Energy and Buildings 78 (2014) 35–42

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Thermal insulation alternatives of historic brick buildings in Baltic Sea Region

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ARTICLE INFO

Article history:
Received 5 February 2014
Received in revised form 25 March 2014
Accepted 2 April 2014
Available online 18 April 2014

Keywords:
Historic buildings
Retrofit
Energy performance
Façade insulation
MCDM
TOPSIS with grey numbers

ABSTRACT

The growth in building refurbishment works is creating a demand for suitable materials, retrofitting techniques and research. The differences between refurbishment of new-build projects and historical or valuable buildings are insufficiently recognized – mostly the buildings without further cultural preservation requirements are studied. This article covers the theme of retrofitting the historical buildings, when due to the valuable façade or other heritage preservation requirements only the inside insulation is allowed. The problems of moisture in brick wall construction, loosing space, etc. are discussed and method for selecting best insulation option is shown. The 5 modern insulation materials are selected, measurements are made and best alternative is found using TOPSIS method with grey numbers.

1. Introduction

Climate change and global warming are recognized as one of the largest and the most serious problems humankind is facing in this century. Climate scientists have provided analyses that yield very high confidence in rises of human-caused greenhouse gases. This process will lead to the sequence of environmental and economic losses [1]. The policy sector drove that research and the result has been an ever-increasing call for worldwide reductions in greenhouse gas (GHG) emissions [2,3]. Buildings are a crucial sector for controlling energy demand because currently buildings account for around 30% of the total energy use in the world [4,5]. The buildings as energy consummators are important also because they will consume future energy. Thus, failing to retrofit old buildings to improve their energy and environmental performances may endanger GHG mitigation [6]. Fig. 1 shows the part of energy consumed in buildings with low energy efficiency.

The current policy attempts concentrate on creating the building energy performance certification system which will be applied not only to the new, but to all existing buildings, including the ones with historical value. It is clear that the improvement of building energy performance and certification can act as a catalyst for behavior change of all building-users [7,8]. However, the historic buildings usually have limited retrofitting possibilities and can be shifted by two-three energy efficiency labels only (e.g. from class F to class C or D). The energy performance standards for this category of buildings in most European countries are not applied at the moment, but the current trends in policy show that this can change in near future.

With every year number of building refurbishment works is growing and in many economically developed countries worldwide is now taking about 50% of all building construction market [9–11]. The main reason for this tendency is, of course, the increasing price of energy and the will of stakeholders to pay less for the maintenance of the building. According to the changes in construction market it can be predicted that today's homes will comprise at least 80% of the 2050 housing stock and because of rising prices on energy they will need to be retrofitted for better energy performance [12]. A significant part (from 20% to 30% in European countries) of these buildings have unique outlook which has to be preserved.

2. Studies on historic building refurbishment

Energy and sustainability are a hard challenge in building heritage, both the technical solutions in order to solve impact of energy

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http://dx.doi.org/10.1016/j.enbuild.2014.04.010
0378-7788/

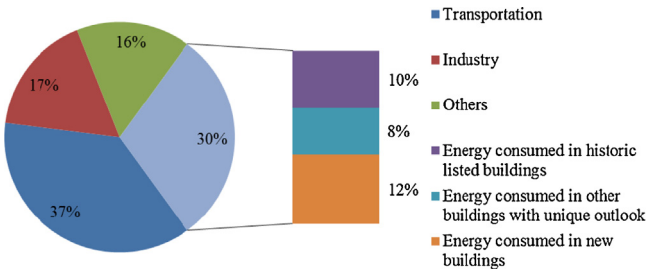

Fig. 1. Energy use and part of energy consumed in historic listed buildings and buildings with unique outlook in Europe [4,5].

conservation and aspect of conservation and maintenance of architectural heritage [13]. Energy efficiency and architectural heritage of brick buildings are two controversial topics. It is important to address these two issues in such a way that obtained result can meet today's requirements of energy efficiency and, at the same time, promote the preservation of historical buildings for future generations [14]. Currently developed simulation and visualization methods and measurement technologies can assist developers and energy managers at different stages of their activity and have the potential to achieve energy savings on a large scale [14–16].

The energy consumption for heating and cooling takes up to 80% of the total energy consumed in buildings. There were many attempts to find the most effective retrofit measures in modern buildings like EnergyPlus program tool [17], a multi-objective optimization model to assist stakeholders in the definition of intervention measures aimed at minimizing the energy use in the building in a cost effective manner, while satisfying the occupant needs and requirements [18], the scalable methodology based on Bayesian calibration of calibrated normative models which can correctly evaluate energy retrofit options [16], the framework for handling the uncertainties associated with the prediction of energy savings in the retrofit analysis of a housing stock [19] and others [20–26]. The retrofit measures which can be applied in historic buildings are much more limited due to preservation of valuable properties of the buildings.

There is a lack of understanding of historic building energy performance in industry and in policy, and a lack of connection between good research, standards, certification processes, guidance and practice. There is significant uncertainty with regard to the application of models and performance simulation software for this class of buildings. Some methods for assessing traditional buildings are inappropriate and give incorrect results, and some are misapplied and thus give false confidence in some measures. Traditional buildings require different assessment and practice with regard to the control of moisture in buildings, which is vital for fabric and human health.

3. Historic building refurbishment specifics

Energy efficiency can be greatly improved without touching the building construction – through optimization of the performance of the building envelope and intelligent operation and management of HVAC (Heating, Ventilation and Air Conditioning) system [27–29], changing the doors and windows, improving building air tightness, etc. High energy performance buildings feature airtight building envelopes with high levels of thermal resistance and have control over the flows of heat, air, and moisture into and out of the building. Historic buildings built before current building codes in most cases have high levels of air leakage and inadequate insulation. Both issues increase heating and cooling losses and demands on Heating, Ventilation, and Air-Conditioning systems and decrease occupant comfort and indoor air quality. Houses built before 1980 often have little or no wall insulation. Given that walls can represent most of the building envelope area, ensuring that walls have proper levels of insulation is an essential part of any historic building energy retrofit [30]. Post-insulation of outer walls is the most challenging and most energy effective measure for historic building. The retrofit of interior insulation is commonly implemented to improve energy performance of these buildings, while maintaining their often historic exterior appearance [31].

Historic buildings usually have listed valuable properties which must be preserved when refurbishing the building. The building facades are the most common thing that has cultural value and therefore very often when refurbishing historical building there is only one option to achieve better heat transfer coefficient – to insulate from the inside.

Insulation from the inside is quite a problematic issue itself. There are many risks and disadvantages while doing this kind of refurbishment including:

- The risk of the outer walls becoming too cold and not being able to evaporate accumulated moisture.
- Risk of closing the pores of wall material (bricks, etc.) and preventing moisture from coming out.
- Moist walls in few freezing cycles can become damaged, especially ceramic brick walls.
- Disadvantage of losing inner space when adding the layer of insulation and covering the insulation with some appropriate finish material.
- The disadvantage of not seeing the original materials from the inside.
- Complexity of the installation.

However this is the only method which highly increases the energy efficiency of the building. This refurbishment method is allowed in many cases when refurbishing historic buildings. There are some commercial products developed with special application technologies and the price and complexity of work shows how much effort is needed to overcome the moisture problem in the walls, especially in colder climate countries.

Modern materials usually help to eliminate the problem of losing much space, but these materials have to be examined in practice to see how they work concerning moisture regime.

4. Post-insulations of historic brick buildings

Selection of insulating material for historic brick wall requires analysis of its u-value, hydrophobic properties, etc. It requires expertise to find the best alternative from hundreds of new insulation products which are now sold on the construction market. Some recent studies show how the effectiveness and eligibility of insulating products are estimated using expert methods, but very few studies deal with specifics of interior insulation of brick walls [32–34]. When selecting the insulation the cost of insulation material, cost of energy, efficiency of the heating system, cooling equipment, lifetime of building, inflation and discount rates dictates the optimum insulation thickness. It is undesirable to have extreme or incomplete insulation. Extreme requires too much capital investment and lower life cycle whereas with incomplete insulation desired energy savings cannot be achieved. It is essential that the materials chosen are appropriate, particularly with historic buildings that are considered 'breathable' constructions. Some studies on insulation of historical buildings are already done, but there is a lack of information about new materials and methods. There is a danger that when adding insulation to an existing wall, moisture can be trapped inside the wall and become harmful to the structure and human health in the long-term. In the rush to insulate