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ANNA NAPIÓRKOWSKA*, MARTA LASKA*, AGNIESZKA ISAŃSKA-ĆWIEK*

THE INFLUENCE OF BUILDING REGULATIONS ON THE EFFICIENCY AND POLLUTION LEVEL OF THE HEATING SYSTEM

In order to adjust Polish regulations to the Energy Performance of Building Directive, new requirements have been introduced to Polish legislation. The well known Polish Standard PN-B-03406:1994 has been replaced by new PN-EN 12831 which raises a lot of controversies especially regarding the final results of heat load calculations based on the described procedures.

The paper indicates possible discrepancies in calculation results arising from imprecise guidelines and the consequences of relying on the results gained by the described method. Additionally, later aspects of the system operation and their negative influence on the estimated efficiency level and CO_2 emission have been analyzed.

1. INTRODUCTION

Poland's accession to the European Union in 2004 was a turning point not only in the political and economic but also in the legislative sphere. The smooth functioning of our state in the Community required the introduction of a number of actions to align all the functional and organizational structures with the ones existing in the European Union. In many areas the adaptation began even before the accession (before May 1, 2004) and in some other areas further extension of the adjustment was required. One of the pillars of the state organization which needs to be reorganised to meet the EU requirements is the area of legislation which has to undergo a multi-process. Poland had to align its legal system with the EU system before the accession in May 2004. The primary legislation for building regulations in the area of construction and environmental engineering are the Building Regulations. They had to be modified in order to adapt them to the EU requirements.

* Faculty of Environment Engineering, Wrocław University of Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland. E-mail: anna.napiorkowska@pwr.wroc.pl, marta.laska@pwr.wroc.pl, agnieszka.isanska@pwr.wroc.pl

In the second half of the twentieth century, the policy to protect the natural environment was introduced in the EU Member States in order to tackle climate change. The reason for this were natural phenomena had not occurred previously and thus raised interest of the state government. The actions were taken in the areas of economy and technology to make it possible to reduce the destructive human activity and achieve measurable results in halting or slowing down climate change. One of them was introducing a number of regulations at the state level in the field of construction and environmental engineering. Simultaneously, there was a growing number of tools such as IAMs (Integrated Assessment Models) used to assess the quality of air and ecosystems and to propose cost effective emission reduction strategy on a regional scale [1]. The main purpose of introducing new legislation was to unify environmental policies and joint actions in environmental protection and conservation of natural resources. The climate change will entail new conditions for the construction industry, especially for building construction and building services. Climate change considerations should be taken into account in planning, design, specifications, construction, operation and ongoing maintenance of buildings. In 1972, at the UN Conference on the Human Environment in Stockholm the term *sustainability* was defined [2]. Today the considerations to minimise the climate change impact should also involve looking for opportunities to reduce energy and fuel consumption. However, in order to compel the public to do so, it was necessary to implement relevant legislation imposing pro-ecological initiatives.

On 16th December 2002 the European Parliament and the Council of the European Union introduced Directive 2002/91/EC on the energy performance of buildings [3]. The construction industry needs to take specific measures to encourage actions to improve energy efficiency and reduce building energy consumption, which translates directly to reducing the emission of air pollutants such ac CO, CO_2, etc. The directive states that *The residential and tertiary sector, the major part of which is buildings, accounts for more than 40% of final energy consumption in the Community and is expanding, a trend which is bound to increase its energy consumption and hence also its carbon dioxide emissions. …The measures further to improve the energy performance of buildings should take into account climatic and local conditions as well as indoor climate environment and cost-effectiveness... The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at regional level, that includes, in addition to thermal insulation, other factors that play an increasingly important role such as heating and air-conditioning installations, application of renewable energy sources and design of the building*.

Poland joined the European Union in 2004, however, the implementation of EU legislative took longer. The primary legislation for construction and building services is the Construction Law of 7th July 1994 [4] and implementing regulations. Since 1994 a number of amendments have been introduced to the Act. Part of the process of adapting Polish law to the requirements of EU legislation was imposing the obligation to provide the energy performance certificates for buildings and premises on January 1, 2009. As a result Polish Building Regulations had to be reviewed.

The Minister of Infrastructure Regulation on the technical conditions for buildings and their location [5] was changed and the Minister of Infrastructure Regulation on the methodology of calculating the energy performance of buildings and flats or parts of a building; the specimen and way of preparing energy performance certificates [6] became effective. If it is justified and necessary, the regulations cite the use of standards. The Minister of Infrastructure Regulation on the technical conditions (§ 134.1) [5] states that the peak power of heating facilities and equipment for a building should be determined in accordance with Polish standards. However, annex No.1 to the Regulation invokes the PN-EN 12831: 2006 standard for heating systems in buildings – calculation method of the design heat load [7].

Since this Regulation [6], [7] was issued on 6th November 2008, the use of the PN-B-03406: 1994 standard: Heating – Calculation of heat demand for rooms up to 600 m^3 [8], binding at that time, was possible until 31st December 2008. The Polish standard PN-EN 12831 issued in June 2006 [7] consists of the English text of the European standard EN 12831:2003. The only change in this standard was the addition of two annexes. The first annex consisted of the list of Polish standards invoked in PN-EN 12831. The second annex consisted of the values and parameters used in the design calculations. The adaptation of Polish legislation to EU law has forced the building industry, particularly architects and building services engineers, to carry out the calculations according to methods given in the standard PN-EN 12831:2006 [7]. The calculation methods presented in this standard differ radically from the methods in the standard PN-B-03406: 1994 [8], which were used before 1 January 2009. The main difference between the standards is the way of determining the heat loss by diffusion.

2. COMPARISON OF THE CALCULATION METHODS GIVEN IN THE STANDARDS PN-B-03406: 1994 AND PN-EN 12831:2006

It is necessary to determine heat losses and gains in the building in order to size the heating system. For this purpose a method for calculation of the heat supply needed under standard design conditions is used in order to make sure that the required internal design temperature is obtained. This temperature should meet the thermal comfort requirements, especially in residential and public buildings. According to the standard PN-EN 12831 [7], the required heat flow necessary to achieve the specified design conditions is called the *design heat load*. The design heat load for a heated space consists of the design heat losses through the building envelope, design ventilation heat losses and possible heating-up capacity required to compensate for the effects of intermittent heating of the heated space.

The standard PN-B-03406 [8] provided the calculation method of the rate of heat loss through individual components of the building envelope. The rate of this heat loss depends on the thermal properties of a building component represented by its thermal transmittance, *U*-value, the area of the component and temperature difference between inside and outside, i.e.:

$$Q = A \cdot U \cdot \Delta t, \quad \text{W}, \tag{1}$$

where:

A – area of the component, m^2;

U – thermal transmittance of component, $Wm^{-2}K^{-1}$;

$\Delta t = (t_i - t_e)$ – temperature difference between inside and outside, K.

The total heat load of the building was calculated as the sum of heat losses of all the components of the building (i.e., roof, walls, floor and windows).

The PN-EN 12831 [7] characterises the whole building by a transmission heat loss coefficient, *H*, i.e.:

$$H = A \cdot U \cdot f, \quad \text{WK}^{-1}, \tag{2}$$

where f is the temperature reduction factor taking into account the difference between the temperature of the adjacent space and external design temperature.

The design transmission heat loss for a heated space is calculated by adding all transmission heat loss coefficients for all building elements and then multiplying them by temperature difference between inside and outside. The sum of the transmission heat loss coefficients includes those from the heated space to the exterior through the building envelope, through the unheated space, to the ground and to a neighbouring heated space heated at a significantly different temperature. Since all the transmission heat loss coefficients are multiplied by the same temperature difference, it is necessary to introduce the temperature reduction factor taking into account the difference between the temperature of the unheated space or the annual mean external temperature or the temperature of the adjacent space and external design temperature. This approach significantly complicates the calculation, however, it should give the same result as the calculation method presented in the standard PN-B-03406 [8].

In the PN-EN 12831 [7], the problem occurs when the heated space is connected to a neighbouring heated space heated at a significantly different temperature. Unfortunately the standard does not explain what *significantly different temperature* means. As a result the designers may interpret it in various ways. On the other hand the standard PN-03406-B [8] states that the heat transfer between two spaces in the building will be taken into account if there is a difference between them of at least 4 K. If the temperature difference is less than 4 K, the heat transfer is negligible. Since the concept of *significantly different temperature* is not clear, most building services engineers will use the guidelines from the old standard [8].

In the PN-EN 12831 [7], in order to take into account the difference between the temperature of the adjacent space and the external design temperature, the heat transferred by transmission from a heated space to a neighbouring heated space heated at a significantly different temperature is multiplied by temperature reduction factor *f*, given by:

$$f = \frac{\theta_{\text{int}} - \theta_{\text{adjacent space}}}{\theta_{\text{int}} - \theta_e}, \tag{3}$$

where:

θ_{int} – internal design temperature of the heated space in Celsius degrees, °C,

$\theta_{\text{adjacent space}}$ – adjacent space design temperature in Celsius degrees, °C,

θ_e – external design temperature in Celsius degrees, °C.

The internal and external design temperatures depend on what temperature is required for the specific uses of the building and the location, respectively. The temperature of the adjacent space is defined in three different ways depending on the location in the building. Current national annex to the standard [7] considers three cases which are the same as in the normative annex [7].

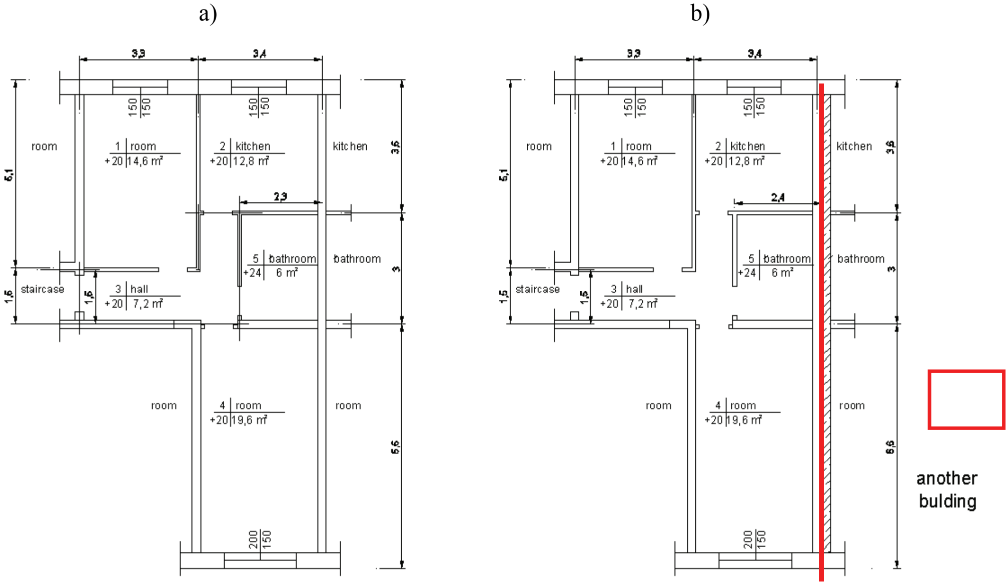

Fig. 1. Plan of the flat – BABW architectural concept:
a) related to options 1 and 2, b) related to option 3

If heat is transferred from the heated space to an adjacent room within the same building entity, the temperature in the adjacent space should be determined appropriately for the type of heating space. This means that the exchange of heat within the flat, such as from a bathroom to a room, should be calculated for temperatures 24 °C and 20 °C, respectively. At the same time there will not be any heat exchange between the heated space with the same temperature of 20 °C (e.g. kitchen, living room, bedrooms). The same calculation methodology was presented in PN-B-03406 [8].

If heat is transferred from the heated space to an adjacent room belonging to another building entity (e.g. flat), the internal temperature in the adjacent space is calculated as the arithmetic average between the internal temperature and the annual mean external temperature. For example, when heat is transferred from a bathroom, where the internal temperature is 24 °C, to an adjacent room belonging to another flat, the internal temperature in this room varies depending on climate zone from 12.7 °C in 5th climate zone to 13.9 °C in 2nd climate zone in Poland. If the heat is transferred from the heated space to an adjacent room belonging to a separate building (heated or unheated), the temperature in the adjacent space is equal to the annual mean external temperature. It means that the temperature of the adjacent space should be between 5.5 °C and 7.9 °C depending on climate zone. It seems that these default values for the temperature of adjacent heated space are not appropriate for Polish climate conditions, due to the fact that during the normal operation of the building the internal temperature should not be reduced to such low level.

The following calculation was carried out to show the consequences of using this methodology of calculating the heat loss from heated spaces to adjacent spaces. According to the standard PN-EN 12831 [7], the calculation of design heat load takes into account heat losses through:

- a building envelope,
- unheated spaces,
- neighbouring spaces,
- ventilation,
- heating-up capacity for space heated intermittently or weakening.

3. CALCULATION EXAMPLE

The example calculation was performed on the flat shown in figure 1. This flat was located on the middle floor in a multi-storey building therefore there was no contact with the ground and unheated spaces. The flats above and below were the same. The apartment consists of a kitchen, a living room, a bedroom and a bathroom. It has two external walls and the floor area of 57.6 m^2.

The calculation of heat losses was performed for the following 2 different cases:

- the flat was adjacent to the rooms within the same building entity,
- the flat was adjacent to the rooms belonging to another building entity.

The description, thickness and transmittances of building elements are summarized in table 1.

Table 1

Building elements

No.	Building element	Description	Thickness m	Transmittance U-value W/m^{2}K
1	External wall	– dense plaster – Porotherm 25 P+W brick – mineral wool insulation – dense plaster	0.39	0.28
2	Internal wall (type1)	– dense plaster – reinforced concrete – dense plaster	0.26	2.35
3	Internal wall (type 2)	– dense plaster – reinforced concrete – dense plaster	0.5	1.76
4	Internal wall (type 3)	– dense plaster – Porotherm 11.5 P+W brick – dense plaster	0.13	1.94
5	Floor	– screed – polystyrene insulation – cast concrete – dense plaster	0.31	0.53 – heat transfer downwards 0.58 – heat transfer upwards
6	Window	Double glazing	–	1.30
7	Internal door	–	–	5.10
8	External door	–	–	2.50

The design heat load calculations were performed according to the PN-EN 12831 [7] standard issued in June 2006. Three analysed options depended on the temperature in the neighbouring rooms:

Option 1 – the temperature in adjacent spaces is the same as in the heated space, i.e. in the kitchen the temperature is 20 °C and in the bathroom – 24 °C,

Option 2 – the temperature in adjacent spaces equals the arithmetic average between the internal temperature and the annual mean external temperature,

Option 3 – the temperature in adjacent spaces equals the arithmetic average between the internal temperature and the annual mean external temperature for the heated spaces in the same building entity and the annual mean external temperature for the heated spaces in a separate building.

Other assumptions used for calculations are:

- the building is located in the 5th climate zone in Poland with the design external temperature in winter of t_e = – 24°C and the annual mean external temperature of t_{me} = 5.5 °C,

• the building air tightness: $n_{50} = 3\ h^{-1}$,
• exposure coefficient: medium,
• data on thermal bridges were calculated according to PN-EN ISO 14683 Thermal bridges in building construction – linear thermal transmittance – a simplified method and default values [9].

The results of the transmission heat loss calculation are shown in table 2 and figure 2.

Table 2

Transmission heat losses for each heated space

Room No.	Heated space	Transmission heat losses W			Difference between transmission heat losses in comparison with Option 1 %	
		Option 1	Option 2	Option 3	Option 2	Option 3
1	Room	331	539	539	163	163
2	Kitchen	549	673	743	123	135
3	Hall	77	200	200	260	260
4	Bedroom	310	712	839	229	270
5	Bathroom	154	245	316	159	205

Transmission heat losses for whole flat are shown in table 3.

Table 3

Transmission heat losses for the whole flat

Transmission heat losses	Option 1	Option 2	Option 3
W	1421	2368	2637
%	100	167	186

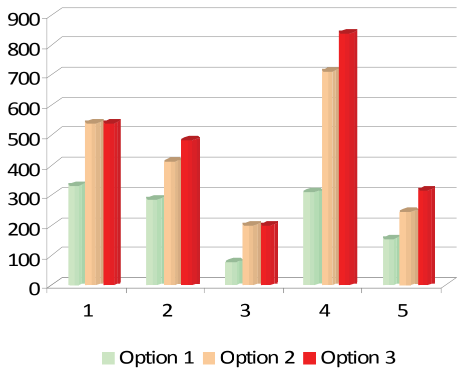

Fig. 2. Transmission heat losses for each space in the flat

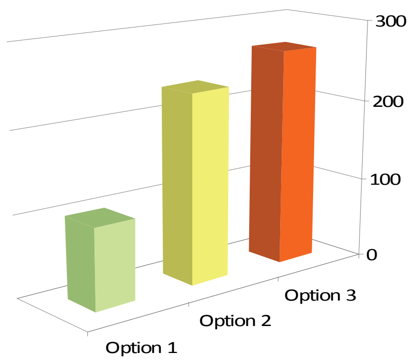

Fig. 3. Air pollutant emission

The example calculations show that transmission heat losses for the same heated spaces might differ significantly depending on the selection of temperature in the adjacent rooms. The differences in transmission heat losses between the cases might be up to 270%. The calculations based on the assumption of such low temperatures might result in oversizing the heating system. This not only makes the new system more expensive to install, but also forces it to break down more often, and cost more to operate. Oversized heating equipment often creates uncomfortable and large temperature swings in the building. In addition to this, an oversized system operates inefficiently. All these aspects lead to an increase in the emission of pollutants.

Table 4 shows the differences in the size of radiators for one sample room (No. 4). The assumptions used for the selection were:

- radiator type Purmo C11 with a height of 450 mm,
- inlet/outlet parameters of heating water 70/55 °C,
- thermostatically controlled radiator valves (coefficient $\beta = 1.15$).

Table 4

Heaters statement for the room No. 4

Option	Transmission heat losses in room No. 4 W	Radiators size	Radiator output W	Radiator weight kg	Weight difference %
1	356	C11 450/600	369	8.64	100
2	819	C11 450/1400	861	20.16	233
3	964	C11 450/1600	984	23.04	267

The results show that the difference in the weight of steel required to produce the radiators in option 2 and 3 compared to option 1 were 233% and 267%, respectively. As a result of radiator production, the air pollutants are emitted into the atmosphere. On the basis of this simple example, the air pollutant emission may be estimated (figure 3) as a percentage of the difference in the use of material for the production of radiators. It should be noted that this calculation does not take into account the emission of pollutants during transport.

4. SUMMARY

The logical conclusion is that a careful choice of the heating equipment is very important. It should be noted that it is necessary to adjust the national annex to the PN-EN 12831 standard in order to obtain reasonable results in a different climate. The lack of the Polish annex results in an inappropriate assessment of heat demand and losses. The national annex should have the same structure as normative Annex D, however, some cases in the tables should be added and some deleted. This would allow building services engineers to design the heating systems for Polish climate conditions correctly, and this in turn is significant as it would also result in the reduction of air pollutant emission, especially carbon dioxide.

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