
> 3.9 *Condensation within the construction*
> 3.10 *Summer condensation on the vapour control layer*
> 3.11 Fire spread due to combustible insulation
> 3.12 Spread of fire gases in the cavity behind insulated linings
> 3.13 *Condensation at thermal bridges*
> 3.14 Risks associated with electrics

BRE 2002 (emphasis added)

The guidance includes straightforward solutions to these risks, but assumes the construction is not affected by other issues, particularly wind driven rain and rising damp, nor by conservation requirements. This makes the offered solutions unsuitable here.

Figure 2 *Internal wall of sitting room. Cement rendered*.(Photo llifespacedesign 2009)

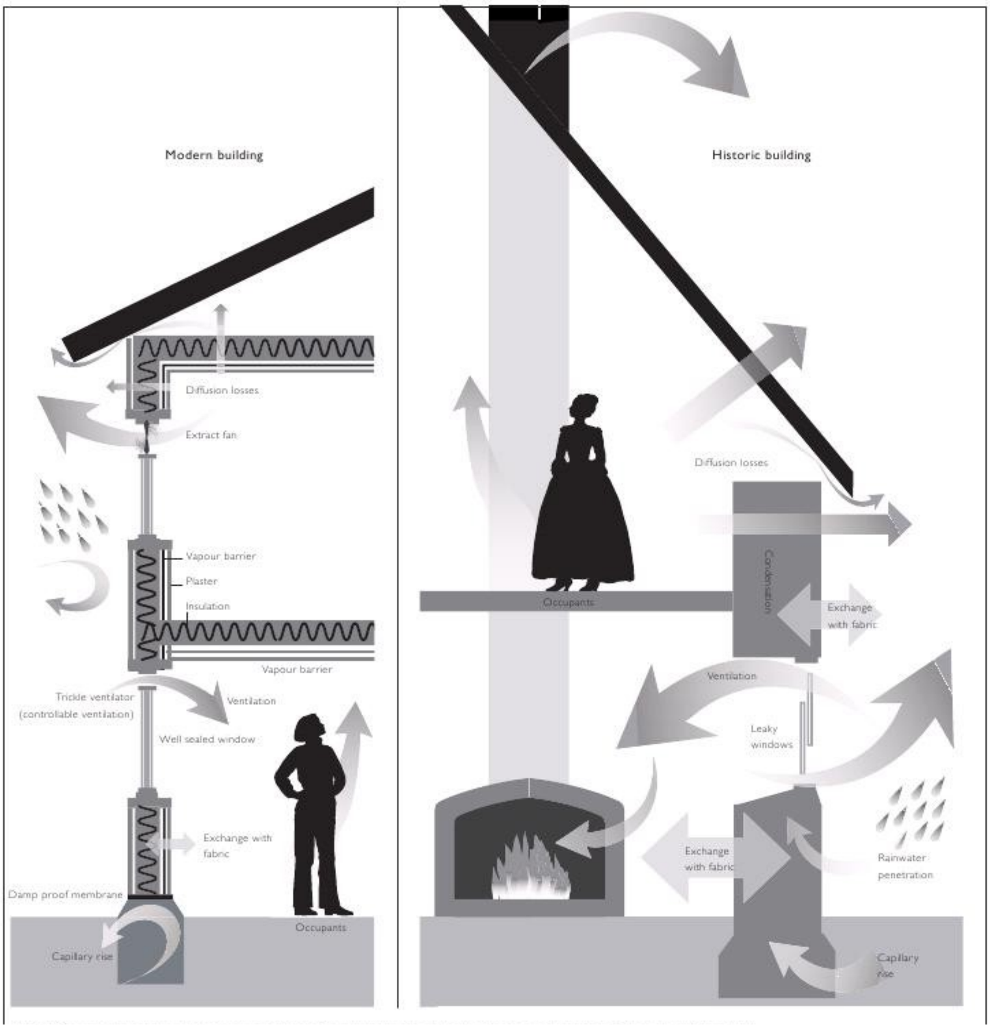

Figure 3 *Historic vs modern approaches to management of Heat Air and Moisture within the building conditioned spaces.* (English Heritage 2004)

The original construction, typical of the region, has no integral damp control course within the wall; it would have relied on coal burning and natural ventilation to manage moisture within the shell. (See figure 3).

The coating of bitumen on the west wall begs the obvious suggestion that the wall was suffering from the ingress of water from driven rain, interfering with the natural transport of internal vapour and of rising damp (ground moisture) out of the wall fabric. This bitumen acts as an impermeable barrier, stopping driven rain from entering, but also preventing the escape of interior and ground water. A similar but lesser effect can be expected where OPC based mortars are used for pointing, as on the south wall. This invites examination of the extent to which driven rain was entering the fabric of the wall, and the rate at which it can subsequently leave. The factors to examine are the permeability of the wall, wind driven rain index according to BS 8104 1992, (BSI (1992)) plus movement of internal moisture into and through the wall as internal vapour and as rising damp.

To begin with the permeability, the available information sources on permeability of building materials do not treat slate as masonry, so no data are available, and do not cover historic lime based mortars; so again no data are available. Additionally, in the matter of historic mortars they will have considerable variation of physical properties depending on local sourced aggregates (Llanas et al 2004). These variations will impact on porosity to water in liquid and vapour phases.

> *"Vapour diffusion is most important in large pores, whereas liquid transport takes place at pore surfaces, in crevices and small capillaries"*

Kunzel and Kiesel 1997

As no data are available for the porosity or permeability of mass slate, and it has historically been used as a damp control layer in brickwork and as a roofing material it *may* be safe to assume that the slate component of the wall has effectively no capacity to absorb or transport moisture other than at its boundaries with the mortar. This now leaves the question of the relative cross sectional areas of the two components across the wall thickness. Given traditional methods of solid stone wall construction with dressed face stones being infilled with assorted random rubble, there is no reason to suppose that this building enjoys any higher standard of materials or workmanship, and therefore that the relative areas of the stone compared to mortar will be at a maximum at the outer face. In addition over time it is expected for voids to form in the mortar (almost impossible to measure) due to settlement and washing out; which will increase vapour permeability of the section. A study has been made of the use of pressurised gas transport as a device for non invasive testing for permeability in historic buildings which showed massive variation between samples even within a single building; leading to the conclusion that such tests are site and sample specific and demand numerous sample points. (Valek et al 2000)

The modellers agree that vertical movement of moisture due to gravity can be ignored (Kunzel and Kiesel 1997) , but this ignores the possible impact of rising damp which must be considered in historic fabric using highly hygroscopic mortars.

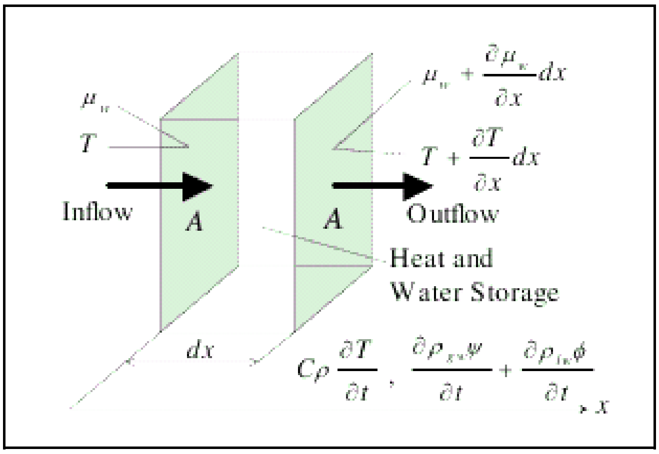

Figure 4 Typical Conductive heat and moisture transfer model (Ozaki and Tsujimaru 2005)

The core equations offered by the modelling software are critically dependant on the various coefficients for moisture and heat transfer through the section as well as the assumption of homogeneity. The modelling tools examined so far treat any given masonry wall element as a uniform homogeneous material (figure4) and therefore would struggle to accurately model the true case of this type of building. Given these limitations and lack of time, it was not appropriate to apply a numerical modelling tool to this case.

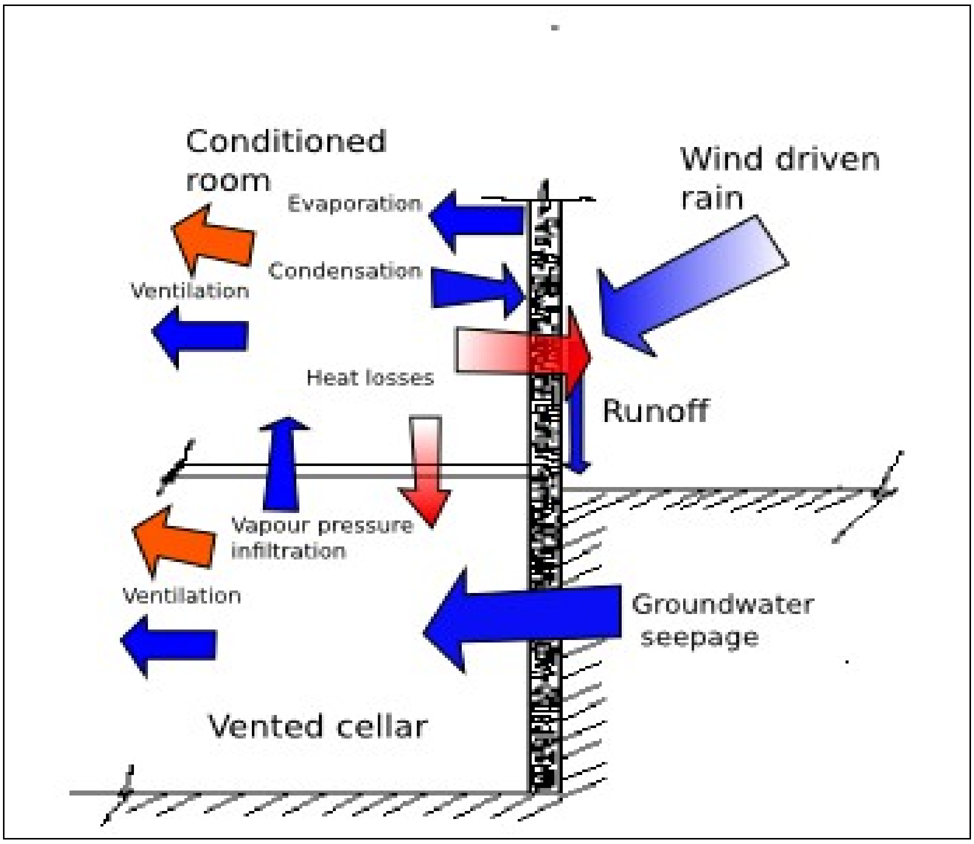

Figure 5 *Illustration of heat (red) and moisture (blue) movements in the existing wall.* Movement of water within the wall in the vertical plane (rising damp) is omitted, but NOT negligible.

Pragmatic solutions to the insulation requirement by fitting insulating materials inside the walls could simultaneously offer a vapour seal to prevent vapour movement from warm interior air to the colder wall fabric. This raises two issues, firstly it creates the risk of bringing the dewpoint within the fabric of the wall by lowering temperature across the section.(BRE 2002) In the case of damp lime mortar this will damage the fabric, perhaps impairing structural integrity. Secondly it fails to take into consideration the known issue of rising and trapped moisture. Only if moisture is able to leave the fabric by drying from the outside would such a solution be viable. Solutions to protection of exposed walls do exist, by installing a wind/rain barrier in the form of a thin, durable material hung from the wall with a vented air space behind, such as this slate hung elevation in Newtown, Powys. (Fig 6 below) which shows that this can be done with sensitivity to the building character.

Figure 6. *Slate hung exposed elevation*; (photo; lifespacedesign 2009)

Such a solution would effect both the fabric and visual appearance of the building so may well be forbidden in the case in point. If permitted this solution would open the option of external application of insulation materials, but would not be applicable to the other elevations. Insulation solutions allowing moisture to pass, such as hemp/lime composites could only be applied here if the other moisture issues were solved.

Interventive solutions to the rising damp fall into two classes, physical barrier and remedial works plus electro-osmotic pulse devices. According to an exhaustive study by the US Army Corps of Engineers the latter is unsuitable where voids and other physical defects are present, and may also have adverse effects on the materials in the lime mortar. (Mcinerney et al 2002). Of the barrier types; fitting a bitumen damp proof course by gradual removal and replacement of the stone raises structural hazards, especially as the number and location of through the wall binders is not known. This leaves injection of water resistant materials: as these methods depend on the displacement of retained water by the active chemicals and subsequent achievement of a moisture free zone within the fabric there are problems in ensuring their effectiveness in this case. A quick search of various online forums yields numerous cases of failures of this (and indeed all other) damp proof techniques in solid stone walls. (Period Property UK; AECB; Green Building Forum).

Outcomes

Given the limitations of time and resources it was not possible to attempt a computer model of this case. Even if such had been tried, from a realistic viewpoint it would have little value as a design tool due to the inherent weaknesses of the tools, namely the lack of meaningful coefficients of permeability and thermal conductance for slate and the known unknowns of traditional masonry wall building. For the client the first best measure to remove trapped water from the wall is to remove the bitumen coating and install a lean to conservatory, which would require listed building consent. Figure 7 shows the revised heat and moisture flows for this case.

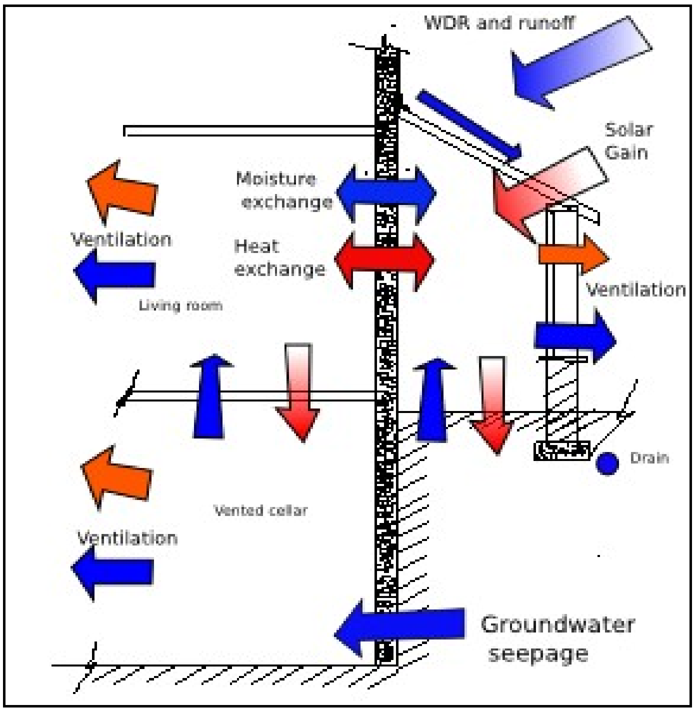

Figure 7 Schematic of heat and moisture flows after remedial measures, no insulation to main wall.

One simple low visual impact measure would be to excavate around the foundations and install a french drain. This would have the effect of removing groundwater from the fabric but would depend on a suitable gradient and discharge point, below the level of the cellar floor/footings. The rest of the property would benefit from remedial measures to the windows as suggested by the design guide, but this would also have to be re-negotiated with the SNPPA. Internally the opc based renders should be replaced with lime. Only after sufficient time to evaluate the impact of these measures would it be sensible to revisit the property with a view to internal insulation.

Conclusions

For occupiers of the 33% of Welsh homes dating from pre 1919 ,(Rhodes et al 2007) and the National Parks in particular, achieving modern standards of comfort at reasonable cost in energy remains challenging. The Brecon Beacons and Snowdonia Parks are both areas of high rainfall (Met Office 2009) and driven rain exposure (BS 8104: 1992) Recent work has demonstrated that

> *WDR loads can have significant impact on the indoor climate, energy consumption and mould growth risk*

Abuku et al (2009)

A trawl of pictures of holiday cottages shows many traditional dwellings have been rendered with cement, which will have long term consequences similar to those caused here by the bitumen application; confirmed by this writer's own experience and by postings on building forums. (AECB, Green Building Forum, Period Property UK) If these properties are to be maintained and occupied in future measures must be taken to remedy previous bad practice (removing cement renders and modern impervious paint).

Figure 8 *Cement rendered traditional dwellings* (Holiday Rentals) left and *insulated houses* right (photo- lifespacedesign) *Two of the three houses in this terrace have 50mm foam external insulation, can you tell which?*

External insulation could be applied simultaneously without damaging the landscape value of the dwellings, as demonstrated by the example of a terrace of houses in figure 8. As always this is only applicable where rising damp from groundwater can be eliminated first. Making these homes comfortable at reasonable energy cost is crucial to their continued year round occupation, providing accommodation for a local workforce and their families. In order to achieve their social agenda to maintain the Parks as living communities the

National Parks need to take a more flexible approach to energy saving measures without imposing too great a financial burden on owners. A useful study could examine the effect of interseasonal occupation patterns on moisture trapped in these rendered buildings- perhaps they *should* only be used for holidays?

The papers examined in this study concerning computer modelling show that this is still a crude technology in terms of values of outcomes for historic buildings. The models are critically dependant on the physical properties of natural materials which are highly variable, and continue to regard solid masonry sections as homogeneous elements , questionable as this ignores the different properties of the stone compared to the binding mortar. Even within given stones and mortars there are considerable variations in physical properties. It would be helpful for the industry for a full physical Hygrothermal monitoring study of each of the main traditional construction types in the National Parks to at least establish some values for moisture permeability and heat transfer; but it seems these may always remain site specific.!

Appendix A

Floors are of softwood joists and boards, internal partitions are stud with lath and lime plaster finish; all of which are highly hygroscopic. Windows are large sash single glazed; originally with full closure shutters now mostly removed. There is a full height half cellar, to the west side the cellar wall carries the gable end of the building. Two ground floor rooms have fireplaces, one serviceable, the other with a fitted solid fuel fire with boiler. Electric storage heaters are installed throughout. Kitchen and bathrooms have extraction ventilation.

At some time in the 20th C the shop was closed and the front altered to resemble the opposite side. OPC mortars were used throughout this work. At present the west end wall is painted with modern impermeable masonry paint, but close inspection reveals that this is painted over a layer of bitumen. Close examination of the 19th C photograph suggests that this dates from that period. The masonry of the rear ground floor level has been repointed with OPC based mortar. In many places on the ground floor the internal walls have been replastered with OPC based cement renders.

The ground floor joists above the cellar are decayed where they are embedded in the wall and have been supported with supplementary timbers. First floor timbers were not examined but damp on the walls is suggestive and further examination is highly recommended.

The present owner (sole occupier) reports historical occupation of 15 to 20 persons. Energy use is not documented but must have been solid fuel based. Typical electricity use (includes heating and DHW) is 14,634 kWh p.a.(5/11/07 to 16/10/08 taken from bills).

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