

WELLS O' WEARIE, EDINBURGH

THERMAL UPGRADES TO WALLS, ROOF, FLOORS & GLAZING



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Historic Scotland Refurbishment Case Study 2

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1. Introduction

This report forms part of a series of *Refurbishment Case Studies* following the theme of thermal upgrades in a range of traditionally built properties in Scotland. This project, like the others that follow, sought to demonstrate that effective thermal upgrades were possible in parts of a traditionally constructed stone building without excessive cost and disruption for the owner, nor requiring extensive removal or damage to the building fabric. There was also an aspiration to use, where possible, natural materials that maintained appropriate levels of water vapour movement through the fabric. Current refurbishment approaches tend to take the ‘all or nothing approach’ with respect to intervention – most internal fabric is typically removed and replaced. While such a template can yield significant thermal improvements, the interventions to the building are considerable and the financial cost is invariably high. Either consideration makes such an approach problematic for many homeowners and property managers who wish to commission improvements on pre-1919 structures.

2. The site

The cottage used for this upgrade trial is a small single storey detached building dating from the early 19th century, with an addition to the east dating from c.1880, and is Category ‘B’ listed. It is constructed of sandstone rubble, bound with lime and finished with ashlar quoins and margins (Fig. 1).



Fig. 1. View of Wells o' Wearie Cottage from the North

Most of the external masonry elevations have been subsequently cement pointed to various degrees. The roof is pitched Scots slate on sarking with zinc ridges and the un-floored attic is used for storage. The accommodation comprises of three rooms, plus a bathroom and a kitchen. The property is managed by Historic Scotland as part of the policies of Holyrood Park, and recently became vacant at the end of a lease. The area used for the trial was limited to a single room, the living room, which is the later addition seen on the left hand side of Fig. 1. Prior to commencement of the works, the room had been cleared and was in reasonable order (Fig. 2). The building is situated in a sheltered dell, and as such there were no exposure issues or considerations of wind driven rain which can be common in more exposed areas of Scotland.



Fig. 2. The living room, prior to commencement of the works

In this report the works are described in terms of the interventions to individual fabric elements, following the outline hierarchy of interventions, set out in the Historic Scotland Short Guide *Fabric Improvements for Energy Efficiency in Traditional Buildings*.

3. Pre-intervention thermal performance

Prior to the works, existing thermal performance was measured by Edinburgh Napier University and consisted of in situ U-value measurements of the external walls, the floor and the ceiling, using the standard heat flux plate and associated equipment (Fig. 3). As glazing of the type present at the cottage had been tested before, this was not carried out. Relative humidity values for the void behind the existing lath and plaster was also tested. This allowed a pre-intervention baseline figure to be made in

order to judge the effectiveness of the upgrade works (Table 1). Techniques and the analysis are described in Historic Scotland *Technical Paper 10*, and the specific results for this site are described in *Technical Paper 17*. The results are very similar to other in situ measurements that Historic Scotland has monitored in traditional built fabric, and as such need no further discussion here.



Fig. 3. The heat flux meter and other equipment configured for floor measurements

Building element	U-value (W/m ² K)	Notes
Ceiling	1.4	Some mineral wool extant
South wall	1.4	Lath and plaster
East wall (right of window)	1.3	Lath and plaster
East wall (left of window)	1.3	Lath and plaster
North wall	1.3	Lath and plaster
Floor	2.4	Suspended timber
Window	5.4	Single glazed

Table 1. Pre-intervention U-values

4. Delivery of the work

While Historic Scotland operatives carried out the majority of the work, with oversight from the District Architect, some work was delivered in conjunction with three industry partners – an insulation installer, a building products manufacturer and an industrial fixings supplier (Fig. 4). This approach allowed a degree of discussion and experimentation with alternative insulation materials and installation techniques, responding to the particular conditions found on site.



Fig. 4. The contractors and suppliers for the project

5. Improvements to roof space

The ceiling consisted of lath and plaster with a later polystyrene coving. There was a modest amount of mineral wool in the loft space, which had been fitted some time ago and had slumped in areas. It was decided to replace the mineral wool with a sheep's wool product to a depth of 280 mm (Fig. 5), the standard depth for loft work. As there was no storage requirement, additional height was not necessary for the ceiling joists (Fig. 5), although this could be implemented if required. When insulating such roof spaces, and in effect turning a warm attic space into a cold one, additional roof ventilation is sometimes required. However, in this case, the slates are fixed directly onto the sarking, with no roofing or under-slate felt, and the ventilation to the roof space was considered sufficient. This is in contrast to more modern roofs, where if there is a non-breathable layer in place (such as under-slate bitumous felt) then slate vents might be required.



Fig. 5. The sheep's wool insulation laid in the attic space

6. Improvements to windows

The existing windows were of traditional sash and case pattern, in good condition with working shutters. As the sashes were '6 over 6' (six panes in each sash), the cost of inserting double glazed units into the existing sashes would have been considerable for such a small glazed area. Conventional secondary glazing would likewise have been expensive, so an alternative polycarbonate system was used – this is essentially a single sheet cut to size and applied with magnetic strips onto timber bearers within the staff beads (Fig. 6). This glazing arrangement allowed the shutters to continue to function, addressed thermal heat losses and air leakage and, while not to the standards of more mainstream options, it nevertheless made a significant difference.



Fig. 6. Polycarbonate secondary glazing in place; note the shutter is free to close

7. Improvements to floor

While the rising of warm air in a room is seldom questioned and a high priority is thus given to loft insulation, the thermal performance of floors is often overlooked. Upgrading floors can make a significant difference to an occupant's perception of thermal comfort – for if one's feet are warm you will feel thermally more comfortable and consequently content with a more modest air temperature. The floor was therefore an important element to be addressed in the works programme. The guiding principle of water vapour permeable materials was applied and vapour barriers were not used. A wood fibreboard was therefore selected, being able to buffer changes in humidity and manage water vapour at this important junction in the building fabric.

The floor was a suspended timber floor, consisting of largely original tongue and groove planks laid on timber joists of standard dimension. The solum was dry and well ventilated via two standard cast iron grilles through the walls in two locations, and the height of the solum void was approximately 200 mm.

It was found that in many areas only selected floorboards needed to be lifted (every sixth board) to gain access for the work, depending on the reach and skill of the joiner. In order to minimise damage to the boards when lifting, the feathers of the boards were cut with a 'skill saw' to allow easy prising up. Once the condition of the joists was confirmed as being sound, timber rails were fastened to the lower edge of each joist using ring shank nails (Fig. 7). By minimising the number of boards lifted, disruption was kept to a minimum although the skirting boards were removed. Proprietary wood fibreboard, 80 mm thick, was cut into bats to fit between the joists. This was initially done by hand, but cutting such composite materials with a handsaw proved difficult and led to a lot of dust; it was quickly decided to cut the material in the workshop with a bandsaw, which proved to be a much better solution. The bats were then eased into the space between the joists and held in place by the fixed rail. The floorboards were then replaced (Fig. 8).

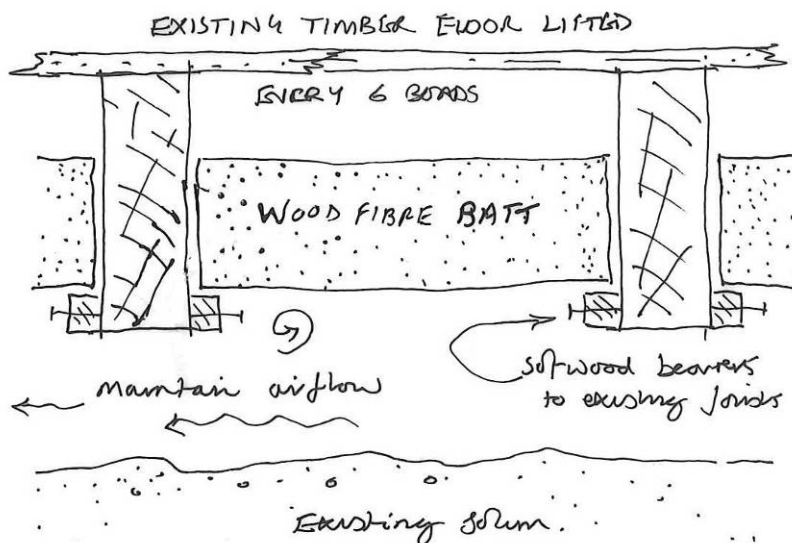


Fig. 7. Indicative detail for the floor insulation



Fig. 8. Floor being fixed down over wood fibre bats

8. Improvements to external walls

Internal wall linings consisted of lath and plaster, with some plasterboard patching, and the void behind the plaster was approximately 40 mm. As the room had three external walls, there was an opportunity to trial three different upgrade approaches without removing the existing linings. Two of these methods involved blowing insulating material into the void behind the lath and plaster; one involved the application of a thin layer of high performance insulant onto the surface of the existing lining.

The use of blown materials in insulation has been carried out for some time in new build and in refurbishment work, but it had not been used behind lath and plaster before. Existing techniques for the insulation of mass walls are mostly based on impermeable materials and the use of vapour barriers to manage water vapour at the insulation junction. These techniques can be damaging to the fabric of older buildings and invariably require the removal of internal linings. Such an approach does not acknowledge how mass walls handle water and water vapour, as well as the actual thermal properties and performance of the structure. Many such walls are not as poor insulators as assumed and modelled (Historic Scotland trials have proved the performance of these walls to be much better than previously assumed). The improvement required can therefore be more modest, as can be provided by applying insulation into the void behind the existing lining.

Key to the proper functioning of blown insulants is that both faces of the masonry wall are kept vapour permeable to allow dispersal of any vapour build up, and that the wall is not subjected to high water loading, such as in an exposed location where wind driven rain is prevalent. In areas of high exposure, filling cavities behind lath and plaster should therefore be approached with caution. Wells o' Wearie Cottage

sits in a sheltered location and the exposure to wind driven rain is low. This, combined with the good condition of the masonry, meant that the walls were dry and blown measures were therefore considered appropriate.

Condensation risk

When intervening in voids and cavities the question of condensation has to be addressed. Modelling of thermal performance and water vapour movement is still at a fairly early stage, but simulations were run by Edinburgh Napier University, Centre for Sustainable Construction, using standard software that used the Glaser method to establish the risk of interstitial condensation within the insulated wall. Their report on the calculated and measured humidity profiles forms part of *Technical Paper 17, part 2*. The results indicate that by using conventional methods, condensation risk is over estimated. Longer term monitoring (continuing until 2013) will allow further consideration of the results.

The modelling showed that in steady state conditions, the presence of blown insulation changed the temperature profile of wall as would be expected, but with no condensation risk. In more extreme steady state conditions (external air temperature of minus ten degrees Celsius), as is occasionally experienced in parts of Scotland, the dew point is occasionally reached. However, given the known limitations of the modelling and the rarity of prolonged extreme steady state conditions in Scotland's maritime climate, the risk was judged to be minimal in this case. In areas where such steady state conditions are more prevalent, such as for example in parts of the Central Highlands, more in-depth modelling is required. With these considerations in mind, the following options were trialled:

Measure 1 - Blown cellulose

Prior to the works, all decorative coverings were removed and defective plaster made good. This was required not just for the subsequent decoration works, but to ensure that the surface of the plaster was able to handle moisture for reasons described above. The skirting boards had already been removed as part of the floor works, and this allowed us to check that the floorboards were tight against the masonry (Fig. 9), preventing any loss of material down into the solum space.

A series of holes, approximately 25 mm in diameter, were drilled at 1 m centres across the face of the wall. A long hose was used to deliver the product, tailing back to a vehicle containing the blowing equipment. While parking was not an issue in this case, in some urban locations this could be a significant limitation on site works. The material was then blown into the void, working upwards from the lowest holes (Fig. 10). By the change in the audio tone around the nozzle, the operatives were able to detect when the cellulose had reached the level of the hole, and move on to the next opening. The wall was completed in approximately 30 minutes.

Following the blowing in work, facings and skirting boards were replaced, the holes were made good and lining paper was applied. In order to assess the potential benefits of better managing humidity in upgraded buildings with reduced ventilation level, distemper paint was applied onto the lining paper.



Fig. 9. Skirting boards removed to check wall and floor junction



Fig. 10. Blowing in the cellulose fibre

Measure 2 - Other blown materials

As part of this project, a blown aerogel (a bead type high performance silica product) was trialled on the second wall. However the pressures required for the blower were too high for the material, which although in a bead form, broke up in the hose and when in contact with the wall, producing a fine dust that proved difficult to control. The material was able to make its way into the solum and through very small gaps in the skirting boards, and as levels in the wall void were not rising appreciably, it was decided to discontinue the trial. This product, an extremely effective insulator, will be trialled again with a different delivery system in the future.

Measure 3 - Surface applied insulation

Where there are concerns with wind driven water penetration into mass walls (and it has to be accepted that this does happen in some situations) then the infilling of the void behind the linings should not be attempted, as the ventilated void plays an important role in water dispersal. Instead, an insulation material can be applied to the surface of the existing linings. In this trial a 10 mm layer of aerogel blanket was used, secured to the wall behind an expanded mesh sheet and fastened with thermally decoupled fixings (Fig. 11). To allow proper coverage of the wall, the skirting boards and facings were removed and two coats of renovating plaster were then applied to finish (Fig. 12).

In this case, issues of vapour permeability are not considered significant, as the existing void behind the lining is successfully managing the vapour, and passage of water vapour through the plaster layer is not important from a building fabric point of view. Likewise, the type of paint on the plaster is also not important, as it is not required to transfer moisture. As with other measures, skirting boards were replaced and the wall finished with lining paper and a modern distemper.



Fig. 11. Aerogel blanket held behind mesh



Fig. 12. First coat of plaster on top of the mesh/insulation layer

9. Improvements to chimney

The room had one chimney with a wood burning boiler / stove of obsolete design in the hearth. In many energy efficiency upgrade works, flues are closed off and stacks are dismantled. This is effective in reducing air leakage and advection heat loss but also removes an important means of ventilation. In addition, the chimneystacks are often a defining feature of traditional structures and its retention was considered important. In this case, as other areas of air infiltration had been addressed (from the floor and window), it was felt important not only to keep the stack, but also to keep the flue open, allowing passive ventilation of the room. As an alternative to permanent closure, a chimney balloon (Fig. 13) was fitted into the flue just above the grate to restrict air movement in winter and during times of high winds. The balloon can be removed when ventilation is required, such as during the summer and other warm months. Given recent changes in Scotland's weather, resulting in a shorter winter heating season and higher temperatures overall, the risks of overheating in well-insulated buildings are becoming also increasingly relevant. It is thus likely that traditional passive ventilation features such as chimneys may become increasingly important in keeping occupants cool in buildings of all types.



Fig. 13. Chimney balloon used to temporarily close off the flue

10. Post-intervention thermal performance

Following the works described above, a range of measurements was taken to assess the thermal improvements made by the interventions. In all areas there was a significant reduction in the U-value. The floor results were particularly encouraging and achieved with a simple new technique. Other interventions were less beneficial, notably the more modest reduction in U-value achieved with the aerogel blanket.

Building element	Pre-intervention U-value (W/m ² K)	Post-intervention U-value (W/m ² K)	Notes
Ceiling	1.4	0.2	Sheep's wool, 280 mm
South wall	1.4	1.0	Aerogel behind plaster
East wall (right of window)	1.3	0.6	Blown cellulose behind lath and plaster
East wall (left of window)	1.3	0.8	Blown cellulose behind lath and plaster
North wall	1.3	0.7	Blown cellulose behind lath and plaster
Floor	2.4	0.7	80 mm wood fibre insulation batts
Window	5.4	2.4	Secondary glazing – magnetised acrylic sheet

Table 2. Thermal monitoring results

11. Occupant feedback

After a few months of occupation, the resident was asked to comment on the works. Feedback was not as positive as might have been expected, and the room was still felt to be cold. That said, it was not regularly used and only intermittently heated. The room has three external walls and the adjacent room is the bathroom, itself modestly heated, which may explain the low temperatures.

12. Conclusion

The work at Wells o' Wearie has proved that with a range of relatively simple interventions, the thermal performance of traditional fabric can be improved. The building has now been re-occupied and has completed its second winter. The technical reservations regarding the filling of cavities, while understandable, seem unfounded although the results of longer term monitoring and assessment of the relative humidity within the walls and the filled cavity will be required to answer this definitively. More in-depth analysis of energy and financial savings for the building is complicated and not realistic because the works were limited to one room. This project has shown that a range of simple and appropriate techniques can show significant benefits in a traditionally built structure.

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