Possibility of using super-thin liquid thermal insulation for protection of steel beams embedded in brick wall exterior under building reconstruction

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Abstract. The article presents the results of calculations on changing the thermophysical properties of the connectivity node of the outer wall and the balcony plate resting on the cantilever fixed steel beams. A variant of insulation of steel beams with super-thin liquid insulation under the reconstruction of existing brick buildings with single-layer brick walls is proposed. The graphical analysis of the problem was carried out. The results of calculations of temperature with linear thermophysical properties show that the method of steel beams insulation within the conditions of reconstruction of residential buildings makes it possible to increase the building life. When using super-thin thermal insulation coatings, it is possible to reduce the local freezing of the balcony plate.

1. Introduction

Currently, energy-saving technologies are the most popular technologies in construction. The development of energy-efficient construction is aimed at creating high-quality real estate, reducing the cost of maintaining these facilities. Therefore, the choice of thermal insulation materials for various parts of walling, technology of their device, the degree of reliability of these coatings is crucial in the development of technological solutions for the protection of buildings from temperature changes [1-4].

As an independent structural element of the facade, the balcony is an important component of the architectural style. Partial destruction of balconies is a common problem in countries with low winter temperatures (Figure 1, A) Hidden from the eyes of the destruction sometimes reaches such an extent that the balcony itself becomes dangerous for both the owners and the around people (Figure 1, B). Operating experience shows that the most common damage is inherent in all balcony structures and is observed in the most vulnerable areas, such as points of interfaces of various structures, the joint of the balcony plate and the outer wall, the protruding bearing elements of balconies.

The practice of reconstruction and major repairs of buildings showed that the existing embedding of steel embedded details (such as steel angles, pipes, etc.) in a multilayer outer wall causes a number of problems with local freezing of the structures and deterioration of the thermophysical properties of such a site while in operation.

The steel element of the balcony plate becomes a cold bridge. Meanwhile, the introduction of such an element in the wall body is sometimes necessary for structural, operational or architectural and artistic reasons. Freezing of the steel element gradually leads to premature failure of the wall structure [1].
The use of super-thin ceramic liquid insulation such as "Korund" or "Bronya" allows to increase the thermal characteristics of the facade system by reducing the negative impact of embedded metal element of the balcony plate [2,3].

2. Relevance and scientific merit of the subject
Extension of service life of building structures by means of thermal insulation protection is one of the actual directions of the construction industry today. Application as protection against the penetration of cold of a heat-conducting element is an actual direction in the researches devoted to a problem of creation of energy-saving construction materials and technologies [5-11]. This problem is particularly acute for countries with significant temperature changes. In our research the innovative approach to the solution of a problem of increase in reliability and durability of constructive elements of buildings which promotes reduction of number of cycles of reconstruction and capital repairs of buildings is offered.

3. Research objective and theoretical part
For effective use of liquid super-thin thermal insulation materials, it is necessary to ensure adequate relative stability of the polymer coating structure in the structure. The reliability of the thermal insulation coating depends on external destabilizing factors. Corrosion on the metal surface is excluded during the period when the insulation retains flexibility, extensibility, excellent adhesion to the coated materials. Only full consideration of specific operating conditions can guarantee the durability of structural materials, reduce labor costs, improve energy efficiency of buildings [12-14].

To research the effect on the thermal recoil of the surface of the steel frame of the balcony plate of different structural variants of its insulation super-thin liquid insulation, a package of modeling of physical processes COMSOL Multiphysics was used [7,8,15]. Western scientists are actively using this software package to simulate various technical developments [1,16-18].

For the comparative analysis of the temperature fields distribution two variants of the design solution were used. Regarding the first option, structural design is an existing single layer brick wall (the building is under reconstruction) with thickness of 510 mm. The steel beam (I-beam 200+100 mm) is embedded in the wall. The height of the balcony plate is 260 mm. The protective layer of concrete around the steel beam is 30 mm (Figure 2, A; 3, A).

On the second structural design, with all other things being equal, the insulation of the steel beam with super-thin liquid thermal insulation proposed by the authors is added. For protection from the freezing of the steel beam in the winter in the body of monolithic balcony plate, coating with super-

Figure 1. Photo of the existing situation: A - balcony plate with a steel load bearing element as a supporting frame; B - visible destruction of the wall when using a steel element.
thin liquid thermal insulation of the surface of the steel element and the subsequent embedment of the balcony plate is used. (Figure 2, B; 3, B).

Figure 2. Cross-section of the considered design. Options of structural solution: A - structural design 1; B - structural design 2. The balcony plate materials: 1 - steel I-beam 200x100x5.2 mm, 2 - a monolithic concrete balcony plate, height 260 mm, 3 - coating of the I-beam with super-thin liquid thermal insulation 3 mm.

Figure 3. Longitudinal section of the considered design. Options of structural solution: A - structural design 1; B - structural design 2. The balcony plate materials: 1 - brick wall 510 mm; 2 - a monolithic reinforced concrete balcony plate, height 260 mm; 3 - steel I-beam 200x100x5.2 mm, 3 - coating of the I-beam with super-thin liquid thermal insulation 3 mm.

The list of materials used to solve the problem is presented in Table 1.

Table 1. Design parameters of the materials.

| Name of material | Heat conductivity, \((W/(m^*K))\) | Density, \((kg/m^3)\) | Heat capacity, \((J/(kg^*K))\) |
|------------------|-------------------------------|------------------|------------------|
| 1 Solid sand-lime brick | 0.76 | 1800 | 880 |
| 2 Reinforced concrete | 2.04 | 2300 | 840 |
| 3 Steel | 44.5 | 7850 | 475 |
| 4 Super-thin liquid thermal insulation | 0.001 | 1600 | 1470 |

As a result of the calculations the grid of finite elements was found (Figure 4, A, B)
Figure 4. Finite element mesh: A - finite elements – 29000; B - degrees of freedom – 22600.

The problem is calculated in a stationary mode with constant thermal properties of materials of construction layers. The stationary mode is considered as for the plane problem [19]. The following results are obtained by calculations using COMSOL Multiphysics: on the first structural design (Figure 5, A), on the second structural design (Figure 5, B), Figure 5, C - temperature scale.

Figure 5. Temperature distribution according to the structural design: A - on the first structural design (Figure 3, A); B - on the second structural design (Figure 3, B); C - temperature scale.

Structural design 1 (Figure 5, A). In the body of the steel element (I-beam) the temperature of minus 12.08°C is obtained. The temperature of minus 14.78°C is obtained at the end of the steel element at the standard solution on the outer surface of the I-beam.

Structural design 2 (Figure 5, B). In the body of the steel element (I-beam) the temperature of minus 9.4°C is obtained after the coating with proposed super-thin liquid thermal insulation. The temperature of minus 10.45°C is obtained at the end of the steel element on the outer surface of the I-beam.

By calculations using COMSOL Multiphysics, the following temperature fields, shown in Figure 6., are obtained.

The temperature fields show the movement of heat flow. Based on the temperature fields distribution, it can be seen that the I-beam body, when coated with super-thin liquid thermal insulation, is in more favorable temperature conditions.
Figure 6. Temperature fields distribution: A - according to the structural design 1 (Figure 3, A); B - according to the structural design 2 (Figure 3, B).

4. Results obtained in experimental studies

Calculations show that the above described variant of protection of the studied elements during the overhaul of existing buildings can be used to improve the thermal insulation of some unfavorable areas. The proposed treatment of the steel element allows to increase the temperature in an unfavorable zone, which is especially important for regions with a cold winter climate, since the presence of dense heat-conducting inclusions leads to the rapid destruction of the balcony slab. It should be noted that when using this method of thermal protection of building structures, it is important to be guided by the principle of a differentiated approach to local conditions, especially in areas with significant temperature differences. The theoretical calculations obtained in the article were confirmed by practical experiments during the overhaul of buildings.

5. Conclusions

Studies have shown that in existing balcony plates freezing and their further destruction is possible [19-21]. Steel elements inside the balcony slabs are the most vulnerable part of the concrete structure [6,10,20,22]. It is important to remember that various defects in concrete elements, such as cracks, technological voids and other structural deficiencies of balcony slabs, play an important role in changing the distribution of temperature flow [21,23-25].

Due to correct design decision and after the conducted study, the following parameters were obtained: under the standard solution - the temperature in the thickness of the steel element (I-beam) is minus 12.08°C, at the end of the steel element on the outer surface of the I-beam - is minus 14.78°C. After the proposed coating with super-thin thermal insulation in the body of the steel element (I-beam), the temperature of minus 9.4°C is obtained, at the end of the steel element on the outer surface of the I-beam - is minus 10.45°C. Thus, the coating with super-thin thermal insulation allows to reduce the freezing of the steel element body by 2.65°C, the temperature on the surface of the end of the I-beam can be increased by 1.14°C.

The reached engineering solution was used in construction practice [3, 11, 23, 26].

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