**FACTA UNIVERSITATIS**
Series: **Architecture and Civil Engineering** Vol. 3, N$^o$ 1, 2004, pp. 57 - 68

# THE APPLICATION OF THE FACADE THERMAL INSULATION SYSTEMS DURING THE ENERGY CONSERVATION REMEDIAL MEASURES OF THE STRUCTURES BEING HEIGHTENED

*UDC 692.2:699.8+697.1:728.1(045)=20*

**Veliborka Bogdanović, Slobodan Samardžić**

Faculty of Civil Engineering and Architecture, University of Niš, Serbia and Montenegro

**Abstract**. *Bearing in mind the fact that during the design and construction of the additional stories to the residential buildings the standards about the heat technology in the civil engineering were not met for the entire structure, and very often not even for the additional stories of the structure, we deemed that it is necessary to emphasize the possibility of the heat balance improvements through the application of the facade thermal insulation systems on the non-insulated facade walls.*

*That this concept is valid, is supported by the fact that in practice, the aesthetic and functional repairs of the existing facade walls of the heightened buildings, offer a favorable substrate (basis) for the application of the facade thermal insulation systems and offers an opportunity for the regular remedial measures of the building, from the aspect of energy issues.*

*Therefore, the objective of the study is the quantification of the participation of the facade walls in the heat balance in several typical procedures of the heightening of residential buildings, and the analysis of the possibility of a correction by the application of the FACADE THERMAL INSULATION SYSTEMS.*

*Thus, the relevant parameters of the heat balance for the previous status of the building were analyzed for several characteristic building heightening cases, and they were compared to the parameters after the additional application of the facade thermal insulation systems.*

*The research results on the structures-models have been illustrated with sketches, graphs, diagrams and tables.*

**Key words**: *facade walls, heat balance, thermal insulation systems, building heightening.*

---

Received September 08, 2004

## 1. INTRODUCTION

In the national civil engineering practice, the heightening of the existing buildings has been introduced on a massive scale since the mid eighties. At first, the process was motivated by the remedy of the flat roofs and the protection from the rainwater leakage, so the lofts – mansards were constructed and the new apartments were obtained in such manner. Now, the heightening of the buildings became the dominant aspect of construction activities, and a very profitable business, irrespective of the fact whether there is a leakage problem in the roof structures or not and often disregarding the fulfillment of the minimal legislative regulations requirements and the professional conventions. Thus, in the individual cases two and even more stories were built over the existing ones. Without regarding the problems of stability and installations, we have wished to point to the problems in the field of the energy conservation and the energy efficiency in construction of the additional stories.

Namely, during the design and construction of the additional stories of the residential buildings, the standards of the heat technology in civil engineering are being neglected [2], not referring to the whole object, but only the added section is treated. It is not a rare occasion that even the heightened section of the structure does not include the thermally correct structures.

In practice, on the existing facades only the aesthetic and functional repairs are carried out, and the façade walls of the heightened part are constructed of the foamed concrete 20 or 25 cm thick, or of the hollow bricks.

Since a large part of the buildings being heightened was build prior to the enactment of the heat protection regulations, we assumed that their façade structures are not satisfactory in terms of the heat protection and energy conservation and that the remedial measures in terms of energy improvement is necessary.

As, in practice, the heat performances of the façade walls are not improved, one should expect that the heat balance of the entire structure will not be satisfactory. For this purpose, the analysis of the heat balance according to the JUS standards that regulate this field has been carried out on the model of a characteristic building with the variants of the loft heightening, of one floor and the loft and the two floors and the loft. The cases where no insulation is predicted are analyzed, then when only the added stories have the insulation and finally, when the insulation of the entire building is predicted.

For the insulation of the structures, in the analysis, the thermo-insulation systems [3] were chosen, having in mind their simple and fast application, with fulfilling all the functions of the insulation and façade siding. They are especially convenient for the subsequent application on the façade structures, which do not contain the thermal insulation materials, that is do not fulfill the requirements in terms of heat protection and heating energy conservation. The aesthetic and functional repairs of the existing façade walls of the heightened buildings form a good basis for the application of the thermal insulation façade systems and offer a realistic opportunity for the subsequent energetically correct remedy of the buildings.

At the end of analysis, the estimation of the cost-effectiveness of the investment into the application of the thermal insulation façade systems observed through the energy consumption saves is created.

## 2. THE ANALYSIS OF THE HEIGHTENED BUILDINGS HEAT BALANCE

The specific transmission heat loss $\Phi vt,doz$ (W/m$^3$) of the residential buildings whose premises are heated during the entire heating season to the temperatures higher than 12°C are, according to the standard JUS U.J5.600, limited depending on the relation of $f_0$ [1/m] surface area of the building siding structure A [m$^2$] and the contained heated volume of air V [m$^3$], according to the expression:

$$\Phi vt, doz \leq 7 + 14 f_0 \quad [\mathrm{W/m^3}] \tag{1}$$

The specific transmission heat loss Φvt u [W/m$^3$] is the transmission loss Φt in [W/m$^3$] of the building:

$$\Phi vt = \frac{\Phi t}{V} \quad [\mathrm{W/m^3}] \tag{2}$$

Calculation of the transmission heat loss is done with the following expression:

$$\Phi t = \frac{km \cdot A \cdot \Delta t}{\mathrm{V}} \quad [\mathrm{W/m^3}] \tag{3}$$

The coefficient $k_m$ in respect to JUS U.J5.510 is determined according to the expression:

$$km = \frac{\Sigma kz \cdot Az + \Sigma kpr \cdot Apr + 0.5 \Sigma kp \cdot Ap + \Sigma ksv \cdot Asv + \Sigma c \cdot kkr \cdot Akr}{A} \quad [\mathrm{W/m^2K}] \tag{4}$$

The indices associated to the coefficients denote, respectively, the exterior structures of the building: wall, window, ceiling over the basement that is floor on the ground, ceiling over the open passages, and the roof, that is floor towards the loft [4].

As during the heightening of the buildings, the surface area of the building siding and the heated volume of the structure vary [5], the analysis of the degree of influence of these variation on the specific heat loss has been carried out, on the models representing the heated volume of the existing building with the dimensions: 46.70m × 10.15m height 13m (Fig. 1), the same building with one additional loft constructed (Fig. 2), one storey and the loft (Fig. 3) and two stories and the loft (Fig. 4).

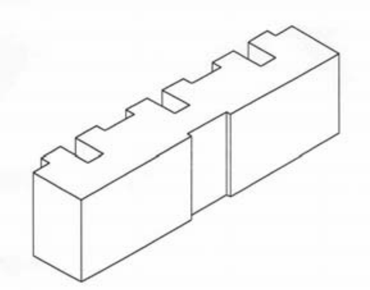

Fig. 1. Model of the heated volume of the existing building

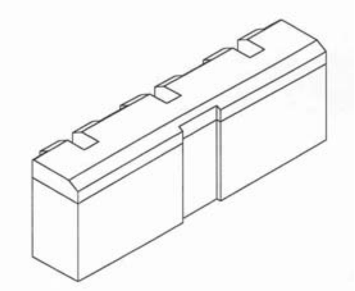

Fig. 2. Model of the heated volume of the existing building with an additional loft

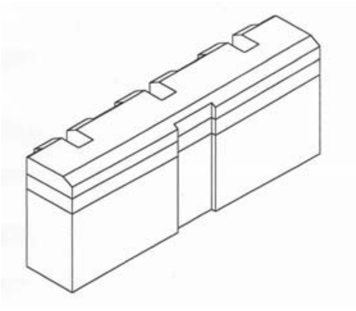

Fig. 3. Model of the heated volume of the existing building with an additional storey and a loft

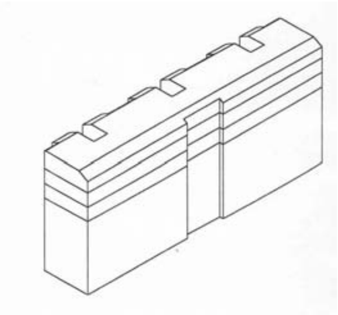

Fig 4. Model of the heated volume of the existing building with two additional stories and a loft

The chosen building is at a location in Nis, it has an unheated basement and the loft with an inclined roof above it [6]. The siding of building is composed of the structures which are characteristic for the period till 1970 for which the heat transfer coefficients are calculated. The existing walls of the unheated staircase – the internal walls are made of solid masonry units 25 cm thick, and the façade – external walls of the solid masonry units 25 and 38 cm thick. The new structure of the walls is made of the foamed concrete, and the roof structure is assumed to be constructed in accordance with the regulations. The new windows have the double glass with a layer of air 12mm thick. The heating energy is the electric energy.

The appearance of a characteristic building prior to addition of the stories is presented in the Figs. 5 and 6, and after the heightening in the Figs. 7 and 8.

Fig. 5. Appearance of the building prior to heightening viewed from the southwest side

Fig. 6. Appearance of the building prior to heightening viewed from the northwest side

It can be seen that the facades of the building are in good condition and that the heightening of the building in this case was not motivated by the leakage of the flat roof.

Fig. 7. Appearance of building after the heightening viewed from the west

Fig. 8. Appearance of the building after the addition of a storey and loft viewed from the southwest side.

The façade walls of the added section of the building are insulated, and the existing façade walls were just painted, without the additional insulation.

The results of the analysis of the current condition are presented in the Charts 1 and 2.

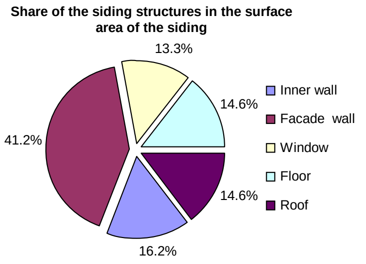

Chart1. The current condition Share of the siding structures in the surface area of the siding

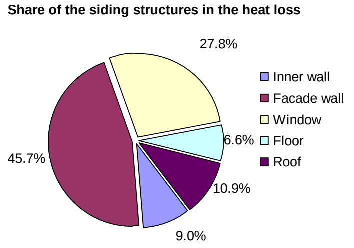

Chart 2. The current condition Share of the siding structures in the heat loss

The results of the analysis of the status after the addition of the loft are presented in the Charts 3 and 4.

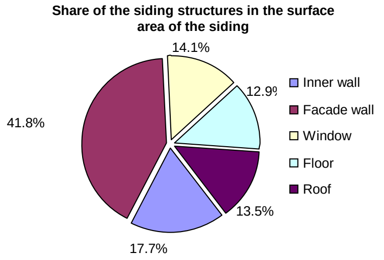

Chart 3. Addition of the loft Share of the siding structures in the surface area of the siding

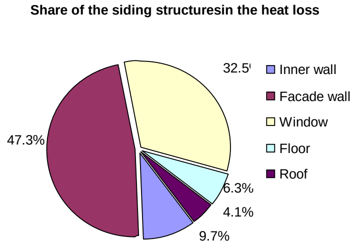

Chart 4. Addition of the loft Share of the siding structures in the heat loss

In order to analyze the trend of the influence of the siding structures on the heat loss with the increase of the heightening, an analysis in case of the addition of a storey and a loft and two stories and a loft was conducted and presented in the Charts 5 and 6.

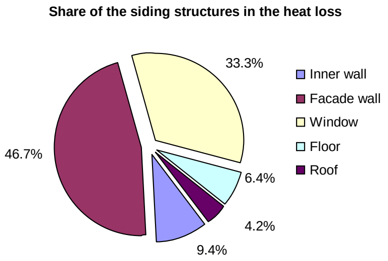

Chart 5. Addition of a storey and a loft Share of the siding structures in the heat loss

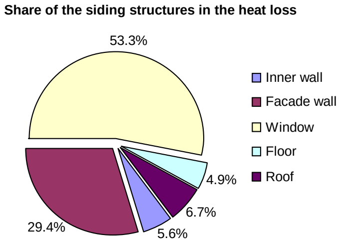

Chart 6. Addition of two stories and the loft. Share of the siding structures in the heat loss

It can be seen that the external walls and the windows have the most important influence on the heat loss. Owing to the fact that the new common windows have the similar coefficient of the heat conductivity as the existing – old windows, and that their remedy and change entails significant expenses, they were not treated in this analysis.

The trend of the influence of the various degrees of heightening on the shape factor may be seen in the Chart 7.

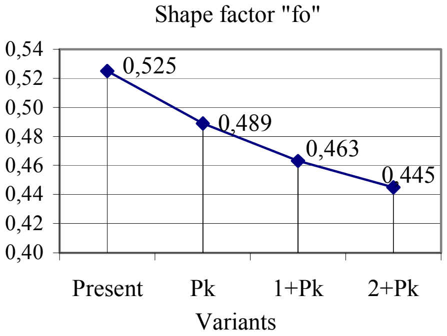

Chart 7. Change of value of the shape factor with the increase of the degree of heightening of the existing structure.

With the increase of the building height, the shape factor diminishes, which is energetically more favorable. Less energy is required for the building heating, for the case of the same degree of insulation for the lower and the higher building. However, along with the reduction of shape factor, the permissible specific transmission loss is lower. So the increase of the building height cannot contribute to the fulfillment of the limiting conditions of the specific transmission loss in cases when the existing section of the building is not insulated. In order to analytically verify this thesis, the heat design for the four variants with different shape factor and degree of insulation was done, and the results are presented in the Chart 8.

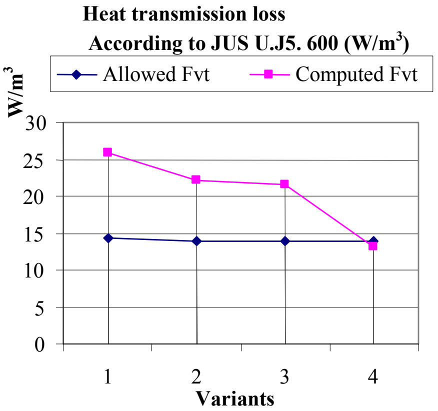

Chart 8. Reduction of the value of the heat loss with the increase of the degree of application of the thermal insulation system.

*Variant 1.*

Current status

*Variant 2.*

Heightening of the loft without the additional wall insulation

*Variant 3.*

Heightening of the loft with the application of the thermal insulation system $d = 6$ cm only on the walls of the added section.

*Variant 4.*

Heightening of the loft with the application of the thermal insulation system $d = 6$ cm of all the walls (including the existing walls)

In the Chart 8 it may be observed that the prescribed condition may be fulfilled only after the external and internal walls have been insulated, which was done here via lining with the façade thermal insulation system.

## 3. DIMENSIONING OF THE FAÇADE THERMAL INSULATION SYSTEM

Dimensioning of the thickness of the façade thermal insulation system for the model of the structure was done by the iterative procedure, and only at the thickness of $d = 6$ cm of the system, it has been achieved to contain the true specific heat loss of the building within the permissible limits, and only in the variant 4, which leads to the conclusion that the only correct measure in the energy remedying of the external building walls is the application of the system on all the external walls.

The most optimal and the most economical solution is the application of the system, $d = 6$ cm thickness on the façade walls with the additional insulation of the walls towards the unheated staircase, till the values prescribed by the standard are achieved. The possible compensation of the heat losses through the joinery is the simplest by the installment of the thermal screen in the cases when the attainment of the favorable heat balance by the increase of the thickness of the façade thermal insulation system is not rational or technically feasible [7].

## 4. COST-EFFECTIVENESS ANALYSIS OF THE FAÇADE THERMAL INSULATION SYSTEM APPLICATION

One of the frequent motives of the investors in avoiding the application of the façade thermal insulation systems during the heightening of the buildings is the increase of the construction costs, so usually only the walls are painted. In this way, the existing problems in terms of the durability of the existing walls are neglected, the thermal bridges remain, as wall as the cost for the heating of the existing apartments (except for the last existing storey). In order to determine the justification of these motives, we conducted an analysis of the cost-effectiveness of the additional insulation of the buildings, through the attained conservation of energy.

The value of the total heat transmission loss for the entire building for all of the four mentioned variants was calculated (Chart 9) as well as the heat transmission loss for the characteristic structure of the façade walls per 1 $m^2$ of the walls (Table 1), and the difference in the heat loss, and the saves in fuel consumption. The investment repayment time through the energy was determined as the quotient between the estimated value of the investment in the application of the thermal insulation system and the attained conservation in the fuel consumption.

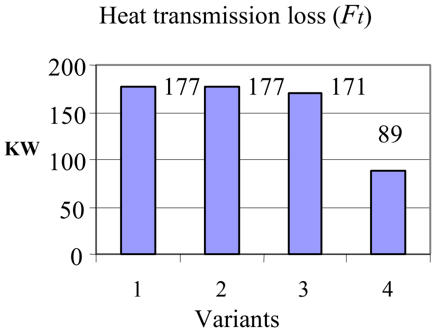

Chart 9. Heat Transmission loss for the four variants of remedial measures

The boundary conditions have been given for the city of Nis, for normal windiness and for a shielded building, for the residential building constantly heated with electric energy with a limitation in overnight heating and the temperature in the premises of 20ºC. For the calculation of energy consumption reduction, the expression 5 was used [8]

$$\Delta B = \frac{24 \cdot 3.6 \cdot e \cdot y \cdot SD \cdot \Delta\Phi t}{(tu - te) \cdot Hd \cdot \eta} \tag{5}$$

*e* – heating limiting coefficient (0.9)

*y* – simultaneity coefficient – building position (0.63)

*SD* – number of degree days for Nis (2613)

$\Delta\Phi t$ – difference in heat loss prior to and after the application of the thermal insulation systems

(*tu*–*te*) – temperature difference of the internal and external design temperature

*Hd* – heat capacity of the fuel - 3600 (kJ/KWh) for electric energy

$\eta$ – degree of the system efficiency (0.97) for the electric energy

By the application of the thermal insulation system 6 cm thick on the wall made of solid masonry units $d = 25$ cm thick, the save of the electric energy of 42.94 KWh per 1 m$^2$ of the façade wall is attained during one heating season. (Tab.1, Row 1. Col. 6.).

In case the price of electric energy of 0.04 €/kWh is taken into account, the save of 1.65 € per season by one square meter of the façade wall is obtained. Given the costs of providing and installing the thermal insulation system are 12 €/m$^2$ it means that the investment repayment time is 7.24 years. (Tab.1, Row 1. Col. 7.).

In Table 1 the results of the analysis of the cost-effectiveness of the application of the thermal insulation façade system on the characteristic types of the façade walls structures for the buildings built till 1980 were presented. In 1980, the "Codex of the Yugoslav standard for Heating Technology in Civil Engineering" came into effect [9].

The most favorable results in terms of the energy conservation and the cost-effectiveness of investment in the application of the façade thermal insulation system are when there are hollow brick walls $d = 19$ cm (which was applied en masse in the individual residential buildings) and the most unfavorable in the walls of the reinforced concrete panels, which already have the thermal insulation materials in them (applied in high-rise buildings after 1970).

Table 1.

| Wall designation | Wall materials | $d$ cm | $D$ cm | $k1$ W/m$^2$K | $k2$ W/m$^2$K | $\Delta\Phi t$ kWh/m$^2$year | Investment repayment time (year) |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Z1 | render<br>solid masonry unit<br>render | 2<br>25<br>2 | 29 | 1.67 | 0.54 | 42.94 | 7.24 |
| Z2 | render<br>solid masonry unit<br>render | 2<br>30<br>2 | 34 | 1.38 | 0.50 | 33.44 | 9.30 |
| Z3 | render<br>solid masonry unit<br>render | 2<br>38<br>2 | 42 | 1.25 | 0.48 | 29.26 | 10.63 |
| Z4 | render<br>hollow brick<br>render | 2<br>19<br>2 | 23 | 1.92 | 0.56 | 51.69 | **6.02** |
| Z5 | render<br>hollow brick<br>render | 2<br>24<br>2 | 27 | 1.66 | 0.54 | 42.56 | 7.31 |
| Z6 | render<br>hollow brick<br>hollow brick<br>render | 2<br>19<br>12<br>2 | 35 | 1.41 | 0.51 | 34.20 | 9.09 |
| Z7 | concrete<br>polystyrene<br>concrete | 16<br>5<br>6 | 27 | 0.67 | 0.36 | 11.78 | **26.40** |
| Z8 | render<br>concrete<br>hollow brick | 2<br>19<br>12 | 33 | 2.03 | 0.57 | 55.48 | 5.60 |
| Z9 | render<br>foamed-concrete<br>render | 2<br>20<br>2 | 24 | 0.93 | 0.43 | 19.00 | 16.37 |
| Z10 | render<br>foamed-concrete<br>render | 2<br>25<br>2 | 29 | 0.77 | 0.39 | 14.44 | 21.53 |

$k1$ – Heat transfer coefficient of the existing wall (W/m$^2$K)

$k2$ – Heat transfer coefficient of the existing wall, with the facade thermal insulation system is applied, $d = 6$ cm (W/m$^2$K)

It should be pointed out that this analysis does not account for the reduction of the transmission loss which is the consequence of the reduction of the linear heat loss and the interruption of the heat bridges, which would certainly indicate even higher energy efficiency in the application of the façade thermal insulation systems.

The analysis of the cost-effectiveness of the investment in the energy remedial measures of all the structures of the building siding is slightly more complex and requires a specific calculation for each individual building, because of the presence of different structures and differences in their degree of participation in the heat loss. The analysis for the presented building, yielded the investment repayment time of 8.85 years, which is optimal from the point of view of the building duration, and in respect to the price-increasing trend of the energy, it can only be shortened.

Both the users and the state benefit from the investment in the energy remedial measures of the building, but the investors do not have a direct profit from it.

## 5. ADDITIONAL POSITIVE EFFECTS

When it comes to the additional positive effects of the application of the thermal insulation façade systems, primarily the improvement of the physical performances of the wall should be pointed out as well as the reduction of the costs of reparation and maintenance. The thermal bridges are obstructed and the linear heat loss is reduced, which is one of the preconditions for the formation of the energetically rational and efficient buildings. The parameters of the heat comfort and comfortableness of the premises is improved due to the increase of the internal temperature of the walls. There are multiple effects, since there are a lot of buildings which could be remedied in the described way [10]. The wider application of the façade thermal insulation systems would bring about the significant reduction in the fossil fuels consumption, and thus would reduce the emission of the $CO_2$, $SO_2$ and other gasses that are the products of combustion, which, released into the atmosphere, cause global ecologic problems [11].

## 6. CONCLUSION

The aesthetic and functional repair of the facades of the heightened building and avoided additional insulation of the existing façade walls is a good basis for the application of the facade thermal insulation systems and the realistic opportunity for the subsequent correct remedy of the building in terms of energy conservation.

The research indicates that it is necessary to (in future designing practice) insist on the application of the regulations of the heat protection of buildings during the heightening, that is to fulfill the regulation requirements on the energy conservation by the remedial measures in relation to the entire building being heightened, and the that the most optimal method of the energy conservation remedial measures is the application of the façade thermal insulation systems.

The investors do not profit directly from the energy saves whose beneficiaries are the users and the state, but this is exactly the reason to have the interested parties participate in the affirmation of the thermal insulation systems.

The state should define the affirmative criteria for the improvement of the energy efficiency during the remedial measures and the heightening of the buildings, and introduce the measures which would be economically profitable for all the participants, in respect to the fact that the life time of the building is significantly longer than the investment repayment time, and that there are other positive accompanying effects.

## REFERENCES

1. Božović-Stamenović R. i dr.: "Nadgradnja višespratnih stambenih objekata - kritička analiza postojeće prakse", Zbornik radova sa naučnog skupa "Stanovanje 2/97; Prosveta, Niš, 1997, str. 135-140.
2. Pravilnik o jugoslovenskim standardima za toplotnu tehniku u građevinarstvu „Službeni list SFRJ" broj 6/2-02-1/10, 1998
3. Cziesielski E.: "Lehrbuch der Hochbaukonstruktionen", Teubner, Stuttgart, 1997, s. 341-349
4. Bogdanović V.: "Arhitektonsko građevinske konstrukcije toplotna zaštita zgrada", Građevinsko-arhitektonski fakultet u Nišu, Prosveta, 2000, str. 47-50.
5. Samardžić S.: Arhitektonsko preoblikovanje starih zgrada kao mogućnost uštede prostornih i energetskih resursa, Arhitektura i urbanizam, broj 8, Institut za arhitekturu i urbanizam Srbije, Beograd, 2001, str 73-78.
6. Samardžić S.: Metode sanacije višespratnih stambenih ygrada u cilju racionaliyacije preostornih i energetskih resursa, Magistarska teza, Građevinsko-arhitektonski fakultet u Nišu, Niš, 2001, str 157-165
7. Reyer E., Willems W. und Fouad H.A.: "Fassadensanierung", Lehrstuhl für Baukonstruktionen, Ingenierholzbau und Bauphysik der Ruhr Universität Bochum, Reyer E., Bochum 1993
8. Todorović B.: Projektovanje sistema za centralno grejanje, Mašinski fakultet Beograd, 1996, str. 45-76
9. Pravilnik o jugoslovenskim standardima za toplotnu tehniku u građevinarstvu 1980
10. Jovanović-Popović M.: Energetska optimizacija zgrada u kontekstu održive arhitekture, deo 1, Analiza strukture građevinskog fonda, Arhitektonski fakultet Univerziteta u Beogradu, 2003, s 59-76
11. Gerken D.: Wärmedämmverbundsysteme (WDVS) im Wohnbau, Instutut für Bauforschung e. V., Hannover, Fraunhofer IRB Verlag, Stuttgart, 1997, s. 95-110.

# APLIKACIJA TERMOIZOLACIONIH FASADNIH SISTEMA PRI ENERGETSKIM SANACIJAMA ZGRADA U NADGRADNJI

**Veliborka Bogdanović, Slobodan Samardžić**

*Polazeći od činjenice da prilikom projektovanja i izvođenja radova na nadgradnji stambenih zgrada nisu ispunjeni uslovi standarda o toplotnoj tehnici u građevinarstvu za celi objekat, a često ni kod nadgrađenog dela objekta, smatrali smo za potrebno da ukažemo na mogućnost poboljšanja toplotnog bilansa objekata aplikacijom termoizolacionih fasadnih sistema na neizolovane fasadne zidove.*

*U prilog ovom konceptu ide i to što praksa estetske i funkcionalne popravke postojećih fasadnih zidova nadgrađenih zgrada formira dobru podlogu za aplikaciju termoizolacionih fasadnih sistema i pruža realnu šansu za naknadnu energetski ispravnu sanaciju zgrada.*

*Stoga smo za cilj rada utvrdili kvantifikaciju učešća fasadnih zidova u toplotnom bilansu kod nekoliko tipičnih postupaka nadgradnje stambenih zgrada i analizu mogućnosti njegove korekcije naknadnom aplikacijom TERMOIZOLACIONIH FASADNIH SISTEMA.*

*U tom smislu su analizirani relevantni parametri toplotnog bilansa za prethodno stanje zgrada i za nakoliko karakterističnih slučajeva nadgradnje i upoređeni sa parametrima nakon dodatne aplikacije termoizolacionih fasadnih sistema.*

*Rezultati istraživanja na objektima-modelima su ilustovani skicama, grafikonima, dijagramima i tabelama.*