3.0 CASE STUDY- MONITORING OF ROSEWARNE HOUSE STABLE BLOCK CONVERSION (Fig.3)

3.1 Introduction

A stable block with solid local stone walls at the rear of a grade 2\* listed building is being converted to four separate cottages. Cottage A is being upgraded conventionally with internal non permeable Celotex PUR closed cell dry lining. The other three cottages are being internally insulated with different types of natural breathable insulation. Cottage B is being insulated with woodfibre board and clay plaster, Cottage C with ecoCork plaster and Cottage D with Cork board. 60mm insulation is being fixed to internal walls and 20mm insulation fixed to internal window reveals.

Monitoring will analyse:

* Whether breathable internal insulation affects the thermal performance of solid walls and whether damp problems are reduced and good air quality is maintained.
* The relative life cycle impact of retrofitting historic buildings compared to demolishing and building new. A retrofitted building’s thermal performance will usually be worse than that of a new building leading to higher in use energy and emissions. The analysis looks to what extent this is mitigated by lower embodied energy and carbon of the retrofit and how this is affected by choice of materials.

Heat Flow measurements to date compare Cottage A with Cottage D (with normalised floor areas) and provide estimates of the embodied in use and overall energy and carbon of the conversion compared to a new building with masonry/ cement construction.

3.2 Monitoring

The 600 mm thick stable block walls have granite facing stones with a central core of stone, earth and air voids. This makes an accurate thermal resistance estimate difficult. Presuming the stone is granite and the earth/stone core ratio range is 20/80 to 80/20 then a steady state U-value calculation would estimate the R value of the stone wall to be 0.37 to 0.65 W-1 K m2, giving a U-value of 1.5 to 2.7 W K-1 m-2. Steady state calculations for finished walls after adding insulation give U values of 0.31 – 0.34 for Cottage A, and 0.74 to 0.94 for Cottage D.

Direct heat flux measurements by other authors such as Baker (Baker, 2011) and (Biddulph *et al.*, 2014) have consistently shown, however, that the effective U-value of thick solid walls is lower than the steady-state value, at least in the UK climate.

The heat flux measurements were carried out over several days in the same manner as the authors mentioned, using thermistors pressed to the interior and exterior surfaces to measure temperatures *T*in and *T*out, together with a Hukseflux HP5 heat plate on the interior wall surface to measure the heat flux *Q*. The data were analysed in the manner of Biddulph and co-workers (Biddulph *et al.*, 2014), in which the walls were modelled as two thermal resistances *R*1 and *R*2, linked to an internal wall heat capacity *C*, with the initial temperature of the wall interior parametrised as *T*m,init. We used a maximum likelihood estimation, using the mle() function in R to find the best fit values of these parameters. Plots of the temperature measurement and real and modelled heat flow measurements are shown in Figure 1.

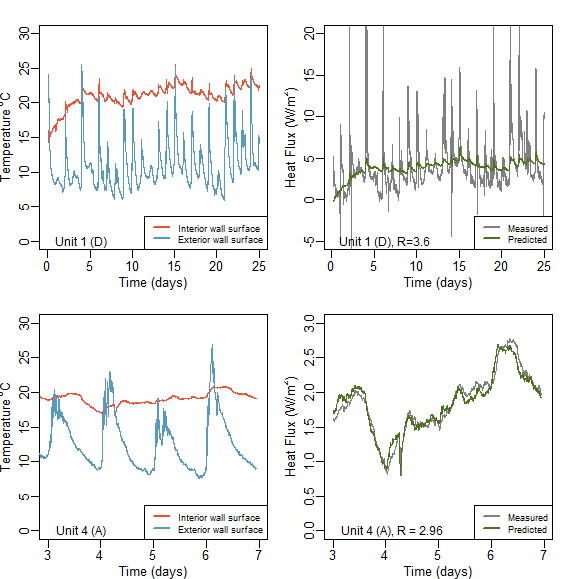


Figure 1: (left panels): Interior and exterior wall surface temperatures of the two retrofitted units studied within the stable block at Rosewarne House. (right panels): measured (grey) and modelled heat fluxes through the walls of these units.

Results show that that the walls of Cottage D have a thermal resistance of 2.65 W-1 K m2, and a U-value of 0.39 W K-1 m-2, while corresponding values for Cottage A are 2.96 W-1 K m2 and 0.34 W K-1 m-2. A bare wall U value measurement of Cottage A before insulation was applied was 1.3 W K-1 m-2.

The method of analysis used here means that these results are valid despite in some cases short measurement periods, and that on occasions internal temperature exceeded the external temperature. These results are consistent with those of Baker and Biddulph and co-workers, in that the U-values are lower than steady-state calculations would suggest.

This reduced difference in U-value, between what is achievable with modern materials and what is achievable with historic, breathable materials in thick, solid-walled buildings, has a considerable impact on the relative life-cycle impacts of the two type of construction.

A process LCA model has been used with embodied energy and carbon values from the Bath University Inventory of Carbon and Energy (Hammond and Jones, 2011), along with a simplified building physics model based on SAP (BRE, 2012) to estimate the embodied and in-use carbon and energy of each of the cottages compared to that of a new-build residence of the same size. Construction, repair and refurbishment contributions are not available yet but energy and carbon that would arise from demolition and disposal in the case of rebuild from new strategy have been included. The result of Moncaster and Symons (Moncaster and Symons, 2013), which is that this part of the life cycle accounts for 21% of embodied carbon and 5% of embodied energy has been assumed. The results are summarised in Table 1 below:

Table 1: Summary of the embodied, in-use and lifetime (50 year) energy and carbon of the two retrofitted units and a conventional new-build of the same size.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | Unit A | Unit D | New Build |
|  | Wall construction | 600 mm granite/earth/50 mm PUR closed-cell foam | 600 mm granite/earth/60 mm cork board/NHL finishing render | 2 leaves of 100 mm concrete block, 125 mm cavity inc. 75 mm PUR closed-cell foam. |
| Embodied Energy (kWh m-2) | 458 | 183 | 792 |
| Embodied carbon (kg CO2 m-2 ) | 138 | 80 | 298 |
| Steady state | In-use energy (kWh m-2) | 48.3 | 87.1 | 22.1 |
| In-use carbon (kg CO2 m-2 ) | 8.9 | 16.1 | 4.1 |
| Lifetime energy (kWh m-2) | 2874 | 4537 | 1972 |
| Lifetime carbon (kg CO2 m-2 ) | 585 | 886 | 627 |
| Dynaimc | In-use energy (kWh m-2) | 47.4 | 58.6 | 22.1 |
| In-use carbon (kg CO2 m-2 ) | 8.8 | 10.8 | 4.1 |
| Lifetime energy (kWh m-2) | 2829 | 3114 | 1972 |
| Lifetime carbon (kg CO2 m-2 ) | 576 | 622 | 627 |

5.0 Conclusion

* A striking result is that proper consideration of the dynamic nature of heat flow through the thick walls of the historic properties considered here means that the lifetime carbon emissions of the retrofitted cottages are comparable to those of the new build, even for the cottage in which a less thermally insulating cork layer was used. Without this dynamic treatment, an incorrect view that the lifetime emissions are in fact considerably greater would be arrived at.
* There is also scope for the natural product retrofit in particular to achieve lower emissions than either the modern material or new build options, given the likely reduction over coming decades in the carbon intensity of electricity, if space and water heating were switched to an electrical form.
* It is noteworthy that the cork boards and plasters used in Cottage D, as well as the slates used for roofing used in all units were imported from Portugal and Spain. Using carbon intensities supplied by DEFRA , we find that the additional transport emissions due to this distance of travel are less than 1% of the lifetime building emissions, and thus not a major consideration.
* Further work will seek to establish any difference expected in energy and emissions due to lifetime refurbishment and repair, in particular to determine whether use of breathable materials for insulation confers advantages in terms of damp avoidance and air quality.

**5.0 References**

[1] A traditional skills training programme summary and ‘Improving Energy efficiency in Cornish Historic Buildings’ guide and can be accessed from the Camborne, Roskear, Tuckingmill Regeneration, Energy and Skills Townscape Heritage Initiative website: <http://www.cornwall.gov.uk/environment-and-planning/conservation/heritage-led-regeneration/camborne-roskear-tuckingmill-townscape-heritage-initiatives/>

[2] Heritage Lottery Fund Townscape Heritage –: <https://www.hlf.org.uk/looking-funding/our-grant-programmes/townscape-heritage>

[3] Hukseflux heat flux, thermocouple sensors and NRG data loggers: <http://www.hukseflux.com/page/products-services>

[4] EVM-7 Air Quality Monitors: <http://www.shawcity.co.uk/air-and-dust-quality/gravimetric-sampling/evm-7-all-in-one-environmental-monitor-temperature-rh-pid-co2-co-particulates>

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Figure 3. Monitored internal insulation, Stable Block, Rosewarne House,

A lifetime envonmental impact study and life cycle analysis is being carried out on the Rosewarne stable block comparing the conversion to a new-build of comparable size (built to current Building Regulations with standard masonry construction) examining the diference made if low impact, natural and breathable materials are used instead of modern, petrochemical based materials. The embodied energy difference has been estimated based on materials used and the difference in in use energy and emissions calculated (given that each unit has the same 25KW gas boiler). The difference between the sums of these is an estimate of the differential environmental impact of the respective retrofit methods.

The results are summarised in Table 1 below, where U-values have been calculated based on plans for the buildings and given an estimated thermal resistance of 0.76 W-1m2K for the existing solid walls. This is based on preliminary heat flux measurements using a Hukseflux HFP01 heat plate left in-situ for two weeks.. This value is lower than default values for solid walls of comparable thickness, but comparable to those found by Heritage Scotland in a recent study on similar properties.

***Table 1.***

|  |  |  |  |
| --- | --- | --- | --- |
|  | U- Values (Wm-2 K-1) | | |
| Element | Unit D | Unit A | New Build |
| Walls | 0.67 | 0.4 | 0.3 |
| Roof | 0.41 | 0.26 | 0.2 |
| Floor | 0.37 | 0.3 | 0.25 |

Assuming an estimated infiltration value of 10 m3h-1m2 annual space  heat demands on Units A and D are 4300 kWh and 3000 kWh while a comparable new-build would be around 1300 kWh. The figures reverse when embodied energy is considered with values of 3000 kWh for Unit A, 6000 kWh for Unit D and 43000 kWh for a combarable new build.

Over a 50 year lifetime, a new build property could still have a lower energy impact than the retrofitted properties, given the insulations specified here although this difference could be reduced or even reversed by improving the retrofit insulation specification. Other factors have yet to be considered such as the relative impact of embodied carbon (where the sequestered carbon and absorbed carbon of the timber and lime materials will make a difference), the results of the air quality studies and impact of demolition. These factors will be further analysed when all monitoring is complete and full results will be available for the conference in October.