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Optimisation of opaque components of the building envelope. Energy, economic and environmental issues

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Abstract

The European Directive 2002/91 will enforce the Member State to promote the implementation of new measures, instruments and calculation methodology to improve the buildings energy performances. The thermal performance and quality of the Italian residential buildings is generally poor, depending on the age of the building stock and the lack of application of the existing energy regulations. This study aims at demonstrating the global benefits of good insulated building envelopes. Energy benefits are easy to understand, meanwhile the economic issues are critical, since the final users see them as an additional useless extra cost for the dwelling at the purchase phase, with small attention to the future managing costs. The study demonstrates that significant economic advantages come out from high–performance building envelope. The study also shows that environmental extra loads due to a bigger use of the insulating material is paid back in few years, with consistent social benefits, if the life cycle of the building is taken into account.

Keywords: Envelope insulation; Building thermal performances; Environment analysis

1. Introduction

The global environmental emergency is worldwide recognised, except for few dissonant voices. Acid precipitation, stratospheric ozone depletion, the greenhouse effect and other effects are menacing the life on the planet. The most important environmental problem related to energy utilisation is global warming, also known as greenhouse effect. CO_2 contributes for about 50% to the anthropogenic greenhouse effect [1,2]. While the use of energy contributes for about 80% to manmade CO_2 emissions, nearly all of the anthropogenic NO_x emissions and 30% of the methane emissions are caused by energy use. The rational and efficient use of energy can strongly reduce energy-related emissions.

The building sector is still the major responsible for energy end uses, the industry sector having nowadays reached a high level of efficiency and the transport sector still increasing its uses. The buildings sector is responsible for 40% of the energy end uses in Italy and, in particular, 70% can be imputed to the residential only [3]. A strong increase of cooling demand was registered during the few past years; nevertheless the energy bill of Italian dwellings is still dominated by the heating demand. All the studies run at European level and aiming at framing the energy performance of residential buildings and their insulation levels, stressed the poor performances of Italian buildings, especially when normalised to the climatic conditions. This study aims at evaluating the best insulation levels of the opaque components of the building envelope according to the heating season energy performance. By the way, under some specific conditions, which are not considered in this study, the increases of insulation levels can be useful in the hot season as well.

The first legislative acts related to the building energy issues date back to the mid 1970s, when the oil crisis outlined the importance of improving and rationalising the energy uses. Since then framework laws, decrees and technical standards have been continuously published but their impact on the way buildings were constructed and retrofitted was absolutely weak. By the mid 1990s Italy had

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Nomenclature

R	annual actualised energy savings (€/m^2)
NPV	net present value (€/m^2)
PBR	payback rate year
EPC	energy present cost (€/Wh)
U	thermal transmittance (W/m^2 K)
DD	degree days (°C day)
m	insulation material fixed costs (€/m^3)
q	insulation material variable costs (€/m^3)
s	insulation material thickness (m)
V	volume of the building (m^3)
Q	heat gains (W/m^2 K)
S	global external surface of the building (m^2)
n	hourly flow rate (h^{-1})
L	length of the heating season day

Greek symbols

Δ	degree days reduction factor (K day)
λ	thermal conductivity (W/m K)
ρ	density (kg/m^3)

Subscript and superscript

0	reference value
1…13	component configurations
m	average
i	indoor
e	outdoor
fa	global floor area
T	tower building
S	single family house
*	corrected value

one of the most advanced framework normative, Law 10/1991, with one of lowest application rates. The situation still persists, meanwhile the European Directive 2002/91/CE on the energy performance of buildings fixes a set of conditions that new and existing buildings will have to comply with. The reasons depend on both the lack of implementing decrees needed to make the law effective and the practically complete lack of control procedures, needed to check that the construction process was coherent with data declared during the design phase, especially for the insulation levels. Another not negligible reason was the choice of complex performance indicators, instead of simple indicators that could be easily understood by users.

Many studies were carried on during the last decades showing how the energy performance of buildings can improve with a properly insulated building envelope [4,5]. The heating loads of buildings depend on the thermal transmittance of envelope components, in principle the lower the latter, the lower the former. This dependence is not linear but has an asymptotic value, that means, in practice, that insulating a wall/roof over a certain thickness is not effective. Such thickness depends on the climatic conditions of the site, the building geometry, the material characteristics and so on.

Insulating costs. This is one of the most typical answers heard whenever the energy performances of buildings are debated. It is obviously true that a well-insulated building as a higher initial delta cost if compared with a poorly insulated one. How this delta costs affect the financial performances of the building during its life cycle is seldom taken into account. One important issue of this paper is the economic analysis and evaluation of the envelope components based on the optimisation of the insulating materials thickness.

Better insulation levels imply, not only higher initial costs, but higher environmental loads as well, due to the production of the insulating materials. A further analysis, presented in this paper, aimed at verifying if the environmental performances of buildings were compatible with the energy and economic performances previously evaluated.

Defining the optimisation of the insulation levels of the opaque components of the building envelope requires the three-level analysis: energy, economy, environment. This integrated approach allows solving the problem without penalising the actors of the construction process: owners, building construction companies, building end users and the whole community. On the contrary, the objective is to provide them with added value.

2. Methodology

The aim of the research is a sensitivity study aimed at finding out the insulation levels that optimise the costs/benefits ratio for the opaque components of the building envelope. Two parameters are considered to evaluate the efficacy of the investment: the net present value (NPV) and the payback rate (PBR).

The latter indicator, generally expressed in year, defines the time length needed so that economic benefits of an investment even up the initial economic pay. The net present value of an investment is a financial indicator, generally expressed in €, giving the amount of money saved at the end of the life cycle of the investment itself [6]. The investment in this case is the added insulation needed to improve the energy performance of the buildings. The calculation procedures are explained in Section 2.2.

To reach the aim of the research, the methodology is based on several steps:

1. Market and cost analyses of the insulation materials for building applications.
2. Calculation of the optimal insulation, and related thermal transmittance U, of the opaque components of the building envelope.