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Original Research Article

THERMAL RENOVATION OF BUILDINGS WITH THE USE OF STRAW - EUROPEAN EXPERIENCE

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Abstract

The selection of building materials to a huge extent shapes building impact on the environment. In the era of widespread awareness of health problems arising from toxicity of chemical substances, healthy and safe materials of organic origin are even more important. The work discusses examples of the use of straw-bales in thermal retrofitting of buildings located in Austria, Czech Republic and Hungary. The experience of the practical applications of this material in renovations of buildings located in similar climatic conditions indicate that these solutions can be used successfully in Poland. The prevalence of this technology can make a significant contribution to reduction of gaseous emissions, waste, as well as the emission of noise, vibration radiation.

Keywords: natural building materials, ecological homes, straw-clay walls, thermo-renovation

1. ENERGETIC EFFECTIVENESS IN A LIFE-CYCLE OF A BUILDING

European Union Directives plan the reduction of greenhouse gas emissions by 80%, compared to 1990, as a long-term objective for 2050. The implementation of this ambitious target will require the reduction of energy consumption in existing and newly designed buildings. The recent financial crisis has limited the pace of new investments, and so the modernization of existing buildings has gained greater importance.

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National and international regulations in the construction sector are mainly focused on the reduction of energy use, by improving energy efficiency of buildings, modernization of installation and increasing the share of renewable energy in the overall energy balance. Investment activities are characterized by both a determined financial cost and an impact on the environment. The life-cycle of materials, structures and entire buildings can be estimated with the use of methods: life-cycle analysis (LCA) and life-cycle costs (LCC) [4]. These tools, overall, take into account not only heating energy saved thanks to additional thermal insulation, but also the investment costs and the environmental burden resulting from the building materials used and the introduced solutions. The production of popular insulating materials, which base on minerals (rock and mineral wool) or fossil fuels such as oil (polystyrene), is not, contrary to producers' declarations, indifferent to the environment [3]. Processes taking place in their production are also becoming more expensive due to rising energy prices, and involve emissions of harmful pollutants. Numerous studies also indicate health risks [1,3,8,9]. Straw is cheap, sourced locally and has negligible "ecological footprint". Contrary to conventional insulation materials, straw is of plant origin, and the absorption of carbon dioxide during photosynthesis makes it a valuable contribution to climate protection. Straw external insulation of a single detached house contains the approximately 20 tonnes of CO_2 [10].

2. STRAW BALE CONSTRUCTION

Construction of houses of straw bales became widespread in Nebraska, the USA, in the late nineteenth century and was directly related to the invention of the straw press. The compressed straw bales are best suited as a filling for walls in buildings of a timber frame while applying exterior plaster or a façade system. Its additional advantage is the fact that it enables vapor-permeability in building partitions. However, due to the risk of humidification, the technology requires accuracy in designing and performance [7].

Straw bales are characterized by very good thermal conductivity coefficients (0.025-0.045 W/m K) and thermal transmittance coefficients (0.12-0.14 W/m²K, for 40 cm thick bales) [7.10]. Their fire resistance was described in ISO 8301: 1991, which was confirmed by tests at the Technical University in Vienna carried out according to standard ÖNORM B 6015-1. Unsecured with chemical preparations, straw bale plastered with 5cm clay, exposed to the fire - were not damaged for 90 minutes, thanks to which were granted assessment of the resilience F90 and received certification B2. Due to this fact, Austrian and German construction laws permit their usage [10]. In Poland, the legal basis for obtaining a building permit for a building designed in this technology is the record of a unit product in the Construction Products Act of 16 April 2004 (Dz. U. 2014.

Item 883). The construction of the first house in Poland was started in 2000. In 2010, the number of completed buildings and the ones being under construction exceeded twenty. Currently, it is difficult to determine the number of buildings thermally retrofitted with the use of straw throughout the country, due to the limited interest in this subject of the scientific community and the lack of documented examples of implementation.

3. EXAMPLES OF IMPLEMENTATION

Thermal renovation of external walls with the use of pressed straw consists in coating the building with a layer of straw bales, stacked one on another, covered on the outside with clay or limestone plaster, often reinforced with a mesh. Straw bales are placed on heightened pedestal and attached to the existing wall using special anchors or a light wooden structure. For walls which are particularly vulnerable to weather factors, external cladding with ventilation slots are applied. Roof insulation requires its adaptation to the weight and thickness of straw bales (35-45 cm). Due to the additional costs resulting from the reconstruction of the roof structure, thermal insulation the floor of an unused attic is popular.
To illustrate the issue of thermal renovation with the use of straw bales, three examples from Central European countries (Austria, the Czech Republic and Hungary) are presented below. Three single-family houses of different location, shape and structure (masonry and wooden frame) have been selected to present three different cases: roof thermal insulation, the insulation of external walls and the ceiling above the ground floor and the insulation of just external walls.

3.1. Austria - Vienna

Austria is a country where construction based on alternative building materials has been growing rapidly and dozens of investment have been implemented over the years. Research undertaken by the Technical Universities of Vienna and Graz and by independent institutes refer to both physics and biology of such buildings. Demonstrative actions have also been undertaken, an example of which is the construction of the “House of the Future” - a prefabricated building made of straw S-House [10]. Straw is a recognized building material in Austria, where it is used not only in rural areas. Vienna's first building insulated using straw is an outbuilding from 1890 located at Mollardgasse Street. The thermal retrofitting, carried out in 2003, was applied to an element of reconstruction and superstructure of the building. The ground floor of the building preserved its former garage function, but the existing roof was demolished. A residential storey with extensive terraces was designed above it (the floor area 180 $m^{2)}$. The structures of the floor, the walls and the roof were built of wood. The roof was insulated with pressed straw bales arranged between the rafters. The architects,

from a Viennese design office Allmermacke, decided on straw not only because of environmental considerations. They were encouraged to do so by favourable price-performance ratio and by the specific physical characteristics of the insulating material.

Fig. 3. The roof of the building insulated with straw bales, Vienna, Austria [10]

Fig. 3. The building before and after thermal modernization, Vienna, Austria [10]

Bales of straw placed in the roof due to its relatively high density provide a solid thermal mass of the building. They make a significant contribution to the regulation of micro-climate in the premises. The phase shift helps to stabilize the internal temperature and protects the building from overheating, while the beneficial value of coefficient lambda for pressed straw provides excellent thermal performance of the partition ($U = 0.15$ W/m^{2}K). The walls and the ceiling are insulated with injected cellulose. To avoid thermal bridges, the designers decided to perform the insulation inside. The demolition bricks, tiles and wooden rafters and beams were reused as building material. The investment cost was approximately 1,000 € / m², and the estimated energy consumption for heating in the facility stands at 45 kWh/m² [10].

3.2. The Czech Republic - Bražec

A thermal modernization bonus, introduced in the Czech Republic in May 2009, helps the owners of old buildings to improve their thermal parameters.

Unfortunately, the solution completely ignores the use of natural materials, preferring the traditional energy-intensive insulation: polystyrene and mineral wool. Thermal renovation of a building from the 50's of the twentieth century in the village Bražec, carried out in 2009, was conceived as a model investment, presenting an effective insulation with the use of straw. Amazonails group, which unites recognized authorities of natural construction: Barbara Jones (England) and Jakub Wihan (Czech Republic), was responsible for the design and construction during a 12-day workshop.

Fig. 1. The building before and during the thermal renovation with the use of straw bales, Bražec, Czech Republic (Source: www.jakubwihan.com)

The outer walls of brick, 40cm thick, were insulated with straw bales, 27cm thick, and covered with clay plaster. The existing concrete floor was removed and replaced with an insulating layer made of expanded clay and limestone concrete (limecrete). The plinth of the building was also insulated with a layer of expanded clay extended to the height of 35cm above the ground level. The ceiling above the ground floor was insulated with a layer of straw with (54cm thick) and covered with clay pugging. The geometry of the roof was changed. In order to protect the outer walls, the breadth of the hood was significantly expanded.

3.3. Hungary - Nyíregyháza

In Hungary, the use of straw in construction has grown in popularity over the last few years. This is due to the excess production of straw, which makes it an inexpensive and locally available material.

In 2010, a pre-war, half-timbered house located near Nyíregyházy, was subjected to thermal renovation with the use of straw bales. The investment was financed with EU funds, and realised on a farm belonging to a Hungarian environmental association, E-misszió. The implementation of the project helped lower the initial value of U from 1.39 W/m^{2}K to 0.15 W/m^{2}K [6]. Thus, it improved the performance of external wall insulation, which will reduce energy bills.

Fig. 2. Building before and during thermal renovation, Nyíregyháza, Hungary [6]

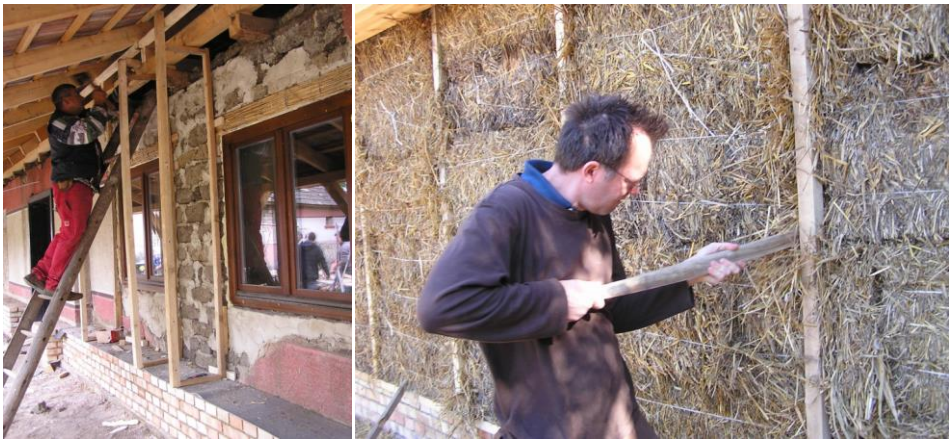

Fig. 3. Thermal renovation with straw bales, Nyíregyháza, Hungary [6]

4. CONCLUSIONS

In construction, alternative environmental movements have successfully developed in most Western Europe countries over the years. Polish architects, designers, contractors and investors are just discovering the benefits of using organic products as building materials. Straw is a renewable material, having good thermal insulation properties and unlike majority of popular building materials, it has a negligible impact on the environment [4]. Also other, more pragmatic benefits resulting from the use of materials of organic origin are highlighted. Their production, processing, use and utilization imply low economic cost. In the era of widespread awareness of the occurrence of health problems stemming from toxic substances that surround us, healthy and safe materials of organic origin are gaining in popularity. In addition, erecting buildings out of straw and clay, which has had a long tradition in the European history of

construction, can be combined with the idea of an energy efficient, passive house. Traditional building techniques based on natural materials, in a heavily modernized version, are becoming increasingly common in individual housing. The new generation of building materials applies the achievements of modern technology. Austria, Germany, Great Britain and Lithuania have already begun to even produce prefabricated façade and roof elements filled with straw, designed for private construction. Construction based on alternative materials is still considered to be avant-garde and unconventional in our country.

In the past, it resulted from poverty, thriftiness and the necessity to use cheap and available materials. The limited natural resources of our planet, rising prices of construction materials and the need for energy savings during a building construction process and then in its regular operation, force us to revise our conventional approach to construction. In the future, the use of local, cheap and healthy building materials may become a priority and economic necessity in modern housing.

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TERMORENOWACJA BUDYNKÓW Z UŻYCIEM - DOŚWIADCZENIA EUROPEJSKIE

S t r e s z c z e n i e

Wybór materiałów budowlanych w olbrzymim stopniu kształtuje wpływ budynku na środowisko naturalne i na zdrowie użytkowników. Praca omawia przykłady technologii straw-bale do termorenowacji istniejących budynków zlokalizowanych w Austrii, Czachach i na Węgrzech. Doświadczenia praktycznych zastosowań naturalnych materiałów w docieplaniu budynków zlokalizowanych w podobnych warunkach klimatycznych wskazują, że rozwiązania te z powodzeniem można zastosować w Polsce. Rozpowszechnienie tej technologii może w znaczący sposób przyczynić się do redukcji emisji zanieczyszczeń gazowych i odpadów, a także emisji hałasu, wibracji i promieniowania.

Słowa kluczowe: naturalne materiały budowlane, termorenowacja, domy ekologiczne, budownictwo z gliny i słomy

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