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PASSIVE BUILDING - ANALYSIS OF WALL CONSTRUCTION SOLUTIONS

Aspirations to reduce consumption of natural resources combined with increasing energy prices have contributed to the search for solutions to reduce costs to end users. This is a translation into promotion of equitable use of various types of appliances and equipment with lower demand for electricity. House heating represents the highest level of energy consumption. According to this, it is important to put intention on lowered costs in buildings thanks to reduced demand for energy. Achievement of this goal is possible mainly thanks to the basic factor of installing better insulation throughout the buildings. It means that a new challenge has been raised for the engineers - energy efficient construction. Recently this field has been developing very dynamically. A challenge was raised for buildings to achieve the nearly zero energy consumption. Also the standard requirements of newly constructed buildings impose guidelines with a maximum thermal transpiration of the barrier. Many modern materials and old, well-known but modernized ones were used in these new solutions. The review and analysis of these energy efficient building's structure are the main topics developed in this study. This review shall present the solutions that are currently in use and are available on the Polish market. The evaluation of them has provided useful information and results.

Keywords: **thermal insulation of external partitions, energy-efficient construction, passive building**

INTRODUCTION

Modern approach to reduce building energy demand could be a challenge, but also a priority of the modern world. The result will be not only a beneficial effect on climate protection at the local or global level, but also an economic gain to the constantly increasing prices of raw materials.

The demand of solutions for lowering the cost of materials has forced the building market to collect research and initiatives towards a radical reduction in energy consumption in this sector. A special category of these objects is called passive constructions. They became the internationally recognized standard for sustainable architecture, which has numerous projects around the world.

The passive house standard defines the building performance and thermal comfort of residents. The issue of the structure remains in the architect's and investor's responsibility. Therefore, almost every well-insulated building may be applied in the field of the passive house standard. Such elements as thickness of the whole structure, strength, cost, and climatic conditions for the location should be taken into account in the planning process.

1. ENERGY EXPENDITURE IN BUILDING ENGINEERING IN FACE OF EUROPEAN UNION STRATEGY

The strategy adopted by the EU in the fight against climate change is based on three objectives which have to be achieved by 2020. Those objectives are: reducing greenhouse gas emissions by 20 percent, increasing the participation of renewable energy to 20 percent and reduce total energy expenditure by 20 percent. An important element of these activities should be reducing consumption of raw materials for the building heating [1].

However, in 2012 an evaluation of the plan for energy efficiency showed that the previously executed actions and implemented measures would have achieved only about half of this 20% energy efficiency in 2020. Therefore, it indicates that there is a need for change and action especially in the construction industry [2].

According to the European Environment Agency (EEA), the housing sector consumes 26.5% of total final energy expenditure in Europe (data for 2009) [3]. But in Poland this figure reaches 31% (data for 2009), which is above the European average [4]. High energy expenditure in our houses was and still partly is the result of improper position and shape of buildings, high heat transfer coefficients of walls, roofs and floors, the occurrence of thermal bridges, low efficiency of heating systems, and well as residents' bad habits and lack of willingness to save.

2. PASSIVE BUILDINGS

A passive object combines a high level of comfort with very low energy expenditure in buildings, both residential and public.

Thus, we can define a passive house based on the theory of Wolfgang Feist as an object with extremely low energy requirements for the interior heating - 15 kWh m^{-2} per year. Thermal comfort in these buildings is ensured by passive heat (residents, electrical appliances, solar energy, and heat recovery ventilation), reheating, and air ventilating of the building. However, a low level of such energy is needed, and it was shown that the best example of a 20 m^2 room can be heated with body heat of four people, even in the middle of winter. In reality, this kind of buildings is heated with an efficient and comfortable heating system. The overall energy expenditure remains at a very low level. [5, 6]

It is important to focus on some key elements in planning process of passive houses. In order to reach the highest properties of this kind of building, the following features must be implemented:

– unbroken low thermal conductivity insulation ($\lambda \leq 0{,}04$ W·m^{-1}·K^{-1}),
– thermal bridge - free construction,
– well-insulated windows with high quality glazing (U ≈ 0,6÷0,8 W·m^{-2}·K^{-1}),
– very airtight building enclosure,
– comfortable mechanical ventilation with efficient heat recovery [5, 7].

3. CONSTRUCTION REVIEW OF THE APPLICABLE PASSIVE CONSTRUCTIONS

Recently designed passive houses in the assumptions should resemble vacuum flasks, both in terms of construction and properties. First of all, they must have a very solid structure and perfect airtight and thermal insulation. A key element is also that all details of the building should be designed and constructed in accordance with obligatory standards and norms.

As it was mentioned, houses can be built in a variety of construction technologies, however with adequate thermal insulation, where the emphasis should be placed also on the above mentioned airtightness. The thermal layer must be of the highest quality and designed in order to ensure continuous protection of the entire facility. It may be interrupted only with the well-connected window.

Below there is an overview of the types of possible structures for use in passive houses. Exterior vertical building walls will be considered. Justification of such an approach issue is their role in losses in buildings. Out of all elements of the building, the external wall construction to the greatests extent may affect the increase of its energy needs. Through this barrier comes out, which should be stressed, as much as 40 percent of total heat loss in single-family houses.

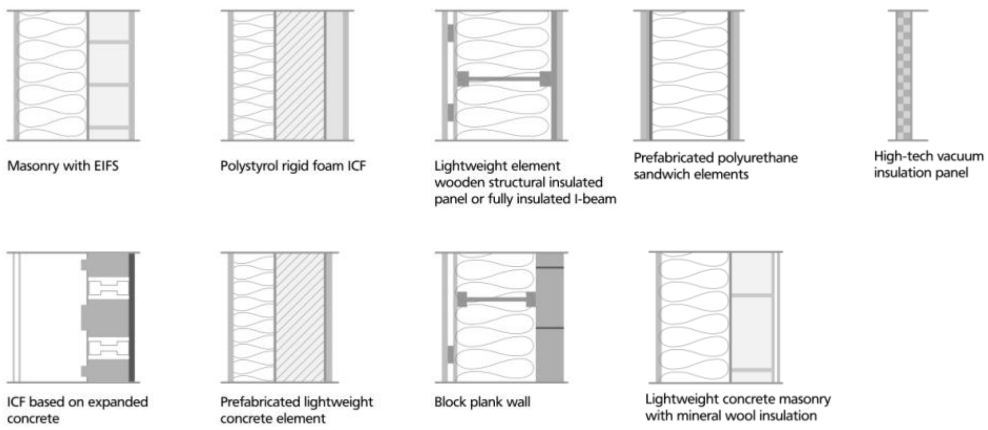

Fig. 1. Passive construction possibilities [8]

In recent years, thanks to the rapid development of the construction industry, a number of external wall structures suitable for passive houses have been developed. Among them, modern and proven solutions can be specifically pointed out. A passive object designer can use one of the most common of these solutions. Some examples in Poland are technologies used in the construction of these types of buildings such as aerated concrete masonry and insulation. However, the analysis should also consider other equally popular types, among which there can be distinguished, inter alia, frame structures (wood, steel), concrete wall, traditional brick/block masonry and other alternatives such as advanced technology based on vacuum thermal panel (Fig. 1).

Within those types of structures only fifteen partitions have been analyzed.

To analyze the selected walls, there are two computer - aided programs to perform thermal calculations and certificates called ArCADia THERMO PRO and Build Desk Energy Professional Certificate. Evaluated types of partitions and the configurations of used layers are shown in Table 1. The calculations were made while also taking into account the thermal layer and its lack (w.i. - without insulation). This form of the listing provides a more detailed and accurate view of the thermal properties of the type of the structure.

In order to standardize components such as plaster or thermal insulation, in cases where it was possible for the rational construction of the partition, the same material was implemented.

In relation to the considered possibilities of using different types of structures, it can be stated that rated partitions meet the requirements imposed for passive houses. This statement is based on the recommendations for, inter alia, λ thermal conductivity coefficient of thermal material (it should not be greater than 0.04 $W \cdot m^{-1} \cdot K^{-1}$) and the heat transfer coefficient through a structure at $U = 0.15\ W \cdot m^{-2} \cdot K^{-1}$. Perspective of improving these results has its justification in the continuing work on a new generation of insulation materials such as vacuum panels mentioned above. They provide a very high insulation and simultaneously reduce the wall thickness [9, 10].

Table 1 shows the position of the individual partitions in the ranking of the most effective construction solutions. The determinant of the classification was to achieve the lowest coefficient relative between wall thickness and U coefficient. The concept applied to highlight the partitions was based on a combination of the most energy-efficient solutions, but also with the finest structure. The factor which is the price was not included.

The results seem to be slightly surprising, because some materials are quite commonly seen and promoted as ideal for use in low-energy buildings. They occupy one of the last places in the comparison below. As it has been stated, the best features and correlation for the heat transfer coefficient and the thickness of the walls have been obtained with wood and steel light-frame, rarely applied in Polish climate due to lack of buyers' confidence in that technology. However, increasingly, such examples can be found in Poland. The cost factor of both, construction and installation, would be an important element in the further evaluation. The difference in the cost-effectiveness of mentioned methods can verify and strengthen the list. This problem should be the subject of further separate analysis.

Table 1. **List of the analyzed partitions**

Name of partition		Heat transfer coefficient - U	Thickness	Thickness of insulation layer	U·s ratio	Ranking the most effective solutions of vertical partitions
		$W \cdot m^{-2} \cdot K^{-1}$	m	m		U·s·100
Masonry of:	calcium silicate block (w.i.)	1.69	0.21	–	35.49	12
	calcium silicate block	0.14	0.41	0.2	5.74	4
	aerated concrete block	0.15	0.56	0.05	8.40	9
	aerated concrete block (w.i.)	0.19	0.51	–	9.69	10
	lightweight expanded clay aggregate concrete block	0.14	0.45	–	6.30	5
	insulating hollow clay brick (w.i.)	0.23	0.47	–	10.81	11
	insulating hollow clay brick	0.14	0.55	0.08	7.70	8
	concrete block	0.10	0.57	0.25	5.70	**3**
	brick (w.i.)	1.91	0.28	–	53.48	13
	brick	0.14	0.48	0.20	6.72	6
Concrete wall	molded by formwork (w.i.)	2.88	0.28	–	80.64	14
	molded by formwork	0.15	0.48	0.2	7.20	7
	stay-in-place formwork	0.10	0.48	0.3	4.80	**2**
Timber light-frame construction		0.15	0.31	0.22	4.65	**1**
Steel light-frame construction		0.15	0.31	0.22	4.65	**1**

The results collected in Table 1 highlight another important fact. Frequently, wrong ideas are manifested. It is not true that the structure of (old) buildings cannot meet the requirements for passive objects. It is possible to observe the solution of brick masonry. With twenty centimeters of insulation, it can be achieved at the level of 0.14 $W \cdot m^{-2} \cdot K^{-1}$. This does not solve the problem of nonairtight or thermal bridges. However, the available technologies also allow to solve these issues.

SUMMARY

Passive houses from the literature and the authors' point of view will give the development directions of energy efficiency structures. In a perfect world the development of technologically new solutions would be brought into mainstream use and the characteristics of such objects would be improved and make it more and more popular and widespread. It is important to evaluate the own results of this analysis of the types of most effective structures in use in passive construction. Requirements and directions indicated by the European Union lay out the need to integrate the activities of designers, builders, engineers, ecologists and economists. All activities in the field of energy savings in the construction industry will promote the merge of this sector into sustainable development.

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BUDYNKI PASYWNE - ANALIZA ROZWIĄZAŃ KONSTRUKCYJNYCH ŚCIAN

**Dążenie do zmniejszenia zużycia zasobów naturalnych w połączeniu ze wzrostem cen energii przyczyniło się do poszukiwania rozwiązań mających na celu obniżenie kosztów eksploatacji budynków. Stanowi to doskonały powód do uświadomienia korzyści wynikających z użytkowania różnego rodzaju urządzeń i sprzętu o niższym zapotrzebowaniu na energię elektryczną. Ogrzewanie budynku pochłania znaczną część całkowitego zużycia energii, dlatego też można znacznie obniżyć koszty eksplo-
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tacji poprzez zmniejszenie zapotrzebowanie na energię do ich ogrzewania. Osiągnięcie tego celu jest możliwe m.in. przez polepszenie izolacyjności cieplnej budynków. Oznacza to postawienie nowych wyzwań przed inżynierami, którzy powinni tworzyć i promować budownictwo energooszczędne. Ostatnio dziedzina ta rozwija się bardzo dynamicznie. Celem działań jest osiągnięcie standardu budynku zeroenergetycznego. Wymagania dotyczące ochrony cieplnej dla nowo wznoszonych budynków narzucają konieczność stosowania wysokiej izolacyjności cieplnej przegród. Wiele nowoczesnych oraz starych, dobrze znanych, ale unowocześnionych materiałów jest wykorzystywane w nowych rozwiązaniach przegród. Przegląd i analiza energooszczędnych rozwiązań konstrukcji budynków to główne tematy tego opracowania. Przegląd przedstawia rozwiązania, które są obecnie używane i dostępne na polskim rynku.**

Słowa kluczowe: **izolacyjność cieplna przegród, energooszczędne rozwiązania konstrukcji przegród, budynki pasywne**