Optimization of The Connection Node of The External Wall, Interfloor Slab, Balcony Slab and Seismic Belt for Improving Thermal Efficiency

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Abstract

The article proposes a structural solution for the connection node of the external wall, interfloor slab, balcony slab, and seismic belt, which includes the use of thermal inserts along the entire length of the balcony slab support. This structural solution makes it possible to reduce heat losses through this type of thermal bridge by 60–70% while ensuring strength and reliability under seismic loads. The reliability of the proposed solution is confirmed by structural calculations of the balcony performed using the LIRA-SAPR software package.

Keywords: Anti-seismic belt, balcony slab, interfloor ceiling, external wall, thermal bridge, thermal field, heat losses, thermal insulation, thermal insulation, thermal insulation, strength, reliability.

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1. Introduction

Under modern conditions of increasing requirements for the energy efficiency of buildings, special attention is paid to reducing heat losses through building envelope structures. One of the most common sources of heat loss is the so-called thermal bridges that occur at the junctions of various structural elements of a building. Such nodes include the connection areas of external walls, interfloor slabs, and balcony slabs.

This problem is particularly relevant for buildings located in seismic regions, where the design process must consider not only the thermal performance of enclosing structures but also the requirements for ensuring the strength and stability of structures under seismic loads. Under such conditions, structural solutions must simultaneously ensure high energy efficiency and structural reliability.

One of the most problematic areas is the joint node of the external wall, interfloor slab, balcony slab, and seismic belt. In this node, a significant thermal bridge is often formed, which leads to increased heat losses, reduced energy efficiency of the building, and deterioration of the operational performance of structures.

In this regard, an urgent task is the development and study of structural solutions aimed at reducing heat losses through this node without reducing its load-bearing capacity and seismic resistance. In this paper, a structural solution of the connection node with the use of thermal inserts along the entire length of the balcony slab support is considered, which makes it possible to significantly reduce heat losses while ensuring the required strength and reliability of the structure.

2. Methods

Analytical and computational research methods were used in this study. An analysis of existing structural solutions for the joint node of the external wall, interfloor slab, and balcony slab was carried out. To assess the strength and reliability of the structure, numerical modeling and structural analysis of the balcony slab were performed using the LIRA-SAPR software package. A comparative analysis of the thermal performance of the traditional and the proposed structural solutions was also conducted.

3. Results and Discussion

The residential sector is one of the largest consumers of heat and electricity in the Republic of Uzbekistan. Moreover, residential buildings in Uzbekistan consume 2-3 times more energy during operation compared to similar facilities in European countries. In this regard, one of the priority areas in the construction industry of the republic is increasing the level of energy efficiency of the housing stock [1, 2, 3].

The influence of heat-conducting inclusions (heat bridges) in Uzbekistan is assumed to be quite significant. This is due to the national characteristics of the constructive solutions of fences, which necessarily include monolithic elements - anti-seismic belts, interfloor ceilings, cores, frame elements, and core stiffness. These elements, while ensuring the strength, rigidity, and stability of structures, are simultaneously powerful heat-conducting inclusions in warmer wall masonry materials.

From the point of view of thermal protection, a homogeneous structure is an infinite structure consisting of flat-parallel layers of any material. Any local deviation from homogeneity in form or material characteristics of any part of the structure causes thermal heterogeneity.

Thermal heterogeneity (cold bridge, thermal bridge) - an area of the enclosing structure with a heterogeneous temperature field, the distortion of which is caused by thermal conductivity and/or a change in the cross-section of the structure. Real enclosing structures, due to their unevenness, the presence of traditional heat-conducting elements, and adjacent structures, are always heat-technically heterogeneous. Increasing heat loss to 30-50% of losses through a conditionally homogeneous structure, thermal bridges become a subject of detailed elaboration by responsible architects and project designers. If they are ignored, errors in the design of heating systems occur, which inevitably affects the thermal comfort of the premises, the formation of condensate zones and mold in the cold zones of the inner surface of the enclosures.

When examining a seven-story residential building, the following heat bridges can be distinguished: external corners, the junction of external walls and attic floors, window and door openings, etc. A significant portion of heat loss occurs at the junction of the external wall, the interfloor slab, the balcony slab, and the anti-seismic belt. Foreign experts compare these losses to those that create several square meters of unheated brick wall [2, 5-7]. In addition, the temperature difference arising at the junction of the unheated balcony slab with the floor slab can lead to cracks due to uneven thermal expansion of the reinforced concrete. The deterioration of concrete integrity over time will increase, leading to reinforcement corrosion and, consequently, the loss of the balcony slab's load-bearing capacity [11].

Figure 1. Residential building in the Mirobod district of Tashkent city.

Considering that the use of balconies in modern residential building architecture is increasing, considering this unit from the perspective of minimizing heat loss through it is quite relevant.

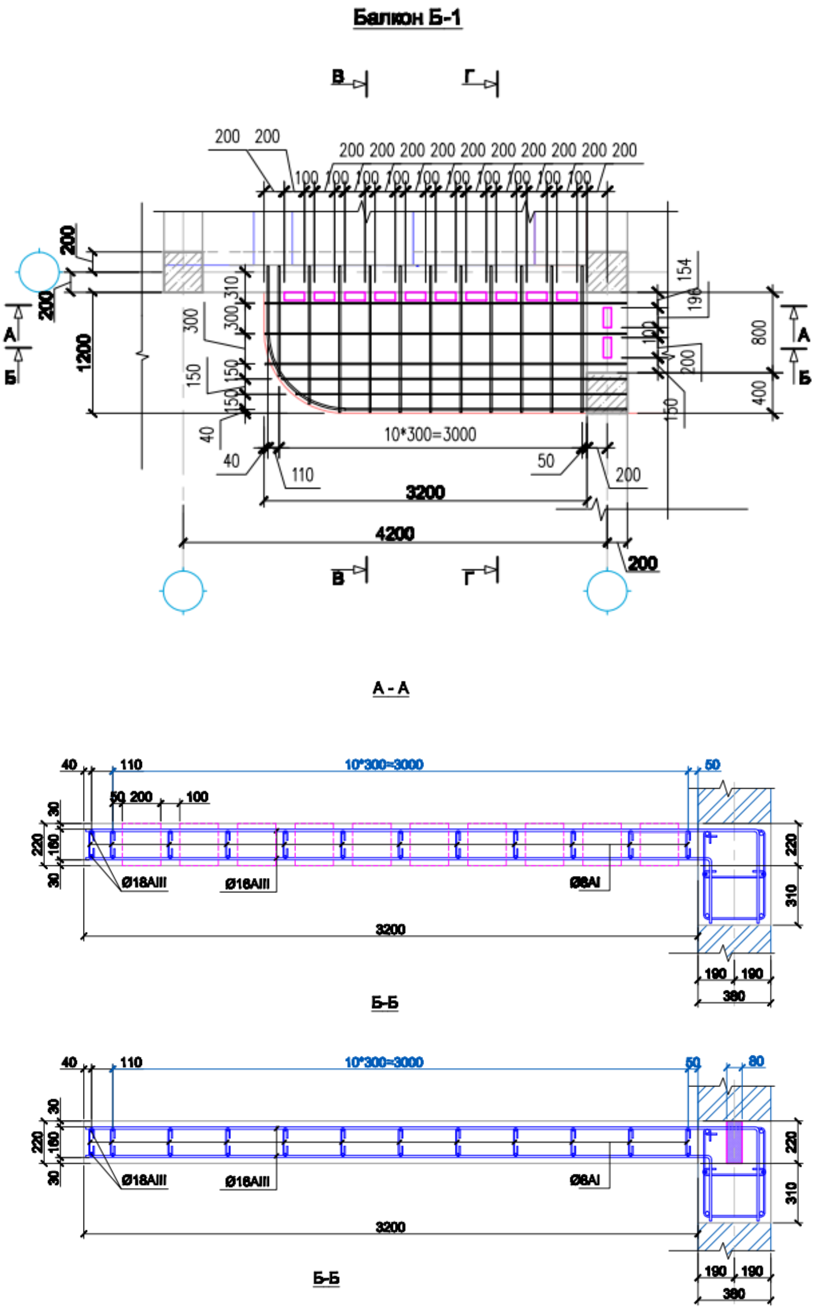
When studying the junction of the external wall, interfloor ceiling, balcony slab, and anti-seismic belt provided for in the studied seven-story residential buildings, it was established that there were no insulation measures at all, i.e., no measures were provided for thermal disconnection of this thermal bridge from the building's thermal contour.

Taking into account the experience of insulation of the external wall, interfloor ceiling, and balcony slab junction assembly in foreign countries[8-9]., as well as the specifics of the assembly structure in buildings intended for construction in seismic areas, a structural solution based on the partial use of polystyrene-foam thermal inserts is proposed, which will significantly reduce heat losses, will not be expensive, and will ensure the required strength of the balcony slab connection with the building's load-bearing structures [8]. To implement this solution, at a length approximately equal to 2/3 of the balcony slab's length, the concrete at the point of its support on the reinforced concrete belt is replaced with extruded polystyrene foam. The balcony slab reinforcement passes through the belt for anchoring at a length of 1/3 of the balcony slab length (i.e., the width of the concrete with the passage of reinforcement remains approximately 30-35 cm per 1 l.m). The proposed balcony design for a seven-story residential building is shown in Figure 2.

In the adopted decision, it is proposed to place inserts made of extruded polystyrene foam between the balcony slab and the anti-seismic belt, with a length of 200 mm, a width of 220 mm, and a thickness of 80 mm. The distance between the inserts is 100 mm, which allows for the passage of reinforcing bars through these concrete sections sufficient to ensure the strength of the balcony structure. In this case, the need to pass reinforcement bars through the insulation and, accordingly, the use of stainless steel reinforcement is eliminated.

To prove the strength of this balcony structure with the proposed balcony slab support solution, the calculation of the balcony as a spatial system for static and dynamic impacts was performed by the "LIRA-SAPR" software complex. The calculation was performed for three types of static loads and one dynamic load (from seismic impacts). The seismicity of the construction site was taken as 8 points. The value of the constant load was 1.9 kPa. The calculated value of the uniformly distributed temporary load on the balcony slab was taken according to the KMK "Loads and Impacts" and amounted to 0.7 kPa. The concrete class for reinforced concrete elements was adopted as B25. The concrete class for reinforced concrete elements was adopted as B25. The working reinforcement class is A-III, and the assembly reinforcement class is A-I. As a result of the calculation and based on constructive considerations, it was adopted to reinforce the slab with a spatial frame, in which the longitudinal reinforcement Ø18A-III is located with a step of 300 mm near the wall and 150 mm near the suspension; the transverse reinforcement Ø18A-III with a step of 300 mm; and the assembly reinforcement Ø8A-I (Fig. 2).

This design solution of the external wall, interfloor ceiling, balcony slab, and anti-seismic belt junction allows for a significant reduction (approximately 60-70%) in heat loss through the junction, as well as eliminates significant economic costs.



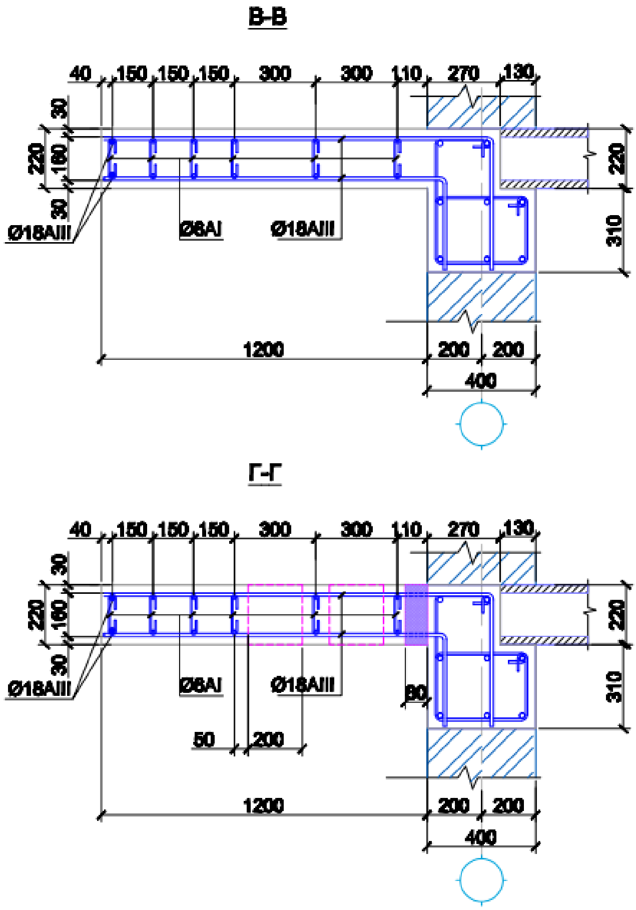


Fig. 2. Location of the insulation in the assembly, structural solution of the balcony slab's support, and its reinforcement.

4. Conclusion

Analysis of existing structural solutions for exterior walls of seven-story residential buildings without external insulation showed that unprotected reinforced concrete cores and anti-seismic belts must be insulated either by applying special heat-protecting elements stylized for architectural wall details (pilasters, cornices, etc.), or by applying continuous external thermal insulation [10-11]. Otherwise, when the external air temperature reaches the calculated values during the winter period (for example, for Tashkent, minus 16°C), condensate deposition near the external corners of the ceiling, walls, and areas of reinforced concrete cores will be quite real.

The social effectiveness of implementing constructive solutions to improve the thermal performance of external walls with heat-conducting inclusions lies in significantly reducing or eliminating cases of "damp corners and slopes" problems in modernized buildings, which will have a positive impact on the quality of construction and the comfort of living.

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