УДК 620.91:697.1

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MINIMIZATION OF BALCONY SLAB JUNCTION THERMAL BRIDGE EFFECTS

Renovation of old residential buildings is a way to enhance thermal efficiency of building stock. Along with thermal insulation of external walls, roofs etc., thermal bridges, essential components of the transmission heat losses of a building, have to be properly treated as well. In the article different strategies to minimize thermal bridges due to balcony slab junctions in an old residential building were analyzed. As a result of the thermal modeling the most favorable approach was proposed.

Keywords*: balcony slab junction, thermal bridge, linear thermal transmittance, transmission heat loss, renovation*

Реконструкція старих житлових будинків є одним із способів підвищення теплової ефективності житлового фонду. Поряд з теплоізоляцією зовнішніх стін, дахів тощо, також повинна бути приділена відповідна увага тепловим місткам, що сприяють значним тепловим втратам будівлі. У статті аналізуються різні стратегії мінімізації теплових втрат через теплові містки у місці сполучення балконних плит в старому житловому будинку. В результаті теплового моделювання запропоновано найбільш оптимальний варіант.

Ключові слова: *сполучення балконної плити, тепловий місток, лінійний коефіцієнт теплопередачі, втрати тепла, реконструкція*

Реконструкция старых жилых зданий является одним из способов повышения тепловой эффективности жилищного фонда. Наряду с теплоизоляцией наружных стен, крыш и т.д., также должно быть уделено соответствующее внимание тепловым мостикам, которые способствуют значительным тепловым потерям здания. В статье анализируются различные стратегии минимизации тепловых потерь через тепловые мостики в месте сопряжения балконных плит в старом жилом доме. В результате теплового моделирования предложено наиболее оптимальный вариант.

Ключевые слова: *сопряжение балконной плиты, тепловой мостик, линейный коэффициент теплопередачи, потери тепла, реконструкція*

Introduction. The the buildings’ energy losses minimization is an urgent task nowadays. Now a lot of energy efficient buildings are erected and old buildings are renovated. Old buildings can offer huge potential for the energy savings that are achievable by a complex refurbishment [1]. To enhance the energy performance of old buildings undergoing renovation a lot of traditional methods are used (installation of additional insulation, replacement of windows etc.). At the same time attention should be paid to the appropriate treatment of thermal bridges.

Thermal bridges are localized areas of low thermal resistance. Thermal bridges can occur at various locations of the building envelope and can result in increased heat flow, which causes additional transmission losses, lower inner surface temperatures and possible moisture and mould problems.

The international standard EN ISO 10211 [2] is dealing with thermal bridges, but there are national standards available in nearly every European Member State that cover calculation, requirements and good practice solutions.

Although new buildings present high insulation levels, thermal bridges affect heating needs for about 30% of the overall value [3]. In case of existing buildings, thermal bridges contribute to 23% of the total transmission heat loss of a building envelope. After renovation, thermal bridges account for only 10% if windows are re-located into additional external thermal insulation and balconies are rebuilt as best practice. Inversely, if the thermal bridges are not treated correctly during building renovation the impact of the thermal bridges might be up to 34%, depending on the wall insulation thickness [4]. This impact may reach up to 67% for a building with a hollow brick cavity wall [5].

At the same time, thermal bridge correction could determine an important reduction of the winter primary energy demand (25% for terraced houses, 17.5% for semi-detached house) with an overall annual energy savings about 8.5% [6].

Balcony is one of the critical elements in building envelope that leads to undesired heat loss. Concrete balcony slabs create a discontinuity in building envelope insulation, offer a less resistant path for heat flow, and result in thermal bridging. Next to windows and doors, exposed concrete balcony slabs are the second-largest source of thermal bridging in building envelope [7].

The aim of the present paper is to investigate the impact of thermal bridges due balcony to slab junction on the energy performance of a typical old residential building located in Kyiv, Ukraine, and explore effective solutions to improve the building's energy performance and address the thermal bridge effects.

Materials and methods. Description of the simulated balcony slab junctions. The balconies of a typical 5-story building (Figure 1) known as "khrushchovka" (seria I-464) built in 1960th were taken for thermal analysis. Such buildings are known for their pure thermal performance. The external walls are made from light weight concrete and their width varies from 0.25 to 0.35 m. The balcony slabs as well as ceiling slabs are made from reinforced concrete.

Figure 1. **A typical 5-story building known as "khrushchovka"**

The simplified geometrical model (reference case) of the connection of the balcony slab to the external wall is represented in Figure 2.

The model consists of a reinforced concrete balcony slab connected to the external wall. The balcony slab as well as the adjacent internal slab have a thickness of 10 cm. The external wall has a thickness of 25 cm.

The thermal conductivity of the external wall is 0.49 W/m·K. The materials of the balcony slab as well as the interior slab have a thermal conductivity of 2.1 W/m·K.

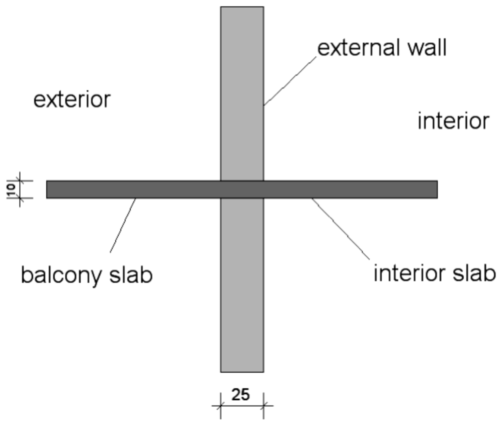

Figure 2. **The model of a reinforced concrete balcony slab. Reference case**

The proposed strategies to enhance thermal performance. The selected insulating material is 5 cm of mineral wool with a thermal conductivity of λ=0.04 W/(m·K).

Regarding the application of insulation such different cases were analyzed: no insulation (reference case); case 1: external wall insulation (5 cm of mineral wool with thermal conductivity of 0,4 W/m·K); case 2: external wall insulation (5 cm of mineral wool with thermal conductivity of 0,4 W/m·K); insulation of the upper side of the balcony slab (5 cm of mineral wool with thermal conductivity of 0,4 W/m·K); case 3: external wall insulation (5 cm of mineral wool with thermal conductivity of 0,4 W/m·K); insulation of the upper side of the balcony slab (5 cm of mineral wool with thermal conductivity of 0,4 W/m·K); insulation of the lower side of the balcony slab (5 cm of mineral wool with thermal conductivity of 0,4 W/m·K).

Thermal bridge calculation. Thermal performance of thermal bridges due to balcony slab junction was analyzed with the two-dimensional (2D) steady-state finite element heat-transfer simulation program Psi-Therm 2D calibrated according to the EN ISO 10211:2007 standard. The linear thermal transmittance of the thermal bridges Ψ, W/(m·K) was calculated by equation (1):

$$\Psi = L_{2D} - \Sigma U_j \cdot l_j, \text{ W/(m·K)}, \quad (1)$$

where L_{2D} is the thermal coupling coefficient obtained from the 2D calculation of the component separating the two environments being considered, W/(m·K); *Uj* is the thermal transmittance of the 1D component *j* separating the two environments being considered, W/(m^2·K); *lj* is the length over which the value *Uj* applies, m; length L_{2D} is equal to Σ*lj*.

In the calculations of linear thermal transmittance, average values of internal surface resistance from the EN ISO 6946:2007 (2007) [8] standard were used.

Point thermal bridges are not taken into account in this paper.

Apart from the minimum internal temperature at the ceiling-external wall junction the so called temperature factor f_{Rsi} has been calculated. The value describes the temperature drop independent of the actual temperature difference.

The temperature factor is used in assessing the risk of mould growth or surface condensation in the vicinity of thermal bridges.

The temperature factor (f_{Rsi}) is defined as follows:

$$f_{Rsi} = (T_{si} - T_e) / (T_i - T_e) \quad (2)$$

where: T_{si} is the minimum internal surface temperature, T_e is the external temperature, and T_i is the internal temperature.

For dwellings, the value of f_{Rsi} should be greater than or equal to 0.75, so as to avoid the risk of mould growth and surface condensation.

The interior temperature is 20°C, whereas the external temperature is -5°C.

Results and discussion. The calculation showed that that the linear thermal transmittance of the junction “balcony slab-external wall” in the building before retrofitting (reference case) is 0.344 W/m·K. It is seen that the lowest temperature at the ceiling-wall junction reaches only 13.78 ^{0}C and the temperature factor is 0.752.

The insulation of external walls with 5 cm of mineral wool decreases the U-value of plane elements. But, on the other hand, the thermal transmittance of the junction ‘balcony slab-external wall” increases. The calculation shows that in this case the thermal transmittance is even greater than in the previous case and constitutes 0.493 W/m·K. The application of the external wall insulation allows to increase the lowest temperature ant the temperature factor at the ceiling-wall junction up to 15.74 ^{o}C and 0.83, respectively .

The results of calculation of linear thermal transmittance in the case of insulation of the external wall as well as the upper side of the balcony slab shows that the thermal transmittance decreases very slightly and reaches only 0.437 W/m·K. It may be said that the case of a single sided insulation is practically ineffective from the reduction of linear thermal transmittance point view.. The modeling results shows that the lowest inner surface temperature at the ceiling-external wall junction is 16.05 ^{o}C, wherein the temperature factor reaches 0.842.

Finally, the calculation of linear thermal transmittance of the joint “balcony slab-external wall” for case 3 gives the lowest value of only 0.212 W/m·K. Wherein the internal

temperature and temperature factor near the joint reach the highest values of 17.3 ^{0}C and 0.892, correspondingly. The temperature profile within the junction is shown in Figure 3.

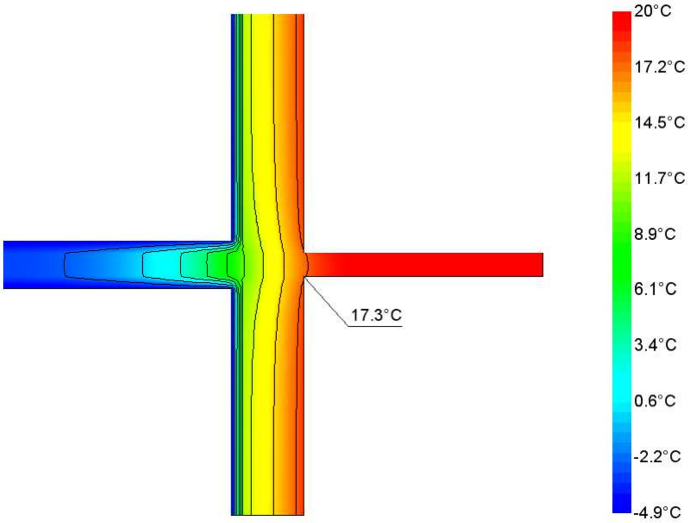

Figure 3. **Temperature profile for case 3**

The most effective way to minimize the heat transmittance of structural components (balconies, parapets, canopies) penetrating the insulation layer of an envelope is to thermally separate the exterior structure from the interior structure with the help of thermal breaks. But such approach may be inappropriate in retrofitting old buildings.

Conclusions. In this work, different retrofitting strategies have been analyzed by thermal modeling of balcony slab junctions. Results show that the simultaneous insulation of the external walls as well as upper and lower sides of balcony slabs to be a valid alternative in order to achieve energy savings. It may be said that the case of a single sided insulation of balcony slabs is practically ineffective.

An important outcome the modeling is that the thermal bridging effect of a balcony slab differs depending on the external wall thermal properties. While, on the one hand, the additional insulation of concrete external walls decreases the energy loss through plane elements, it promotes the rise of linear thermal transmittance of adjacent thermal bridges on the other hand. So, it is important to increase the thermal performance of plane building elements (external walls, roofs etc.) as well as adjacent thermal bridges at the same time.

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