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BASIC RECONSTRUCTION ASPECTS OF FLAT ROOFS ON PANEL BUILDINGS

PODSTAWOWE APSEKTY REKONSTRUKCJI PŁASKICH STROPODACHÓW W BUDYNKACH PŁYTOWYCH

Abstract

This paper deals with basic aspects relating to reconstructions of flat roofs covering panel buildings in the Czech Republic. Panel buildings were built all over Europe mainly in the second part of the twentieth century. Most of these buildings occur in central and eastern Europe and their bad state requires reconstruction. Especially their energy consumption characteristics are insufficient and therefore most of these buildings have been recently thermally insulated and reconstructed. This paper describes typical flat roof fabrics, development of building thermal protection requirements and possibilities of reconstruction.

Keywords: *flat roof, panel building, thermal protection, waterproofing*

Streszczenie

W artykule poruszono podstawowe aspekty rekonstrukcji płaskich stropodachów zastosowanych w budynkach płytowych w Republice Czeskiej. Budynki płytowe wznoszono w całej Europie, głównie w drugiej połowie XX w. Większość tych budynków znajduje się w Centralnej i Wschodniej Europie, są one często w złym stanie i wymagają rekonstrukcji. Szczególnie niezadowalająca jest ich charakterystyka cieplna i z tego powodu większość z nich została ostatnio ocieplona i zrekonstruowana. W artykule opisano typową strukturę stropodachów, rozwój wymagań cieplnych i możliwości rekonstrukcji.

Słowa kluczowe: *stropodach, budownictwo płytowe, izolacja przeciwwodna*

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Denotations

U_N – transmission heat loss coefficient; *U*-value [W/m^{2}K]
$M_{c,a}$ – annual amount of condensed water vapour [kg/(m^2·a)]
$M_{ev,a}$ – annual amount of evaporated water vapour [kg/(m^2·a)]
f_{Rsi} – temperature factor at the internal surface [–]
θ_{ai} – design internal temperature [°C]
θ_{si} – internal surface temperature [°C]
θ_e – design external temperature in winter [°C]
φ_i – relative internal air humidity [%]
φ_e – relative external air humidity [%]

1. Introduction

Panel buildings were very popular in the former Czechoslovak Republic, particularly from 1958 to 1990. They consist of various prefabricated concrete blocks, and their disposition, constructive system, used materials and structural detail solutions vary depending on the specific period which a given panel building type belongs to.

Flat roofs covering panel buildings were mostly of "warm deck" type, in the Czech technical terminology called "single-deck flat roof". It means that rigid thermal insulation is placed below the waterproofing but above the roof bearing construction. This type of roof does not have an air ventilated layer. A correctly designed warm deck flat roof has to maintain all roof layers at a temperature above a dew point and it also must comply with the requirements related to thermal protection of buildings. A typical slope of a warm deck flat roof is about two per cent to gating. Another variety of the flat roof is "cold deck" type, in the Czech technical terminology called "double-deck flat roof". These special roofs have an air ventilated layer and usually cover buildings with high internal humidity. Reconstructions and thermal insulating of these roofs are quite difficult and exceed the range of this paper.

2. Example of the flat roof reconstruction

2.1. Development of building thermal protection requirements

Roof designing, as well as thermal protection of buildings, is regulated by the Czech Technical Standards [6–10]. Development of *U*-value requirements is mentioned below in Table 1.

Table 1

Development of *U*-value requirements for flat roof designing in the territory of the Czech Republic [4]

Date	1.2. 1955	1.4. 1963	1.6. 1964	1.1.1979		1.5.1992		1.5.1994			Type of construction	1.11.2002		4.2007	
Value obligation				Required	Optional	Required	Optional	Required	Recommended	Allowable		Required	Recommended	Required	Recommended
U-value	1.16	0.93	0.90	0.52	0.95	0.32	0.75	0.32	0.22	0.49	light	0.24	0.16	0.24	0.16
											heavy	0.30	0.20		

2.2. Analysis of the typical flat roof before reconstruction

2.2.1. Typical flat roof deck fabric

A typical fabric of flat roofs used in panel buildings represents “warm deck” flat roof. A panel building in the Czech Republic in the city of Brno, Hrusnova Street (see Photos 1 and 2) has been selected as an example for the purpose of this paper. The flat roof of this building is going to be refurbished this year. It does not fulfill waterproof functions as well as thermal insulation requirements.

Photo 1. General view of a typical panel building frontage (Brno, Hrusnova Street)
Fot. 1. Widok ogólny elewacji typowego budynku płytowego (Brno, Hrusnova Street)

Photo 2. View of failures at a flat roof (Brno, Hrusnova Street)
Fot. 2. Widok usterek na stropodachu (Brno, Hrusnova Street)

Table 2

Flat roof fabric before the reconstruction [1]

	Layer – material (from external to internal surface)	Thickness [mm]
1	External reflective coating, degraded	
2	Waterproofing – sealing sheet (asphalt) with disrupted surface	3
3	Waterproof coating made of acrylate rubber	~1
4	Original waterproofing – group of three asphalt sealing sheets with fabric reinforcement	11
5	Concrete layer	50
6	Thermal insulation – formed polystyrene board with upper asphalt coating	50 + ~5
7	Thermal insulation – polystyrene board	25
8	Sloping concrete layer	~125
9	Ceiling panel – reinforced concrete	~140

Comment: flat roof fabric was examined by digging a hole into a roof deck (see Photo 3). Layers 1, 2, 3 have been obviously recently applied.

Photo 3. View of a hole dug in a roof deck (Brno, Hrusnova Street)
Fot. 3. Widok odkrywki w stropodachu (Brno, Hrusnova Street)

Photo 4. View of an attic gable construction and its failures (Brno, Hrusnova Street)
Fot. 4. Widok sposobu wykonania attyki nad ścianą szczytową i popełnionych błędów (Brno, Hrusnova Street)

2.2.2. Thermal analysis of a typical flat roof before the reconstruction

The thermal analysis of flat roofs is regulated by the Czech Technical Standards [7–10], where calculation methods, design value quantities and requirements are determined. According to these standards, resultant values in Tab. 3 have been obtained. Analysing them, one can draw a conclusion that the current flat roof does not conform with the standards.

Table 3

Thermal analysis of a researched typical flat roof before the reconstruction

Evaluated parameter	Required value	Recommended value	Calculated value	Evaluation
U_N [W/m^{2}K]	0.24	0.16	0.52	Fail
$M_{c,a}$ [kg/(m^2·a)]	< 0.1 or up to 0.5% of the material surface mass		0.2216	Fail
Annual moisture asset rating $M_{c,a} < M_{ev,a}$ [kg/(m^2·a)]	Active (> 0)		Passive	Fail
f_{Rsi} [–], θ_{si} [°C]	> 0.808 > 14.10°C		0.878 16.62°C	Pass

Comment: the following input data have been used for the calculation: θ_{ai} = 21°C, θ_e= –15°C, φ_i = 50%, φ_e = 84%, internal spaces with high humidity, climate data of Brno, the Czech Republic; software used – Teplo 2007.

2.3. Possibilities of flat roof reconstructions

2.3.1. Reconstruction of current flat roof fabric

There are many methods of the flat roof reconstruction. Two of them, which seem the best to me, are described below in Tables 4 and 5. In each case, the current roof deck has to be repaired and prepared for the application of new layers. The alternatives presented below differ in the applied waterproofing. An asphalt sealing sheet has higher diffusion resistance than a PVC-P sheet. This is connected with worse moisture ratio in a roof fabric and leads to higher thickness of thermal insulation (see required values of layer number 2 in Tab. 4 as compared with Tab. 5). Both roof fabrics have to be mechanically anchored because of low quality of ground layers.

Table 4

Flat roof fabric after the reconstruction – alternative with asphalt sealing sheet

	Layer – material (from external to internal surface)	Thickness [mm]
1	Waterproofing – sealing sheet of modified asphalt with glass – polyester fabric reinforcement	4.4
2	Thermal insulation – formed polystyrene board with upper asphalt sealing sheet and with sloped shape 1.5%. Polystyrene type at least EPS 100 S Stabil. Sealing sheet made of oxidated asphalt with glass fabric reinforcement (4 mm). Mechanically anchored layer	130 + 4.0 180* + 4.0
3	Current flat roof fabric – repaired, see Table 2	see Table 2

* Recommended values are marked with *.

Table 5

Flat roof fabric after the reconstruction – alternative with PVC waterproof insulation

	Layer – material (from external to internal surface)	Thickness [mm]
1	Waterproofing – PVC-P sheet with PES fabric reinforcement, designed for mechanical anchoring	1.2
2	Non-woven fabric (geotextile) of surface mass at least 300 g/m^2	
3	Thermal insulation – formed polystyrene board with sloped shape 1.5%. Polystyrene type at least EPS 100 S Stabil. Mechanically anchored layer	110 180*
4	Current flat roof fabric – repaired, see Tables 2	see Table 2

* Recommended values are marked with *.

2.3.2. Thermal analysis of reconstructed flat roof

The methodology of thermal analysis is briefly described in item 3.2.2. The resultant values are summarised in Tables 6 and 7. It seems obvious that both alternatives mentioned above completely fulfill all related requirements.

Table 6

Thermal analysis of a typical flat roof after the reconstruction – alternative with asphalt sealing sheet

Evaluated parameter	Required value	Recommended value	Calculated value	Evaluation
Designed thickness of thermal insulation [mm]			130 180*	Pass
U_N [W/m^{2}K]	0.24	0.16*	0.20 0.16*	Pass
$M_{c,a}$ [kg/(m^2·a)]	< 0.1 or up to 0.5% of the material surface mass		0.0026 0.0026*	Pass
Annual moisture asset rating $M_{c,a} < M_{ev,a}$ [kg/(m^2·a)]	Active (> 0)		Active Active*	Pass
f_{Rsi} [–], θ_{si} [°C]	> 0.808 > 14.10°C		0.953, 19.29°C 0.961, 19.60°C*	Pass

* Recommended values are marked with *.

Comment: the following input data have been used for the calculation: θ_{ai} = 21°C, θ_e = –15°C, φ_i = 50%, φ_e = 84%, internal spaces with high humidity, climate data of Brno, the Czech Republic; software used – Teplo 2007.

Table 7

Thermal analysis of a typical flat roof after the reconstruction – alternative with PVC-P waterproof insulation

Evaluated parameter	Required value	Recommended value	Calculated value	Evaluation
Designed thickness of thermal insulation [mm]			110 180*	Pass
U_N [W/m^{2}K]	0.24	0.16*	0.22 0.16*	Pass
$M_{c,a}$ [kg/(m^2·a)]	< 0.1 or up to 0.5% of the material surface mass		0.0001 0.0001*	Pass
Annual moisture asset rating $M_{c,a} < M_{ev,a}$ [kg/(m^2·a)]	Active (> 0)		Active Active*	Pass
f_{Rsi} [–], θ_{si} [°C]	> 0.808 > 14.10°C		0.948, 19.12°C 0.961, 19.60°C*	Pass

* Recommended values are marked with *.

Comment: the following input data have been used for the calculation: θ_{ai} = 21°C, θ_e = –15°C, φ_i = 50%, φ_e = 84%, internal spaces with high humidity, climate data of Brno, the Czech Republic; software used – Teplo 2007.

2.3.3. Typical details of reconstructed flat roof

A new flat roof fabric design and its thermal analysis is only one part of successful reconstruction. Another very important task is to find a solution to the critical technical details. Two of them are presented in Figs. 1 and 2.

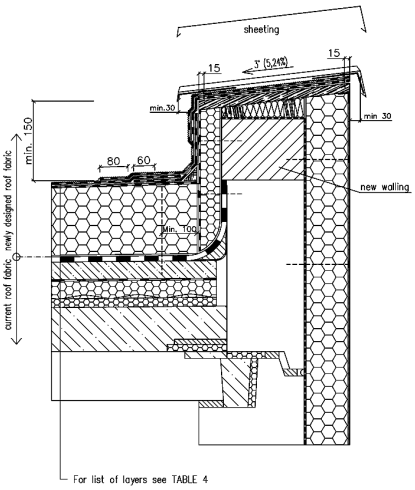

Fig. 1. Detail of insulated attic gable – alternative with asphalt sealing sheet waterproofing

Rys. 1. Detal izolowanej ścianki attykowej – alternatywa z asfaltową powłoką wodoszczelną

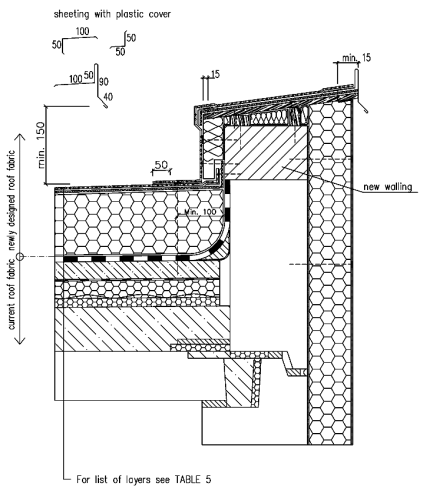

Fig. 2. Detail of insulated attic gable – alternative with PVC-P waterproof insulation

Rys. 2. Detal izolowanej ścianki attykowej – alternatywa z powłoką wodoszczelną z PCW-P

3. Conclusion

Panel buildings are specific type of building structures affected by numerous defects and failures. Most of them (high energy consumption among the others) are related to the insufficient thermal insulation of their flat roofs. Taking into consideration the fact that these buildings still provide housing for great number of inhabitants all over Europe, one should find their reconstruction aiming at complying with the required standards as a high--priority issue. This paper briefly describes one of the reconstruction solutions.

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