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INFLUENCE OF THE THERMAL MODERNIZATION OF PANEL BUILDINGS ON TRANSNISSION HEAT LOSSES

ANALIZA WPŁYWU TERMOMODERNIZACJI BUDYNKU WIELKOPŁYTOWEGO NA STRATY CIEPŁA PRZEZ PRZENIKANIE

A b s t r a c t

It is commonly known that the thermal modernization of existing buildings reduces the energy requirements for heating. In the last twenty years many large panel blocks of flats built in the sixties and seventies have been insulated. In one example of an 11-storey building the heating energy demand before and after thermal modernization was analyzed. The transmission heat losses before and after thermal modernization, including the thermal bridges simulated in AnTherm program, were included in the calculations.

Keywords: *large panel buildings*, *W-70 system*, *thermal modernization*, *system joints*

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

Powszechnie wiadomo, że zabiegi termomodernizacyjne istniejących budynków prowadzą do redukcji zużycia energii na cele ogrzewania. W ostatnich kilkudziesięciu latach tymże zabiegom poddano tysiące budynków wielorodzinnych wzniesionych w technologii wielkiej płyty w latach 60. i 70. XX wieku. W artykule przeanalizowano redukcję zużycia energii na cele grzewcze przed i po termomodernizacji, na przykładzie 11-piętrowego budynku wielorodzinnego. W obliczeniach uwzględniono straty przez przenikanie obudowy budynku, z uwzględnieniem występowania mostków cieplnych, których analizę przeprowadzono z użyciem programu AnTherm.

Słowa kluczowe: *budynki wielkoplytowe*, *system W-70*, *termomodernizacja*, *połączenia systemowe*

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1. Prefabricated buildings in Poland

In the nineteen-fifties, the erection of large panel-system buildings began in Poland. Over the following decades about 4 million flats were built in this way. The thermal insulation of these buildings was low and the seasonal heating energy demand was usually 50% higher than the national requirements [1]. In the eighties, loans for removing the technological defects were taken out and the subsidization of energy prices was ended. At the beginning of the nineties, the Building Research Institute started to tackle thermal modernization issues. As a result of the Act on Supporting Thermo-insulation Works, December, 1998 [3], investment loans covering projects reducing heating energy demands become available. It was the beginning of extensive thermal modernization of panel buildings.

At present more than 10 million Poles live in these buildings. That is the main reason why thermal modernization problems became so prevalent.

2. W-70 System

System W70 is the "open" system used for the erection of multi-family buildings, in which, contrary to the "closed" system, all construction walls within the flats were eliminated. It allowed for changes of the partition wall pattern and therefore enabled the design of flats with different areas and room arrangements. It is estimated that about 15% of all panel-system buildings were erected using this system.

Prefabricated system elements were made of B15 crushed gravel concrete, while the connection joints used concrete of at least B15 grade. The elements were reinforced with welded wire meshes made of steel, grade 34GS, 18GS, St0 or St0S. As thermal insulation for the multi-layer external walls, a layer of Styrofoam "15" or mineral wool "120", 4 to 6 cm thick was used.

Regarding the building envelope, during the design process and the initial construction stages, PN-64/B-03404 [6] was the applicable standard. Based on this standard (depending on climate zone) the maximum permissible thermal transmittance coefficients were k = 1.25 W/m^{2}K and k = 1.42 W/m^{2}K (this coefficient is now denoted as "U"). In the nineteen-eighties, the new standard PN-82/B-02020 [7] reduced the value to k = 0.75 W/m^{2}K. The next revision, standard PN-91/B-02020, limited the value to k = 0.55 W/m^{2}K.

Per the current national standard [1,2] since 1st of January the max. U value of external walls should not exceed U = 0.25 W/m^{2}K (since the end of 2013, the max. U value has been U = 0.3 W/m^{2}K). The European Energy Performance of Buildings Directive Recast states that buildings designed and modernized after 2020 should be zero-energy buildings. According to those regulations, after 1st of January 2021 the thermal transmittance U of the heated building components should not exceed 0.20 W/m^{2}K.

Based on the information above, it can be concluded that none of the panel system buildings would meet the current thermal requirements. However, those requirements can be met after specific thermal modernization such as: additional insulation of the walls, replacing the windows, insulation of the roof and the ceiling above the basement, as well as the modernization of heating and ventilation systems.

3. Description of the analyzed building

The analyzed multi-family building, built using the W70 system, is located in the Krowodrza district of Cracow, and has been used since 1974 (Fig. 1)

Building description:

1. Number of storeys: 11.
2. Dimensions: 21.5 m × 13.2 m.
3. Area: 2279 m^2.
4. Basement below entire building.
5. Flat roof.
6. Depth of building below ground: 2.5 m.
7. Ground floor 1.0 m above surrounding ground

Fig. 1. North and East elevations of analyzed building

According to the building administrator, for the first 30 years of the building's life no thermal modernization has been carried out.

In 2004 and 2005 the windows in all apartments were replaced. The new ones have a thermal transmittance of between 1.5 and 1.8 W/m^2K. In 2006, partial thermal modernization of the building was carried out; the external walls were insulated with 10 cm of Styrofoam (thermal conductivity $\lambda = 0.04$ W/m^2K). The applied solutions were not complex, as the roof and the ceiling above the unheated basement were not insulated. So far none of the installed systems have been modernized.

4. Analysis of transmission heat losses through the building eavelope

In the empirical analysis the transmission losses through the building envelope, before and after thermal modernization, were taken into consideration, with a particular emphasis on the influence of panel joints which act as additional thermal bridges and affect the value of transmission losses.

Figure 2 shows joints between prefabricated panels; Fig. 3 shows additional thermal losses through the panel connections, and Fig. 4, temperature distribution in the connections based on computer analysis.

Fig. 2. Panel connection joint – external view

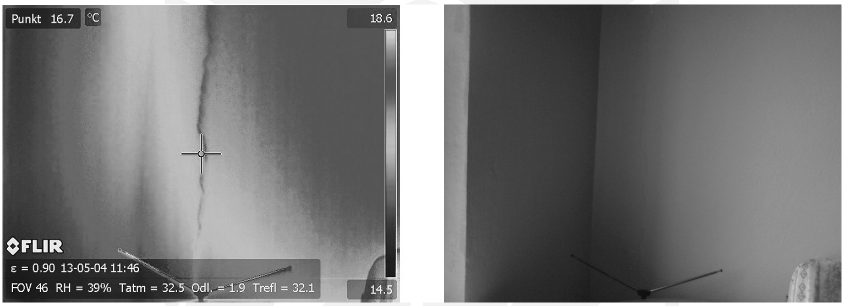

Fig. 3. Thermogram with additional thermal losses at panel joint

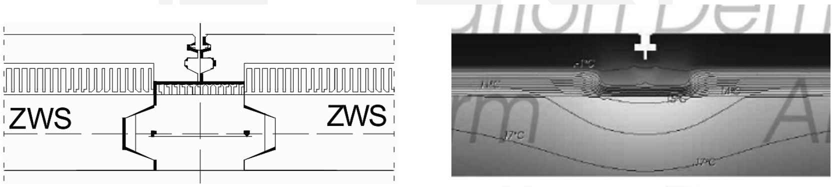

Fig. 4. Panel joint. Temperature distribution in the panel connection (from AnTherm program)

Based on standard EN ISO 13789 [5] and [9], the heat transfer by transmission coefficient H_{tr} was calculated. It describes the transmission losses through the building envelope. The ventilation losses were omitted in the analysis as the ventilation system has not been modernized.

$$H_{tr} = \sum_i \left[b_{tr,i} \cdot \left(A_i \cdot U_i + \sum_i l_i \cdot \psi_i \right) \right], \quad [\mathrm{W/K}]$$

where:

b_{tr} – coefficient describing reduction of temperature difference [non-dimensional]
A_i – area of the building component i [m^2],
U_i – thermal transmittance of the specific i component [W/m^{2}K],
l_i – length of linear i thermal bridge [m],
ψ_i – linear thermal transmittance of thermal bridge [W/mK].

Thermal transmittances of all building components were calculated based on standard PN-EN 6946 [8] – Table 1: values of linear thermal transmittances based on computational analysis in AnTherm (Table 2).

Table 1

Thermal transmittances of building components

Building component	U [W/m^2 K] before thermal modernization	U [W/m^2 K] after thermal modernization
External walls	0.69	0.25
Roof	0.50	0.50
Ceiling above basement	0.35	0.35
Windows	2.80	1.40
Entrance door	2.80	1.80

Table 2

Linear thermal transmittances for different thermal bridges

Description of thermal bridge	Ψ_e – before thermal modernization	Ψ_e – after thermal modernization
Window frame in the curtain wall – window head	0.047	0.007
Window frame in the curtain wall – window sill	0.205	0.089
Horizontal connection of curtain wall with ceiling slab	0.293	0.029
Horizontal connection of gable with ceiling slab	0.276	0.029
Vertical connection of curtain wall and basement wall with floor slab	0.160	0.200
Balcony slab and external wall	0.764	0.253
Balcony slab with balcony door and external wall	1.034	0.315
Vertical connection of gable with internal partition wall	0.169	0.019
Vertical connection of curtain wall with internal partition wall	0.198	0.020

The heat transfer coefficient was calculated for five different stages of the building's modernization. All results are presented in Table 3.

Table 3

Heat transfer by transmission coefficient for different calculation steps

	Modernization stage	Htr [W/K]	Share of transmission losses through the building envelope A_i U_i in H_{tr}	Share of losses through thermal bridges $\Sigma l_i \psi_i$ in H_{tr}
1	Building before thermal modernization	3490.6	2091.0 (60%)	1399.6 (40%)
2	Building before thermal modernization with windows replaced	2995.8	1596.2 (53%)	1399.6 (47%)
3	Building with existing windows but with insulated external walls	2047.7	1771.0 (84%)	276.7 (14%)
4	Building with windows replaced and with insulated external walls	1419.2	1142.5 (80%)	276.7 (20%)
5	Building with windows replaced and with insulated external walls – *U* of external walls 0,20 W/m^{2}K, as per standard that will be in force from 1st of January 2021	1014.9	808.0 (80%)	206.9 (20%)

The conclusions based on the results listed in Table 3 are as follows:

1. Both replacing the windows and the insulation of the external walls significantly reduced the value of the heat transfer by transmission coefficient from 3490.6 [W/K] to 1419.2 [W/K], i.e. by almost 60%.
2. Replacement of windows and doors lessened the transmission losses by about 15%, while the insulation of external walls alone decreased the H_{tr} value by about 40%. This proves that insulating the walls is a more effective measure.
3. The insulation of the external walls significantly decreased the transmission losses due to thermal bridges from 1399.6 [W/K] to 276.7 [W/K]; an 80% decrease compared with the building as originally designed. The tight insulation layer closes the connection joints between panels.
4. Comparing percentage share of losses through thermal bridges in the insulated building with the original windows and with the replacement windows (steps 3 and 4), the influence of thermal bridges is higher when the windows are replaced (14% in step 3 and 20% in step 4). It proves that the influence of thermal bridges is greater after complex thermal modernization.
5. Thermal modernization of the building to the 2021 standard would lower the thermal losses in the already insulated building by a further 30%. In the case of buildings which have yet to undergo any thermal modernization processes, a decrease of transmission losses of almost 80% could be expected.

5. Actual energy consumption for heating

In the period of time between 2000 and 2008 the monitoring of energy use for heating was carried out by the building administrator. The results are presented in Table 4 and confirm the reduction of heating costs after thermal modernization.

Replacing the windows in 2004 and 2005 reduced amount of energy usage by about 20%, while the insulation of external walls, conducted in 2006, reduced this by a further 20%. The percentage values cannot be compared with the calculation results as real energy demand is also affected by ventilation and infiltration losses.

Table 4

Energy consumption for heating in the analyzed building

Year	Heating costs of the building [zł/year]	Energy usage in GJ
2000	71350	1615
2001	70751	1558
2002	71065	1569
2003	76095	1736
2004	64850	1476
2005	61912	1263
2006	56344	1077
2007	51553	988
2008	50220	962

6. Conclusions

Based on the conducted analysis it can be concluded that both the replacement of windows and the insulation of walls significantly improved the building's energy parameters, reducing transmission losses by up to 70%. The calculation results are confirmed by the monitoring of energy consumption in the analyzed building.

In the case of large panel buildings, the insulation of external walls significantly lessens the influence of thermal bridges as it tightens the building envelope.

In this analysis, only the modernization of the building's external walls was taken into consideration. Additional reductions in heat loss could be achieved by the modernization of the ventilation system and the insulation of the roof and the ceiling above the basement.

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