

The improvement of aseismic horizontal frame's thermal insulations

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Abstract. Recommendations about elimination of the thermal insulation's defects are offered in this research. The recommendations are based on the thermal imaging inspection of residential buildings, which were built with aseismic demands. The designing construction solution of filler structures taking into account the increase of comfort in the room is presented.

In the proposed work the typical designs structures of the site supporting floor slab on a brick wall (width 770 mm). Aseismic horizontal frame is abutting to the floor slab on the same level. The insulation layer of 140 mm width made with expanded polystyrene sites on the whole height of the wall. This layer is braked aseismic horizontal frame on the floor slab level. The aseismic horizontal frame is covered by the expanded polystyrene of 20 mm width. The thermal bridge in the direction of the facade is very typical for this designing construction solution. The thermal bridge is in the mid-height of the floor slab near the insulation layer.

The purpose of the research is to find a solution which will minimize or elimination thermal bridge with using additional insulation layer sites in the different level. Repeatability of thermal imaging inspection of designing construction solution and theoretical calculations in the software package ElCut are confirmed.

The presentation is illustrated with examples of temperature fields for the different residential buildings.

Keywords. Aseismic horizontal frame, floor slab level, temperature field, thermal bridge, an insulation layer, stationary heat temperature, an energy efficiency of civil engineering, heat losses.

1. Introduction

Khakasia is a territory which belongs to the seismic belt (7-points). Owing to the need to design buildings in Khakasia within the aseismic demands the aseismic horizontal frame and cores have widely used from 2002 till now. The designing construction solutions with the reinforced-concrete aseismic horizontal frame and cores [1-3] are used in 5-storied residential buildings in Abakan. On the other hand, the increase of reliability and strength of buildings leads to increase of the heat flow and the heat losses across the aseismic horizontal frame and cores (figure 1).



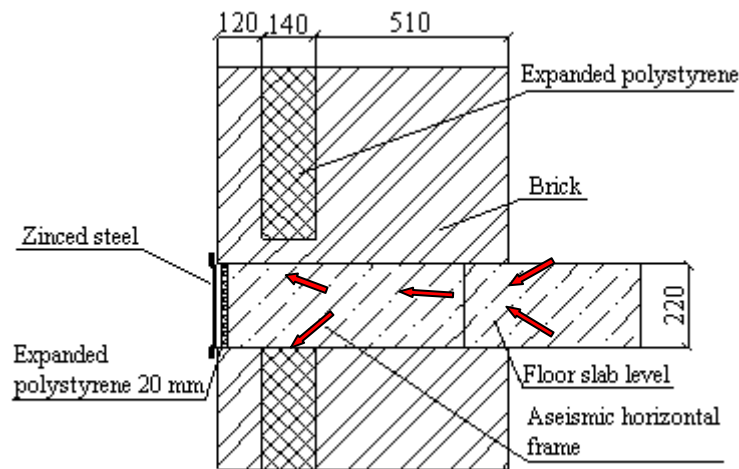


Figure 1. The heat flow across the external walls

The aseismic horizontal frame and cores are the thermal bridges along the heat flow. The thermal bridges are the cause of decrease inside wall surface temperature and a dew point that results in lower of a floor temperature. A thermographic analysis is used very often to find the heat losses place. [4-6]

In [7] a study is presented a thermovision monitoring results of the thermophysical field testing one-type blocks of flats in Volgograd region. It is interesting to know the solutions for increase thermal insulations presented – to add an isolation layer.

The authors [8] also show the thermovision monitoring results of buildings with thermotechnical uniformity places and says about the thermal bridges.

However, the decision to decrease the heat losses across the aseismic horizontal frame and cores hasn't found.

The purpose of the research is to find a solution which will minimize or elimination thermal bridge with using additional insulation layer sites in the different level using the thermophysical field testing the residential building and the computation of the temperature field of sites.

2. Methods

A study of the thermal insulation of building envelopes consists of three parts. The first part is a visual inspection with Thermal imaging FlirB200 to find cracks, structural defects, the heatlosses places and mold places.

The second part is a computation of structural sites using the soft package Elcut [9-12] and a finding of the most rational way to increase the thermal insulation of a structural design.

The third part is a comparison and analysis of results. An economic viability of all options is calculated. The most effective method of envelop's thermal insulation is presented.

3. Results

An object to be tested is a five-storied neighboring apartment house located in Abakan, Khakassia. The house has a brick wall width 770 mm and an attic. The expanded polystyrene with a density 35 kg/m³ (PSB-S-35, Russian GOST 15588-86) width 150 mm is used as a thermal insulation of an attic overlap. The wall has three layers. An exterior layer width 120 mm is made of face brick. An interior layer width 510 mm is made of baked brick. And an intermediate layer width 140 mm is made of expanded polystyrene. The walls are floor-by-floor supported by the floor slab and the aseismic horizontal frame. Vertical cores made of reinforced concrete are attached to the aseismic horizontal

frame and a foundation of the building. The expanded polystyrene with a density 25 kg/m^3 (PSB-S-35, Russian GOST 15588-86) width 140 mm is used as a thermal insulation of the exterior wall.

As a result of the visual inspection, the thermal bridges were found in the mid-height of the aseismic horizontal frame near the insulation layer and near the cores (figure 2).

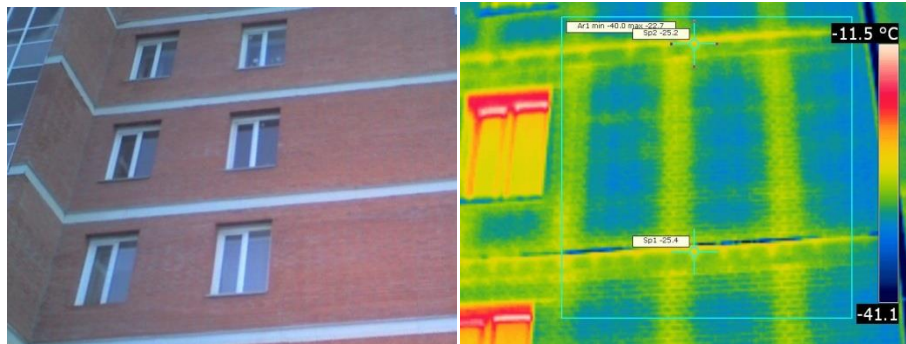


Figure 2. The photo and the thermogram of the part of the building's façade

Besides, the thermal bridges were found in the other places:

- The exterior and the interior walls angle (figure 3);
- A site the floor slab and the aseismic horizontal frame are offer to the exterior wall (figure 4).

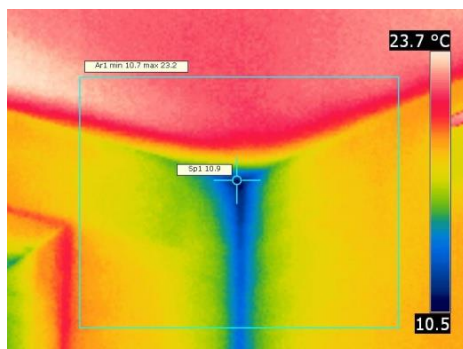


Figure 3. The thermogram of the exterior and the interior walls angle

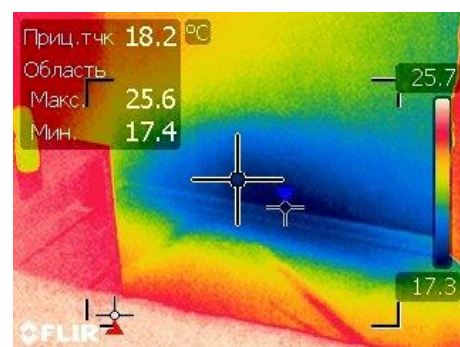


Figure 4. The thermogram of the site the floor slab and the aseismic horizontal frame are offer to the exterior wall

Figures 2–4 shows the temperature field in the area of abutting the floor slab, the interior walls and the cores to the exterior wall. Temperature defects in these zones are the primary cause of decrease internal surface wall temperature and condensate (the dew point) [13-15].

The thermal insulation was made doesn't conform to the designed level of the thermal insulation. One of the rational decisions is an application of a supplementary thermal insulation. It was done in the research building (figure 5) to decrease the heatlosses and the heat flow that passes through the aseismic horizontal frame and the cores.



Figure 5. The supplementary thermal insulation layer

In this paper, the different solutions of the buildings thermal insulation of the coupling joint between the aseismic horizontal frame and the floor slab are presented. Calculations were done through the standard soft package Elcut, using an approximation of the Laplace equation by the finite element method. Four options were calculated.

The first option is shown in figure 1. It is the option was done in the research building.

The option 2 is the design solution for many buildings in Khakasia. This option differs from the first in the width of the expanded polystyrene – 50 mm. The expanded polystyrene is attached to the aseismic horizontal frame by filling foam and dowels. The expanded polystyrene is protected from weathering by the zinc steel.

The option 3 has an improved thermal insulation. This option was actually implemented in Abakan (figure 5). It is the improved design solution. A supplementary (second) insulation layer made of expanded polystyrene width 30 mm is attached to the first insulation layer made 50 mm. Also, the supplementary insulation layer is located above and under the floor slab level on 65 mm height. So, the height of the supplementary insulation layer is 350 mm. The expanded polystyrene is protected from weathering by the zinc steel too.

The option 4 differs from the third in the height of the supplementary insulation layer – 580 mm.

4. Discussions

Mathematical modeling of the thermal regime of the structure in the cold season was carried out under the following boundary conditions:

- inside air temperature in the building $t_{int} = 20\text{ }^{\circ}\text{C}$ (Russian standard GOST 30494–2011);
- outside air temperature $t_{ext} = -37\text{ }^{\circ}\text{C}$ (Russian construction norm SP 50.13330.2012);
- heat transfer coefficient at the internal surface of the envelope $\alpha_{si} = 8.7\text{ W}/(\text{m}^2\cdot\text{K})$ (Russian construction norm SP 50.13330.2012);
- heat transfer coefficient at the external surface of the envelope $\alpha_{se} = 23\text{ W}/(\text{m}^2\cdot\text{K})$ (Russian construction norm SP 50.13330.2012).

Table 1. Characteristic of the materials

Material of layer	Width, m	Material density ρ_0 , kg/m ³	Thermal conductivity λ , W/(m·K)
Face brick	0.12	1600	0.64
Expanded polystyrene	0.14	20-25	0.038
Baked brick	0.51	1800	0.81
Reinforced concrete	0.22	2500	2.04

Design of the joint existing and strengthened by an additional thermal insulation are presented in figures 6–9. There are cross-sections and the temperature fields of the couplings joint between the aseismic horizontal frame, the external wall and the floor slab for four options described below.

Economic and technical parameters by each option of a thermal insulation are resulted in table 2 and 3 for an external and internal surface.

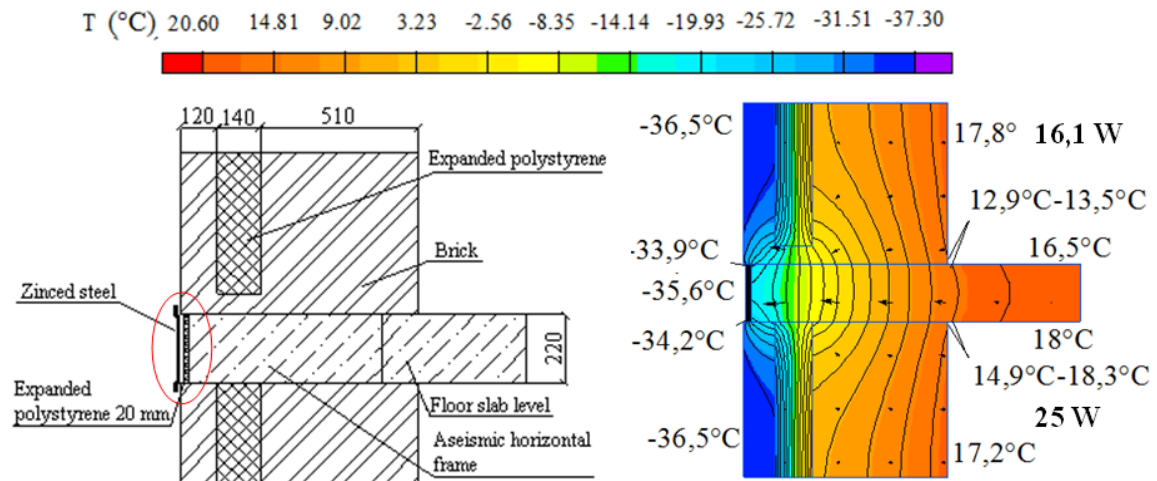


Figure 6. Option 1: the thermal insulation made 20 mm of the aseismic horizontal frame (Implemented solution)

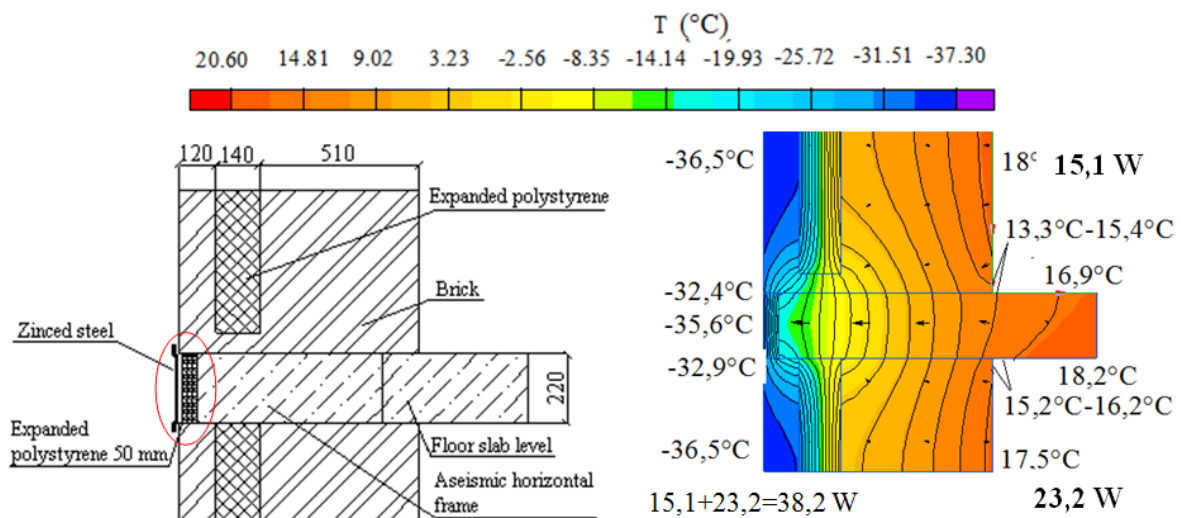


Figure 7. Option 2: the thermal insulation made 50 mm of the aseismic horizontal frame (design solution)

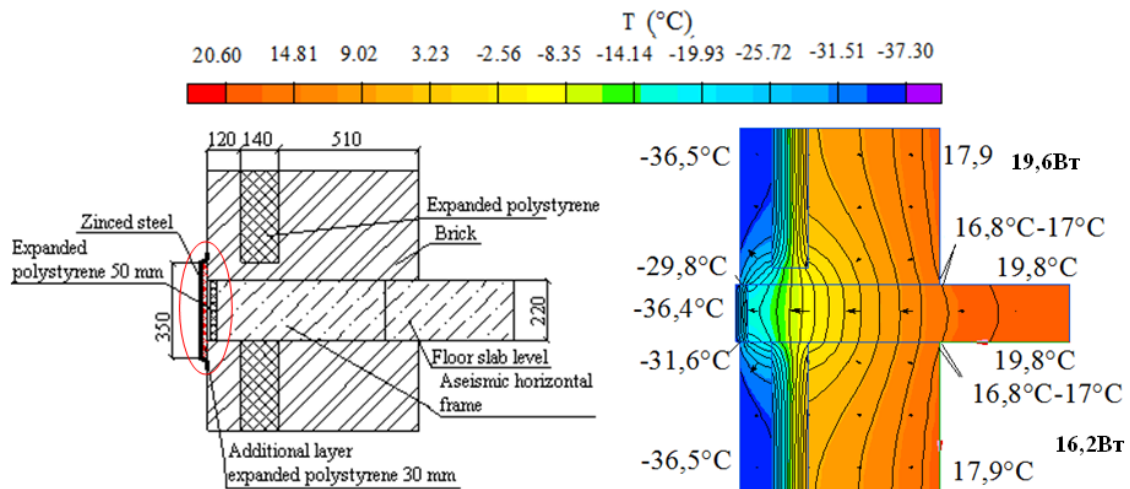


Figure 8. Option 3: the thermal insulation made 50 mm solution of the aseismic horizontal frame with the application of supplementary insulation width 30 mm and height 350 mm

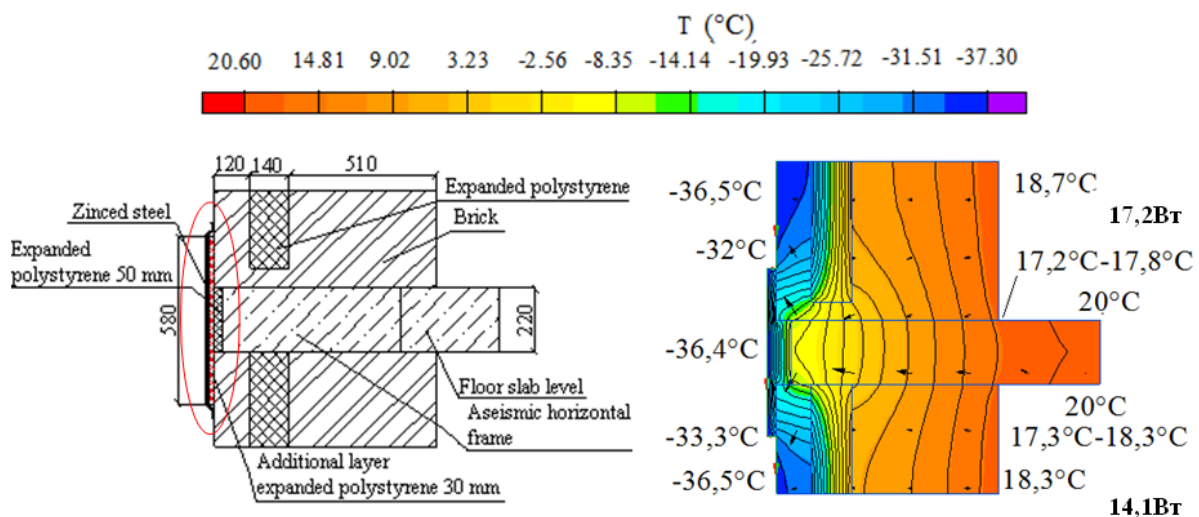


Figure 9. Option 3: the thermal insulation made 50 mm solution of the aseismic horizontal frame with the application of supplementary insulation width 30 mm and height 580 mm

For the given constructive decision the thermal bridge in a direction to face brick is characteristic significant. The thermal bridge takes place through a wall and a cross-section of a floor slab, as through header line of a bricklaying arranged above a level of a floor slab on a height of a brick (figure 6). At outdoor temperature -37°C the temperature on a surface of a wall in the field of the aseismic horizontal frame combined with a floor slab, makes -35 – -36°C . On border where the layer of a thermal insulation adjoins to face brick of a bricklaying temperature of a surface has made -34 – -35°C and -33 – -34°C . Such temperature deviation speaks rounding by the heat flow of an obstacle in the form of expanded polystyrene and passage of heat through header line of a bricklaying.

Table 2. Thermal characteristics on internal contours ($T_{\text{int}} = 21\text{ }^{\circ}\text{C}$)

Options	Heat flow	Ratio, %	Heat economy, %	The wall surface temperature T , $^{\circ}\text{C}$
Option 1	41–42	100	–	16–17
Option 2	38–39	93	7	17–18
Option 3	35–36	85–86	14–15	18–19
Option 4	31–32	76–77	23–24	18–19

Table 3. Thermal characteristics on external contours ($T_{\text{ext}} = 37\text{ }^{\circ}\text{C}$)

Options	Heat flow	Ratio, %	Heat economy, %	The wall surface temperature T , $^{\circ}\text{C}$
Option 1	40–41	100	–	-35–36
Option 2	39–40	97	3	-35–36
Option 3	34–35	85–86	14–15	-35–36
Option 4	30–31	75–76	24–25	-35–36

The total heat flow of the option 1 constructive unit on internal contours is made with 41–42 W (figure 6). The surface temperature of a coupling joint of an adjunction of a floor to an external wall of a living room has made from 12–13 $^{\circ}\text{C}$ up to 13–14 $^{\circ}\text{C}$. The minimal temperature 12 $^{\circ}\text{C}$ is characteristic for a point in a corner of a room in a place of an adjunction of a wall with a floor slab. The temperature of a surface of the floor slab is 16–17 $^{\circ}\text{C}$.

At the option 2 designs of a constructive unit (figure 7) as a result of the device of an additional thermal insulation width 50 mm in a level of a floor slab reduction of heat losses through the given constructive unit on an internal contour makes 7 % (table 2), on an external contour of 3 % (table 3). Thus rise in temperature of a surface of a corner up to 16–17 $^{\circ}\text{C}$ and decrease in capacity of the heat flow not considerably 38–39 W (against 41–42 W) is marked. The average temperature of a surface on an internal contour is 16–17 $^{\circ}\text{C}$.

The option 3 and 4 performances of a constructive unit are developed for the elimination of the thermal bridge through the site. The decision of a variant 3 constructive units is the device of an additional layer of expanded polystyrene width 30 mm atop of a thermal insulation in a level of a floor slab on 65 mm above and below a level of a floor slab. The height of an additional layer of expanded polystyrene makes 350 mm (figure 8). The capacity of the heat flow through the considered site is made with 35–36 W. The economy of heat on an internal contour in comparison with an initial variant has made 14–15 %, average temperature of a surface 18–19 $^{\circ}\text{C}$ (table 2). The analysis of the result of a thermal imaging research of a fragment of a facade of a building with the device of an additional heat-shielding in the field of an interfloor floor slab (figure 1) according to a variant 3 has shown the efficiency of the given decision. However, the increase in height of a thermal insulation at 115 mm above and below a level of a floor slab is expedient.

The option 4 investigated constructive units differs from previous only in height of an additional layer of a thermal insulation. Value of height of the device of expanded polystyrene is accepted 580 mm, i.e. on 180 mm above and below a level of blocking (figure 9). Thus, the efficiency of a constructive unit raises on 23–24 % (table 2), the minimal temperature makes 17–18 $^{\circ}\text{C}$ is characteristic in a corner of a room where the wall borders on a floor slab. Cited data testify to increase of thermal comfort of a room. The capacity of the heat flow of the given constructive unit is made with 31–32 W. The average temperature of a surface makes 18–19 $^{\circ}\text{C}$.

5. Conclusions

According to results the following was found:

1. The study of two-dimensional temperature field revealed the most effective solution for improving aseismic horizontal frame's thermal insulations.
2. An experimental site 32 m long made with the supplementary insulation layer has shown a big effect against existing solutions nowadays.

3. From the point of view of efficiency of thermal protection, the most rational variant is the variant 4: the device of an additional layer of expanded polystyrene width of 30 mm atop of a thermal insulation of 50 mm stipulated by the project. Thus the height of an additional layer makes 580 mm, i.e. on 180 mm above and below a level of a floor slab. The given decision allows lowering heat losses of a room through the site on 23–24 %. On an experimental site, the third variant is applied. By the parameters presented in table 2, 3 by the third variant, the temperature of a surface of a floor slab on an internal contour and a thermal stream through the given site have optimum values. Responses of proprietors of this apartment are positive.

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