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5th INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

EDITORS
ALEKSANDRA KRSTIĆ-FURUNDŽIĆ
MILENA VUKMIROVIĆ
EVA VANIŠTA LAZAREVIĆ
AND ALEKSANDRA ĐUKIĆ

PLACES AND TECHNOLOGIES 2018

THE 5TH INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

EDITORS:
Aleksandra Krstić-Furundžić, Milena Vukmirović, Eva Vaništa Lazarević, Aleksandra Đukić
FOR PUBLISHER: Vladan Đokić
PUBLISHER: University of Belgrade - Faculty of Architecture
DESIGN: Stanislav Mirković
TECHNICAL SUPPORT: Jana Milovanović
PLACE AND YEAR: Belgrade 2018
ISBN: 978-86-7924-199-3
PRINTED BY: University of Belgrade - Faculty of Architecture

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REFURBISHMENT OF POST-WAR PREFABRICATED MULTIFAMILY BUILDINGS

Aleksandra Krstić-Furundžić[1], PhD
Full Professor, Faculty of Architecture, University of Belgrade, Bulevarkralja Aleksandra 73/II, 11000 Belgrade, Serbia, e-mail: akrstic@arh.bg.ac.rs
Tatjana Kosić, PhD
Research Associate, Innovation Center, Faculty of Mechanical Engineering, University of Belgrade, KraljiceMarije 16, 11000 Belgrade, Serbia, e-mail: tkosic@mas.bg.ac.rs

ABSTRACT

Several suburban settlements had been built in Belgrade after the World War II. In that time, a few prefabricated systems were mostly in use in our country which resulted in housing settlements consisting of numerous buildings with the same or similar layouts. They are all characterized by poor energy performance causing high energy consumption (for heating and cooling) and CO_2 emissions. One of the examples of such architecture is the Konjarnikhousing settlement. Different scenarios-hypothetical models for the energy performance improvement of the envelope of the central block of the prefabricated multifamily building in Konjarnik are created. The design of improvements of the envelope of the existing buildings is created according to Belgrade's climatic conditions, building orientation and technical characteristics of the building structure.The assessment of the reduction in energy consumption for space heating and thus the reduction of CO_2 emissions has been carried out in the paper. Methodological approach entails the following steps: creation of models of the improvement of existing buildings, consideration of the results of thermodynamic simulations of energy performances of the modelsin terms of energy consumption and CO_2 emissions, and comparison of the results (models).

Keywords: **Building refurbishment, Prefabricated buildings, Energy savings, Reduction of CO_2 emission, Post-war residential buildings.**

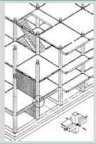
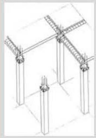
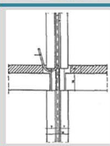
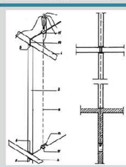
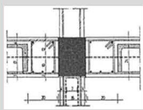
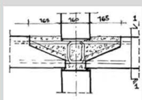
Introduction

New energy-efficient buildings represent a small percentage in relation to the total building stock. Until 1970s, buildings were designed without consideration of energy demands andconsumption. According to the data collected by Serbia's Statistical Office, about 55 percent of the total of 583,908 existing housing units in Belgrade was built in this period (Krstic-Furundzic and Bogdanov, 2010). This figure reveals that Belgrade's building stock has a significant number of buildings whose energy performance has to be improved. It should not be disregarded because significant energy savings can be achieved.

Many suburban settlements had been built in Belgrade after the World War II. In that time, a few prefabricated systems were mostly in use in our countryresulting in housing settlements which consisted of numerous buildings with the same or similar layouts.Various precast panel and skeleton-frame systems were used. The most frequently used panel systems were: ″Trudbenik″, ″Napred-Dillon″, ″Komgrap-Standard beton″, ″Neimar Beograd-NB″ and ″Rad-Balency″, while mostly applied skeleton-frame systems were: ″IMS″, ″Ramit-Ratko Mitrovic″ and ″Dom″ (Table 1).

1 Corresponding author

Table 1: Industrialized prefabricated systems for housing in Belgrade

TYPE OF THE INDISTRIALIZED SYSTEM		PERIOD OF PRODUCTION	APPEARANCE OF THE BUILDING	CONSTRUCTION DETAILS
Skeleton structure	IMS	1957-1982		
Skeleton structure	RAMIT-Ratko Mitrovic	1966-1980		
Skeleton structure	DOM	1970-1980		
Panel structure	KOMGRAP-Standard beton 'KSB'	1960-1980		
Panel structure	TRUDBENIK	1962-1980		
Panel structure	NEIMAR Beograd-NB	1963-1980		
Panel structure	RAD-BALENCY	1973-1980		

During the construction period from 1957 to 1982, the number of new residential units in a variety of prefabricated systems amounts to approximately 56,500, as shown in Table 2. The most intensive construction in prefabricated systems was in the period 1968-1978 when approximately 38,200 apartments were built, while the average annual number of prefabricated housing units in this period was around 3,500.In the period of 28 years (from 1945 to 1973) in Yugoslavia 2.1 million homes were built in prefabricated systems of which 1.313 million dwellings were built in 10 years, from 1965 to 1975 (Cagicet al., 1978).Most of these residential buildings have precast facade made up of rows of parapets and windows, especially in the first period of prefabricated construction.

Table 2: Production of prefabricated housing units

Type of the structure	Name of the industrial system of housing construction	Beginning of the construction in the system	Origin of the system: License	Origin of the system: Local authors	Realized production of housing units 1957–1967	Realized production of housing units 1968–1978	Realized production of housing units 1979–1982	Average annual number of housing units in the period 1968-1978	Total housing units since the beginning of the exploitation until 1982
Skeleton structure	IMS	1957	-	+	4,908	12,222	3,320	1,111	20,450
	RAMIT-Ratko Mitrovic	1966	-	+	547	4,530	133	412	5,210
	DOM	1970	-	+		2,289	983	208	3,272
Panel structure	KOMGRAP-Standard beton 'KSB'	1960	-	+	660	1,912	440	174	3,012
	TRUDBENIK	1962	-	+	1,700	9,863	627	897	12,190
	NEIMAR Beograd-NB	1963	-	+	820	3,200	480	291	4,500
	RAD-BALENCY	1973	+	-		1,972	1,780	179	3,752
Combined systems with prefabricated facades			-	+	1,100	2,173	927	198	4,200
TOTAL					9,735	38,161	8,690	3,470	56,586

The main concern of this research is to estimate different possibilities of energy performance improvement ofexisting prefabricated buildings in Belgrade, Serbia. As a case study, a multi-family building located in Konjarnik settlement in Belgrade was selected.Regarding the Rulebook on energy efficiency of buildings, the existing buildings in Konjarnik, as well as in majority of housing settlements built after the World War II in Belgrade, have unsatisfactory energy performance due to poor technical characteristics of the building envelope. Due to the insufficiency or absence of thermal insulation and inadequate construction/structural details in terms of building physics, ~~the~~inherited residential buildings are "squanderers"of energy with poor indoor environments - "sick houses", badly influencing human health (Krstic-Furundzic, 2010) and indicating the need for energy renewal. Different solutions for reducing energy consumption of existing prefabricated buildings are proposed and examined.

The research methodology

Different scenarios-hypothetical models of energy performance improvements of the existing building envelope are proposedand reductions of energy demands for space heating, and the related reduction of CO_2 emissions, are estimated. The methodological approach includes the analysis of the characteristics of the existing buildingand the hypothetical models of building envelope improvements, as well as the comparative analysis of the results.This approach could generally be applicable for building refurbishment, but generalization of technical solutions and possible benefits have to be carefully individually considered.

Energy renewalof the envelope of existing prefabricated multifamily building

One of representatives of post-war architecture is housing settlement Konjarnik. Due to the city development, nowadays it is part of the urban city zone about 4 kilometers far from the city center. The building is located in a semi-closed block, on the south oriented hillside. Its longer, east-west axis is parallel to the isohypses. The neighbouring buildings are sufficiently far to prevent overshading. The subject of the analyses is the central block of the 8-storey dwelling building. Each block has a typical floor layout with four one-side oriented flats.

In the settlement Konjarnik all buildings were built in the late 1960's and beginning of 1970's as reinforced concrete prefabricated structuresin the panel system "Trudbenik".This panel system is one of the most commonly used systems in which about 12,200 apartmentswere built in the period 1957-1982.The simple layouts and unappealing appearance of the buildings were recognised as negative characteristics of the selected structural system.The main characteristics of the facades are the alternating rows of large windows and parapet walls, which influence the energy performance of the building envelope.

Regarding thermal performances, the prefabricated parapet structures of existing buildings in Konjarnik have the following properties: high thermal transmittance, i.e. U-value; low inner surface temperature; condensation onthe internal wall surface with possible freezing and mould growth(Krstic-Furundzic, 2010). Thesebuilding envelope properties cause poor thermal comfort and living conditions which have a negative influence on human health.

Design of improved models of the prefabricated building envelope

Design of different models of the envelope improvements is proposed according to Belgrade climatic conditions and building location and orientation (Figure 1), as well as technical characteristics of the existing building structure.

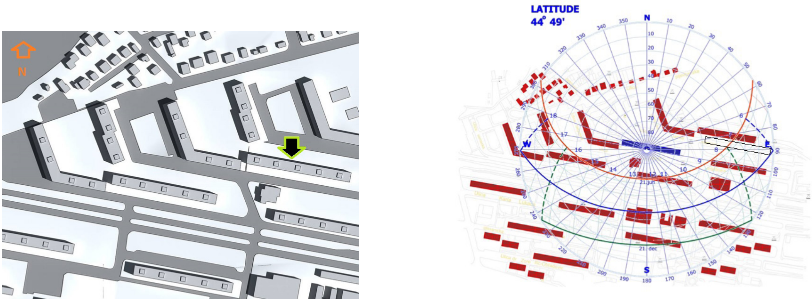
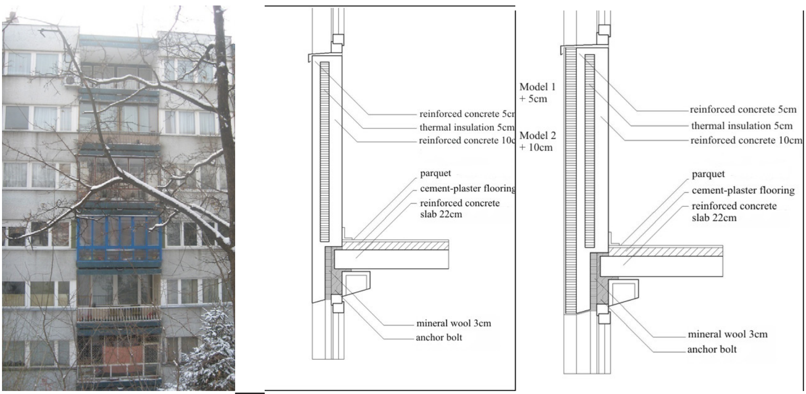


Figure 1: Building location(left) and Sun path (right)

New Serbian regulations on energy efficiency of buildings, in case of building refurbishment, require U-value of 0.4 W/m^{2}K, which is the case of Belgrade as the second climatic zone. As shown in Table 1, existing parapet walls do not meet this requirement (U=0.67 W/m^{2}K). The uninsulated concrete frame at the parapet edges acts as thermal bridge which results in the U-value of 1,034 W/m^{2}K (Kosic et al., 2009). In terms of thermodynamics, the windows are the problem for both the size and poor thermal characteristics (U>3.0 W/m^{2}K) as well as air infiltration. The box-type timber windows have single glazing of 4mm glass for each sash and internal cloth blinds.As the most suitable, the following improvement measures are selected: increasing the thickness of thermal insulation, including thermal bridges break, complete replacement of the windows with modern ones with high thermal and solar characteristics, and glazing of loggias. The structure of the existing and two selected improved models of the building envelope (M1 and M2) are shown in Figure 2 and Table 3.



a) b)

Figure 2: The facade of the building and details:a) existing wall structure; b) improved wall structure.

Table 3: Thermal performance of the envelope of the existing building and models with applied improvement measures

MODELS	PARAPET WALL		ATTIC SLAB		GLAZING				Predicted exchanges of the air flow
					Windows		Loggias		
	Wall structure	U-value [W/m²K]	Thickness of thermal insulation	U-value [W/m²K]	Type of glazing and profiles	U-value [W/m²K]	Type of glazing and profiles	U-value [W/m²K]	
Existing building Model	internal concrete 10cm, thermal insulation 5cm, external concrete 5cm	0.67 (1.034 due to thermal bridges)			single glazing with 4mm float glass in box-type timber windows	3.0			
Model M1 of thermal performance improvement	internal concrete 10cm, thermal insulation 5cm, external concrete 5cm + 5cm added expanded polystyrene total TI thickness = 10cm	0.371	10cm of added hard mineral wool resulting in 22cm of thermal insulation	0.171	double glazing (4+12+4mm) laid in five-chamber PVC profiles	2.30	double glazing (4+12+4mm) laid in five-chamber PVC profiles	2.30	2 - 3
Model M2 of thermal performance improvement	internal concrete 10cm, thermal insulation 5cm, external concrete 5cm + 10cm added expanded polystyrene total TI thickness = 15cm	0.255	10cm of added hard mineral wool resulting in 22cm of thermal insulation	0.171	low-emission glazing with argon filler laid in five-chamber PVC profiles	0.90	double glazing (4+12+4mm) laid in five-chamber PVC profiles	2.30	0.8 - 1

Energy consumption for space heating – comparison of models

For simulation of building energy performances 3D mathematical models are created: Model 1 and Model 2, which are characterized by different energy performances. The thermodynamic simulations of the models were realized in specialized software package TAS[2]. The simulations were run considering the maintenance of the point values of the indoor air temperature (from 20C° in the rooms to 22C° in bathroom) which provide satisfactory thermal comfort conditions through the heating period. For analyses and mathematical simulations of models, the Belgrade climatic conditions related to daily temperatures during the year, frequency of temperatures, frequency of solar radiation intensity, frequency of overcast, frequency of wind speed and its direction in winter, summer and transitional period, are taken into account.

The official records from the Belgrade Institution of Thermal Power Plants, based onenergy consumption data for heating in 2006-2008 (for the period from 15th October to 15th April),

2 The thermodynamic simulations of the models were realized by BDSP YU, New Belgrade.

show that the average annual energy consumption for space heating for existing building (all five blocks) is 1,769 MWh. The annual final energy consumption for the central block is 353,810 kWh, and 283.60kWh/m^2 respectively. These figures reveal that there is a very high energy consumption,anenergy-inefficient building. The reason for such energy consumption is inadequate thermal performanceof the envelope structure resulting in: thermal (transmission) losses,overheating of the building andgreat infiltration losses.Distribution of thermal energy by the Belgrade Institution of Thermal Power Plants is not in accordance withthe temperature fluctuations in the winter, which is also reflected in the consumption of energy.

Results of improvement of thermal performances of building envelope were considered and presented through reduction of energy consumption and reduction of CO_2 emissions.

As a national software package is not yet adopted, determination of the energy class of the building is based on the energy required for heating (according to the Rulebook on Energy Efficiency of Buildings and the Rulebook on Conditions, Content and Manner of Issuing Energy Performance Certificate of Buildings).The results of the thermodynamic simulation for both models of improvement show/confirm the contribution of the applied improvement measuresin terms of reducing energy consumption (Table 4).The annual space heating energy consumption, as well as annual heating energy consumption per m^2 are compared to the existing building heating energy consumption, as shown in Table 4 and Figure 3.

Table 4: Annual primary energy consumption for space heating according to the models

Model of the building	Energy consumption (kWh/a)	Energy consumption (kWh/m^{2}a)	Energy class
Existing building Model	424,572.00	339.66	G
Improved Model 1	44,690.00	35.75	C
Improved Model 2	22,135.00	17.70	A

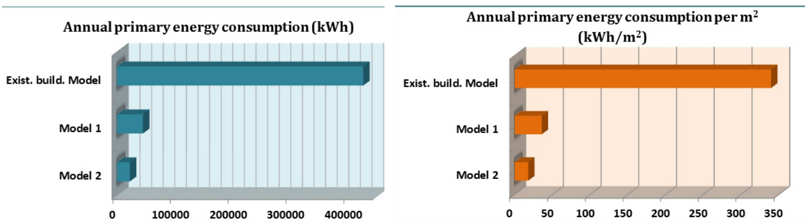


Figure 3: Comparison of annual primary energy consumption for space heating of the existing building and improved models

Benefits of predicted improvements can be identified through primary energy savings and reduction of CO_2 emissions. It is noticeable that annual primary energy savings for heating, as well as annual energy savings per m^2 are significant and these energy benefits of improved models are shown in Table 5 and Figure 4.

Table 5: Annual primary energy savings for space heating according to the models

Model of the building	Energy savings (kWh/a)	Energy savings (kWh/m^{2}a)	Reduction of energy consumption (%)
Improved Model 1	379,882.00	303.90	89
Improved Model 2	402,437.00	321.95	94

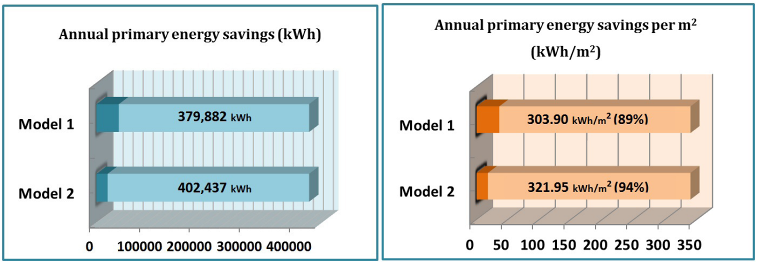


Figure 4: Comparison of annual primary energy savings for space heating of the improved models

The primary energy consumption for space heating in the case of improved models is reduced by more than 89% for Model 1, and more than 94%for Model 2. This confirms that yearly reduction of energy demands of approximately 379,882 kWh is obtained for Model 1, while for Model 2 the reduction is 402,437 kWh. In relation to the effective heating surface, yearly reduction of energy demands of approximately 304 kWh/m^2 for Model 1 and 322 kWh/m^2 for Model 2 are achieved.These energy savings are provided by addition of thermal insulation, glazing of loggias and replacement of existing windows by the new window type.

The calculation of CO_2 emissions takes into account the fact that district heating based on fuel oil is available in housing settlement Konjarnik (specific emission for fuel oil is 0,26 kgCO_2/kWhaccording to the Rulebook on Energy Efficiency of Buildings). In Table 6 and Figure 5, values of yearly CO_2 emissions and reductions for the considered central block are shown.

Table 6: Annual CO_2emissionand reduction according to the models

Model of the building	CO_2 emission (kg/year)	CO_2 reduction (kg/year)	CO_2 reduction (%)
Existing building Model	110,389	--	--
Improved Model 1	11,619	98,770	89
Improved Model 2	5,755	104,634	94

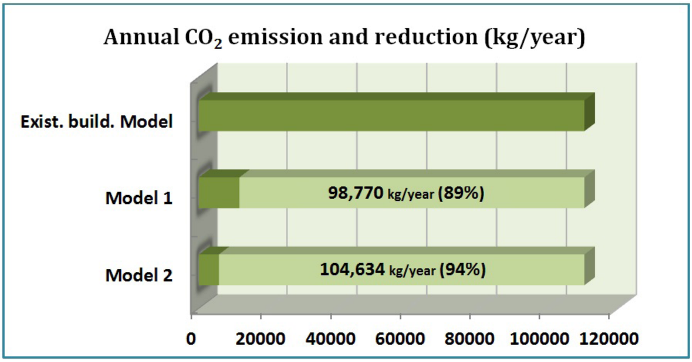


Figure 5: Comparison of annual CO_2 emission and reduction of the existing building and improved models

According to presented results, it is evident that a significant reduction of CO_2 emissions can be achieved by improving the building envelope.

Conclusion

This work has highlighted the problems of poor energy performances of existing Belgrade's building stock and necessity and possibilities of energy performance improvement of buildings and thereby ecological impact. Refurbishment option could be seen as more modest and simple at the first glance compared to demolition and new construction, but results obtained in this research show efficiency in energy savings and CO_2 reductions, as well as housing quality improvement.

By improvement of thermal insulation and windows replacement, contribution to energy savings and improvement of the building appearance are achieved.

According to the Regulations on terms, content and method of issuing certificates of energy performance of buildings, existing and improved models of building belong to the following energy classes of apartment buildings:

- The existing building, in relation to specific annual heating energy consumption (339.66 KWh/m^{2}a), is classified as energy class G.
- The improved Model M1, in relation to specific annual heating energy consumption (35.75 KWh/m^{2}a), is classified as energy class C.
- The improved Model M2, in relation to specific annual heating energy consumption (17.70 KWh /m^{2}a), is classified as energy class A.

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, legislation, authorities, project design industry, building industry, etc.

Acknowledgements

The research is done within the scientific research projects "Physical, environmental, energy, and social aspects of housing development and climate change–mutual influences"(TR36035) and "Development of methods of project documentation of installation networks in buildings compatible with the BIM process and relevant standards "(TR36038), financed by Ministry of Education, Science and Technological Development of the Republic of Serbia.

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CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

711.4.01(082)(0.034.2)
711.4:005.591.6(082)(0.034.2)

INTERNATIONAL Academic Conference on Places and Technologies (5 ; 2018 ; Belgrade)
Conference Proceedings [Elektronski izvor] / 5th international Academic Conference on Places and Technologies, [Belgrade] ; [conference organisers University of Belgrade - Faculty of Architecture and Professional Association Urban Laboratory] ; editors Aleksandra Krstić-Furundžić ... [et al.]. - Belgrade : University, Faculty of Architecture, 2018 (Belgrade : University, Faculty of Architecture). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovnog ekrana. - Tiraž 150. - Bibliografija uz svaki rad.

ISBN 978-86-7924-199-3
1. Krstić-Furundžić, Aleksandra, 1954- [уредник] 2. Faculty of Architecture (Belgrade)
а) Градови - Мултидисциплинарни приступ - Зборници b) Урбанистичко планирање - Технолошки развој - Зборници
COBISS.SR-ID 262556428