**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 was fixed to internal walls and 20mm to window reveals to counter cold bridging. Monitoring will analyse:

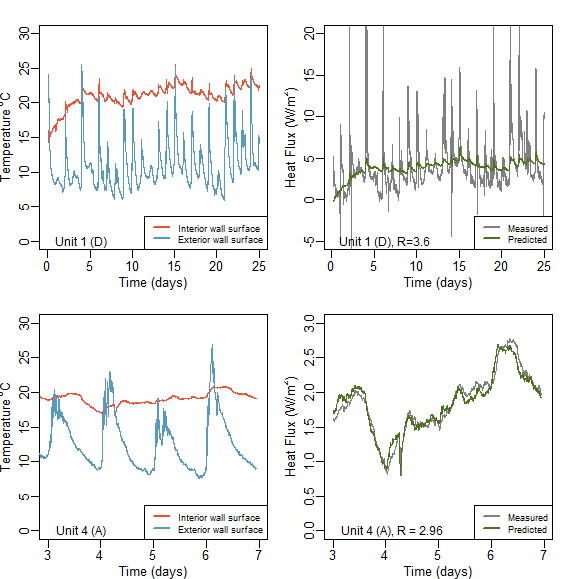
* Whether breathable internal insulation affects the thermal performance of solid walls and whether damp problems are reduced and good air quality is maintained.
* The relative life cycle impact of retrofitting historic buildings compared to demolishing and building new. A retrofitted building’s thermal 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 the 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.

The heat flux measurements were carried out over several days in the same manner as the Baker, P. (2011) and Bidulp *et al.* (2014), 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 , by modelling walls 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. A maximum likelihood estimation, using the mle() function in R was used to find the best fit values of these parameters. Temperature measurement plots and real and modelled heat flow measurements are shown in Figure 4.



*Figure 4: Left panels show interior and exterior wall surface temperatures of the two retrofitted cottages. Right panels show modelled (green) and measured (grey) heat fluxes through the walls of these units*

Results show Cottage D walls have a thermal resistance of 2.65 W-1 K m2, and a U-value of 0.39 W K-1 m-2, while those of 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 insulationwas added was 1.3 W K-1 m-2. This reduced U value difference impacts on the relative life-cycle impacts of the two types of construction. An estimate of embodied and in-use carbon and energy use (including demolition and disposal) was made comparing the cottage conversion to a similar sized new building. This used a process LCA (Hammond and Jones, 2011) and a simplified building physics model based on SAP (BRE, 2012). Demolition and disposal contributions where relevant were taken Moncaster and Symons (2013) to contribute 21% of embodied carbon and 5% of embodied energy. 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 |

**3.3 Conclusion**

* When the dynamic nature of heat flow through the thick solid walls is taken into account the lifetime carbon emissions of the retrofitted cottages are found to be comparable to those of the new build, even for the cottage where less thermally insulating cork layer was used. Using this dynamic treatment significantly reduces estimates of lifetime emissions.
* There is 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.
* Cork boards and plasters used in Cottage D, as well as all roofing slates were imported from Portugal and Spain. Carbon intensities supplied by DEFRA show 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.
* Full detailed results from the ongoing thermal and air quality monitoring carried out in the stable block will be available for the conference in October.

**4.0 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 THI 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>

[5] Baker, P. (2011) ‘Historic Scotland Technical Paper 10: U values and traditional buildings’. Historic Scotland. Available at: http://www.historic-scotland.gov.uk/technicalpaper10.pdf.

[6] Biddulph, P., Gori, V., Elwell, C. A., Scott, C., Rye, C., Lowe, R. and Oreszczyn, T. (2014) ‘Inferring the thermal resistance and effective thermal mass of a wall using frequent temperature and heat flux measurements’, *Energy and Buildings*, 78, pp. 10–16. doi: http://dx.doi.org/10.1016/j.enbuild.2014.04.004.

[7] BRE (2012) *Standard Assessment Procedure (SAP 2012)*. Available at: http://www.bre.co.uk/sap2012/page.jsp?id=2759 (Accessed: 27 May 2016).

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[9] Hammond, G. and Jones, C. (2011) ‘Embodied Carbon: The Inventory of Carbon and Energy’. BSRIA.

[10] Moncaster, A. M. and Symons, K. E. (2013) ‘A method and tool for “cradle to grave” embodied carbon and energy impacts of UK buildings in compliance with the new TC350 standards’, *Energy and Buildings*, 66, pp. 514–523. doi: 10.1016/j.enbuild.2013.07.046.

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.

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.

Analytical methods used means that results are valid despite some short measurement periods, and on occasions internal temperatures exceeding external temperature.

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

between what is achievable with modern materials and what is achievable with historic, breathable materials in thick, solid-walled buildings

model with embodied energy and carbon values from the Bath University

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.