Keywords: energy consumption, refurbishment, historic building, improving performance

Summary

The restoration of a building erected mostly in the period 1481-1483 has been considered. The European Directive 2002/91/EC on the energy performance of buildings (Art.4) indicates the reduction energy consumption of some categories of buildings as an option. Particularly this regards buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic value, where compliance with the requirements would unacceptably alter their character or appearance.

In any case higher attention to the energy saving in the restoration of old and historic buildings can lead to a better management of the expenses in the future, when rising costs of primary resources will be expected.

The case study wants to highlight the opportunity to operate on the basis of specific choices that can connect the needs of the preservation of volutes, frescoes, wood surfaces, stones, etc to a better performance of the building.

The investigation cannot be performed deeply without the aid of dedicated software: in this case the energy performance of the building has been studied by means of DesignBuilder modelling to develop a dynamic energy simulation.

The most suitable solutions (insulation and HVAC systems) have been evaluated and compared in terms of annual energy costs. Good results, if compared with the previous conditions, have been reached without working on older parts of the building.

1. Energy saving and historic building conservation

The exclusion of historic buildings from onerous energy conservation improvements is justified by their inner value and by the need to preserve the historic heritage. On another side, before the advent of mechanical air conditioning, most historic buildings featured natural ventilation, usually based on the chimney effect.

Certainly some historic buildings should not be altered at all, e.g. those where any change would damage their character or special interest. However, the majority can accommodate some improvements, even though the modern standards and techniques might not be appropriate. Improvements to the building envelope, and especially thermal insulation, can be particularly difficult for architecturally or historically important buildings. Alterations are often impossible – at least to some elements – without unacceptable damage to the historic fabric or cultural record, or the creation of uncertain technical risks, e.g. exacerbating risks of decay in timber [1]

A contribution towards national energy conservation requirements can be given from the heritage stock energy restoration. However, special care and a flexible approach are needed so that the interests of historic buildings can be preserved.

Some historic buildings are sensitive to even slight alterations, particularly externally, moreover if they retain important interiors, fixtures, fittings and details. Others may have changed significantly and restoration is not considered feasible or sensible. These considerations will influence the extent of change that is appropriate to improve energy efficiency.

When alterations for energy conservation are proposed, regard should be given to:

- ensuring that the building is well known, to avoid damage
- minimising disturbance to existing fabric
- reversing the changes easily without damaging the existing fabric (especially changes to services)
- considering that some buildings or parts of buildings are of such quality, importance or completeness that they should not be altered at all, save in the most exceptional circumstances.

Better energy efficiency can be achieved by physical change to the building fabric and services and by more mindful behaviour of the occupants.
Means to reduce energy consumption in historic buildings can be summarised in the followings:

a) Limiting the heat losses caused by conduction and air infiltration is the most common area of conflict between building and energy conservation.

b) Limiting the heat loss from pipes and ducts will not normally be a problem, except where access is difficult, or the installations are of historic interest or part of the architectural character.

c) Providing energy-efficient space heating and hot water will occasionally cause problems where historic equipment is to be conserved or – for example – where electric systems are preferred to avoid disruption to surface finishes or fabric caused by pipework or to limit the risk of flooding. High efficiency boilers may sometimes also be unacceptable i.e. where the ‘steam’ plume from a condensing boiler could be unsightly or could put items in its path at greater risk of damp and decay.

d) Occasionally the need to limit solar heat gains may be a problem.

e) Air conditioning installed in historic buildings may sometimes be less efficient than in new buildings, owing to restrictions placed on appearance, access or space.

f) Insulation to air ducts, chilled water and refrigerant pipes and vessels may sometimes be restricted for appearance’s sake, or because of limited space.

g) Historic buildings usually need more ventilation than modern ones. In the past, they were often more ventilated than strictly necessary because of loose-fitting doors, windows and other openings. In addition, open fires created generous rates of exhaust ventilation through chimneys at times when condensation risk might otherwise have been high. However, if ventilation of a historic building is reduced too much, condensation, mould and fungal growth may occur, leading to deterioration of the fabric and contents, and possibly health problems for occupants.

2. Improving energy performance of an historic building

2.1 Walls

Historic buildings display a wide range of materials and forms of construction, ranging from stone or earth walls perhaps one or two metres thick. The appearance of the external walls is usually one of the most important aspects of a historic building, while the materials give the building its unique and often local character.

The opportunity to improve the thermal performance of walls externally will often be limited in historic buildings because of the impact external insulation has on the appearance of the building. However, there may be opportunities to insulate externally, for example where a wall suffering from chronic driving rain problems has to be re-clad or where rendering requires complete replacement.

Internal walls often can hide plaster and paint schemes in the plaster or behind panelling or other coverings. Timber panelling, plaster mouldings or enriched decorations need to be preserved.

Where complete internal re-plastering is required – particularly where it has been done before and when little or nothing of historic interest survives – there may be opportunities to incorporate internal insulation.

However the dimensional changes may be unacceptable at window and door openings. The loss of space may also be unacceptable. Moreover moisture may be trapped and interstitial condensation may occur and besides the mass of internal walls, covered by internal insulation, offers a reduced effect in stabilising the indoor temperature and humidity levels.

2.2 Floors and roofs

The appearance of a floor can be a highly distinctive feature of a historic building. However, if floors have to be lifted or replaced, there are opportunities to improve insulation and to design a low temperature heating system by means of radiant floors.

The roof of a historic building is often its most remarkable feature. The actions for the energy consumption reduction can be very efficient as the roof is a delicate element of the whole building structure.

2.3 Windows

Old glass is becoming increasingly rare, but where it still exists, it must be retained and alternative means of thermal improvement must be considered. Often that doesn’t happen, therefore the application of new windows and window frames could reach good results in terms of thermal energy saving.

2.4 Heating system

The complete invisibility of the piping net, which is followed up in the new edification, necessitates hiding piping and ductwork within wall and floor systems. It is not often appropriate for historic buildings.
The heating system must require the least intrusion into the historic fabric of the building and must be updated or altered without major intervention into the wall and floor systems. These elements should be considered in weighing the decision to replace the existing system with a new one, even though more efficient [2].

3 Energy performance analysis by means of dedicated tools

The complexity of the energy performance calculation of a building cannot imply the use of simple tools, but must be solved by means of more accurate methods. Energy calculation tools can predict the annual building energy consumption in terms of thermal and electrical kWh, euros, or pollution avoidance.

Energy analysis programs offer different levels of accuracy, effort and costs. For example, a tool such as DOE-2 or BLAST, requires more input time and detail. Consequently, they are generally applied in a later phase of design process when many architectural decisions have already been finalized.

On the contrary, national regulations are followed by software expressly created for the verification of the building energy consumption in the national context: their results are given in terms of the parameters that have to be verified by national laws.

DesignBuilder is a software that combines rapid building modelling with dynamic energy simulations. The model can be created by using the program but there is also the possibility of importing plans saved as .dxf files.

The energy performance of the building is calculated by means of the latest EnergyPlus simulation engine. It builds on the most popular features and capabilities of BLAST and DOE-2 but also includes many innovative simulation capabilities such as time steps of less than an hour, multizone air flow, thermal comfort, and photovoltaic systems.

EnergyPlus is a stand-alone simulation program without a 'user friendly' graphical interface: which is where DesignBuilder comes in.

Simulation data, that can be shown in annual, monthly, daily, hourly or sub hourly intervals, regard:
- energy consumption;
- internal temperatures;
- weather data;
- heat transmission through building fabric including walls, roofs, infiltration, ventilation etc.;
- heating and cooling loads;
- CO2 generation.

These output data may be selectively graphed or exported in table format for use in other applications.

Figure 1 - Walls with high problems (rising water, etc.), corrosion on steel elements
4 Energy performance of an ancient building

The restoration of an ancient building was examined with the aid of Design Builder. The analysis of the potentials of the thermal energy control was performed by acting on the elements that could be modified without distressing delicate, ancient, valuable elements, materials and structures.

The ancient building was designated to government offices and its restoration was finalised to the consolidation of walls and structures, the renewal of roofs and windows. The European Directive 2002/91/EC on the energy performance of buildings (Art.4) indicates the reduction energy consumption of some categories of buildings as an option. In buildings and monuments officially protected because of their special architectural or historic merit, compliance with the requirements would unacceptably alter their character or appearance.

However, high attention to the energy saving in the restoration of old and historic buildings can lead to a better management of the expenses in the future, to control rising costs of primary resources.

The performed calculations focused on the reduction of the annual thermal energy consumption through actions studied to avoid the modification of the historic building value.

Figure 2 - Ancient elements of the building
The analysis was developed starting from the present situation: empty existent building, with deteriorated walls and windows, without heating system (step 1).

The hypotheses considered for the calculations have been:

- Step 1 – existing building
- Step 2 – existing occupied building with heating-cooling system
- Step 3 – Step 2 + insulating the roof of the ancient part (1400 ac) of the building
- Step 4 – Step 2 + double glass windows
- Step 5 – Step 3 + 4
- Step 6 – Step 5 + insulating walls of the most recent part (1700 ac) of the building
- Step 7 – Step 6 + insulating roof of the more recent building + insulating walls of the ancient building

While steps from 2 to 6 are all reasonable and applicable, the 7th step results unfeasible due to the presence of frescoes on the walls. This step was anyway considered for a more complete comparison with the other actions and to have information on the best results that could be reached for the thermal energy saving.
The first step was utilised to show the effects of the walls thermal capacity on the indoor temperature that varies slightly in the period day-night. In summer, when the external temperature is 32°C, the operative temperature reaches 27°C in the building. In winter there is always a positive difference between indoor and outdoor temperatures, as highlighted in figure 5.

In the calculations the following interventions were considered.
- Insulating walls
- Insulating roofs
- Windows features

Regarding the heating and cooling system, the height of ceilings and the need of a uniform temperature distribution have determined the choice of a radiant floor heating and cooling system. The floors must be restructured; therefore this solution looks suitable to hide as much as possible the presence of heating and cooling elements. Avoiding dew-point temperature on the floor surfaces in summer is a primary need, that must be considered with high attention, taking into account that the dehumidifiers action could be required to reduce the condensation risk.

4 Results

Even if the energy performance of the building cannot reach the levels considered in the European Directive, good results have been obtained to reduce energy consumption.

The roof insulation represents one of the most effective actions as the heat loss reduction is up to 60%, by inserting 6 cm of mineral wool with 0.036 W/mK conductivity. On the contrary the substitution of windows, from single-paned to double paned, leads to a 25% reduction of heat transmission in winter (Figure 6). In the whole calculation of the energy performance, only 5% improvement is obtained. The summer calculations are even better, with a higher reduction of heat transmission.

Even if wall insulation could be more difficult, due to the presence of painted elements and frescoes, a partial covering of internal walls can be considered. In this case also interstitial condensation must be verified.

As represented in Figure 7, 5 cm thickness panels (same conductivity of the roof) could reduce the heat transmission to 93%, if only the most recent parts of the building (1700 a.c.) would be covered, and to 70% considering the complete covering of the internal walls of the two parts of building (1400 and 1700 a.c.). The last conditions are not applicable, even if the heat loss reduction could be more satisfactory, as it is not possible to coat painted walls.
5 Conclusions

An indicative evaluation of the annual thermal energy consumption can be performed and the comparison among the results can quantify the entity of energy saving for each solution (Figure 8).

5 Conclusions

The restoration of ancient buildings can lead to a more efficient use of primary resources and to reduce the waste of energy.

The compromise among avoiding to work on the untouchable ancient parts of the building, the need of reducing managing costs of the heating system, the reaching of better thermal comfort conditions in the offices, can be obtained by a deep analysis of the possible solutions that can be applied in this case. Except for the 7th step, unrealistic hypothesis, the other solutions allow to obtain better performances of the building, even if they will not reach the values indicated in the European Directive.

The difficulties of the problem make the software analysis indispensable, but not necessarily by means of tools that are built to follow the national regulations. In this case the situation is different from the restoration of a conventional building and the solutions can only partially obtain the hoped results.
References
