REFURBISHMENT OF MASONRY BUILDINGS – A SUSTAINABLE OPTION?

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SUMMARY

The paper describes the recent refurbishment of a row of 200-year old terraced masonry properties in Leeds, England to provide new accommodation for staff at Leeds Metropolitan University. Environmental impacts of the refurbishment are examined in relation to two other options, namely, demolition of the existing properties and the erection of a new building on the same site and refurbishment that included upgrading the existing properties to comply with current UK standards for the thermal performance of buildings. The factors influencing decisions about whether masonry properties in the UK should be refurbished or replaced are also examined.

INTRODUCTION

A common feature of the principal UK publications and design tools for evaluating the environmental and economic performance of buildings is the assumption of a sixty-year life span for all new buildings, irrespective of their purpose or function [Anderson et al 2002, Department of Communities and Local Government 2007, Building Research Establishment 2007]. After this it is assumed they are demolished with the materials from the fabric of the property either being reused to some extent or disposed of to landfill.

This 'one-size fits all' approach to evaluating the sustainability of buildings is, however, overly simplistic and does not address some of the broader key issues associated with sustainability such as reducing consumption of raw materials and global energy by refurbishing and reusing existing buildings. This aspect of sustainability is of particular importance for properties built out of clay brick as this material is capable of lasting centuries with very low post-factory gate environmental impacts from maintenance. Whilst recent work has shown that bricks in solid masonry walls can last up to 650 years before they are all replaced [Bown 2007], how relevant and important is this in relation to curbing greenhouse gas emissions from UK buildings?

It is against this background that the paper examines the recent refurbishment of a row of 200-year old terraced masonry houses in Queen Square, Leeds, England to provide new accommodation for staff at Leeds Metropolitan University. The long-term environmental impacts (burdens) of the refurbishment (Option 1) are compared with those that would have arisen if the existing properties had instead been demolished and replaced by a new building of brick/block masonry construction on the same site (Option 2). As no attempt was made to

upgrade the thermal performance of the external walls and roof of the existing properties during the £1.1million refurbishment, the environmental implications of this are quantified (Option 3).

Conclusions are drawn regarding the relative environmental impacts associated with the above three options for an assumed service life of 100 years. This includes the energy required to heat the various properties. The factors influencing decisions about whether to refurbish or replace existing masonry properties in the UK are then discussed.

DESCRIPTION OF REFURBISHED PROPERTIES

The properties that were refurbished form the North Terrace of Queen Square in Leeds (Figures 1a & 1b). This is one of only two Georgian squares in Leeds that remain in their original state. The square consists of three rows of terraces on its north, south and west sides and is bounded by a dual-carriageway road, which is one of the main arteries into the centre of Leeds, on the remaining side. The square was originally planned in 1803 and a total of 22 houses were built on the site between 1806 and 1822. The central square was at this time bought by the residents to prevent developers from building on the land, which was used as an ornamental garden - a role which continues today.

Figures 1a & 1b. Refurbished properties in Queen Square

The whole of Queen Square was originally intended for residential housing. Over the years individual houses have, however, been used for different purposes. This includes office space, meeting rooms, a drug rehabilitation centre and, more recently, a public house.

All the properties in the square are individually Grade II listed i.e. they are of ‘special architectural or historic interest’. As such, any alterations to their interior or exterior must respect their character and receive listed building consent.

TIMESCALE

Refurbishment of the properties, which were in a neglected state, began in 2004 and was completed the following year. The work included the creation of new doorways, the conversion of dilapidated cellars into new rooms and general redecoration. In addition, the properties were rewired and new heating and telephone systems installed. The refurbished

properties also now contain lifts for disability access as well as showers, changing rooms and dedicated cycle parking. Due to the listed nature of the properties no work was carried out to improve the thermal performance of the roof or the external walls, which do not comply with current UK standards. In general, the external brickwork walls of the properties were in very good condition, with refurbishment limited to minor re-pointing of the mortar joints.

To provide additional teaching and laboratory space new accommodation was also added to the rear of the existing properties but this is not considered here.

ENVIRONMENTAL IMPACTS

Environmental impacts were determined using the methodology developed by the UK Building Research Establishment (BRE) [Howard et al 1999]. These were expressed in terms of 'eco-points'. This is a notional unit developed by the BRE whereby 100 eco-points represent the environmental impact of one UK citizen in one year with respect to the thirteen environmental impact categories in the BRE environmental profiles methodology. These include climate change, ozone depletion, air pollution, fossil fuel depletion and extraction, and transport pollution and congestion.

Unlike embodied energy and carbon emissions, eco-points provide a measure of the overall environmental impact of a particular product or process [Dickie and Howard 2000]. A major drawback to their use, however, is that they are a weighted single-score system in relation to the UK only. Whilst a single-score approach to assessing sustainability is essentially flawed [International Organization for Standardization 2006] from an end-user perspective eco-points do offer the advantage of simplicity of use.

For comparison purposes, one eco-point can be considered to be the equivalent of one of the following [Thistlethwaite 2004]:

- 320 kWh electricity
- 83 m^3 water (equivalent to one-thousand baths)
- 65 miles by articulated truck
- The land-fill from 1.3 tonnes of waste
- Manufacturing ¾ tonne (250) of bricks
- 540 tonne.km of freight by sea
- The extraction of 1.38 tonnes of mineral
- 300 miles of urban driving in a new petrol-engine car.

For this analysis, a building service life of 100 years was assumed. The impacts of materials used for internal services and fittings and fixtures in each of the buildings in Options 1 to 3 were not determined as it was assumed these would essentially be the same in all three cases. The environmental impacts of maintenance were determined only for the external brickwork walls and were based on recent research into the whole life performance of masonry buildings [Bown 2007]. Other maintenance activities such as general painting and decorating, replacement of windows, roof tiles, carpets etc were ignored as again these would essentially have been the same for all three options considered.

Heat losses and gains were determined using simple methodologies [Burberry 1997, McMullan 2002]. Whist these calculations were approximate, they did nevertheless give an

indication of the relative amounts of heating required for the three different properties being considered.

Although the central heating systems would most probably have been gas-fired, eco-point data for UK-supplied mains gas were unavailable. Heating requirements were therefore converted into equivalent eco-points using the conversion factor for electricity shown above i.e. 1 eco-point = 320kWh. As carbon dioxide, sulphurous oxides and nitrous oxide emissions are much lower for mains gas than electricity [DEFRA 2005] the environmental impacts of gas-fired heating would in practice probably have been much lower.

RESULTS

Table 1. Environmental impacts of the three options

Option	Construction materials (eco-points)	Maintenance of external walls (eco-points)	Heating* (eco-points)	Total (eco-points)
1. Refurbishment	0	239	113,805	114,044
2. Demolition and new build	7,267	426	43,194	50,887
3. Upgrade thermal performance	307	468	43,194	43,969

* based on published data for electricity [Thistlethwaite 2004]

Option 1. Refurbishment of existing properties

Table 1 shows the impacts of the refurbishment over the assumed building life of 100 years. As the properties were already 200 years old the environmental impacts of the materials used in the initial construction have been ignored; these are shown as zero in Table 1. This was because, as the architect Quinlan Terry has already noted, *‘fossil fuel emissions produced for the construction of existing homes are already in the atmosphere’* [Terry 2005].

Option 2. Demolition of existing properties and construction of new building

Table 1 shows the impacts that would have arisen if the existing properties had been demolished and a new building of the same height and overall floor area (1440 m^2) had been erected on the same site. For this, it was assumed that the replacement building was of similar construction to the original properties i.e. a masonry structure but with external brick/block cavity walls rather than solid walls. In addition, unlike the existing properties, the windows in

the new building were now double-glazed and loft insulation was added.

Option 3. Upgrading of existing properties to current UK standards for thermal performance

As with Option 1 the impacts of the materials used for the construction of the properties were ignored (Table 1). The impacts of construction materials shown in Option 3 are for external applied solid wall insulation, roof insulation and double glazing, profiles for which were readily available. In practice, due to the listed nature of the properties external wall insulation (EWI), in the form of sheets of insulation fixed to the outside face of the brickwork followed by a protective render, would not have been permitted by the local planning authorities. On the other hand, some form of internal wall insulation (IWI) would probably have been allowed.

DISCUSSION OF RESULTS

Table 1 shows that heating is the principal source of environmental impacts for all three options considered over their assumed 100 year life span. By comparison, the impacts caused by maintenance of the external masonry walls are very low i.e. 1% or less of total impacts in all cases. Maintenance of the external walls is slightly higher for Option 3 than Options 1 and 2 as the external render would need to be replaced during the assumed 100 year life span.

In Option 1 the relatively high environmental impacts of heating are due to the poor thermal characteristics of the existing properties which have single-glazed windows, no roof insulation and solid 330mm thick brick external walls. In Options 2 and 3 the impacts from heating are considerably less than in Option 1 as these elements would now comply with current UK standards of thermal performance e.g. a U value for external walls of $0.35W/m^2K$ [ODPM 2006].

In percentage terms, the overall environmental impacts of Option 2 are only 45% of Option 1 i.e. 50,887 cf. 114,044 eco-points, respectively. Option 2 is, therefore, clearly preferable to Option 1. In Option 2 the impacts of the materials used in the new building are relatively low in relation to those from heating it, accounting for only 17% of total impacts over the assumed 100-year life. These would be recouped within 10 years through the reduced heating demand of Option 2.

Option 3 has the lowest impacts overall and, as such, could be considered to be the least environmentally-damaging of the three options considered. The benefits of installing double glazing and insulating the walls and roof of the existing properties to current standards would clearly have been significant i.e. around 300 additional eco-points would have produced savings of 70,611 eco-points (113,805 – 43,194 eco-points) in heating the properties over their 100 year life i.e. a 62% reduction in heating demand. In addition, the thickness of external insulation could be increased at later ages to further improve the energy efficiency of the refurbished properties, should this become necessary.

GENERAL COMMENTS

Table 1 shows that space heating is a major source of environmental impacts for the three buildings considered here. In addition, the impacts from heating are significantly higher than

those associated with the materials forming the fabric of the new building in Option 2. In practice, space heating is, of course, the primary source of carbon emissions from the UK building stock, accounting for around 53% of carbon from domestic properties [Department of Communities and Local Government 2006a]. To reduce these emissions, significant efforts are therefore now being made to improve the overall operational energy efficiency of commercial and residential buildings i.e. that used for space heating, cooling, lighting, cooking etc.

REFURBISHMENT v. REPLACEMENT OF MASONRY PROPERTIES

This paper has been concerned with the environmental impacts of refurbishing a small number of terraced masonry properties of special architectural or historical interest. As such, they were exempt from most UK regulations relating to the refurbishment of buildings. A valid question is therefore, 'how relevant and applicable is refurbishment (including upgrading thermal performance) to the rest of the UK housing stock given that the vast majority of properties are not of architectural or historical interest?' Also, is it better from an environmental, economic and social viewpoint to refurbish properties that do not meet current standards of performance, or should they simply be demolished and replaced with new dwellings?

To answer these questions it is first necessary to briefly consider the make-up of the UK housing stock. This consists of approximately 25.5 million properties. Most of these are built out of brick, block or stone and perform badly in relation to modern standards of thermal performance. Around 25% of properties are more than 140 years old, with eight million or so having external walls of solid masonry [Department of Communities and Local Government 2006b]. The latter are classified as 'hard-to-heat'. To reduce UK carbon emissions it has been proposed that 3.2 million of these should be demolished by 2050 [ECI 2005]. This would require a four-fold increase in the current rate of demolition.

This radical option fails, however, to recognise that many properties can be refurbished to modern standards of thermal performance using measures such as solid wall insulation and double glazing [Building Research Establishment 2006, Sustainable Development Commission 2006] in the manner of Option 3 described above. In addition, it ignores the highly sustainable aspects of masonry's performance such as it ability to last for centuries with minimal maintenance. The feasibility of demolishing such a large number of homes is also questionable as many are privately owned and of relatively high value [Department of Communities and Local Government 2006a].

As part of a wider package of improvements, measures such as solid wall insulation and double glazing would lead to significant reductions of around 40 % in the level of emissions from these properties [Riley and Hulme 2006]. The cost and cost-effectiveness of items such as solid wall insulation is, however, currently a major issue in the UK (Table 2) although when compared with demolition and new build it is still relatively cheap. A distorting influence in this respect is that 17.5% VAT is payable on refurbishments whereas demolition and new house building in the UK are zero-rated for VAT. There is consequently a somewhat perverse financial incentive for UK developers to demolish rather than refurbish [Sustainable Development Commission 2006].

Table 2. UK Domestic energy efficiency measures – estimated costs and savings
[Adapted from Department of Communities and Local Government 2006a]

Measures	Average cost (£)	Cost saved (£/yr)	Carbon saved (kgC/yr)	Pay- back (yrs)	Potential homes (‘000)	Potential total carbon saving (MtC/yr)
Hot water cylinder insulation	14	29	53	0.5	1,137	0.1
Cavity wall insulation	342	133	242	2.6	8,500	2.1
Loft insulation (full and top-up)	284	104	190	2.7	6,186	1.2
Improved heating controls	147	43	77	3.4	2,102	0.2
Draught proofing	100	23	43	4.3	9,793	0.4
Micro CHP	1,571	230	508	6.8	12,000	6.1
Solid wall insulation	3150	380	694	7.5	7,479	5.2
A-rated boiler	1,500	168	177	8.9	17,128	3.0
Micro wind	2,363	224	263	10.5	-	–
Ground source heat pump	4,725	368	990	12.8	17,000	16.8
Photovoltaic (PV) electricity	9,844	212	249	46.4	9,892	2.5
Solar water heating	2,625	48	88	54.7	19,330	1.7
Windows (single to double glazing)	4,000	41	26	97.6	10,746	1.7

Note: There is significant variation in costs for some measures, particularly where professional installation is required. Potential savings are based on a typical 3-bed semi-detached property. The figures for micro-generation in particular are subject to a high degree of variability and uncertainty and should therefore be treated as indicative only. The savings shown are gross and take no account of comfort taking (estimated to be up to 30% of potential savings).

Less tangible but nevertheless important reasons for refurbishing the UK housing stock include the fact that people prefer older buildings [English Heritage 2007]. In addition, it has been shown that a Victorian terraced house is cheaper to maintain over a 100-year period (at an average of £ 2,648 per 100 m^2 of floor space per year) than a house built in the 1980s (which would cost £ 3,686 for the same area) [English Heritage 2003]. This is because of the greater quality and durability of the materials used in the construction of older houses, and their higher standards of design and construction compared with modern homes.

CONCLUSIONS

Whole life environmental impacts of refurbishing a row of 200 year old terraced properties were compared with those from demolishing the existing properties and erecting a new masonry building on the same site and a refurbishment that included upgrading the thermal performance of the existing properties. The investigation found that

1. Heating the properties was the primary source of environmental impacts for all three options considered over their assumed 100 year life span.

2. The environmental impacts from maintaining the external masonry walls over a 100 year life span were very low i.e. 1% or less of total impacts in all cases.

3. The impacts of the materials used in the new building were low in relation to those from heating, accounting for only 17% of impacts over the assumed 100 year life.

4. Refurbishment that included upgrading the thermal performance of the existing properties would have had the lowest impacts overall and, as such, could be considered to be the least environmentally damaging option.

FINAL COMMENTS

Sustainability in its broadest sense involves consideration of environmental, economic and social issues. Given that the current UK housing stock performs poorly in terms of its energy efficiency there is clearly a need to improve overall performance in this area. Large scale demolition is not considered to be the only solution to this problem as it fails to recognise the other highly sustainable aspects of masonry's performance such as its long life, low maintenance and aesthetic appeal. Instead, retro-fit techniques such as solid or cavity wall insulation, double glazing and improved heating systems should be used more widely to improve energy efficiency of buildings. This approach would offer a more sustainable option overall particularly in view of the fact that that some of the recent lightweight modular designs for new homes in the UK are likely to have lifespans of only 30 years [Building Products Magazine, 2007].

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