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THE ENERGY COST VERSUS ENERGY ABSORPTION OF SINGLE FAMILY HOUSES – A CASE STUDY OF CITY OF JASŁO

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Summary

The paper presents an analysis of energy absorption and the costs of the energy for heating single family houses situated in the city of Jasło. The conducted research demonstrated a considerable diversification of material and construction solutions of the walls and the applied heating systems. Values of the heat transfer coefficient for exterior walls exceed the currently applied standards in most buildings. Heating systems are mostly hard coal fired. Warm water preparation supported by solar thermal collectors was used only in several houses. Analysis of the research results revealed a lack of correlation between the energy costs and heat transfer coefficient for the external walls.

Keywords: energy absorption, thermal insulation, heating system

INTRODUCTION

Analysis of the current state of buildings considering their energy absorption seems a starting point for realization of the objectives stated by the European Union Directive 2010/31/EU, associated with the improvement of energy efficiency in buildings. The energy absorption assessment is conducted by means of energy absorption indicators computed and stated in the statements of energy performance of buildings. The costs of heating make up the greatest share of building maintenance costs, therefore in this field the highest energy savings may be achieved. Activities targeting decreasing the building energy absorption should focus on improving their thermal insulation through thermomodernization of walls but also through modernization of heating systems. While planning a thermomodernization, one should consider the selection of thermal insulation materials with the parameters ensuring the possibly lowest risk of water vapour condensation in the walls (Nawalany *et al*. 2015) and on their surface (Radoń and Künzel 2006). Decreasing energy demand of buildings may be also achieved through increasing the share of renewable energy sources in meeting the energy demand (Weber 2010). However, actual energy consumption depends not only on the technical characteristics of a building and its equipment, but also to a major extent on the way it is used (the number of users, their habits concerning the maintained room temperature, airing, etc.). The purpose for which the buildings are used also considerably affects their energy demand (residential, public or farm buildings) (Szul 2005).

As evidenced by the data collected by the Builddesk Report (2012), in the Podkarpackie voivodship, single family homes constitute 80%, multi-family houses 2%, apartment buildings 3%, non-residential buildings 12%, and independent building units constituting technical and functional entities constitute 3%. According to the data provided by the Jasło city hall, also single family housing prevails as detached houses, more rarely semi-detached numbering ca. 5700 houses. Multi-family dwellings are situated mostly in the city centre. Both the existing and newly constructed buildings are usually stone constructions with reinforced concrete ceilings, one or two-storey, with or without basements. The research strived to assess the energy absorption of single family housing considering the rational energy management.

THE AIM AND SCOPE OF RESEARCH

The investigations aimed at analysis of single family houses thermal insulation and the costs of energy for their heating on an example of the city of Jasło. The scope of investigations comprised survey conducted in 70 houses situated in various parts of the city. The data obtained from the surveys contain: the usable floor area, the number of inhabitants, the building age, material and structural solutions of walls, the kind of heating system, application of renewable energy sources and estimated heating costs. Conducted investigations served to assess the amount of final energy used by the buildings over the year.

RESULTS AND ANALYSIS

In Table 1 the houses were compiled according to their usable floor area. The most numerous group, reaching 50% consists of houses with the area between 101 and 150 m^2.

Table 1. Usable floor area of investigated single family houses in the Jasło city area

Usable floor area (m^2)	Numer of buildings (pcs.)	Percentage (%)
≤50	1	1.4
51-100	11	15.7
101-150	35	50
151-200	21	30
≥200	2	2.9
total	70	100

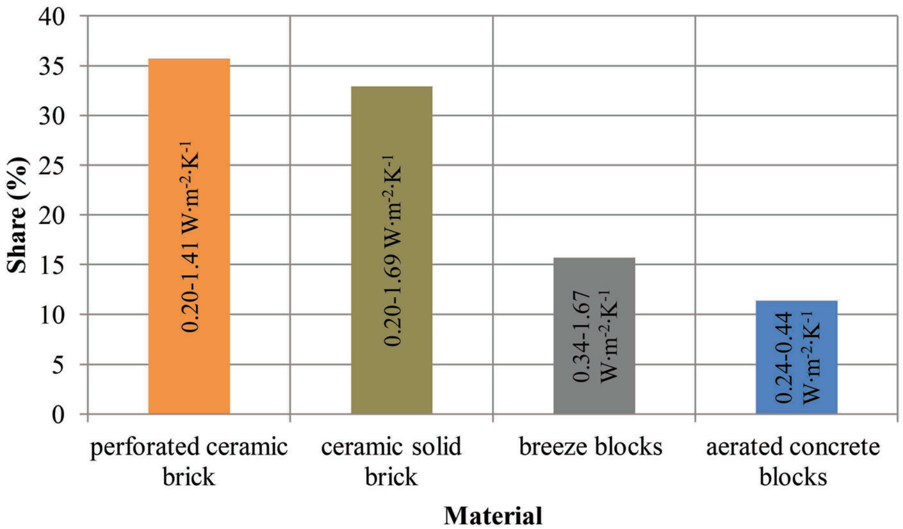

Figure 1. Values of heat transfer coefficient of various material and structural solutions of external walls of single family houses in the area of the Jasło city

Both the material used for the walls construction and construction solutions of walls affect the energy demand of a building. According to the Builddesk Report (2012), heat losses through the walls in a single-family house constitute ca. 66% of total heat losses in the whole building. They may be considerably reduced by the house thermomodernization.

The investigations demonstrated that 35.7% of the objects built in the area of Jasło were constructed of perforated ceramic brick, 32.9% of ceramic solid brick, 15.7% of breeze blocks and 11.4% of aerated concrete blocks (Pięta 2015). Figure 1 shows the share of individual materials in the occurring solutions for external walls together with the values of heat transfer coefficient. The value of this coefficient ranged from 0.20-0.58 ($W \cdot m^{-2} \cdot K^{-2}$) for insulated houses, resulting mainly from the applied thermal insulation layer thickness, and between 1.3 – 1.69 ($W \cdot m^{-2} \cdot K^{-2}$) for non-insulated houses.

Heat transfer coefficients of the external walls in the analyzed buildings are too high and in most cases exceed the permissible values. It applies particularly to the houses with walls without thermal insulation. Only new buildings or recently subjected to thermomodernization meet the requirements WT 2014, stated in the Resolution of the Minister of Transport, Construction and Maritime Economy of 5 July, 2013. Maintaining the required insulation parameters of the external walls allows to reduce heat losses, and therefore decrease the costs of house heating.

An attempt was made, on the basis of obtained research results, to assess the relationships between the costs of energy consumption and the value of heat transfer coefficient for external walls. The relationship is shown in Figure 2.

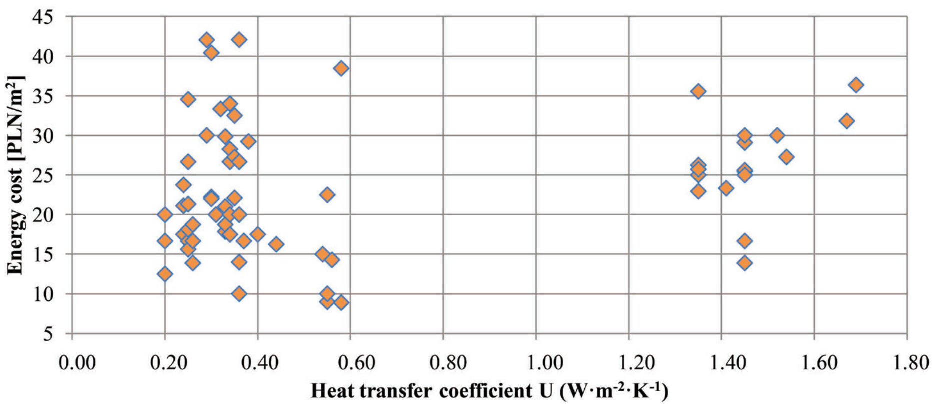

Figure 2. Energy cost per 1m^2 of usable floor area depending on the value of heat transfer coefficient of the external walls

A considerable diversification of energy costs for identical values of the heat transfer coefficient U may be seen in Fig.2. It means that the cost of energy consumption, apart from the material and construction solution of the wall, was seriously affected also by other factors resulting from the building utilization, e.g. ventilation or other value of maintained indoor air temperature. It may be supposed that the energy consumption for building heating is also influenced by the behaviours and habits of inhabitants. For example, various room airing by opening the windows gives different multiplicities of air exchange. Ventilation losses are also affected by uncontrolled air exchange, so called infiltration.

The conducted research demonstrated a diversification of the average house maintenance costs value depending on the material applied for external walls construction. Average energy costs per $1m^2$ of usable floor area of the building constructed from aerated concrete blocks and ceramic perforated bricks was about 23 PLN/m^2. When ceramic brick was used the cost was much lower, ca. 22 PLN/m^2, whereas for breeze blocks ca. 25 PLN/m^2.

In most of the analysed buildings (52 houses, constituting 74.3%) thermal insulation of the external walls was applied with 5-20 cm thick styrofoam, whereas 18 houses (25.7%) have external walls without the insulating layer.

Figure 3 shows the costs of energy in buildings with insulated and non-insulated external walls. The analyses revealed that in case of the lack of thermal insulation the energy costs were by ca. 10 PLN/m^2 higher. Decreasing energy costs were observed with increasing usable floor area. Houses with larger areas are new constructions with proper thermal parameters of the outer walls.

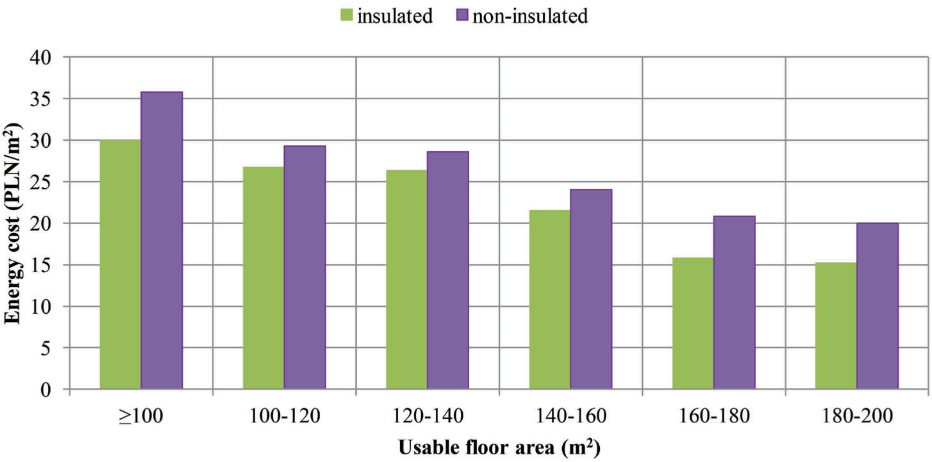

Figure 3. Energy costs depending on the floor usable area of a building and application of a thermal insulation layer on the outer walls

The most numerous group among the houses with insulated external walls (61.5% - 32 objects) are those with between 5 to 10 cm thick thermal insulation layer. They are usually older buildings, after thermomodernization or commissioned for use in the years 1990-2010. New objects, constructed after 2010 have over 10cm thick thermal insulation. The number of buildings compiled depending on the thickness of their external wall thermal insulation layer was presented in Table 2.

Table 2. Thermal insulation layer thickness in the investigated single family houses in the Jasło city area

Thickness of thermal insulation layer (cm)	Number of houses (pcs.)	Percentage (%)
No thermal insulation	18	25.7
5-10	32	45.7
10-15	17	24.3
15-20	3	4.3
total	70	100

Heat insulation of a building is also affected by the kind of applied window frames. The most numerous group - 52 (74.3%) among the analysed houses (Tab.3) are PVC windows with double glazed sealed units, with heat transfer coefficient between 1.0 and 1.4 $W \cdot m^{-2} \cdot K^{-1}$. These comprise both newly erected houses and those after thermomodernization. On the other hand, 15 houses (21.4%) have wooden-framed windows with double glazed sealed units. Wooden-framed casement windows were registered in 3 houses (4.3%), these are older buildings constructed in the 60-ties and 70-ties of the previous century and so far have not been thermomodernized.

Table 3. Applied types of window frames in the analysed single family houses in the Jasło city area

Type of window frames	Coefficient U ($W \cdot m^{-2} \cdot K^{-1}$)	Number of houses (pcs.)	Percentage (%)
PVC	≤1.3	12	17
PVC	1.3-1.6	42	58
Wooden	1.3-1.6	16	22
Wooden casement	>1.6	2	3
Total		70	100

In compliance with recently obligatory standards, only 17% of the buildings meet the requirements concerning the heat transfer coefficient for windows.

The value of energy consumption is also influenced by the kind and efficiency of the heating and warm water preparation system. Central heating is used in all houses. The most frequently used fuel is hard coal and natural gas (Pieta 2015) (Fig.4).

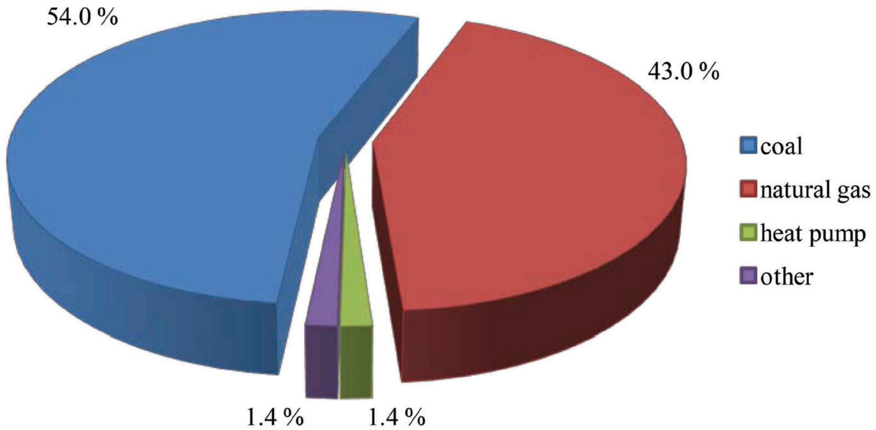

Figure 4. Fuels used in the analysed single family houses in the Jasło city area

As results from the Builddesk Report (2012), the use of natural gas (32%) prevails in the Podkarpackie voivodship over biomass (24%) and hard coal (19%). Obtained results of research in Jasło reveal a different structure of fuels from the data for the whole voivodship.

Figure 5 presents the costs of energy per one square meter of the usable floor area depending on the applied fuel: natural gas and hard coal. Investigations demonstrated that heating costs per 1m^2 of usable floor area are decreasing with increasing usable floor area of a building.

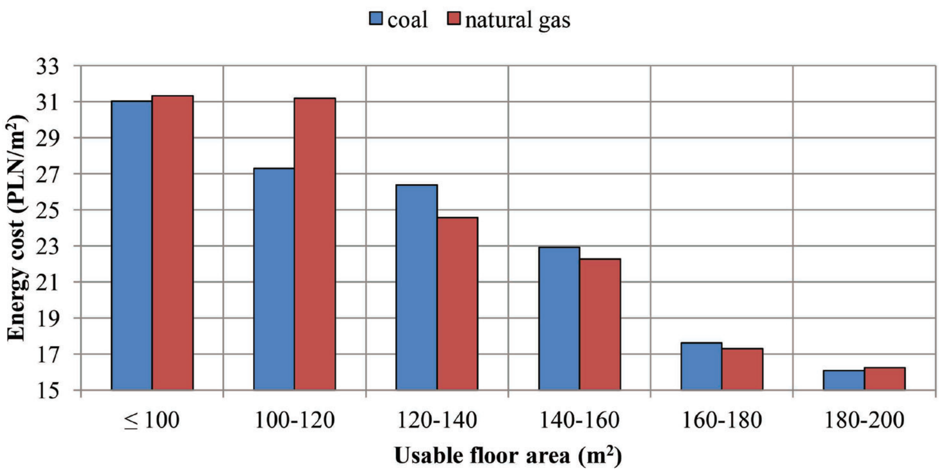

Figure 5. Energy costs depending on the fuel used in single family houses in the Jasło city area

In the houses heated by natural gas, a part of the installation is powered by condensing boilers (12 houses – 17.1%), whereas in the other by a low-temperature water boilers. One house was using a heat pump. Most installations are made of copper (46 houses – 65.7%), steel installations are in 18 buildings (25.7%), the rest are constructed of plastics. In order to lower the costs of heating many inhabitants are using supplementary heating installations, such as wood burning fireplaces.

Preparation of warm water is supported by solar installations, the project has been implemented in Jasło with financial support of the European Union.

Analysis of the heating systems reveals their diversification with respect to their modernity, which undoubtedly affects the heating efficiency. Application of modern heating systems and the use of renewable energy sources may decrease the demand for primary and final energy by about 30%. It has been estimated that 50% of the analyzed houses require a modernization of their heating systems.

CONCLUSIONS

Analysis of the research results revealed a lack of correlation between the energy costs and heat transfer coefficient for the houses external walls. This was caused mainly by the factors resulting from the house use, such their inhabitants' preferences concerning the indoor air temperature and airing.

The costs of house heating per 1 m^2 of usable floor area are decreasing with increasing floor usable area of the building.

The energy for heating houses in the investigated region is obtained mainly from solid fuels burning: hard coal (ca. 54%, including 4% of eco-pea-coal) and natural gas (ca. 43%).

The investigations demonstrated that about 45% objects had coal–fired boilers and heating installations are old fashioned and low efficiency appliances. The energy costs may be lowered by improving the efficiency of heating and ventilating systems.

Supporting warm water preparation system by solar thermal collectors decreased the costs by about 40%.

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Rozporządzenie Ministra Infrastruktury z dnia 2 lipca 2014 r. w sprawie metodologii obliczania charakterystyki energetycznej budynku i lokalu mieszkalnego lub części budynku stanowiącej samodzielna całość techniczno-użytkowa oraz sposobu sporządzania i wzorów świadectw ich charakterystyki energetycznej (Dz. U. z 2.07.2014, poz. 888).

Rozporządzenie Ministra Transportu, Budownictwa i Gospodarki Morskiej z dnia 5 lipca 2013 r. zmieniające rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz.U. 2013 poz. 926)

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