CONFERENCE PROCEEDINGS

3RD INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

EDITORS
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MILENA VUKMIROVIĆ
ALEKSANDRA KRSTIĆ-FURUNDŽIĆ
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PLACES AND TECHNOLOGIES 2016

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MULTIFAMILY HOUSING IN BELGRADE – ENERGY PERFORMANCE IMPROVING POTENTIAL AND ARCHITECTURAL CHALLENGES

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ABSTRACT

Although Serbian residential building fund is dominated by single-family housing, multifamily housing is prevailing in central zones of major cities, as well as in numerous suburbs planned and constructed during socialist period. This phenomenon can be observed particularly well in Belgrade metropolitan area, where significant portions of entire municipalities are almost exclusively dedicated to multifamily housing.

Majority of multifamily housing units was constructed during the 1960s and 1970s following the socialist doctrine and exploring modern(ist) approaches in architectural design and urban planning. These buildings are characterized by poor energy performance and it is estimated that today they account for 20% of total energy consumption in housing sector, and improving their energy performance thus presents a strategic issue of national importance. Overall architectural values of these buildings are quite diverse, ranging from basic utilitarian, nowadays obsolete, to some of the most significant assemblies of the time. On the other hand, the geometry, structure, materials and facade finishes vary a lot in this period, presenting a specific challenge for contemporary adaptations. Architectural interventions regarding energy upgrades therefore require complex, holistic approach, capable of transcending the purely technical modifications that often compromise the original architectural values or don't recognize, let alone fulfil, the overall potential of such interventions. Being 40-50 years old, these structures have accumulated numerous unresolved questions while aging: poor physical and technical condition (leaking roofs, deteriorated facades, dysfunctional technical systems etc.) and, what is even more important, functional layouts that do not match contemporary housing needs and standards. The paper is exploring the capability of resolving these issues through various adaptation/refurbishment options, which combine energy efficiency, technical, functional and aesthetic aspects into cost-effective, sustainable proposals. The research is based upon the study "Belgrade IR Atlas: energy characteristics of Belgrade's building envelopes", further exploring the topics derived from initial study results.

Keywords: Multifamily housing, Energy optimisation, Building adaptation, Facades upgrades

[1] Corresponding author

INTRODUCTION

Belgrade's building stock is comprised mostly of buildings that were built in the second half of 20th century, with more than 57% of buildings constructed from 1946 to 1980, with very poor energy performance. Energy optimisation of these buildings is a complex issue, involving architectural, technical, legislative and economic aspects. In 2011 and 2012, the extensive research on this issue was conducted at the Faculty of Architecture, resulting in a study "Belgrade IR Atlas: energy characteristics of Belgrade's building envelopes". In the meantime, a major research project of defining the National Typology of Residential Buildings in Serbia was completed (designed and executed by the team from the same institution), and new legal framework was established. Out of 32 buildings examined within "Belgrade IR Atlas", 10 buildings were selected and energy improvement models were explored by adjusting the original methodology to the new Rulebook on Energy Efficiency of Buildings [*Pravilnik o energetskoj efikasnosti zgrada*] and by further developing strategies defined in National Typology in order to provide comprehensive material for stakeholders (on-going project "Conserving Energy" and work on author's PhD thesis). The paper presents findings of two different buildings, showing the refurbishment options in relation to energy savings and expected payback.

BELGRADE BUILDING STOCK

Area of the City of Belgrade comprises of 17 municipalities with quite different characteristics, ranging from flat to hilly terrain, highly urbanized and densely populated districts to almost rural outskirts with agricultural activities. This results in a typologically diverse building stock, with a large number of different manifestations.

Although we perceive Belgrade as a mostly urbanized entity, researches conducted at the Faculty of Architecture during 2011[2] showed that the highest share of residential buildings is, in fact in form of single-family houses (44.43%). Free standing multifamily residential buildings comprise 36.08% (including lamellas in the open city block structure), those within the traditional city blocks less than 15% and high-rise dwellings even less than 4.74% out of the total number of residential building units. These data give a quite different image and indicate a very heterogeneous structure of the building stock with a high percentage of the open city block in the urban layout. This research also gave insight into the age structure of residential buildings, as shown through percentages in Figure 1. It is apparent that most of the existing buildings were built in the post – war period (37.07% were built between 1946 and 1970, and another 20.02% in the following decade). Intensive building activity lasts throughout the 1970s, while its decay starts in the 1980s, and culminates during the politically and economically turbulent 1990s, when not only housing construction was degraded, but also the entire construction industry. With the rising need for appropriate housing units for large number of refugees and emigrants that settled in the Belgrade area, and no strategies and solutions for their situation, ad-hoc solutions in forms of illegal housing units became standard practice, with long lasting consequences on the urban image and housing quality. The beginning of 21st century brings a positive shift, although mostly in small-scale buildings. Only recently we witness some organized attempts of building large-scale residential complexes.

[2] Results published in the form of internal report: Jovanovic Popovic, Milica, Ignjatovic, Dusan et al. 2011.

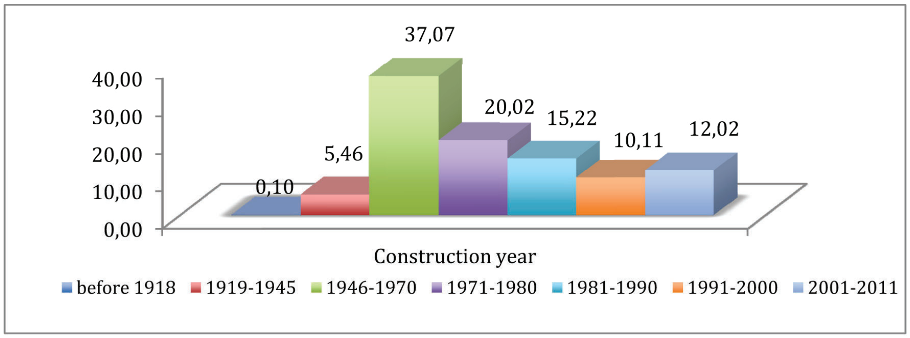

Figure 1: Belgrade multifamily residential building stock by construction year (Ignjatovic Dusan and Cukovic Ignjatovic Natasa 2012)

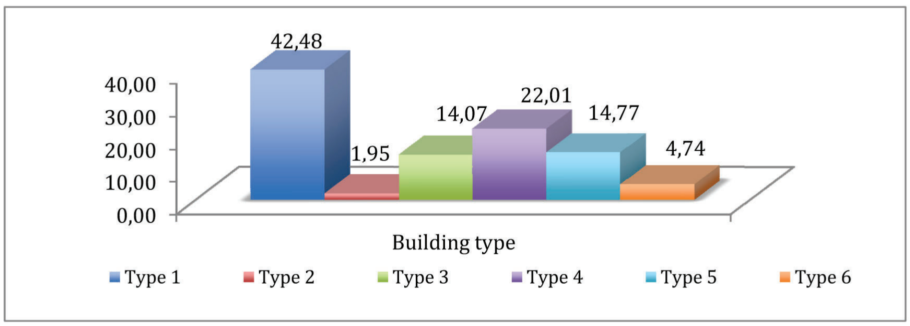

Figure 2: Belgrade residential building stock by building type (Data from 2011 Internal report aligned with 2013 National Typology of Residential Buildings in Serbia)

The National Typology of Residential Buildings in Serbia (Jovanovic Popovic, Milica, Ignjatovic, Dusan et al. 2013) defines 6 building type classes. Types 1 and 2 refer to single-family houses (1- freestanding and 2- in a row), while types 3-6 refer to multifamily housing (3- freestanding, 4- lamella, 5- in a row, 6- high-rise). Distribution of building types in Belgrade region is presented in Figure 2, showing that more than 40% of building stock is allocated within open city block matrix (Types 3, 4 and 6), allowing easy access and offering variety of options for architectural interventions.

METHODOLOGY

Various payback scenarios, together with the estimated investments were considered for each selected building.

As a first step, the elements of the thermal envelope that generate the most of the heat losses were identified; infrared imaging was used to analyse façades. Elements that may not be crucial for the overall building performance but that are related to significant discomfort in certain areas and/or are in poor condition, yielding repairs that are not related exclusively to energy efficiency were also considered. Their payback period calculated via energy savings is rather long, but for the dysfunctional and obsolete elements it may be immediate in practice.

Secondly, the improvement options were considered for each element, having in mind technical and architectural constraints, as well as current regulations. Heat losses were calculated according to the current Rulebook on Energy Efficiency of Buildings for each measure separately as well as for various packages in order to determine which interventions are relevant for each building. The separate savings deriving from single element improvements were calculated as simple payback with current prices.

Finally, various refurbishment packages (combinations of single-element improvements) were considered and the proposed package was calculated in detail, resulting in summary table showing estimated savings and payback period deriving from such intervention. Initial investment is calculated in total, but is also presented as investment per 1m^2 of heated area and investment per flat. Pie chart showing potential energy savings is presented, as well as short and comprehensive description of measures and improvements taken into the calculation. The most interesting observations from the various package analysis and alternative refurbishment scenarios are described in the notes below the pie chart.

SAMPLE BUILDINGS

The sample buildings are selected to show as much variety as possible, regarding architectural design, materials and practical options and refurbishment challenges. Building 01 is a typical post-war construction, built using traditional techniques, modest, simple and compact, while Building 02 is prefabricated concrete structure. Symbols from National Typology were used to illustrate the general characteristics of each building.

Building_01

Building_01 (Figure 3) is typical building from the immediate post-war period. Basic, cubic form and simple geometry form compact layout for small working-class flats. These buildings were constructed using traditional building techniques, with massive load-bearing bearing brick walls covered in mortar with no thermal insulation. Concrete slabs are visible as warmer (brighter colours) in IR image.

Figure 3: Building_01; conventional (top left) and infrared image (top right); National Typology type C4, characteristics shown below

The proposed measures included façade refurbishment with 8cm of thermal insulation and simple finishing, window replacement, 4cm of thermal insulation on the corridor walls and 8cm of thermal insulation on the ceiling floor slab. All proposed measures are designed to meet the minimum code compliance according to the current regulations, with resulting savings and payback period presented in the Table 1. Combined, these measures result in energy upgrade from class F to class D (more than mandatory upgrade for min. one EPC), and reduction of 42%

compared to the existing condition. Since the façade walls refurbishment alone yields savings of 28% with only 3 years payback, it is reasonable to consider better insulation. Also, thicker insulation on the attic would not impact the overall energy performance of the building, but it would significantly improve thermal comfort in the apartments directly below. However, for higher EPC (classes C or B) more elaborated remodelling should be considered, preferably with the sunspace on South facades.

Table 1: Proposed measures and calculated savings and investments for Building_01

		refurbished				Savings				
pos.	measures	Qhnd	Qh,an	EPC	Total	Useful energy saved	Savings	Payback	Energy saving	Remaining energy demands
		[kWh/an]	[kWh/m2an]		[€]	[kWh/an.]	[€/an.]	[years]	%	%
FACADE WALLS	8cm of thermal insulation + new facade	146695	145,70	F	15.759	57959	4751	3	28	72
WINDOWS	PVC windows U= 1,3	192222	157,56	F	26.880	12432	1019	26	6	94
CORRIDOR WALLS	4cm EPS + new paint	197122	161,58	F	5.764	7532	617	9	4	96
CIELING TO UNHEATED ATTIC	8cm of thermal insulation	196880	161,38	F	1.847	7774	637	3	4	96
COMBINED MEASURES		119236	97,73	D	50.250	85418	7024	12	42	58

INVESTMENT [€]	per m2 of heated surface	per flat
50.250	41	2094

Building_02

Prefabricated concrete buildings were designed throughout the 1970's and many apartment blocks like the one shown on Figure 4 were constructed even in the first half of the following decade. Although all the elements of the thermal envelope were designed as insulated, the thermal insulation is insufficient and joints between the concrete panels are displaying significant thermal losses than can be seen on the IR image.

Figure 4: Building_02; conventional (top left) and infrared image (top right); National Typology type F4, characteristics shown below

Table 2: Proposed measures and calculated savings and investments for Building_02

		refurbished				Savings				
pos.	measures	Qhnd	Qh,an	EPC	Total	Useful energy saved	Savings	Payback	Energy saving	Remaining energy demands
		[kWh/an]	[kWh/m2an]		[€]	[kWh/an.]	[€/an.]	[years]	%	%
FACADE WALLS	4/6cm thermal insulation + new facade	618104	130,18	E	90.745	47966	3932	23	7	93
WINDOWS	PVC windows U= 1,3	535344	112,75	E	206.534	130726	10715	19	20	80
FLAT ROOF	10cm of thermal insulation + new finishing	647952	136,47	E	44.795	18118	1485	30	3	97
COMBINED MEASURES		469260	98,83	D	342.073	196810	16132	12	30	70

INVESTMENT [€]	per m2 of heated surface	per flat
342.073	72	5345

The proposed measures included adding 4 or 6cm of thermal insulation on the exterior of the existing multi-layered façade walls, window replacement and flat roof rehabilitation with additional 10cm of thermal insulation. All proposed measures are designed to meet the minimum code compliance according to the current regulations, with resulting savings and payback period presented in the Table 2. Combined, these measures result in one class EPC upgrade (from class E to class D), which is minimum upgrade required by the Rulebook. However, opting for high-performance windows could be a very efficient strategy for this building. Replacing existing windows with the ones with U=0.1 W/m^{2}K results with achieving D energy grade (under 105kWh/m^2) without any other interventions on the building's envelope. For achieving higher energy grades, it would be necessary to explore options for extensive remodelling, probably converting some sections of the assembly into sunspaces, thus providing both more efficient form and buffer zones towards heated areas. These buildings have atriums (Figure 5) that can be glazed, thus providing thermal buffer, covered space in the winter. To avoid overheating in summer, sections of glazing should be operable in order to provide sufficient airflow.

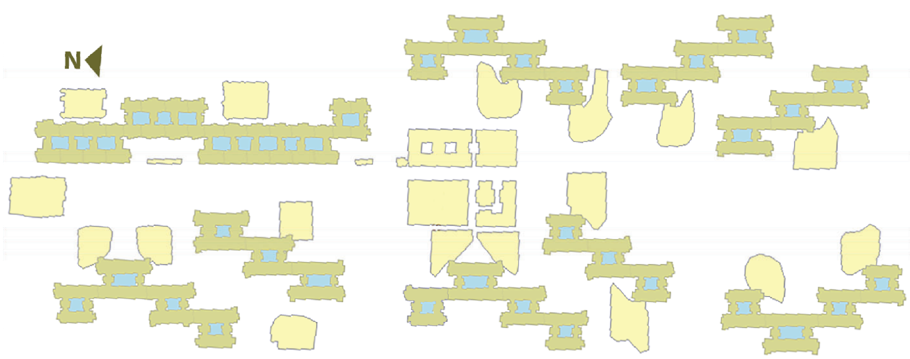

Figure 5: Buildings like Building_02 (shaded darker) in Block 70, New Belgrade, with 40 atriums that can be glazed (shaded blue) | Buildings disposition from geosrbija.com

Table 3: Buildings 01-10: overview of basic data and calculated savings and expected costs

	Construction year	EPC rating (existing)	EPC rating (refurbished)	Calculated savings (%)	Calculated costs (€/m^2)
Building_01	1939	F	D	49	50
Building_02	1951-1957	F	D	42	41
Building_03	1958	F	D	55	56
Building_04	1963	F	D	52	60
Building_05	1972-1975	E	C	47	55
Building_06	1980-1986	E	D	29	44
Building_07	1980	F	E	18	48
Building_08	1974-1984	F	D	30	72
Building_09	1988-1994	E	D	28	58
Building_10	2006	D	D	5	35

Buildings 01-10: an overview of potential savings

Calculations like the ones presented in Table 1 and Table 2 were performed for 10 buildings that were selected to represent various layouts, construction techniques, designs and materials, typical for Belgrade and Serbian building stock in general. The overview of calculated savings is shown in Table 3. It can be noticed that all the buildings constructed in 20th century can be refurbished according to the Rulebook (min. one EPC grade improvement), with highest savings expected for buildings constructed before 1980s.

CONCLUSIONS

Architectural diversity of, sometimes seemingly similar, multifamily buildings doesn't allow use of universal, prescribed sets of measures. Depending on building's layout and structure of thermal envelope, some measures that are extremely efficient and cost-effective for one building, could be completely unnecessary for another. In order to optimise the package of energy efficiency measures, all elements of thermal envelope should be taken into consideration and than filtered through a set of criteria. The detailed calculation executed for 10 different buildings has shown that significant reduction in energy demands for heating could be achieved through various sets of EE measures for all buildings constructed before mid-2000s. Exploring the options for energy rehabilitation of multifamily residential buildings while targeting higher EPC ratings (B or C) yields more elaborated architectural approach, preferably with passive solar features introduced and general redesign of a building.

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