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ATTIC EXTENSION AND THERMAL RENOVATION OF THE RESIDENTIAL BUILDING (Case study)

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Buildings are the only resource growing constantly. Although relevant data for Serbia is not available, it is presumed that even more than 50% of energy production is spent on buildings in our country. This conclusion is based on two facts: the present industrial production and the state of buildings. In order to establish measures for energy efficient refurbishment, one residental building was analyzed in Belgrade. The chosen building represents the construction period when application of thermal insulation was not obligatory according to building regulation. As more than 35% of buildings were built in that period, they represent great potential for energy savings through the process of refurbishment.

INTRODUCTION – Scope of project

Buildings and built environment are the only resource that is constantly growing. At the same time, almost 50% of total energy production in developed western countries is spent in buildings. Although relevant data for Serbia is not available, it is presumed that even more than 50% of energy production is spent in buildings in our country. This conclusion is based on two facts: the present industrial production and the state of buildings. At the same time, according to the results of the Population Census in 2002 by the Statistical office of the Republic of Serbia, more than 35% of buildings in Belgrade were built in the period from 1950. to 1970. when application of thermal insulation was not obligatory and buildings were built without any thermal protection. These buildings represent high potential for energy savings through the process of renovation and refurbishment.

In order to establish measures for energy efficient refurbishment, residental building in Cvijiceva street 112-120 was analyzed. Since the building was built with a flat roof, , a vertical extension of building was designed as one of the measures. The sale of new appartments at the market is proposed as the best way for financing the refurbishment.

Case study treats a multistory residential building in Cvijićeva street No 112-120, Belgrade. The selected building is built in 1957, covers the area of 620 m2 and consists of basement, ground floor and 5 floors. Due to its length it has three separate entrances, and contains, in total, 38 flats, most of them in private property and 2 commercial units located in the ground floor.

The existing building is of a massive structure and in all aspects is built according to relevant regulations of the time of its errection. So far it has not been a subject of any significant changes of its original volume, apart from mass individual interventions of tenants regarding terraces and loggias on the courtyard side of the building. Due to the need for extra space of the existing flats in most cases these parts were closed and transformed into a living space.

In spite of visible consequences of poor maintenance of the building over the time (neglected facade, damaged metal covers along roof and terraces, neglected flat roof) the building is in a satisfactory state today. Having in mind the time of its erection, it is certain that, besides the noted imperfections, comfort of the building, especially thermal one, is far from being satisfactory according to the nowadays practice and regulations.

So far, the building has not been connected to the district heating system, so the heating is provided by the local heating system in individual flats. Today in most cases this considers the use of thermal-accumulated furnaces, while originally a system of individual chimneys in each habitable room has been provided.

As a result of the present state and definded principles and objectives, there are three independent groups of interventions on the building represented in this project:

a) Thermal insulation of the building envelope;
b) Renovation of a heating system, e.g. connection of the building to the district heating system
c) Extension of the building by addition of one more storey over the existing flat roof that is intended for residential and working units for young scientists from the University of Belgrade

It should be noted that Pilot project as a framework for the design project anticipates different forms of domestic and foreign donations. They should be partly realized through donation of a particular materials and products that should be implemented on the building, such as:

- Roof windows, included in the Serbian Product Program, from VELUX A/S
- Radiator thermostats from Danfoss A/S;

- Velocity regulated pumps from Grundfos A/S;
- Insulation products from Rockwool International A/S;

PLANNED INTERVENTIONS

Energy improvement of existing building envelope

Energy improvement of a building envelope of the existing building, proposed by Design program, is realized with addition of a new thermal insulation layer along the thermal envelope of the building, including a renovation of the existing wooden windows.

Addition of a new layer of thermal insulation with appropriate mortar layer finishing should be conducted on the following parts of the building in the noted thicknesses:

- along existing facade walls – 10cm (new U=0.3W/m2K)
- along inner walls surrounding staircases, corridors and halls – 5cm in case of existing 38cm thick walls, or 8cm for 25 or 20cm thick existing walls
- along the lower side of floor structure above the car acces to the courtyard – 10cm
- along the lower side of floor structure above basement or building entrance – 5cm

Addition of thermal insulation layers, in case of walls, should be applied to the masonry wall, in which case the existing rendering should be knocked off from the wall. In case of floor structures, existing reed ceiling should be removed and replaced with a hung armature net and fine steel net as a carrier of the insulation layer and support for final mortar layer.

Renovation of the existing wooden windows concerns their additional sealing and painting, and, in case of those facing the court yard side of the building, suppliance of new external roller shutters. In case of more serious damage of windows, which will be noted during the realization of this intervention, repair or, if necessary, the replacement with new windows will be performed.

Taking into account the diversity of individual tenants' interventions so far, primarily regarding closing of terraces and loggias, use of different colors on wall surfaces (defined on particular drawings in the project documentation) should be performed. This particular intervention will help in the simpliest and easiest way the process of unifying the appearance of the building in spite of present variety in types, shapes and sizes of windows. Regarding thermal renovation and optimization, masonry parts of walls of closed terraces should be treated in the same way as other solid parts of facade walls by addition of 10cm thick thermo insulation layer together with an adquate mortar layer finishing.

Considering the bad state and the lack of thermal insulation in the existing layers of a terrace on the 5th floor of the building along Cvijićeva street, this part of the building needs a special reconstruction. Since its position is in its whole length above the flats on the 4th floor, existing flat roof layer should be removed and further on replaced with new layers including a thermal insulation one.

Described procedure of facade repairment includes replacement of all damaged metal cover along facade openings, terraces and loggias, as well as painting of metal parts of banisters with adequate protective paints.

Connection to the district heating system

Planned connection of the building to the district heating system is a subject of a separate part of the project regarding thermo-technical instaltations.

From the perspective of building interventions neccessary for this purpose, connection to the district heating system requires transformation of part of basement space placed in the I entrance of the building into the heating substation room. This room is placed in the part of the common space of the building towards Cvijićeva street, used for wood storage at the time and not in use nowadays.

For the purpose of implementation of a central heating system, within the staircases and corridors of each unit of the building (entrances I, II and III), main vertical instalations, as well as horizontal distributive installations to each flat within the network were placed. Horizontal parts of instalations are supplied with individual heating gauges. Since the existing chimney channels are not in use anymore, some of the chimneys that were placed along the corridors have been partly demolished and transformed into new channels meant for placing vertical network of the heating system, as well as for other instalation systems that are needed to complete interventions on the building.

Vertical extension of the building

Vertical extension of the building has been done over the existing flat roof by adding a new attic. New floor space covers the total surface of the building, equal to one of the typical existing floors, due to which a new system of columns is placed along the edge of the 5th floor terrace supporting the floor structure extension of the last existing floor.

Volume of the additional floor is respecting the given urban conditions and is matching the height of the neighboring buildings. In order to provide the best possible interpolation with the surroundings, roof terrace along the neighboring building towards Ivankovačka street is made, while on the other end of the building there is a corner terrace on the street side of the building that improves connection of neighboring roofs.

Within the limits of the new attic floor, several units (studios) are designed for residential and work purposes for young scientists – assistants from the University of Belgrade during their postgraduate studies.

In order to provide to most possible space for the attic floor and since implementation of the central heating system is a constitutional part of the Pilot project, the existing chimney channels are closed and their roof endings demolished, wherever it proved possible. However, according to the current building regulations, one chimney for each flat has been provided as a so called spare chimney.

Access to the new residential units are provided trough the existing staircases by adding one more level of stairs. At the same time, adequate reconstruction of existing lift (elevator) houses is also done, in order to provide an unobstructed access to the new storey. Reconstruction considers dimensional change of lift houses by demolition the existing and building a new one according to the current regulations. Position and size of new lift houses are adjusted to functional needs of a new storey, but it should be noted that this intervention does not consider any moving of the existing lift mechanism.

Due to the increasement of number of stories of the building, instalation of a fire hydrant network is planned and placed within the staircase space. This intervention imposes a new connection to the street water pipe and installation of a new water gauge. Besides the fire hydrant network itself, a special room for placing a hydro station unit is made in the basement space of the first entrance of the building. This particular installation system and all relevant interventions are described in details as a part of the technical documentation regarding water supply and sewage system of the building.

New residential and working units in the attics are designed as a system of small independant units for individual users. Depending on the space potentials, there are two types of units: Type A – a studio of approximately 30 m^2, consisting of a combined room, kitchenette and a bathroom, and Type B – a one bedroom unit of approximately 45 – 50 m^2 that consists of the same rooms plus a separate bedroom.

According to the design project, residential units, regardless of their type, are built and equipped in the following way:

Materials and structures

1) Structural elements of a new storey

- *Additional staircase level* towards the new storey - reinforced concrete staircase
- *Walls* - massive, reinforced according to the relevant seismic regulations; depending on demands related to thermal, fire-protection or other building regulations, built with ceramic blocks, or bricks; Disposition of structural walls should be in accordance with position of an existing structure.
- *Roof structure* - wooden, having a form that is in accordance with the relevant urban and technical conditions. Primary roof structure is designed as a system of horizontal roof beams leaned on the edge of a massive floor structure, or a massive wall; secondary structure is made of nailed thin wooden elements 5/25cm that are placed on an adequate distance. Horizontal stiffness of the roof structure is provided with a wooden plank layer placed over the upper side of secondary structure.

2) Roof envelope:

- roof cover - plasticized ribbed steel plates
- thermal insulation - 20 cm mineral wool
- ceiling - gypsum plates

Structure of a roof envelope is designed as a double ventilated one, preventing overheating during the summer period.

3) Facade walls and inner walls around staircases (as in the energy renovated existing part of a building) - thermal insulation layer of mineral wool of adequate thickness (10 cm on a facade; 8cm towards staircase) with an adequate final mortar rendering layer.

Along terraces in the attic floor, facade wall is made as a light wooden structure filled with 14 cm mineral wool and finalized from the inside with gypsum plates, and from the outside with plasticized ribbed steel plates (same is used as a roof cover).

4) Windows - mostly adequate roof windows; in case of facade walls, when necessary, wooden or PVC windows, or balcony doors, the structure is of single frames with thermo-isolated glass and equipped with external roller shutters

5) Partition walls - 6.5 or 12 cm brick masonry walls; depending on a type of a room, walls are plastered and painted, or tiled with ceramic tiles.

6) Floors:

In apartments: in bathrooms and kitchens – 1st class ceramic tiles, in other rooms – 1st class beech parquet.

Staircases and access – casted terrazzo.

Drawings

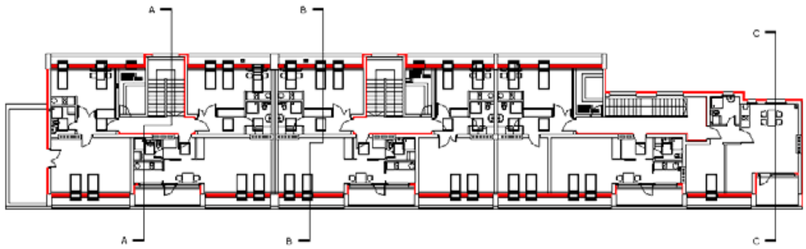


Fig.1. Extension of the existing building, attic layout

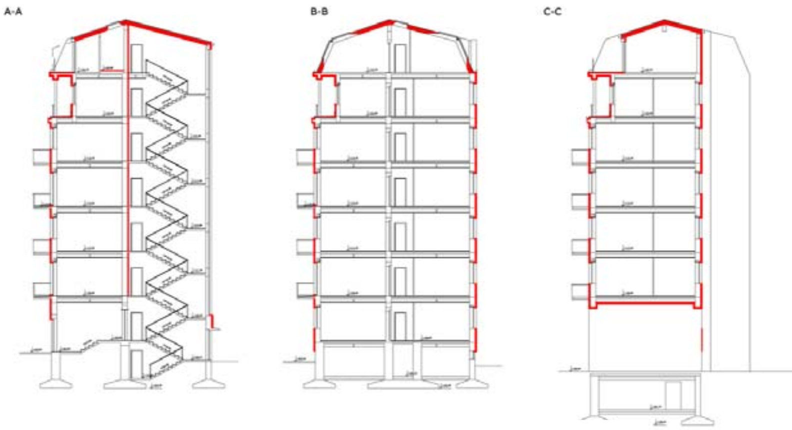


Fig.2. Cross sections, existing building with attic extension

Pictures of existing building and 3D model of suggested refurbishment

Fig.3. Street facade, residential building, Cvijićeva str. 112-120

Fig.4. Street facade after refurbishment, residential building, Cvijićeva str. 112-120

Fig.5. Court yard facade, residential building, Cvijićeva str. 112-120

Fig.6. Court yard facade after refurbishment, residential building, Cvijićeva str. 112-120

Installations and equipment

As proposed by the design, residential units are equipped with electrical and low voltage installations (phone, cable TV, intercom, prepared for local area network). This, requires introduction of new vertical distributive installations through the staircase space. For the need of water and sewage installations, existing vertical installations are extended, or if they cannot provide connection of all units to the existing networks, the installations should go through staircase space. Distribution of these horizontal installations within residential units should be done over the existing roof / under the new floor. Electrical boilers should be installed in each apartment.

These installation systems are subject of separate parts of technical documentation.

Individual residential units are equipped with built-in kitchen elements, including refrigerator and stove, as well as fully equipped bathroom, each of them having a washing machine. The units are designed and equipped with built-in cupboards.

PRELIMINARY ENERGY & IEQ ANALYSIS

The main aim of this analysis is to investigate energy saving opportunities for the reconstructed building. The analysis will emphasize the importance of improving building envelope as well as cost-benefit gain caused by lowering annual energy costs while improving indoor environment comfort.

The dynamic building model (DOE 2.2) is established for the Base case and for the reconstructed case. All building's parameters are determined and they represent typical building's usage and characteristics. The only two differences between analyzed buildings are presented in Table 1. The buildings are analyzed for the Belgrade typical meteorological climate data (TMY2).

Energy Analysis

The obtained results presented hereafter verify suitability of implementing insulation improvements as an effective energy efficiency strategy. Estimated monthly energy load has been reduced by 59÷100%, while estimated annual energy load has been reduced by 65%.

Economic Analysis

The economic analysis is performed for the following assumptions:

- 15 % of heating load is provided by electric resistance heating
- 15 % of heating load is provided by Split system unit Heat pump
- 70 % of heating load is provided by electric resistance heating with heat storage

Electric resistance heating with heat storage is widespread way of heating exploiting the fact that the utility rate has attractive night tariff which is four times cheaper than day tariff. Other tariff specific parameters such as red and blue zone tariff have been also analyzed. The possibility of implementing district heating is also included into consideration.

It is most likely for the Base case that the electricity usage will be at level above 1600 kWh/Mo. i.e. the electricity cost will be calculated by red zone tariff. For the Improved case it is most likely that the blue zone tariff will be used. District heating cost is calculated on €/m^2 basis. There is another way of charging that involves €/kW (Improved case will have reduced Installed Heating Capacity), which could yield lower District heating cost. The last one should be verified by further analysis.

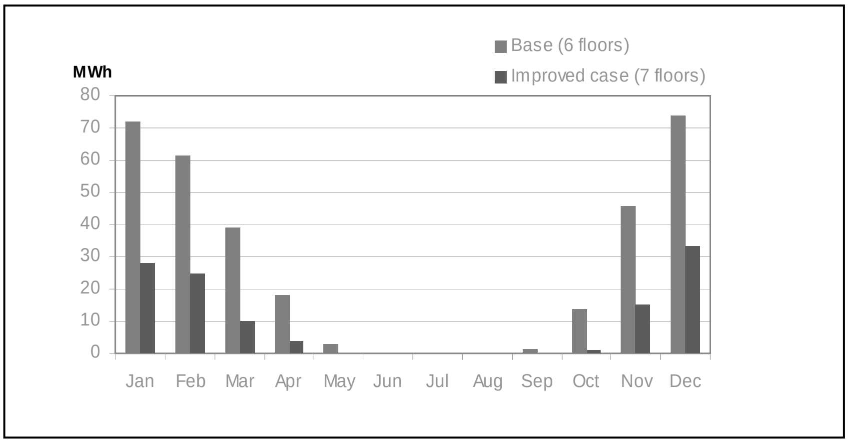
Indoor Environment Quality

Improving insulation level will have significant influence on indoor air temperature as well as issues concerning mean radiant temperature and temperature asymmetry. On the other hand it is possible to introduce more fresh air and still to have lower energy bills comparing to Base case. The only drawback is that the summer indoor air temperatures will be higher, but this could be easily resolved by Natural ventilation.

Table 1. Differences between two analyzed

	Base Case	Improved Case
External Wall Construction	Brick 38 cm	Brick 38 cm + Styrodur 10 cm
Roof Insulation	N/A	Styrodur 20 cm
Number of Floors	6	7

Picture 1. Annual Energy Load



Picture 2. Annual Energy Cost

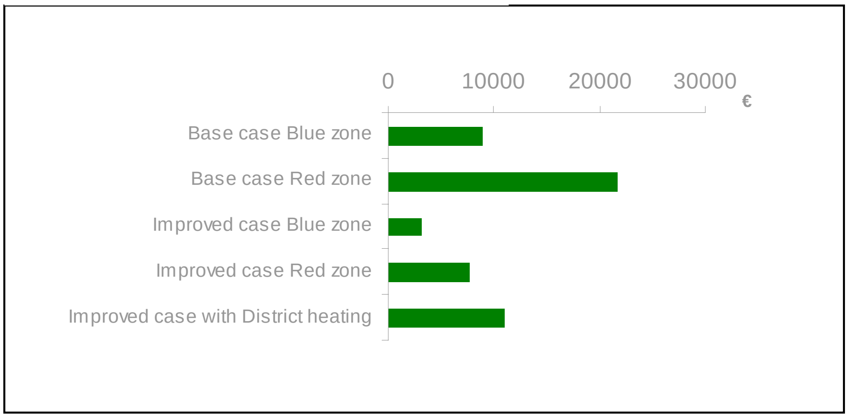


Table 2. Simple Pay Back Period Analysis

	Annual Electricity Cost Savings	Simple Pay Back Period
Improved Case Red Zone	18.629 □	???
Improved Case Dist. Heating	10.785 □	???

CONCLUSION

About 50% or more of produced energy is spent in buildings and about 35% of buildings in Belgrade are built in the period when there were no building thermal protection regulations. Accordingly, energy efficiency improvement through building refurbishment is one of the methods for energy savings at the national level.

Residential building in Cvijiceva street was analyzed as a pilot project. Refurbishment measures were: improvement of envelope thermal characteristics by adding thermal insulation on external walls, repair of windows and doors, connection to district central heating system.

This preliminary energy analysis have shown that improving insulation level will lead to both Energy cost and Indoor environment improvements. Detailed Energy and Indoor Environment Quality analysis should be performed in order to verify and further improve results hereby presented.

The preliminary cost analysis has shown that it is possible to finance all the measures of refurbishment by extending the building, adding attic on the flat roof and selling new flats at the market.

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