Thermal protection of buildings from sandwich panels for Southern Siberia conditions

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Abstract. Article represents recommendations on decrease in heat losses through heat-conducting inclusions of sandwich panels. Recommendations are based on the analysis of calculations by a finite element method in software package Elcut and thermal imaging. The purpose of this study is to increase the thermal protection of buildings built with sandwich panels for the South Siberia conditions. The way of decrease in the factor of cold bridges is studied by adding thermal insulation of panel node connections. The authors analyzed constructive joints: roof parapet, roof cornice and junction of wall panels.

1. Introduction

External fencing sandwich panels are known for a long time. [1] At present, the construction of frame public buildings using sandwich panels as enclosing structures has become very popular in Abakan. Mineral wool and polystyrene foam are used as insulation layers in such panels.

In papers [2–4] the authors note that the sandwich panels, due to the peculiarities of the design, have several disadvantages, including various types of deformations. In the cold climate of Southern Siberia, temperature distortions are especially important.

The disadvantages of panels with mineral wool and metal frame is the possibility of precipitation of insulation and low efficiency of thin insulating gaskets, which impairs the thermal properties of the fence. Although mineral wool is impregnated with phenol-formaldehyde resins, which makes mineral wool a hygroscopic material, it is still the case that in the absence of ventilation the middle layer of the panel accumulates moisture.

The disadvantage of sandwich panels with a middle layer of polyurethane foam is a low fire resistance due to the flammability of the insulation.

An important problem in the operation of sandwich panels is significant stresses and deformations during temperature and humidity effects of the environment. In winter, the temperature difference between the inner layer of a three-layer sandwich panel and the outer one causes bending stresses in the sandwich panels. Especially for roofing panels, where inevitably accumulated snow enters into account, depending on the slope, respectively, and its amount.

The crumpling of the sandwich panel on the supports also affects the self-tapping screws, which eventually begin to “crawl out” of the panel. Because of this, moisture will penetrate under the gasket of the screw, accumulating in the core of the three-layer panel; the process of corrosion of the screw will begin to develop.

However, due to the low cost and speed of construction, this design is very common. The main problems are the thermal diversities that thermal bridges pass through. The main part of heat losses and the thermal bridges meets in the structural sites of exterior walls. [5–9]
Insufficient knowledge of the issues of behavior of sandwich panels on the effects of temperature effects, which requires solving these issues, which are interesting from a scientific point of view and important from a practical point of view.

The purpose of this study is to increase the thermal protection of buildings built with sandwich panels for the South of Siberia conditions.

2. Methods
In order to analyze the joints of enclosing structures made of sandwich panels, the objects were monitored. As the objects of study were selected buildings in operation in the city of Abakan, the Republic of Khakassia (table 1).

Thermal insulation control of the above objects was carried out in December 2018. At the time of the survey objects were heated. The survey was carried out in the absence of wind, precipitation, fog and smoke. In the process of measurements, the enclosing structures of the buildings being examined were not exposed to direct and reflected solar radiation.

The following types of work were performed during thermal imaging:
- inspection of objects using a thermal imager for the formation of a general characteristic of objects and the identification of areas to be further thermographed;
- overview thermography of the external surfaces of the enclosing structures to identify temperature anomalies;
- detailed thermography of selected areas of external surfaces of walling to clarify the temperature anomalies.

| Table 1. Objects of study |
|---------------------------|
| **Object 1:** Swimming pool on Torosova str. There is a stone wool insulation 150 mm. |
| ![Photo](image1) | ![Thermogram](image2) |
| **Object 2:** Shopping centre on Nekrasova str. There is a stone wool insulation 150 mm. |
| ![Photo](image3) | ![Thermogram](image4) |
Object 3: Shopping centre on Igarskaya str. There is a stone wool insulation 120 mm.

The second part is a computation of structural sites using the soft package Elcut to study the thermal field of the external wall, comparison of results depending on the type of insulation.

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 tint = 20 °С (Russian standard GOST 30494–2011);
- outside air temperature text = –37 °С (Russian construction norm SP 50.13330.2012);
- heat transfer coefficient at the internal surface of the envelope $\alpha_{si} = 8.7 \text{ W/(m}^2 \text{°C)}$ (Russian construction norm SP 50.13330.2012);
- heat transfer coefficient at the external surface of the envelope $\alpha_{se} = 23 \text{ W/(m}^2 \text{°C)}$ (Russian construction norm SP 50.13330.2012).

3. Results and discussions

The performed thermal imaging surveys show that there are large heat losses in all the joints of the sandwich panels.

Thermal imaging of objects 1 and 2 shows the temperature difference between the outer surface of the wall and the corner joint, which is more than 25 °C.

The temperature difference in the front butt joint is 8 °C.

For cold climate conditions, such a drop will inevitably lead to the formation of condensate and ice on the inner surface of the fence.

It should be noted that the lifetime of buildings ranges from 3 to 15 years. In this case, the defects of the thermal shell of buildings are almost identical. In the process of inspection of the joints, it was established that the assembly foam completely lost its original properties, has a large shrinkage and detachment from the panel surface. In this regard, it can be said that the design joint of sandwich panels made of assembly foam is ineffective in cold climates and the manufacturer should develop various design solutions for different climatic conditions.

Figures 1–3 show temperature fields in considered joints according to design solution.

Figure 1. Joint 1: cross section of the wall (joint and temperature field)
Analysis of figures 1-3 shows that in all corner joints there is a large exfiltration of warm air, due to which the temperature of the outer contour of the panel is 10–15 °C higher than the temperature of the main part of the panel. In this regard, large heat losses are generated in buildings.

In this regard, for the temperature conditions of the south of Siberia, horizontal and angular joints of the sandwich panels are proposed to be sealed not with assembly foam, but with polyurethane foam, which is elastic and resists significant temperature deformations. The results of calculations of joints with additional insulation are presented in fig. 4-5, table 2.

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Figure 5. Joint 3: roof cornice (joint and temperature field) after additional insulation

Table 2. Temperature on external and internal contour before and after additional insulation

| Number of joint | Before additional insulation | After additional insulation |
|-----------------|------------------------------|----------------------------|
|                 | External surface temperature T, °C | Internal surface temperature T, °C | External surface temperature T, °C | Internal surface temperature T, °C |
| 1               | -17.2                         | +18.2                      | -28.3                         | +25.7                      |
| 2               | -17.2                         | +19.4                      | -27.1                         | +19.2                      |
| 3               | -12.4                         | +15.1                      | -26.7                         | +19.2                      |

Analysis of temperature fields after additional insulation shows that these nodes are more efficient from the standpoint of energy saving, there is no exfiltration. With this solution, the heat loss is reduced by 3 times.

Analyzing the temperature change in the nodes of the enclosing structure in the annual cycle of operation, we can assume in which node connections the processes of precipitation and accumulation of condensation moisture are possible, as well as roughly determine the periods of “wetting” and “drying” of enclosing structures.

4. Conclusions

Based on the research we can draw the following conclusions:

1. In the conditions of Southern Siberia, it is impossible to use a standard constructive solution of sandwich panels without additional thermal insulation.
2. The use of polyurethane foam in butt joints of panels leads to the fact that after 5 years of operation, the properties of the insulating gasket are reduced to zero, which leads to large heat losses and reduces the durability of the outer fence.

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