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Thermal upgrades in traditional buildings – a multi factored approach

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Abstract. Balancing the needs of building conservation and carbon reduction, whilst often considered a challenge, it can also be an opportunity. This paper will start by outlining some refurbishment principles that have been followed by Historic Environment Scotland in a conservation-based approach to the refurbishment of traditional buildings. The principles develop themes in building conservation and retrofit discussed by Historic Environment Scotland and other heritage organisations and add in more recent thinking on resources, embodied carbon, the circular economy and climate change to give what might be called a 'multifactored approach'. These factors or considerations are not new in heritage work but are not often considered in mainstream, less conservation focussed refurbishment projects. These factors go beyond issues of heritage conservation alone and allow the experience and findings of conservation sector to be part of a wider sustainability movement in the built environment, where the retrofit of existing older buildings of all types, protected or otherwise, are seen as part of the solution, not the problem. By adopting a conservation approach in all buildings more carbon can be saved, and more buildings retrofitted appropriately.

Keywords – Retrofit; historic buildings; sustainability; carbon reduction; conservation approach

1. Introduction

Work on the thermal refurbishment of historic buildings has been a focus of heritage agencies in Europe and elsewhere for some years, with various organisations taking forward studies and research on various levels. European Union funding for energy refurbishment projects has been delivered under the FP7 and the Horizon 2020 streams [1]. Joint working in this area has led to some good technical and policy outcomes, as well as a European Standard for the Refurbishment of Heritage Structures [2]. Individual Heritage Agencies with national responsibilities have published guidance on historic building refurbishment, such as English Heritage in 2012 [3] and Historic Environment Scotland in 2014 [4]. Their approaches to refurbishment were based largely on modest fabric measures that were driven on a desire to retain historic fabric and minimise loss, whereas, in the refurbishment domain of unprotected structures, interventions tended to be more significant, utilising a range of modern materials and systems, and achieving high levels of air tightness and low u-values [5]. Historic Environment Scotland continued research on sensitive retrofit upgrades with a series of case study refurbishments focussing on basic fabric measures and the resulting thermal benefits. This fabric focussed approach was summarised by HES in 2016 under the banner of ‘keeping it simple’ [6], where the origins of the refurbishment principles began. While this was good, when the focus was on developing fabric measures for what were termed in the UK ‘Hard to Treat’ properties, other factors in sustainability and refurbishment were emerging under a wider theme of embodied carbon. But as their operational energy costs and carbon use was high, older buildings were under scrutiny [7].

Heritage bodies in many parts of the world started looking at better ways of considering embodied carbon as a way of accounting for the resource contribution of the historic built environment and its continuation versus demolition and replacement [8]. It was clear that if the historic environment was to have a place in a low carbon future, then more extended arguments concerning carbon, resources and society were needed. Many of these were more intuitive and harder to argue from a low research base. In addition, as retrofit gained more experience in delivery, specific areas of concern emerged, especially regarding building condition, the need for measures for climate change adaptation, addressing indoor air quality, as well as heating and cooling. These themes are discussed below in the framework of the developing *refurbishment principles*, developed by HES, that overall give a multifactored *conservation approach* to retrofit to be considered in the upgrade of older buildings.

2. Refurbishment principles

These principles have been developed during the period of the HES Refurbishment Case Studies which ran from 2008. They seek to guide thinking, rather than set designers down a specific route; they can also be of use in refurbishment approaches in other countries, where principles remain the same, even if the building typologies vary considerably.

- The building is in good condition.
- Climate change adaptation is considered and addressed.
- Measures are technically compatible with the existing fabric.
- Upgrade existing fabric elements as opposed to removal and replacement.
- The installed measures are durable and resilient.
- Materials are sustainably sourced.
- Ventilation and indoor air quality are addressed.
- Measures are based on what the building can reasonably take without excessive work
- Measures comply with Energy Standards and Building Regulation where practicable.
- Renewables and low carbon technologies to address M&E requirements

Some of these case studies, the ones carried out between 2010 to 2016, have been summarised in Technical Paper 24 [9], where the buildings were reviewed for condition and performance by an independent surveyor. This body of work allowed broader conclusions to be made and the substance of the principles to be fleshed out. These are discussed in greater depth below:

2.1. The building is in good condition

It goes without saying that a building should be in good condition before work on thermal upgrade is planned. In conservation work this is generally the priority, but in the mainstream retrofit sector, the application of the measures is the primary function, which is separate to maintenance and repair. Many insulation measures fail not because the measure is at fault as such, but that it is applied onto a structure that is defective. As many insulation contracts are ‘Design and Build’, the insulation contractor has no ownership of the building condition. The culture of maintenance in many parts of the world is now entirely absent and repairs only happen when an element fails, or the disrepair reaches an unacceptable level. In Scotland, it is estimated by the Scottish House Condition Survey that 71% of pre-1919 buildings are in a state of disrepair. This will need to be addressed as part of the national effort to retrofit to the required standards.

2.2. Climate Change Adaptation is considered

In many circumstances, maintaining or repairing a damaged part of a building without understanding the decay process is simply to accept that it will need doing again soon. The climate in many parts of Europe is changing. In Scotland, this means milder but wetter winters and hotter summers. Repairing the damage may not be enough; upgrade of certain parts of the building to prevent it happening again will be necessary. For the traditional and historic architecture of Scotland, this means attention to building details that shed water away from the building. The established palette of traditional materials used for hundreds of years will work, if these are properly detailed and finished. Examples might include chimney head details and gable ends, where water ingress is common; measures to address this have been published by HES [10]. While water is often the issue, changed conditions may result in overheating at certain external temperatures and higher relative humidity will also require a response. As such, energy efficiency measures, including internal insulation, may only be part of a solution along with exposed parts of a building needing repair and upgrade. Other adaptive options, such as an appropriate external finish insulation layer may be able to address both the increased weathering and heat loss and, with the right detailing, the building will be resilient against the effects of climate change.

2.3. Materials are technically compatible with existing fabric

Building conservation has always had a strong focus on the correct materials; this is often manifested in the lime and cement mortars discussion. There is consensus that traditional substates and structures need to have materials of similar performance and properties. The question of choice for the insulation type is the same; the water vapour dynamic should be allowed to operate as constructed with compatible materials. Generally, this means materials which are vapour open and capillary active, as these are able to absorb and disperse water, much as they did when the building was constructed. Some of the materials available with these properties are organic in origin and lend themselves to use with traditional fabric. These might be new materials with the right properties, such as a hemp fibre board, or traditional ones with modifications such as an insulated lime plaster. In many cases, these materials also align with the aesthetic and presentation of the building or room.

2.4. Upgrade existing fabric elements

Strongly linked to building conservation philosophy is the need to retain historic or traditional fabric. This is to preserve the authenticity and the original make-up of the structure with its textures and character, but also to retain the embodied carbon of the building, reusing resources and minimising the need for new products. This approach was followed at the HES refurbishments: doors were insulated; existing wall linings were retained and improved with insulation; floors were lifted, insulated and re-laid. While this approach made sense to most conservation practitioners, such retention is not standard practice in retrofit, where most internal linings and features are removed to fit internal insulation. To oblige a less destructive approach in retrofit, wider arguments concerning embodied carbon need to be made to allow the benefits of the existing environment - historic or otherwise - to be made.

Holyrood Park Lodge was the latest in the series of refurbishments and sought to showcase the principles being discussed [11]. What if the Lodge refurbishment had been done differently, as a whole house refurbishment as national guidance recommends, such as PAS 2035 [12], adhering to all the conventional objectives of low U-values and high airtightness: all internal linings removed; phenolic foam insulation fitted to walls and roofs; new triple glazed windows; concrete floors; and mechanical ventilation? The energy assessment would have come out well, reaching a high standard. But how would this have added up in embodied carbon terms: of the materials, carbon released in the waste from landfill, running and maintenance costs over the lifetime of the measures; and disposal costs of non-compostable products compared to the approach followed in the principles? This work to calculate the carbon costs and benefits of the HES refurbishment versus other approaches has been planned (originally as part of this paper but is now is anticipated in Spring 2021) to show what the difference in approach will make.

2.5. The installed measures are durable and resilient

In many developed economies, there is a culture of things not being used for very long, either in changing fashion for interiors, in kitchen fittings, flooring or even buildings themselves. Many products seek to demonstrate their suitability with guarantees which often do not extend beyond ten years. The measures for older buildings, many which have been standing for over a hundred years, should last for the rest of the building's life. However, this is generally not the case; in many refurbishments, particle board floors are popular, as they are low cost and quick to lay. But they don't last long, even under normal use, and if there is a flood or even modest water contact, they break up. A traditional timber floor will be able to dry out with modest repairs but takes longer to lay and requires a little more skill. This example shows the need for considerations of resilience, where materials must be able to take a degree of attrition and if they are damaged, they must be repairable. Zero Waste Scotland, a public body focussed on addressing the unsustainable levels of waste generated in construction, seek to oblige the reduction of waste at source by retention, upgrade and reuse through their construction guide [13].

2.6. Materials are sustainably sourced

The definition of this phrase varies, but it is an obligation on those in construction and retrofit to use materials which do not harm the planet or future generations. The material itself must be safe; but the processes in its manufacture or production should be ethical. In a traditional building, getting the right materials is often difficult as the original local supply, such as brick, may have closed and manufacture moved elsewhere.

In materials choices for retrofit, how much energy is involved in its manufacture, how far it travels, who installs it and how it is maintained, is an additional part of the carbon balance sheet for a refurbished building. Increasingly, the use of an Environmental Product Declaration (EPD) is required. This captures some carbon aspects of the product and quantifies carbon captured through sequestration when the material, such as timber or hemp, was grown. For a conservation retrofit, the use of carbon negative materials can be part of offsetting the operational carbon emissions. At Holyrood Park Lodge a considerable quantity of wood fibre board was used; this material will be modelled to ascertain how much offsetting it can give, and for comparison, other materials will be modelled too. If the right materials are selected, traditional buildings can be carbon sinks, helping to sequester carbon. Such material is lime, a common binder in old mortars and one which reabsorbs the carbon released in its manufacture [14].

Where the materials come from, how they are used and how they are disposed of is part of the circular economy; an approach to manufacture, procurement and waste management that Zero Waste Scotland is promoting with Historic Environment Scotland. The wood fibre board from the Lodge came from Austria, so it had a considerable quantity of road miles associated; this is not a problem, but nor should it be ignored. A new company is developing a hemp-based insulation product that uses hemp grown in the north of England and the manufacturing done in Southern Scotland. This is a material suitable for the retrofit of old buildings, produced in the same region, that is a low carbon product. This material will be modelled at building level, but also at scale to identify how much carbon the historic environment could hold if this type of material was used in retrofit. All this can be used in supporting the case for a conservation approach to retrofit. This type of thinking is not limited to older buildings. Many designers and builders of new low carbon homes use organic materials. HES is not alone in advocating this type of approach; others giving advice in the sector support such approaches to material selection. The Pebble Trust has developed a guide to renovation, which while more invasive in its approach to building fabric, the material choices are similar [15].

2.7. Ventilation and indoor air quality

Good internal conditions in a building are more important than ever. We spend more time indoors than we did. What we breathe and how that air is moved about is important. In northern Europe, there are many studies that show increase in asthma rates in younger people corelating with an increased focus in energy efficiency requirements [16] and reduced customs of ventilation; this dates from the first energy crisis in 1974. The first effect of such ventilation reduction is higher levels of carbon dioxide from respiration. Reduced ventilation often results in high levels of humidity in buildings, resulting in mould growth in cooler areas.

Some modern buildings are prone to overheating, but many refurbished ones are too. Reports from 2015 in London alluded to an overheating problem [17]. The Paris heatwave in 2019 claimed many lives and in many cities that summer was not a comfortable one. As climate change raises temperatures, where do we want to spend the carbon; on heating cooler homes or cooling hotter ones? The winter heating period is reducing; the period of temperate and hotter conditions is increasing. Heat islands in cities can compound the overheating problem.

Many older structures relied on passive ventilation. Public buildings, where large numbers of people gathered for events etc., were ventilated by well-designed passive systems. In addition to the windows, the fleches on the ridges of many theatres and halls were not simply decorative but had an important function. Nearly all of these have been since closed off, and some replaced by large mechanical systems. A lot of refurbishment does not see the reuse of legacy features as a priority. Schools are a good example. In the 19th century, the focus was on high levels of natural light, ample ventilation and high ceilings; the large, often south facing, windows and ventilators on the roofs attest to that. Such features have been modified out; windows sealed and blacked out; ceiling ventilation closed off; and ceilings lowered. The result was high internal temperatures and carbon dioxide levels, affecting pupils' concentration levels [18]. In the summer of 2020, schools in Edinburgh were obliged to open the windows for ventilation for the first time in years. The difference in comfort and air quality was considerable, noticed not just by pupils but by visitors too [19]. Passive measures are not complex; they use no power and need modest servicing.

To progress the understanding of traditional ventilation systems, HES supported the restoring of the 19th century passive ventilation in a former Victorian School in Oban on the West of Scotland. This involved reopening the ducts from the classrooms up to the roof ridge and reinstating the ventilators. The work is still in progress and monitoring will show how effective it is. The building has all the features of an old school: high ceilings, large windows, high ventilation levels; all features that post-war school refurbishments sought to reduce or even remove. This school project unwound these interventions for the building's new community use. It is significant to note that the building was able to open in Summer 2020, when all other venues in the town could not operate due to the pandemic. The reduction of infection risk through good ventilation is well established [20]. Further considerations of indoor air quality and health are being investigated in relation to traditional ventilation and architecture and this will be published in Summer 2021.

2.8. Measures are based on what the building can take

In retrofit, there is a danger that - to quote Voltaire - 'the perfect becomes the enemy of the good'. To deliver retrofit in a thorough and comprehensive fashion is costly. There are many examples of where

EnerPHit standard has been achieved and the results are impressive [21], but at a cost and level of intervention that is unlikely to be widely replicable. Not everyone will be able to afford an intensive package. More modest interventions that save carbon and reduce consumption are more proportionate and, therefore, more likely to be delivered. There are limits on the amount of insulation that is effective; May (2012) has argued that beyond a certain thickness of insulation, the measure no longer delivers savings [22], and there are physical limitations in play as well. In Scotland, the biggest single factor in the energy assessment is the fuel type. Action on decarbonising the grid will be necessary, as well as provision of low carbon and renewable heat sources. Heat pump technology is developing rapidly and may be able to pick up where fabric is no longer able to go.

2.9. Measures comply with energy standards and building regulations where practicable

Many HES case studies were only able to trial specific measures, but the latest one, Holyrood Park Lodge (completed in 2018), was a whole house refurbishment, where most trial measures from previous examples were used together. In Scotland, building assessment is carried out by production of energy performance certificates (EPCs) using the Reduced Standard Assessment Procedure (RdSAP) methodology. To meet climate change targets, the Scottish Government have set targets for building performance based on EPC scores, set into 'Bands'. Band G is the lowest and worst performing; Band A, the best. Many older buildings, especially those built before 1919, do not perform well. Most are at Band D or below (D is the current average for dwellings of all ages across Scotland). Following refurbishment, Holyrood Park Lodge has an EPC rating of Band C - a considerable improvement on its starting Band F and a significant achievement for a property of this type (detached structure with mass-masonry walls). The Refurbishment Case study, describing how this was achieved in a protected structure can be downloaded for free [11]. It shows that a suite of conservative interventions, involved around upgrading the existing fabric, can deliver significant energy improvements to a protected building.

2.10. Renewables and low carbon technologies

Renewable technologies can be viewed as spoiling the architecture and their installation is sometimes resisted. With net zero targets set for many Scottish buildings by 2045 and the practical extent of fabric improvements reached, renewables will have to play a part in bridging the gap to allow pre 1919 buildings to reach net zero. This may not always be solar systems. HES have trialled infrared heating and an air source heat pump in a church in the west of the country. This allowed the building to be heated to a baseline level when not in use, with additional heating being supplied on demand by infrared heating in the pews and nave. The Lodge (EPC Band C), has the potential to achieve band B by the addition of a PV array. Such arrays do not necessarily have to be on the roof slopes; rather they can be mounted elsewhere, where circumstance permits. Other studies have shown that renewables can be utilised in most locations; a group of B-listed buildings, also in Edinburgh, have had roof top solar thermal arrays fitted since 2010 [23] and Kilmelford Church an air source heat pump [24]. Although it is worth noting that low and zero carbon technologies can have relatively high embodied carbon and relatively frequent replacement cycles. These examples demonstrate that where the limits of fabric work have been reached, renewable technologies can play a bridging role in bringing traditional buildings up to the standards required by legislation aimed at carbon reduction.

3. Discussion; towards a conservation led retrofit

It is considered that the principles outlined and their combination as an approach to retrofit can deliver a low carbon, sustainable building. It is accepted that the principles will not generally lead to a property that meets Passivhaus or similar energy standards, although in some cases historic building refurbishment can and has been delivered to that degree [21]. During a retrofit to such a standard, the extent of the required interventions would generally be excessive, unless there had been a fire and catastrophic loss of original fabric. It is also worth noting that, typically, where these more extensive retrofits have been carried out, the carbon cost of discarding original fabric is often not considered. However, once we consider the wider carbon picture and the other factors at play, we find that a conservation approach can deliver retrofit to a standard that meets targets and goes a long way toward achieving long-term carbon savings.

Conservation arguments, although valid, are by their language and value system, selective and with a small audience. However, the arguments of carbon reduction and resource retention have a wider audience. If the historic environment cannot articulate its benefit in more than aesthetic terms, important though they are, it will find it hard to justify its ongoing preservation.

A conservation-led retrofit would improve existing building elements, reaching a standard that improves energy efficiency but also retains carbon within the structure and use carbon-negative insulating materials, such as hemp or wood fibre that sequester more. Furthermore, by analysis of lifecycle carbon emissions, this approach may be able to identify some invasive retrofit interventions that reduce operational energy use, but due to their lifespan do not deliver net carbon savings in the long term. The implications of the ongoing decarbonisation of energy networks and of technological change can also be considered and included. A carbon-intensive retrofit project whose justification rests upon replacing carbon-intensive electric heating may not deliver upon its promised carbon savings, should the carbon cost of that electricity fall. This is already in evidence in Scotland, where a high overall share of nuclear, hydro and wind energy typically leaves the carbon content of the electrical grid well below 150gCO_2/kWh [25], considered low.

4. Next steps

To address the questions discussed above, numbers are needed in these arguments; Historic England has published an overall look at carbon savings and the historic environment [26]. HES will build on this work and, as the start of a wide-ranging carbon modelling project, will commission the Lodge to be modelled in cost and material terms to reflect three scenarios: Demolition and replacement; a standard retrofit (as described above); and a conservation retrofit (as delivered). This can examine in detail the hypothesis made above and the likely energy saved with the measures. (As mentioned in Paragraph 6, delayed by COVID-19). With these numbers, scaled up for national targets, the heritage sector can show the carbon and environmental costs of different approaches. Then the conservation argument is more than architecture and presentation, important though they are, but about reducing carbon emissions as part of national efforts. If validated, through the adoption of a multi factored conservation approach more carbon can be saved, and more buildings retrofitted appropriately.

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