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From 'Nurses' Memorial Home' to 'Royal Standard House': The Upgrade of a Grade II Listed Dwelling in the frame of Sustainable Refurbishment

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Abstract
Sustainable merits are applied to new buildings. However, existing buildings have a reasonable proportion in building stock. This study investigates how to enhance the energy performance of an existing Grade II listed dwelling. The study conducted on-site measurements of daylight distribution of dwelling spaces and thermal imaging. Occupancy survey evaluated users' point of view. Different scenarios were applied to the building envelope and their impacts on the energy use were tested by dynamic thermal simulations. Comparing the results allowed for an insight into the impact of different sustainable refurbishment principles for existing buildings. The study concluded that sustainable refurbishment principles can be applied to a Grade II listed dwelling within the frame of building regulations, which restrict interventions on the facades. The study also showed that the fabric energy efficiency category of CSH can be used to compare the upgrading steps and their impacts on the energy performance of the dwelling.

Keywords: Sustainable refurbishment, energy efficiency upgrade, Grade II listed dwelling, energy performance

1 Introduction
Sustainable architecture generates a built environment that is more conscious about its impact on environment. New buildings are regulated by environmental assessment systems. In the housing context, existing buildings occupy a reasonable proportion in the market stock. That is why; sustainable refurbishment of existing housing would contribute to the impact that environmental assessment standards aims at achieving within new buildings, by upgrading their energy efficiency and decreasing their energy use.

Among the existing housing buildings; listed historical buildings occupy an important place. In higher grades, the regulations don't permit any change on exterior skin. Thus, in listed historical buildings energy efficiency upgrades would be restricted with the interventions that can be done from interior of the building envelope.

This study focused on energy efficiency upgrades that can be applied to a Grade II listed building, such as the Royal Standard House in Nottingham, and their impacts on building's energy performance.

2 Sustainable Refurbishment
UK was the first country that has "legally binding and long-term framework to cut greenhouse gas emissions" with its Climate Change Act 2008 (Henderson, 2010). According to the Act, greenhouse gas emissions are targeted to be "at least 80% lower than the 1990 baseline" (HMG, 2008). The existing homes in Britain, which are approximately 26 million, "account for 27% of total UK greenhouse gas emissions" and expected to "comprise at least 80% of the 2050 housing stock" (Bernier, Fenner and Ainger, 2010). These figures underline

the importance of refurbishing existing houses and upgrading the energy efficiency to result in better energy performance and less greenhouse gas emissions.

Sustainable refurbishment underlines “increasing daylight through roof or facade, upgrading thermal insulation and increasing natural ventilation” (Brophy and Lewis, 2011). Insulation of cavity in exterior wall and double glazing with low emissivity glass are the main steps during refurbishing existing homes (Smith, 2004).

The performance criteria for sustainable refurbishment process of an existing home should be considered well. A recent study developed a building rating system for existing homes (Bernier, Fenner and Ainger, 2010). The authors included performance criteria as energy, air pollution, water efficiency and health & well-being as weightings in this rating system.

3 Royal Standard House

The Nottingham General Hospital was designed by architect John Simpson and opened in 1782 (Bittiner and Lowe, 1990) on Standard Hill. Royal Standard House, known as Memorial Nurses’ Home, was added to this complex after the First World War and opened in 1923. It is a Grade II listed building designed by Evans, Cartwright & Woollett. Its architecture belongs to Classical style (Heritage Gateway, 1995). Figure 1 shows “symmetrical facade with projecting centre and end bays, central portico that is 3 storeys with giant Ionic columns and sash windows with rubbed brick heads” (Heritage Gateway, 1995), which are main features of Classical period.

Figure 1: Royal Standard House (formerly known as Memorial Nurses’ Home) from the Nottingham Castle ground (author’s image)

3.1 Site & micro-climate analysis and research context

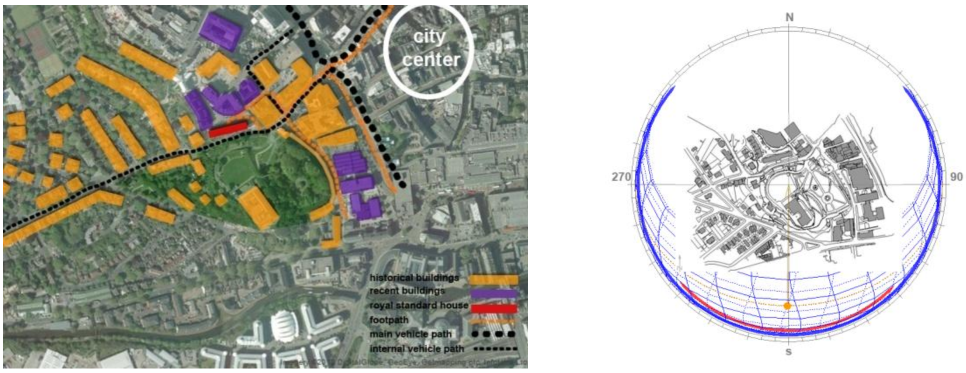

Figure 2: Site analysis (on the left hand side) and sun-path diagram (on the right hand side) for Royal Standard House

Royal Standard House is located on the north of Nottingham Castle. It is surrounded by listed historical building and recent developments. The site is in close proximity to city centre and close to one of the main traffic arteries of Nottingham (Figure 2).

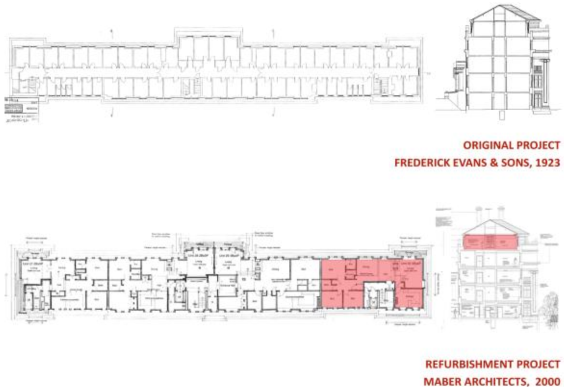

Figure 3: Original project of Memorial Nurses' Home (above) and refurbishment project by Maber Architects (below) (Maber Architects)

A roof flat on the 4th floor and coloured with red in Figure 3, has been studied. The flat has south-east, south-east and north-west facades. When approached from its entrance hall, living spaces are located towards west and bedrooms are located towards east of the entrance. (Figure 4). The south-east facade, has view to the castle and a small terrace hosting delicate view.

Figure 4: Plan of Flat 30 of Royal Standard House

4 Methodology

The research question focuses on how to enhance the energy performance of Royal Standard House as a Grade II listed building by sustainable refurbishment and how to assess it in the frame of CSH. The research started with an initial qualitative analysis, as an occupancy survey that was conducted among residents. The flat was analysed quantitatively by on-site measurements of illuminance levels and thermal images of facade taken by infrared camera from exterior. For quantitative approach, thermal and energy performance of different upgrade scenarios were investigated by dynamic thermal simulation by Bentley TAS software and daylight distribution was analysed by Autodesk Ecotect / Radiance.

5 Thermal & energy performance prediction

Thermal and energy performance of different upgrade options regarding to building envelope were evaluated. In the generated simulation matrix, each case contained one changed parameter and all other parameters remain constant from previous case. The cases contained interventions from inside of building envelope which would affect the envelope's U-Value. The U-Values were based on existing building refurbishment and low-energy design guidelines. While Base Case indicated current situation, Pre-Base Case indicated initial building condition before the refurbishment project was done in 2000 (Figure 5). Case 4 includes roof light and stack ventilation.

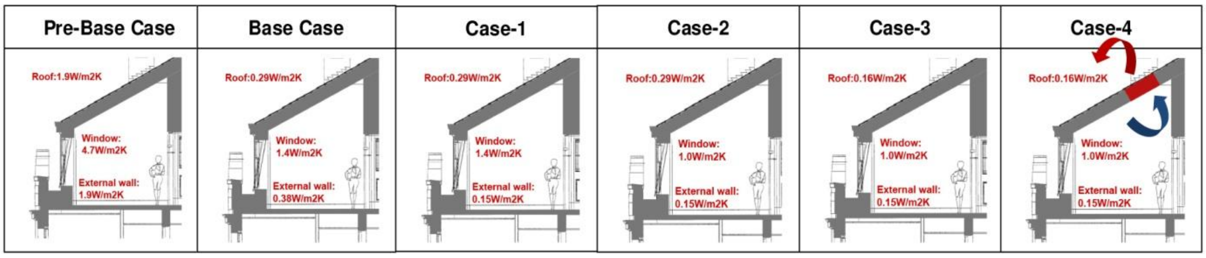

Figure 5: U-Values (W/m2K) of simulation cases shown on the section of Flat 30

5.1 Performance prediction assumptions

Thermal performance analysis was done by dynamic thermal simulation software Bentley TAS. The simulated flat, Flat 30 was divided into 5 thermal zones: Zone 1: Living & dining space, Zone 2: Workspace & hall, Zone 3: Bedroom 1, Zone 4: Bedroom 2 and Zone 5: Entrance hall (communal space). While Zone 1, Zone 2, Zone 3 and Zone 4 were heated spaces in winter, Zone 5 was considered as unheated as electric heaters in communal spaces are switched off. For the heated zones, temperature of spaces was based on the winter operative temperatures indicated in *CIBSE Comfort Guide* (CIBSE, 2006) and differed according to space: In simulations, the indoor temperature for winter was assumed as 22°C for Zone 1 and 19°C for Zone 2, Zone 3, Zone 4. In the calendar of simulations, winter months were defined from January to May and from October to December. Summer months were defined from May to October. For heated zones, heating hours were based on the *SAP 2009: Government's Standard Assessment Procedure (SAP) for Energy Rating of Dwellings 2009* (DECC, 2011) as SAP calculations are used in CSH assessment and indicated as 7am-9am and 4pm-11pm for weekdays and between 7am-11pm for weekends. Internal and occupancy gains were inputs in simulations for Zone 1, Zone 2, Zone 3 and Zone 4; however, weren't defined for Zone 5 as it is a circulation space, where people don't occupy for long time intervals and they don't host any equipment or appliance.

In Pre-Base Case and Base Case, the infiltration rate was assumed as 0.5 ACH. In Case 1, as the external wall was additionally insulated and assumed that it would be well-sealed; infiltration rate was decreased to 0.3 ACH. In Case 3, as the roof was additionally insulated and assumed that it would be well-sealed; infiltration rate was decreased to 0.2 ACH and also assumed as 0.2 ACH in Case 4 as same envelope conditions apply. As natural ventilation was a parameter of Case 4, apertures were defined for Case 4.

6 Analysis of results

6.1 Occupancy survey analysis

For existing dwellings, post-occupancy evaluation (POE) is advised to be conducted "before designing any housing retrofit scheme in order to inform the design proposals more fully" (Stevenson and Leaman, 2010). In the first stages of this research, the occupancy survey aimed at analysing occupants' point of view regarding to building's architecture, comfort conditions and energy performance. Results of the survey showed that majority of participants think that they need heating for their comfort both in flats and in communal spaces (Figure 6). In contrast to this, most of participants think that energy usage both in flats and communal spaces can be less due to better insulation and double-glazing. It is possible to evaluate that applying energy-efficiency upgrades in Royal Standard House would be coherent as occupants are conscious about energy-efficiency and demand less energy consumption, but also want to provide comfort temperatures in their indoor environments.

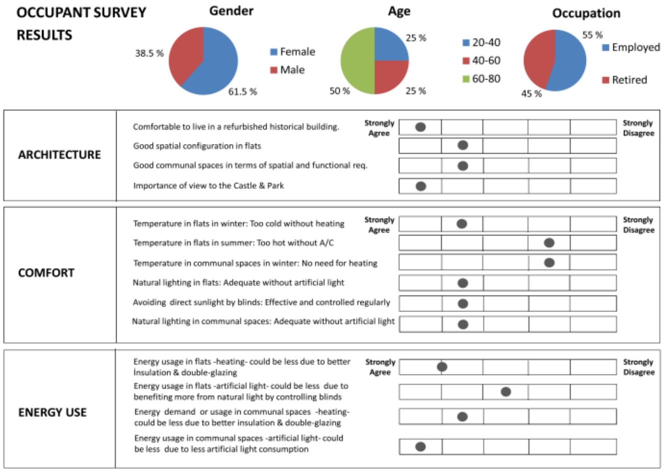

Figure 6: Occupancy survey results

6.2 Thermal & energy performance analysis

The simulation results were evaluated and compared for hottest week, coldest week and winter. In the hottest week, Pre-Base Case provided the lowest indoor temperatures for living & dining space (Figure 7). As the U-Values decreased starting from Base Case and thus room had more solar gains; indoor temperatures increased gradually from Base Case to Case 3 and overheating occurred with temperatures more than 26°C, especially on day 229 as the hottest day. However; in Case 4 temperatures dropped significantly due to natural ventilation. Workspace, Bedroom-1, Bedroom-2 and Entrance Hall presented similar pattern of temperatures for the hottest week.

The energy performance of each case was investigated by evaluating heating load of zones in winter. It was evaluated that better envelope performance of Case 4 caused heating loads to drop significantly when compared with Pre-Base Case in entire winter as seen in Figure 8.

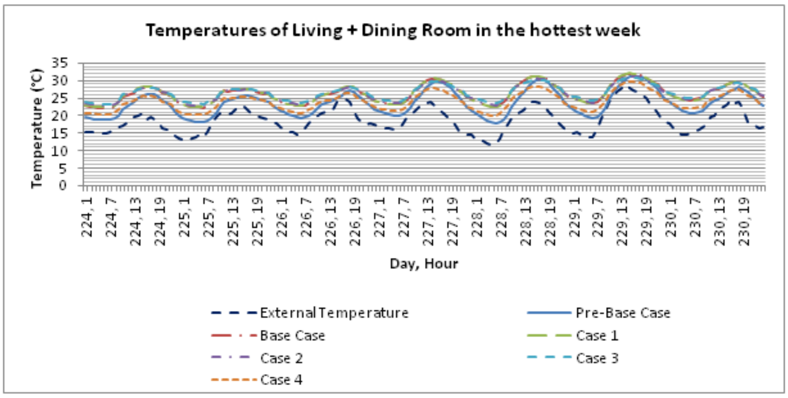

Figure 7: Temperatures of Living + Dining Room in the hottest week for all cases

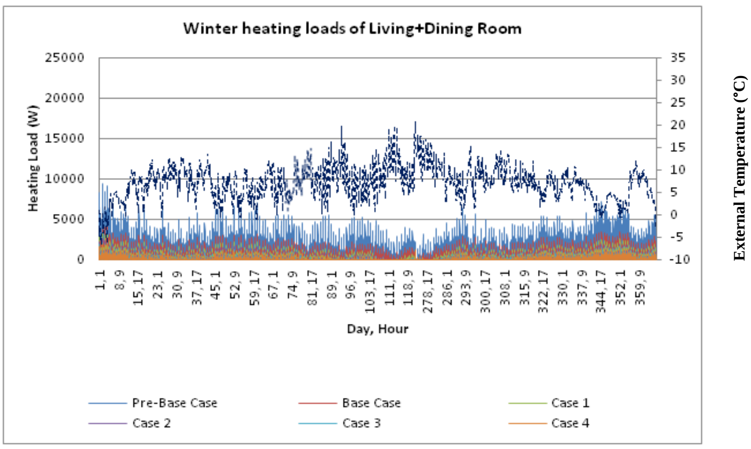

Figure 8: Heating loads of Living + Dining Room in entire winter for all cases

CSH limits the annual heating and cooling energy to 39 kWh/m²/year for achieving Level 5/6. The annual heating load of Base Case decreased significantly due to change in entire envelope (Figure 9). Better performing external wall decreased the load below the benchmark as in Case 1. Secondary glazing as in Case 2 had a similar impact on annual heating loads as in Case 1. Additional roof insulation's impact was quite low when compared to Case 1 and Case 2. In Case 4, roof light increased the solar gains slightly so that decreases the annual heating loads slightly as well.

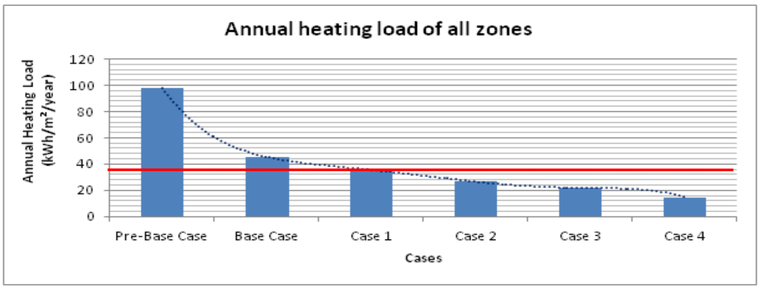

Figure 9: Annual heating load of all zones for each case

6 Conclusion

It is possible to conclude that sustainable refurbishment of listed buildings can be achieved by energy-efficiency upgrades that are applied from interior of building envelope. In winter, annual heating load can significantly decrease and better energy performance can be achieved due to more efficient building envelope. In summer, overheating impact due to better U-Values can be minimised by promoting natural ventilation. 'Fabric energy efficiency' benchmark of Code for Sustainable Homes (CSH) can be used to evaluate the performance of energy-efficiency upgrades that are applied to existing housing buildings. Daylight distribution can be enhanced within the balance of heat gains - heat losses.

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