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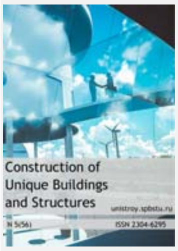

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European Thermal Insulation Technology Implementation to Green Building Concept

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ABSTRACT

The amount of gas, electricity and other energy resources consumption is directly dependent on thermal insulation of the building. When calculating the cost for thermal insulation it should not be forgotten that the service life of the material is at least 20 years, and this procedure can reduce cost for heating by 50-80%. Up to 40% of heat is lost through the walls. The only possible way to reduce heat loss through the exterior envelope is the wall insulation. Heat loss problem applies not only to the harsh climatic conditions of Russia but also European countries with the moderately monsoon climate. Based on the data obtained under the program of international internship «Master Degree in Innovative Technologies in Energy Efficient Buildings for Russian & Armenian Universities and Stakeholders» at the University of Genoa (Italy), the article discusses the possibility of using European technology of thermal insulation of external walls in order to implement the green building concept under conditions of the transition from continental to marine climate of St. Petersburg. Considered technology is actively used in North Italy, Germany and Canada. During the work, data were obtained on the heat engineering characteristics of the method, life cycle assessment of thermal insulation materials was made, and economic feasibility of measures is given.

Content

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1. Introduction

Awareness of the energy consumption problem in the construction industry exists in most countries. A significant economic benefit occurs when the thermal insulation of building envelopes is increased, as substantial savings of energy costs can be achieved through proper insulation [1–6]. Recently, foreign colleagues in their works began to raise the issue of environmental protection, depending on the buildings thermal performance. On a broader perspective, the correct selection of thermal insulation contributes reduce air pollution [7–12].

Drawing attention to the European Directive [13], it can be concluded that the adoption of energy efficiency measures in the construction industry is very important, because this sector in Europe accounts for more than 40% of energy consumption and consequently CO_2 emissions. It is clear that the Directive is a first step for the European Union to reach the commitment made under the Kyoto Agreement. The EU has committed itself reduce to 2020 greenhouse gas emissions by 20% relative to level of 1990.

The Russian government, in turn, has approved state program [14], for which it is planned to reduce energy consumption by 13.5% by the year 2020, which is 2.436 billion tonnes of CO_2 equivalent reduction.

Many methods of facade insulation have been considered in a number of foreign studies [15-19]. Among all the existing ones, external thermal insulation composite system (ETICS) has established itself as a more practical throughout the life cycle. Since the most important element of the system is the thermal insulation material, the urgency lies in the correct selection of the most effective material that takes into account a set of parameters such as climatic features of the region, energy saving factor, impact on the environment and the payback period of these costs.

Proceeding from the foregoing, the goal was formulated to conduct a comprehensive assessment of the European technology for the insulation of non-translucent external enclosing structures and its possible borrowing in a transitional climate of St. Petersburg.

The tasks are as follows:

1) Conduct market analysis of insulation materials in Russia;
2) Carry out their environmental assessment;
3) Bring the business case for this technology.

The article discusses the building envelopes insulation technology used in Europe and the possibility of its use in Russia, for which the energy, environmental and economic efficiency assessment must be made.

2. Methods

In most European countries, for thermal insulation of building envelopes the External Thermal Insulation Composite Systems (ETICS) is mainly used, both in new constructions and in the renovation of existing buildings.

The principal design of an ETICS is schematically shown in Fig. 1. An insulating board is rawlplugged and/or glued to the wall. It is followed by a layer of a cement bound mortar with a thickness of 3–5 mm. It is reinforced by a textile glass fabric placed in the middle of the layer. The rendering is attached to this mortar with a thickness of 1.5–4 mm. In most cases a material with inorganic aggregate and a polymer bond is used [20, 21].

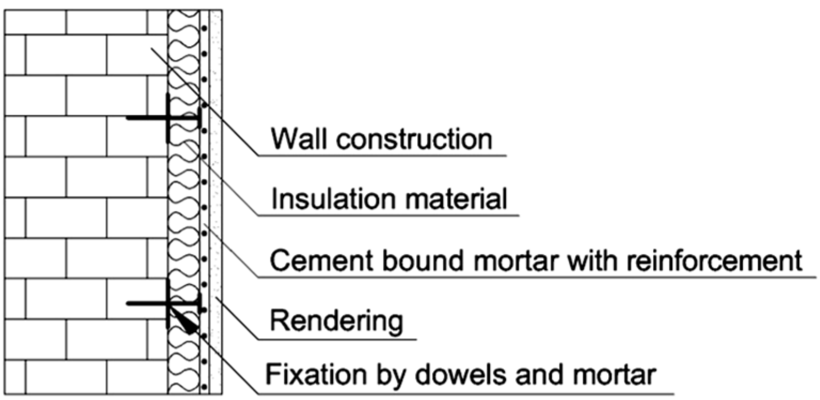

Figure 1. Schematic representation of an external thermal insulation composite system.

In the design, special attention is given to choice of thermal insulation material. In the context of sustainable construction, it should be characterized by the following criteria: safety, environmental friendliness, energetically and economically efficiency, and reduced operating cost.

Today the Russian market of thermal insulation materials contains 60% of inorganic fibrous materials: rock wool, glass wool, ecowool et al., and about 27% of organic foamy materials: polystyrene, polyurethane et al. [22]. Three thermal insulation material most dominating in the European market were considered: expanded polystyrene (EPS), mineral wool (MW) and rigid polyurethane foam (PUR). Data for their thermal and physical properties were derived from handbook [23].

To match the title of "green" material, environmental impact should be minimized in the production. So the environmental assessment was made. To make the analysis more comparable, the calculation was carried out on the amount of material required to insulate of 1 m^2 wall under conditions of St. Petersburg climate for the normative value of heat transfer resistance (R = 2 m^2·°C/W) [24–27].

The basis for the analysis was the Ecoinvent database [28]. To compare the results, Global Warming Potential (GWP) method and EcoIndicator'99 (EI99) were used.

GWP is a coefficient indicating the amount of CO_2 emitted during the material's life cycle. In this case, the average service time of insulation adopted 25 years.

EI99 is a damage-oriented method that allows estimating environmental impact on human health, ecosystem quality and use of resources. It includes the following parameters: carcinogenics, climate change, ionising radiation, ozone layer depletion, respiratory effects, acidification and eutrophication, ecotoxicity, land occupation, fossil fuels, mineral extraction. All figures are added together and the general indicator of impact is given.

3. *Results and Discussion*

Since the insulation materials are very low-density, small masses are needed to provide high levels of insulation. Therefore, negative environmental impact of insulation is generally small taking into consideration the energy saved during the building lifetime [29–31].

The data on the environmental performance of insulation materials are presented in Table 1.

Table 1. Indicative values for thermal insulation materials.

Insulation material	λ, W/(m·°C)	ρ, kg/m^3	σ, m	m, kg	GWP, kg^{-1}	m_{CO2},per m^2	Pt, kg^{-1}	Pt, per m^2
PUR	0.029	40	0.05	2	6.78	13.56	0.48	0.96
MW	0.048	100	0.1	10	1.51	15.1	0.06	0.6
EPS	0.038	40	0.05	2	7.34	14.68	0.36	0.72

Symbols:
λ – material thermal conductivity;
ρ – material density;
σ – thickness of insulation layer;
m – mass of 1 m^3 of insulation;
GWP – global warming potential of 1 kg of material;
m_{CO2} – mass of CO_2 emission of 1 m^2 of insulation;
Pt – eco-indicator point.

According to the estimation, the amount of emissions for the life cycle of considered materials is almost equal, while the PUR has more adverse impact on the environment: 1.5 times higher than MW.

Consider the task of determining the cost-effective insulation material. Methods of calculating capital costs for additional insulation, operating costs before and after thermal insulation, and payback period of energy-saving measures are described in detail in the works [32–34].

Calculation of heat consumption for heating for different insulation variants has been produced in two variants: without taking into account measures to improve the energy efficiency of the building (0.51 m thick walls made of ceramic bricks) and given the wall insulation device. This has provided the value of heat energy-saving (Table 2).

Table 2. Economic analysis of thermal insulation materials.

Insulation material	R, $m^2 \cdot °C/W$	Q, kW	Q_{ins}, kW	K, rub	E, rub	T, years
PUR	2.67	121	43.11	1960	103.7	14
MW	3.03	121	38	2700	110.5	17
EPS	2.26	121	50.93	1430	93.3	12

Symbols:
R – material heat transmission resistance;
Q – heat loss through 1 m^2 without insulate walls per year;
Q_{ins} – heat loss through 1 m^2 of insulated wall per year;
К – capital cost of installation of 1 m^2 of insulation;
E – annual cost savings for heating;
T – payback period of insulation.

The results show that the use of insulation is crucial to decrease the energy demand in buildings, and also to decrease the CO_2 emissions. Energy reductions up to 68% in winter were measured theoretically. The differences between insulation materials are small, but the comparison shows that the ETICS with mineral wool is the one with the lowest energy consumption and with polystyrene is the one with the shortest pay-back period.

4. Conclusions

In this research work an ETICS have been evaluated in terms of three main assessment factors: primary energy consumption, the environmental impact and the financial cost. Based on the life cycle assessment, it can be argued about the advantages of the system that can reduce the energy consumption, CO_2 equivalent emissions and total economic cost in the life cycle by up to 20% when compared without insulation.

Comparative analysis of insulation materials has showed:

1) the most environmentally friendly material is mineral wool;
2) the most economical material is extruded polystyrene foam;
3) payback period for system with mineral wool is 17 years, expanded polystyrene – 12 years and rigid polyurethane foam – 14 years.

According to the results of the study, the following can be affirmed, the stated goal of the research has been achieved, the adoption of the European technology for the insulation of external walls is possible, but fire safety measures are required.

In the selection of thermal insulation is important to be guided not only energy-saving properties of the material, but also to consider the potential effectiveness of environmental impact. The considered method of environmental assessment is not practiced, however, there is a transfer document from the European standard. The authors believe that engineers need to take into account the ecological parameter that will be developing in accordance with international world trends. Adoption of this parameter will also stimulate domestic producers of thermal insulation materials to create innovative and ecologically safe products that can compete with the overseas market and contribute to the development of domestic import substitution policies.

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Реализация европейской теплоизоляционной технологии в концепции "Зелёного строительства"

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ИСТОРИЯ

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КЛЮЧЕВЫЕ СЛОВА

Строительство;
энергоэффективность;
энергосбережение;
теплоизоляция;
система фасадная теплоизоляционная композиционная;
СФТК;
оценка жизненного цикла;
международный опыт;
зелёное строительство.;

АННОТАЦИЯ

Количество потребления газа, электричества и других энергоресурсов напрямую зависит от теплоизоляции зданий. При подсчете затрат на утепление нельзя забывать, что срок службы материала составит минимум 20 лет, и поможет сократить расходы за отопление на 50-80%. До 40% тепловой энергии теряется через стены. Единственным возможным способом сократить тепловые потери через наружную оболочку здания является утепление стен. Проблема потерь тепла касаются не только суровых климатических условий России, но и Европейские страны с мягким муссонным климатом. На основании полученных данных в рамках программы международной стажировки, Master Degree in Innovative Technologies in Energy Efficient Buildings for Russian & Armenian Universities and Stakeholders в университете г. Генуи (Италия), в статье рассмотрена возможность применения европейской технологии утепления наружных стен в условия переходного климата г. Санкт-Петербург от умеренно-континентального к умеренно-морскому. Рассматриваемая технология активно применяется в северной Италии, Германии и Канаде. В ходе работы были получены данные о теплотехнических характеристиках метода, произведена оценка жизненного цикла теплоизоляционных материалов, и приведена экономическая обоснованность мероприятий.

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