Historic Scotland: Innovative solutions to make traditional buildings more energy efficient

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With the drive to reduce CO2 emissions in recent years in response to concerns over climate change, increasing pressure has been brought on traditionally constructed buildings to reduce heat loss and improve energy efficiency. Such buildings have often been termed “hard to treat” and there is a misplaced belief that without costly interventions it is impossible to make any real improvement to such structures. In recent years Historic Scotland has been engaged in research into innovative options for improving the energy efficiency of such buildings. This article will look at 2 testing programmes which are in the process of completion into improvements to windows and wall insulation and also an examination of some future research work which is planned.

Windows Research

Historic Scotland has been working with Glasgow Caledonian University to test various options for improving the thermal efficiency of single-glazed timber sash and case windows. The results have shown that with appropriate interventions the thermal efficiency of such windows can be significantly improved. The results of the U-value testing have been published by Historic Scotland as part of a suite of Technical Papers[1].

A standard six-over-six timber sash and case single-glazed window was tested in the laboratory to provide a baseline u-value against which improvements could be measured. The glass (excluding the frame) had a measured U-value of 5.4 which is representative of windows of this type and age. This rating compares poorly to the current Scottish Buildings Standard maximum permitted U-value of 2.0 for new windows.

Firstly simple measures for improvement which did not impact directly on the fabric of the window were examined.

Draught proofing is a common practice to prevent wind from blowing in through traditional windows. The test window was draught proofed, and although the U value of the window was not improved, the air tightness of the window was enhanced considerably, reducing the air leakage by 86%. This will clearly have an impact on heat loss from traditionally constructed windows and is a good starting point when looking to improve on energy efficiency.

Fig.1 Testing improvement measures in the lab at Glasgow Caledonian University

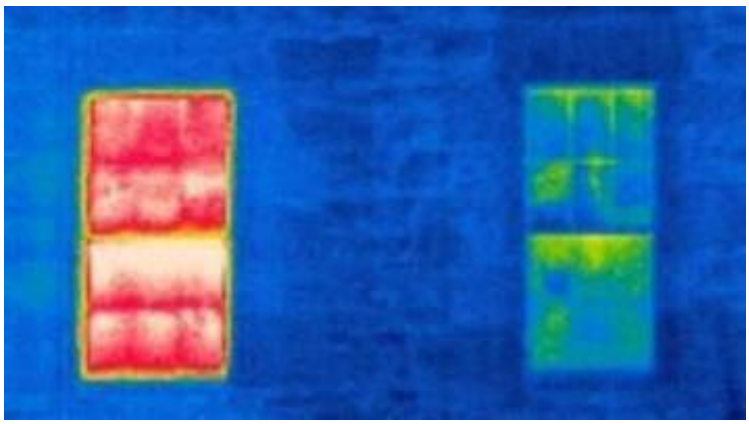

Fig. 2 Thermal image showing the reduction in heat loss with shutter closed (left) and shutter open (right)

[1] Technical Paper 1: Thermal Performance of Traditional Windows, prepared for Historic Scotland by Dr Paul Baker of Glasgow Caledonian University, October 2008

The options tested and the improved u-values are summarised in table 1, below. Of the options tested, secondary glazing was the most effective single option, as it reduced heat loss through the window by 63%. Timber shutters are the most effective option of the traditional methods, reducing heat loss by 51% with the other improvements shown below. The greatest reductions in heat loss came from a combination of measures. Using secondary glazing, or combinations of blind and shutters, reduced the U value of the window to below 2 W/m2K, which is the maximum U value allowed by Scottish Building Standards for timber or uPVC windows in new dwellings.

Table 1, results of u-value testing for improvement measures to sash and case windows

Improvement method	**Reduction in heat loss**	**U-value W/m^{2}K**
Unimproved single glazing (measured at centre of glazing)		5.4
Heavy curtains fitted to rail on inside of insulated panel above window	14%	3.2
Shutters	51%	2.2
Modified shutters, with insulation inserted into panels and covered with 6mm plywood	60%	1.6
Modern roller blind fitted at the top of the window case inner lining	22%	3.0
Modern roller blind as option 4, with low emissivity plastic film fixed to the window facing side of the blind	45%	2.2
Victorian blind fitted to the top of the recess formed by the window case pulley stiles at the side of the upper sash	28%	3.2
A “thermal” Duette honeycomb blind	36%	2.4
Victorian Blind & Shutters	58%	1.8
Victorian Blind, Shutters & Curtains	62%	1.6
Secondary Glazing System	63%	1.7
Secondary Glazing and Curtains	66%	1.3
Secondary Glazing and insulated shutters	77%	1.0
Secondary Glazing and shutters	75%	1.1

In addition to the measures which were included in this test, Historic Scotland is also looking at other interventions to the fabric of the windows which will improve energy efficiency whilst still retaining their character and where possible their existing fabric. This includes a range of double glazed units which can be fitted into existing sash and case windows to greatly improve energy efficiency but without adversely altering the character of the window. These come in a range of types from fairly simple slimmed down double glazing to more advanced vacuum pane technology. Other options such as acrylic “conservation glazing” which can be inserted against the existing wooden glazing bar are being developed and we will be looking to test these on an ongoing basis.

Fig.3a Vacuum double glazed pane

Fig.3b Vacuum double glazed pane in situ

Fig.4 The tenement in Sword Street where the trials are taking place

Fig.5 Insulating board being applied to new metal strapping

Solid Wall Insulation Trials

In the spring of 2009 Historic Scotland began trials of 6 different types of internal insulation to assess the improvement they gave in thermal performance and the impact on the health of the building.

The trials are being conducted at a property in Sword Street in the Denistoun area of Glasgow. The building became available as structural repairs and refurbishment were planned and the building owners, Reidvale Housing Association, kindly agreed to allow us access to the building to carry out the insulation trials. The building consists of 6 flats and it was decided to test one product in each. The products chosen were bonded polystyrene bead, wood fibre, hemp board, blown cellulose and two thicknesses of an insulated board. This encompassed the full range of products from natural to more synthetic with the aim that all should be breathable. All internal wall lings had been stripped out during previous refurbishments meaning there were no issues about removing the existing material.

The aim of the trials was to provide information on two measures of performance: improvement in the thermal properties of the wall and the possible level of moisture build up within the wall caused by the installation of the insulation. Clearly the first measure is of great importance when looking at any product to improve energy efficiency. Without significant improvement in thermal performance there is little point in installing the insulation. The second measure is also significant as any build up in moisture within the wall subsequent to insulation being applied could cause long term damage to the building. For this reason it was requested at the outset that the manufacturers of the products aim for an improved U-value of 0.3 and that the product be designed to avoid the creation of a moisture barrier. The baseline measurement of the unimproved wall gave a U-value of 1.1 measured by Strathclyde University before the trials.

Fig.6 Monitoring equipment was installed to measure both the thermal performance of the wall and the build up of moisture within the wall

The different types of insulation were installed using a variety of methods. The bonded polystyrene bead was injected into the cavity between the existing plasterboard and the wall. The cellulose insulation was sprayed damp directly onto the wall with plasterboard then put over afterwards with the wood fibre material being finished in the same way. The hemp insulation and insulated boards were attached to the wall with a plaster skim coat being applied as a finish. Several of the options required alterations to skirting and other fittings. This would clearly be a consideration where there was a more sensitive interior than existed in Sword Street.

Fig.7 Finishing blown cellulose insulation applied wet directly onto wall

Fig.8 Application of bonded polystyrene bead insulation into cavity between plasterboard and wall

The initial results in terms of improved u-values were as follows:

Table 2, improvements in u-value of solid wall property at Sword Street, Glasgow following the application of various insulation measures

Flat number	Insulation Type	Unimproved u-value	Improved u-value
Flat 1/1	100mm Hemp board between timber straps	1.1	0.21
Flat 1/2	90mm Wood Fibre fitted between timber straps	1.1	0.19
Flat 2/1	30mm insulated board onto timber straps	1.1	0.36
Flat 2/2	50mm Cellulose fibre damp sprayed between timber straps	1.1	0.28
Flat 3/1	40mm insulated board onto timber straps	1.1	0.22
Flat 3/2	50mm Bonded Polystyrene Bead	1.1	0.31

These results are significant as it can be seen that in all but one example the standard of a u-value of 0.33 or below was attained. Whilst in some cases, notably the hemp board and wood fibre insulation, significant thickness of material was required and the injected polystyrene bead required some re-wiring work prior to use, these tests show that a traditionally constructed mass masonry wall can be brought up to a high standard of thermal performance using materials which will hopefully also prove to be vapour permeable. Historic Scotland tests are still ongoing in this area and it is hoped that in the future, options which can be used to improve in situ lath and plaster can be developed to show that traditionally constructed walls can be significantly improved in terms of thermal performance.

Future Research Work

Historic Scotland has plans for significant ongoing research in this area with a number of projects continuing or starting in the coming months. The trust who run Dumfries House Estate have kindly allowed us access to the Garden Bothy where we are planning to test a wide range of materials. The measures which we are likely to look at testing include the following:

- Leca clay pellets behind in-situ lath and plaster
- Insulated lime concrete floor
- Sheep's wool insulation in loft and under timber flooring
- Double glazed units installed in existing sashes
- Biomass heating system

Similarly, we are working with Strathclyde Building Preservation Trust at the refurbishment of the old school building in Campbeltown incorporating many measures to improve the energy performance of the building. By looking at measures to improve the entire fabric of these two buildings it is hoped that a template can be developed for improving energy efficiency in traditionally built structures and that this can be developed into an electronic learning tool similar to the Inform House which Historic Scotland launched in 2009. Moses – do you want to explain a little about Inform House to explain what it does? Why it was developed etc?

In addition to this we are looking at continuing to test various specific building elements, in particular floors. We are currently testing an insulated lime concrete floor at Blackburn House. This is to measure its u-value as it seems it could be an effective way of improving the insulation of traditional floors and will provide the basis for other tests and ways of improving their energy efficiency. Finally, also on the Dumfries House estate, we are hopefully going to test 1 or possibly 2 types of insulated external lime based render. This will most likely take the form of render incorporating hemp fibre or clay pellets although this has not been finalised. The aim is to provide a solution which will allow damaging cement render to be removed from traditionally constructed buildings and replaced with a material that both improves the thermal performance of the building and the longevity of the structure.

Conclusion

It is hoped that what is discussed here provides a useful introduction to the research work which Historic Scotland are carrying out to identify the best solutions for improving energy efficiency in traditionally constructed buildings. The research already carried out into measures to improve the thermal performance of windows and walls has identified measures which can be taken to bring these elements up to or approaching modern standards. The future research work is very much designed to build upon these past projects and ensure that new and innovative solutions continue to be identified. This research will hopefully ensure that such traditional buildings can have good energy performance whilst ensuring that measures taken are sympathetic to the structures.

Fig. 9 Dumfries House Garden Bothy (top) and Campbeltown Schoolhouse (middle), future test beds for various energy efficiency measures

Fig.10 Hemp and lime concrete insulated floor at Blackburn house currently being tested