Improvement of Energy Performances of Dwelling Housing in Belgrade

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ABSTRACT: The main concern of this research is to estimate different possibilities of energy performances improvement of existing dwelling housing in settlement Konjarnik, Belgrade, Serbia. Different solutions for reduction of energy consumption for heating of existing dwelling housing are proposed and taken into consideration. Two hypothetical models of improvement of building envelope are created and the annual energy savings for space heating according to the models is recognized. Comparative analyses of energy performances of existing building and predicted models of improvement are carried out regarding energy savings and reduction of CO_2 emissions. The results show that significant energy savings and reduction of CO_2 emissions can be obtained with a very simple refurbishment measures.
Keywords: energy consumption, energy savings, dwelling housing, improvement, energy performance, CO_2 reduction

INTRODUCTION

New energy-efficient buildings represent yearly a small percentage in relation to total building stock. Up to the seventies the buildings were designed without consideration of energy demands and consumption. According to the data collected by Serbia Statistical Office, about 55 percent of the total of 583.908 existing housing units in Belgrade was built in this period [3]. This figure reveals that Belgrade's building stock has a significant number of buildings which energy performances have to be improved. It should not be disregarded because severe energy savings can be obtained. By appropriate methodological approach, the disadvantages of existing building could be solved.

The main concern of this research is to estimate different possibilities of energy performance improvement of existing dwelling housing in settlement Konjarnik, Belgrade, Serbia. More exactly, different solutions for reduction of energy consumption for heating of existing dwelling housing are proposed and taken into consideration.

Methodological approach includes analyses of characteristics of both the existing building and hypothetical improved models of the building, and comparative analyses of obtained results. This approach could generally be applicable for building refurbishment, but generalization of technical solutions and possible benefits have to be carefully individually considered.

PERFORMANCES OF THE EXISTING BUILDING

Lot of suburban settlements had been built in Belgrade after II World War. In that time a few prefabricated systems were mostly in use in our country which resulting in housing settlements consisted of a numerous of buildings with the same or similar layouts.

One of representatives of such architecture is housing settlement Konjarnik. Due to the city development, nowadays it is part of the urban city zone about 4 km far from the city center (Fig. 1). The subject of the analyses is one of the lamella of the dwelling housing in the street Deset avijaticara no. 7-15.

Urban Layout and Building Shape

Figure 1: Location of Konjarnik on the Belgrade city map

Figure 2: Typical south-west facade

The 8-storey building (ground floor, 6 floors and attic) consists of 5 row lamellas. For the analyses, the one of the central lamellas, entrance no. 11, is chosen

(Fig. 3). The building is situated in semi-closed block, on the south oriented hillside, parallel to the isohypses by its longer axis, which is in the east-west direction. The neighbouring buildings are on the long distance that prevents mutual overshading. Each lamella has a typical floor lay-out with four one-side oriented flats, more exactly two bigger flats are south oriented, meanwhile two smaller flats are north oriented (Fig. 4).

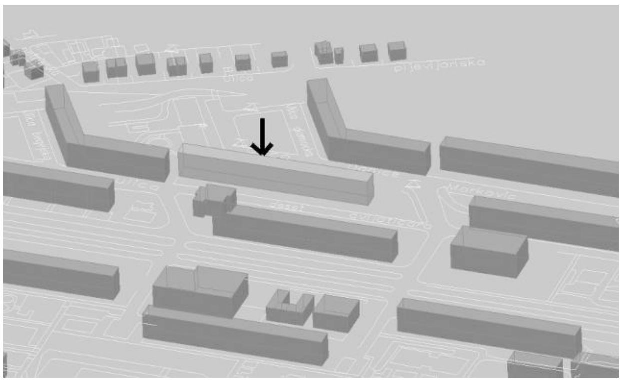

Figure 3: Location of the building in the semi-closed block

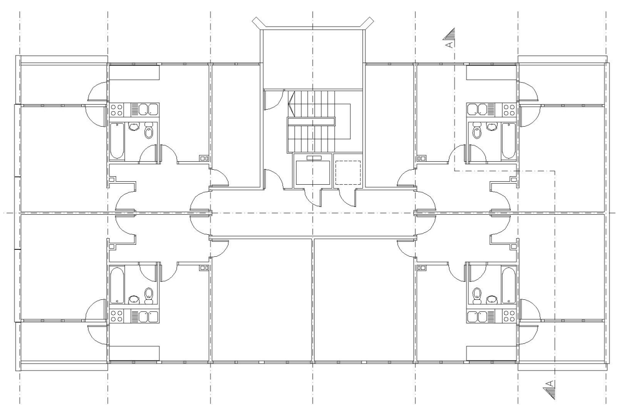

Figure 4: Typical layout of the lamellas floor

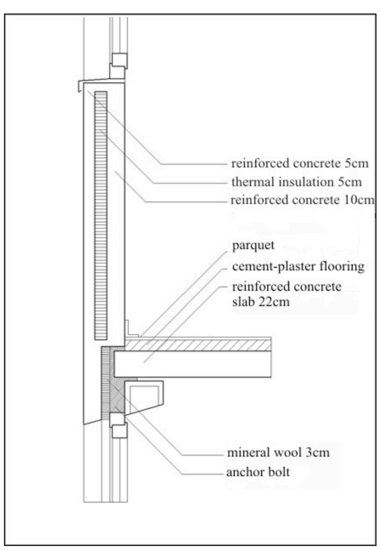

Figure 5: Existing wall (parapet) structure

Existing Building Envelope Structure The existing building was built in the late sixties of the 20th century as reinforced concrete prefabricated structure. Prefabricated panel structure is the rectangular and compact form, with poor energy characteristics.

Longitudinal facades consist of rows of parapets and windows which surfaces represent 70% of the facade and loggias that make 30% of the facade (Fig. 2). Parapets are three-layer prefabricated panels (internal concrete 10cm, thermal insulation 5cm, external concrete 5cm, U=0,68W/m^{2}K) with external finishing layer in ceramic tiles (Fig. 5). Along the edge of facade parapet panel, the concrete frame is present which results in the presence of thermal bridges and exceeding allowed U-value of external wall (actual U=1,034W/m^{2}K; the limit value is 0,9W/m^{2}K for Belgrade as second climatic zone).

Speaking in terms of thermodynamics, the windows are to be mentioned as the problem for both size and inappropriate thermal characteristics (U>3,0W/m2K) as well as the presence of the air infiltration. Windows are box type wooden structures, glazed with float glass of 4mm thickness, with internal cloth blinds.

Energy Consumption The official records from Belgrade institution of thermal power plants, based on data regarding energy consumption for heating in the last two years 2006-2008 (for the period from 15th October to 15th April), show that the average annual energy consumption for space heating for all five lamellas is 1946MWh. As the central lamella is the subject of analysis in the paper, it can be considered that comparing to final lamellas 20% less energy losses are present. Conclusion can be made that the annual energy consumption for central lamella is 353,81MWh, and 283,60kWh/m^2 respectively. These figures reveal that the very great energy consumption is present. It means that considering building is energy-inefficient. The reason for such energy consumption is improper envelope structure in sense of thermal performances resulting in:

- thermal losses
- overheating of the building,
- great ventilation losses
- losses in the heating system.

Distribution of thermal energy by the Belgrade institution of thermal power plants is not related to the Belgrade climatic conditions, which also reflects in the energy consumption.

THE RESEARCH METHODOLOGY

Methodological approach entails three steps:

- creation of two different models of the improvement of existing building

- thermodynamic simulations of the models in specialized software package TAS
- comparison of the results (models).

Design of Improved Models Design of improvement of the envelope of the existing building is created according to Belgrade climatic conditions, building orientation and technical characteristics of the existing building structure.

Climatic Conditions of The Location Climatic conditions of the location strongly influence refurbishment design. Official data of climatic conditions and weather fluctuation obtained by local weather stations are taken into consideration. Belgrade has a moderate continental climate, with four seasons. Autumn is longer than spring, with longer sunny and warm periods. Winter is not so severe, with an average of 21 days with temperature below zero. January is the coldest month, with average temperature of 0.1C°. Spring is short and rainy. Summer arrives abruptly. The average annual air temperature is 11.7C°. The hottest month is July (22.1C°). The average annual number of days with temperature higher than 30C° is 31 and that of summer days with temperature higher than 25C° is 95. Belgrade is the city with global irradiance of 1341.8kWh/m^2 (Polysun 4), and 2123.25 sunny hours per year. The highest insolation of about 10 hours a day is in July and August, while December and January are the cloudiest, with insolation of 2 to 2.3 hours per day. The characteristic of Belgrade climate is also Košava - the southeast-east wind, which brings clear and dry weather. The average speed of Košava is 25-43 km/h but certain strokes can reach up to 130 km/h. Košava is the largest air cleaner of Belgrade. The average annual rainfall on Belgrade and its surroundings is 669.5 mm. The rainiest months are May and June. The average number of snowy days is 27. Mean atmospheric pressure in Belgrade is 1,001 millibars and mean relative humidity is 69.5%.

Building Orientation Characteristics of building orientation are treated in the chapter entitled Urban layout and building shape and presented in Figure 3. Considering that the building is oriented as an ideal model in the north-south orientation, can be said to have good insolation, but only of south oriented apartments, while there is a lack of insolation of those north oriented flats, which are particularly vulnerable during winter. On the other hand it can be talk about overheating of the south oriented flats. The building is relatively well-protected by its position and neighboring buildings in relation to the dominant wind.

Structure of the Improved Envelope The following measures aimed to improve energy performances of building envelope can be listed [4]:

- Laying or improvement of thermal insulation and heat-bridges break, creating conventional structures.
- Addition of bay windows, balconies and loggias (usually glazed) and independent structures to increase the size of flats.
- Annex of attics to flat roofs or reconstruction of existing sloped roof constructions. Attic space can be used as living space (for new flats or expansion of flats underneath), office space of low frequency, community and children area, greenhouse, etc.
- Application of passive solar systems that includes: enlargement of south facing rooms; increase in size of south facing windows; glazing of south oriented external spaces - balconies and loggias becoming sunspaces, accompanied with thermo-accumulating walls in glassed-in spaces, if possible; glazing of north oriented balconies and loggias that become buffer zones; transformation of south facing solid walls into solar walls.
- Application of active solar systems that includes: installation of solar collectors for water and room heating, or PV modules providing electrical energy.

Necessity for reconstruction of flat roofs and housing shortage, increased by great number of last civil war refugees from former Yugoslavia parts, as well as the insufficiency of housing space in existing flats and high prices for newly constructed buildings, caused massive annex of attics on top of flat roofs especially in suburban areas [2]. Housing settlement Konjarnik is interesting example of massive annex of attics. Ten years ago such intervention had been realized on the top of the building which is the subject of this research.

The orientation of existing building points out that only south oriented flats are potential for solar energy usage. For this reason passive solar system such as solar wall is not taken into consideration because the thermal energy can be obtained only for south oriented flats. Glazing of loggias is favourable intervention both on north and south oriented facades. Application of active solar system, considering the possibility of centralized distribution of energy gains, might be considered suitable for the possible equal energy contribution to all apartments.

By the JUS standards which are still valid, the size of the windows in residential buildings is limited to 1/7 of room floor surface. This would require reduction of windows area which means changes in architectural characteristics that require the approval by Urban Planning City Office and author. Because of that, this intervention is not taken into consideration.

Suggestions of improvement which are considered as the most suitable and selected as measures of improvement of energy performances of dwelling housing in Konjarnik are increasing the thickness of thermal insulation, including thermal bridges brake, completely replacement of the windows by modern one, with improved thermal and solar features, and glazing of loggias. Two models of improvement of building envelope are selected:

- Model M1 is characterized by the following architectural improvement: increase in thickness of thermal insulation of the external wall to 10cm - 5cm of added expanded polystyrene (U=0,371W/m^{2}K), (Fig.6); replacement of existing windows with double glazed windows (4+12+4), made of five-chamber PVC profiles (U=2.3W/m^{2}K); increase in thickness of thermal insulation of the attic slab to 22cm - 10cm of added hard mineral wool (U=0,171W/m^{2}K); glazing of loggias with thermoinsulating glass panels (4+12+4), laid in five-chamber PVC profiles (U=2.3W/m^{2}K). Predicted exchanges of the air flow for Model 1 is 2 - 3 exchanges per hour.
- Model M2 is characterized by the following architectural improvements: increase in thickness of thermal insulation of external wall to 15cm - 10cm of added expanded polystyrene (U=0,255W/m^{2}K), (Fig.6); replacement of existing windows with triple low-emission glazed windows with argon filler, made of five-chamber PVC profiles (U=0.9W/m^{2}K); increase in thickness of thermal insulation of the attic slab to 22cm - 10cm added hard mineral wool (U=0,171W/m^{2}K); glazing of loggias with thermoinsulating glass panels (4+12+4), laid in five-chamber PVC profiles (U=2,3 W/m^{2}K). Predicted exchanges of the air flow for Model 2 is 0,8-1 exchanges per hour.

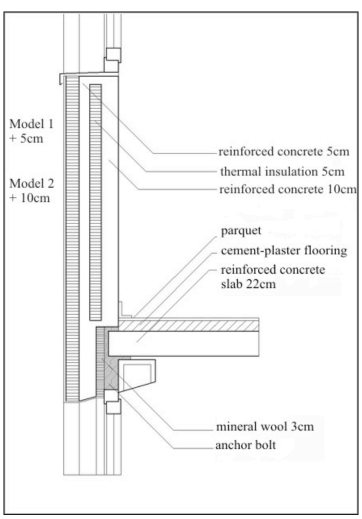

Figure 6: Improved wall (parapet) structure

Simulations of Models For simulation of building energy performances 3D mathematical models are created. Simulation is much more effective when used for comparing the predicted performance of design alternatives, rather then when used to predict the performance of a single design solution in absolute sense [1]. For that reason the following models of improvement are created: model 1 and model 2, which are characterized by different energy performances (Fig. 7).

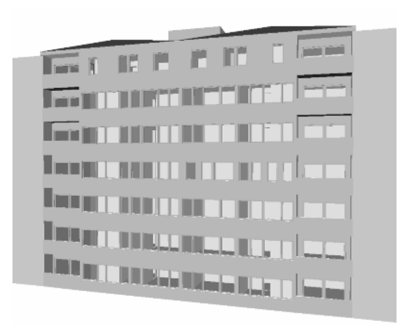

Figure 7: Lamella's facade used in numerical simulations

The simulations were run considering the maintenance of the point value of the indoor air temperature (from 20C° in the rooms to 22C° in bathroom) which providing satisfactory thermal comfort conditions through the heating period. For analyses and mathematical simulations of models the climatic conditions for territory of Belgrade are taken into account, related to daily temperatures during the year, frequency of temperatures, the frequency of solar radiation intensity, overcast frequency, wind speed frequency and its direction in winter, summer and transitional period.

Energy Consumption of Improved Models On the basis of the results of the thermodynamic simulation, model M1 states that the annual energy consumption for heating is 37,242.89kWh, and in relation to the effective lamella heating surface, that is 1250m^2, annual energy consumption for heating is 29.79kWh/m^2.

On the basis of the results of the thermodynamic simulation, model M2 states that the annual energy consumption for heating is 18,446.15kWh, and in relation to the effective lamella heating surface, that is 1250m^2, the annual energy consumption for heating is 14.75kWh/m^2.

Improvement of thermal comfort Regarding thermal performances, the existing parapet structure has following properties (Fig. 8): high thermal transmittance, i.e. U-value; low inner surface temperature; presence of condensation resulting in wet walls with possible freezing and mould growth. Presence of listed wall properties results in bad thermal comfort and poor living conditions badly influencing human health.

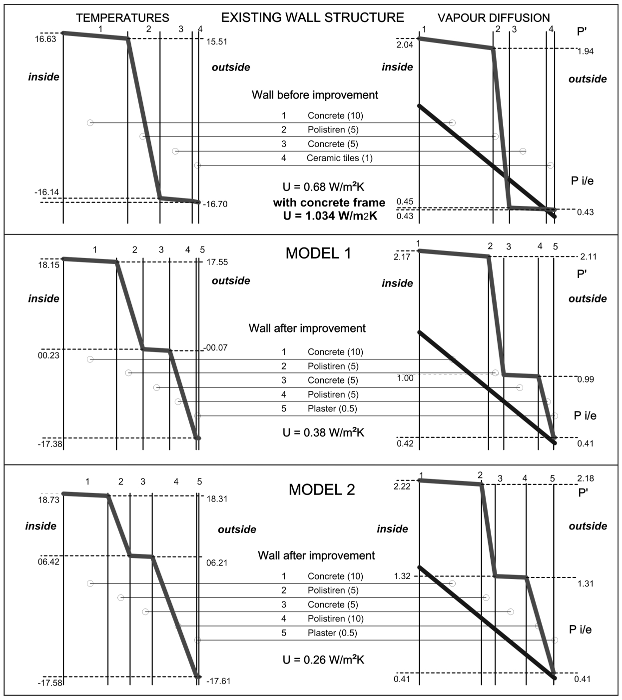

Figure 8:Wall thermal properties before and after improvement

Calculation method is used for evaluation of improvement of wall thermal performances. Belgrade is in the climate zone with the prescribed data that follows: a) for calculation of heat transmission coefficient (U-value) outdoor air temperature is t_o= –18°C, while indoor air temperature is t_i=+20°C; for calculation of vapour diffusion t_o= –5°C, b) for external walls U_{max}=0,9W/m2K in case of central heating and 0,81W/m^{2}K in case of individual heating, c) drying period (for moisture in construction in case of condensation) is 90days.

Laying of external thermal insulation provides the following benefits (Fig. 8):

- lower heat transmission coefficient and higher inner surface temperatures (t_{is}=+18,15°C and +18,73°C) are achieved, condensation and mould growth prevented
- improved wall function as thermal storage layer
- improvement of thermal comfort and living conditions in whole building.

Comparison of Results For all models the annual energy consumption for space heating according to the models is calculated, which is shown in Table 1 and Figure 9.

Table 1: Annual energy consumption for space heating according to the models

Model of the building	Energy consumption (kWh)
Model of the existing building	*353810.00*
Model 1	*37242.89*
Model 2	*18446.15*

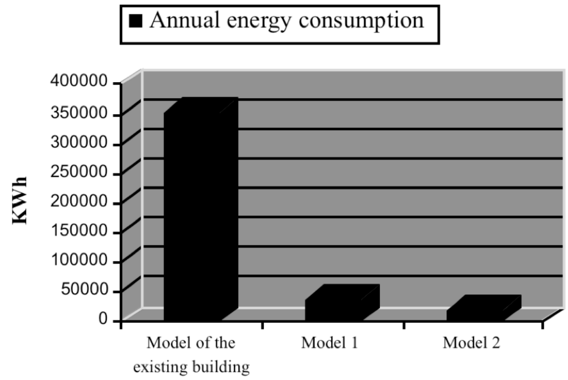

Figure 9: Comparison of annual energy consumption for space heating in existing building and improved models

According to the results of computer simulation in relation to the effective heating surface of the lamella that is 1250m^2, the annual energy consumption for heating per square meter is calculated, which is shown in Table 2 and Figure 10.

Table 2: Annual energy consumption per m^2 for space heating according to the models

Model of the building	Energy consumption (kWh/m^2)
Model of the existing building	*283.60*
Model 1	*29.79*
Model 2	*14.75*

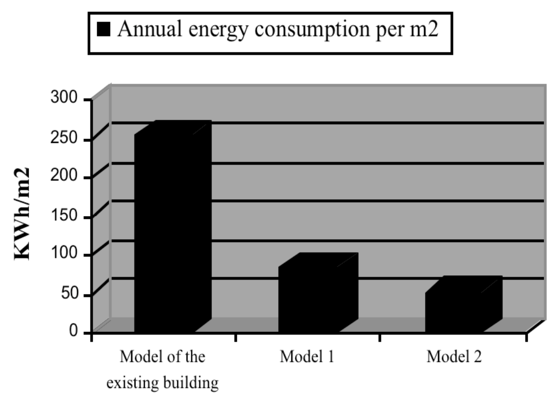

Figure 10: Comparison of annual energy consumption for space heating per square meter in existing building and improved models

Based on the analysis of energy consumption for space heating according to the models and taking into consideration German classification of buildings in sense of energy performances [5], the following conclusions can be made:

- Model of the existing building, with the yearly energy consumption for heating in the amount of

283.60kWh/m^2, shows the energy inefficiency and points out the necessity of improvement.

- Model M1, with the yearly energy consumption for heating in the amount of 29.79kWh/m^2, has performances of low energy building.
- Model M2, with the yearly energy consumption for heating in the amount of 14.75kWh/m^2, has the performance of passive houses whose annual energy needs for heating is less than 15kWh/m^2.

The mathematical simulation does not include losses in the heating system, so it is necessary in relation to the type of the system to predict the energy needs growth of 20–30%.

BENEFITS OF PREDICTED IMPROVEMENTS

Energy Savings The primary energy consumption for space heating in the case of improved models is reduced by more then 66% for Model 1, and more then 83% for Model 2. This stands that yearly energy demands reduction of approximately 316568kWh is obtained for Model 1, while in case of Model 2 amount of reduction is 335364kWh. In relation to the effective heating surface, energy demands reduction of approximately 254kWh/m^2 for Model 1 and 269kWh/m^2 for Model 2 is achieved. These energy demands reduction is produced by addition of thermal insulation, glazing of loggias and replacement of existing windows with new window types.

Reduction of CO_2 Emissions District heating is available in housing settlement Konjarnik, and water heating is based on fuel oil. In Table 3, values of yearly CO_2 emissions regarding existing building, i.e. central lamella, and improved models are presented.

Table 3: CO_2 emissions

Model of the building	CO_2 emissions (kg/year)
Model of the existing building	*91990.6*
Model 1	*9683.15*
Model 2	*4795.99*

In Table 4, values for yearly CO_2 emissions reduction by improvement of building envelope energy performances are presented for both models, showing significant reduction of CO_2 emissions.

Table 4: CO_2 reduction

Model of the building	CO_2 reduction (kg/year)
Model 1	*82307.45*
Model 2	*87194.61*

CONCLUSION

This work has highlighted the problems of existing Belgrade's building stock and necessity and possibilities of improving energy performance of building and their ecological impact. Refurbishment option could be seen as more modest and simple at the first glance referring to demolition and new development, but results made up in this research show efficiency in energy savings and CO_2 reductions, as well as improving housing quality. By improvement of thermal insulation and windows replacement, contribution to energy savings and improvement of the building appearance are achieved.

As in other parts of Europe there is a significant number of housing settlements with the same or similar prefabricated building, like in the case of settlement Konjarnik, presented improvement measures can be transferred into the regions with similar climatic conditions. The results of this research might be of an interest to initiate active involvement and support of all those involved in the building process: owners, consumers, authorities, architects, building industry, etc.

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