TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO

3-B/2014

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ENERGY ANALYSIS OF NF40 RESIDENTIAL BUILDINGS ON SELECTED EXAMPLES

ANALIZA ENERGETYCZNA BUDYNKÓW MIESZKALNYCH NF40 NA WYBRANYCH PRZYKŁADACH

A b s t r a c t

The paper presents an energy analysis of single and multi-family residential buildings in terms of achieving the NF40 standard defined by NFOŚiGW. Obtaining financing from the investor for the construction of energy efficient buildings must meet a number of technical criteria. In this paper, examples of the practical process of fulfilment of the above requirements for the building enclosure will be presented.

Keywords: *energy efficient buildings*, *linear thermal bridges*

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

W artykule przedstawiono analizę energetyczną budynków mieszkalnych jednorodzinnych i wielorodzinnych w aspekcie osiągnięcia standardu NF40 określonego przez NFOŚiGW. Otrzymanie przez inwestora dofinansowania do budowy budynków energooszczędnych wymaga spełnienia szeregu kryteriów technicznych. W niniejszym opracowaniu zostaną przedstawione przykłady praktyczne procesu spełnienia powyższych wymagań w zakresie obudowy budynku.

Słowa kluczowe: *budynki energooszczędne*, *liniowe mostki cieplne*

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1. Introduction

The subject of the study is a designed complex of a single-family house in a terrace building development in Wrocław.

The aim of the study is to analyse the design documentation and execution of necessary energy and numerical calculations leading to the implementation of recommendations allowing to achieve, by the designed complex of buildings, a standard low-energy NF40, or NF15, building as defined by the NFOŚiGW (National Fund for Environmental Protection and Water Management) in specific provisions.

For the adopted purpose of the work, a scope of activities was submitted including:
- presentation of the general requirements of NFOŚiGW,
- selection of typical details related to the existence of linear thermal bridges,
- examples of detailed solutions along with thermal analysis, designed to meet the requirements of NFOŚiGW.

2. NFOŚiGW requirements for buildings of the NF type

The standard for a single-family low-energy NF40 building, as specified by NFOŚiGW (designer) in detailed provisions, is published on the designer's website. This standard assumes that for the analysed single-family building, a unit energy demand for heating and ventilation of 15 or 40 kWh/m^2 of heated surface is not exceeded (EUco indicator).

The minimum technical requirements for single and multi-family buildings, in terms of housing and technical equipment, have been included in the detailed instructions. The requirements for the building enclosure, including thermal insulation of opaque external walls – walls, roof, floor on the ground, and other partitions including windows, doors and garage doors, are shown in the table. Moreover, the requirements were placed in the scope of:
- linear thermal bridges,
- air tightness of the enclosure.

Confirmation that the building fulfils the energy standard requirements in a specific group (NF15 or NF40) must be documented by means of a presentation of the verification document regarding the construction project for which building permits had been obtained on the basis of the provisions of the Building Act. Additionally, necessary trade implementation projects are verified to enable practical implementation of the designed building. All projects must be prepared in accordance with the relevant provisions of the Building Act, and they should have the appropriate calculations confirming the achievement of the specific energy standard by the building. The whole should have a designer's statement that the project is executed in accordance with the Regulation of the Minister of Transport, Construction and Maritime Economy of 25 April 2012, in the scope and form of the construction project (Journal of Laws 2012, No. 0 pos. 462) [2], and in accordance with the guidelines of NFOŚiGW.

A construction project and trade executive projects must be prepared taking into account the minimum technical requirements set out in the guidelines by NFOŚiGW, including requirements relating to housing and all facilities associated with the production and transport of thermal energy. Part of such requirements relating to a building's enclosure is shown in Table 1.

Table 1

Minimum technical requirements mandatory for a single-family building – NFOŚiGW

No.	Requirement		NF15	NF40
			Single-family building	
1.	Block/construction of the building			
1.1	Linear values of partitions' heat transfer coefficients U_{max} [W/m^{2}K]			
a)	– external walls	I, II and III climatic zone IV and V climatic zone	0.10 0.08	0.15 0.12
b)	– roofs, flat roofs and ceilings under unheated attics or above level crossings	I, II and III climatic zone IV and V climatic zone	0.10 0.08	0.12 0.10
c)	– ceilings above unheated basements and underfloor enclosed spaces, floors on the ground	I, II and III climatic zone IV and V climatic zone	0.12 0.10	0.20 0.15
d)	– windows, skylights, balcony doors and non-opening opaque surfaces	I, II and III climatic zone IV and V climatic zone	0.80 0.70	1.00 0.80
e)	– exterior and garage doors	I, II and III climatic zone IV and V climatic zone	0.80 0.70	1.30 1.30
1.2	Limit values of thermal bridges' linear coefficients of heat loss [W/mK]			
a)	Balcony panels		0.01	0.20
b)	Remaining thermal bridges		0.01	0.10
1.3	Air tightness of the building n50 1/h		0.6	1.00

Table 2

Minimum technical requirements mandatory for a multi-family building – NFOŚiGW

No.	Requirement		NF15	NF40
			Single-family building	
1.	Block/construction of the building			
1.1	Linear values of partitions' heat transfer coefficients U_{max} [W/m^{2}K]			
a)	– external walls	I, II and III climatic zone IV and V climatic zone	0.15 0.12	0.20 0.15
b)	– roofs, flat roofs and ceilings under unheated attics or above level crossings	I, II and III climatic zone IV and V climatic zone	0.12 0.12	0.15 0.15
c)	– ceilings above unheated basements and underfloor enclosed spaces, floors on the ground	I, II and III climatic zone IV and V climatic zone	0.15 0.15	0.20 0.20
d)	– windows, skylights, balcony doors and non-opening opaque surfaces	I, II and III climatic zone IV and V climatic zone	0.80 0.80	1.30 1.00
e)	– exterior and garage doors	I, II and III climatic zone IV and V climatic zone	0.80 0.80	1.50 1.50
1.2	Limit values of thermal bridges' linear coefficients of heat loss [W/mK]			
a)	Balcony panels		0.01	0.20
b)	Remaining thermal bridges		0.01	0.10
1.3	Air tightness of the building n50 1/h		0.6	1.00

3. Energy analysis of designed solutions

The building energy analysis was performed via a computer program serving to determine the building's energy characteristics, in accordance with the guidelines of the Minister of Infrastructure of 6 November 2008, based on the methodology for calculating the building's energy characteristics constituting a self-contained, technical-functional whole and the method of producing certificate models of their energy characteristics [3] – program Arcadia Termo version: 4.2.

3.1. Assumptions for energy calculations

The energy calculations assume the following:
- weather conditions for the city of Poznań,
- temperature in living and service quarters: 20°C,
- temperature in the staircases: 12°C,
- a coefficient of shielding against wind 'e' was adopted for the shielding class – average shielding, at a level of 0.07,
- degree of air tightness for a multi-family building – average – standard windows with double glazing,
- number of persons: 3 persons adopted for 1 flat,
- window frames: the heat transfer coefficient for input shaft: $U = 1.0$ W/(m^{2}K), wooden frame, calculated resultant heat transfer coefficients for all sets of windows, unheated glazed lifts and garages,
- ventilation of flats, staircases and service quarters (natural ventilation assisted by exhaust units), according to the standard,
- heating efficiency ($\eta_e = 0.95$; $\eta_d = 0.95$; $\eta_s = 1.0$; $\eta_g = 0.99$).

All calculations of the partitions' thermal insulation were performed using the computational coefficients of thermal heat transfer λ for the materials and values declared by the manufacturers.

3.2. Results of calculations of heat transfer coefficients

Calculations of heat transfer coefficients for partitions limiting the zone of adjustable temperature were calculated on the basis of the applicable standards: PN-EN ISO 6946 [3], PN-EN ISO 13370 [4] (for floors and walls on the ground) and PN-EN ISO 10077 (for windows and doors) [5].

In the calculations, standard heat transfer coefficients λ were used (PN-EN 12524) for the materials and values declared by the manufacturer.

3.2.1. Windows

According to PN-EN ISO 10077-1:2002 "Thermal properties of windows, doors and shutters – Calculation of heat transfer – Part 1: Simplified method" [6]. For each window, the heat transfer coefficient was calculated using the formula:

$$U_w = \frac{A_g U_g + A_f U_f + l_g \Psi_g}{A_g + A_f} \tag{1}$$

For all windows, an equal framework width was adopted, i.e. 12 cm. The results of the calculations are presented in the following table:

Table 3

Results of calculations of the heat transfer coefficient for windows

Window symbol	Window dimensions W-H [m]	Frame coefficient U_f [W/m²K]	Glass coefficient U_g [W/m²K]	Linear coefficient of heat transfer Ψ_g [W/mK]	Glazing perimeter I_g [m]	Glass surface A_g [m²]	Frame surface A_f [m²]	Window coefficient U_w [W/m²K]
01	2.20–0.75	0.74	0.50	0.03	4.94	1.00	0.65	0.68
02	1.30–2.20	0.74	0.50	0.03	6.04	2.08	0.78	0.63

The described boundary value of the heat transfer coefficient U_{max} for windows according to the NF15 standard is: 0.8 W/m²K. The designed heat transfer coefficient U_w for all windows and balcony doors in the building will be less than 0.8 W/m²K, provided that windows with the following parameters will be used:
- heat transfer coefficient of the glazing: $U_g \leq 0.50$ W/m²K,
- permeability coefficient of the total solar radiation of the glass: $g \geq 0.5$,
- coefficient of linear heat loss of the frame: $\Psi_g \leq 0.03$ W/mK,
- window profiles with a heat transfer coefficient of the frame $U_f \leq 0.74$ W/m²K.

3.2.2. External walls

The values of the heat transfer coefficient for opaque partitions were calculated in accordance with PN-EN ISO 6946:2008 [5].

The results of the calculation of the heat transfer coefficients for partitions limiting a temperature-controlled zone are shown in Tale 4 along with a reference to the current requirements of NFOŚiGW. Meeting these requirements means the simultaneous fulfilment of the requirements of the Minister of Infrastructure of 12 April 2002, on technical conditions, buildings and their location, which should correspond with Journal of Laws No. 75, pos. 690, with amendments [1].

Table 4

Results of calculations of the heat transfer coefficient for external walls

Block/construction of the building – third climatic zone			
1.	Limit values of partitions' heat transfer coefficient [W/m²K]	Value	
		Required	Designed
a)	External walls	0.10	0.075
b)	Flat roof	0.10	0.084
	Ceiling under unheated attic		0.084
c)	Floor on the ground	0.12	0.096
d)	Windows	0.80	0.063–0.069
	Balcony doors		0.061–0.065
e)	Exterior doors	0.80	0.70

3.3. Analysis of selected design details for the presence of linear thermal bridges

In a low-energy construction, the enclosure limiting the temperature-controlled zone, except for good thermal insulation, should be characterised by a high quality of thermal connections. This is to minimise uncontrolled heat loss through so-called linear thermal bridges. A parameter characterising the effect of this heat loss is the coefficient of linear heat loss by the transmission of ψ_e for thermal bridges in relation to the external dimensions. Analyses are performed using numerical calculations in accordance with PN-EN ISO 10211on thermal bridges in a building – heat fluxes and surface temperatures, with detailed calculations [7].

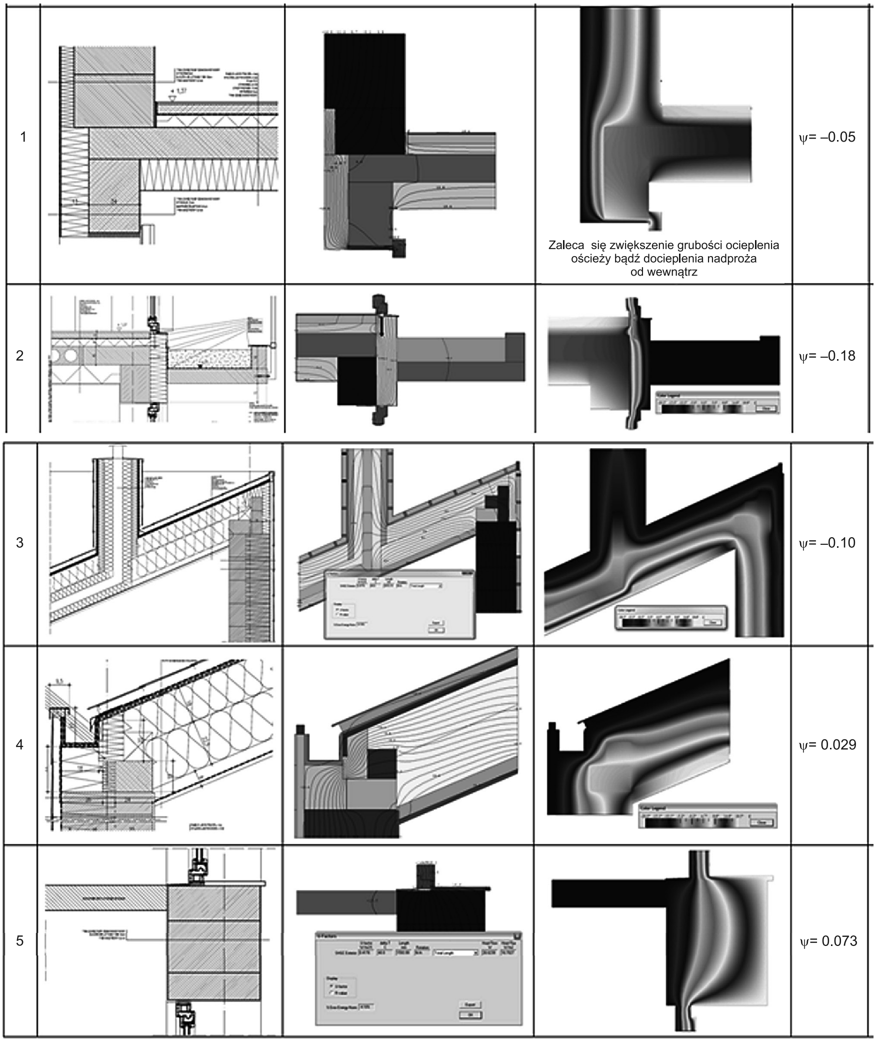

Fig. 1. Summary of the calculation results of the linear thermal bridge values of selected design details with the assessment of fulfilment of standard NF40 requirements

Coefficients of the linear heat loss by the transmission ψ_e were determined using specialised software based on the finite element method. For solutions of standard components connections – the Cobra program; in the case of non-standard solutions –the Therm 7.1.19 program.

It is recommended that in a low-energy construction, the coefficient of linear heat loss through transmission ψ_e be as low as possible, and NFOŚiGW requirements set the limit value at a level of 0.01. This requirement is not a standard regulated by law but only a requirement for the participants in the support programme cited earlier. After a detailed analysis of the project, several architectural details were selected for further analysis that were considered as potential linear thermal bridges. Analysis of the earlier adopted architectural solutions, after introducing minor changes associated with localised thickening of the insulation and the use of insulation in several places that was lower than anticipated in the original project, allowed for the qualification of all the buildings to the NF40 standard. Due to the inability to make all recommended changes to the enclosure and changes in installation techniques due to the lack of permits by the architect and investor, the NF15 standard was not reached, although some partitions, such as windows, have met the conditions of this standard. Figure 1 shows example results of the calculations of selected details.

4. Summary and conclusions

4.1. Summary

Calculated according to the formula (2) [3], the EUco indicator for the complex of buildings in Wrocław was:
– before the introduction of changes to the building's enclosure: E_{uco} = 62.3 kWh/m^{2}a,
– after the analysis of architectural details and amendments: E_{uco} =38.8 kWh/m^{2}a.

$$E_{\mathrm{uco}} = \frac{Q_{H,nd}}{A_f} \tag{2}$$

where:

$Q_{H,nd}$ – annual demand for usable energy for heating and ventilation,
A_f – a temperature-controlled surface in a building.

4.2. Conclusions

Project activities in the obtaining appropriate values of E_{uco} at an appropriately low level should be carried out during the creation of the architectural design and not after its completion.

Matching the existing project to relatively high requirements is possible provided there is close cooperation between the architect, investor and designer in the field of Building Physics, but additional costs incurred by the investor due to the changes should be expected.

References

[1] Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. Nr 75, poz. 690 z późniejszymi zmianami).

[2] Rozporządzeniem Ministra Transportu, Budownictwa i Gospodarki Morskiej z dnia 25 kwietnia 2012 r. w sprawie szczegółowego zakresu i formy projektu budowlanego (Dz.U. 2012, nr 0, poz. 462).

[3] Rozporządzenie Ministra Infrastruktury z dnia 6 listopada 2008 r. w sprawie metodologii obliczania charakterystyki energetycznej budynku i lokalu mieszkalnego lub części budynku stanowiącej samodzielną całość techniczno-użytkową oraz sposobu sporządzania i wzorów świadectw ich charakterystyki energetycznej.

[4] PN-EN ISO 13370:2008. Cieplne właściwości użytkowe budynków. Wymiana ciepła przez grunt. Metody obliczania.

[5] PN-EN ISO 6946:2008. Komponenty budowlane i elementy budynku. Opór cieplny i współczynnik przenikania ciepła. Metoda obliczania.

[6] PN-EN ISO 10077:2007. Cieplne właściwości użytkowe okien, drzwi i żaluzji. Obliczanie współczynnika przenikania ciepła. Część 1: Metoda uproszczona.

[7] PN-EN ISO 10211:2008 Mostki cieplne w budynkach – Strumienie ciepła i temperatury powierzchni – Obliczenia szczegółowe.