PROSTOR

28 [2020] 2 [60]

ZNANSTVENI ČASOPIS ZA ARHITEKTURU I URBANIZAM
A SCHOLARLY JOURNAL OF ARCHITECTURE AND URBAN PLANNING

SVEUČILIŠTE U ZAGREBU, ARHITEKTONSKI FAKULTET
UNIVERSITY OF ZAGREB, FACULTY OF ARCHITECTURE

ISSN 1330-0652
https://doi.org/10.31522/p
UDK | UDC 71/72
CODEN PORREV
28 [2020] 2 [60]
201-496
7-12 [2020]

Af

POSEBNI OTISAK / SEPARAT | OFFPRINT

Znanstveni prilozi | Scientific Papers

346-359

Vesna Lovec
Miroslav Premrov
Vesna Žegarac Leskovar

Thermal Comfort and Indoor Air Quality after a Partially Energy-efficient Renovation of a Prefabricated Concrete Kindergarten Constructed in 1980's in Slovenia

Original Scientific Paper
https://doi.org/10.31522/p.28.2(60).10
UDK 72.025.4:725.573 (497.4) "19/20"

Toplinska udobnost i unutarnja kvaliteta zraka nakon djelomične energetske obnove prefabriciranog betonskog dječjeg vrtića izgrađenog 1980-ih u Sloveniji

Izvorni znanstveni članak
https://doi.org/10.31522/p.28.2(60).10
UDC 72.025.4:725.573 (497.4) "19/20"

Fig. 1 Prefabricated concrete kindergarten building constructed in 1980's in Slovenia
Sl. 1. Prefabricirana betonska zgrada dječjeg vrtića izgrađena 1980-ih godina u Sloveniji

Vesna Lovec[1], Miroslav Premrov[2], Vesna Žegarac Leskovar[3]

[1,2,3] University of Maribor
Faculty of Civil Engineering, Transportation Engineering and Architecture
Slovenia – 2000 Maribor, Smetanova ulica 17

vesna.lovec@um.si
miroslav.premrov@um.si
vesna.zegarac@um.si

[1,2,3] Sveučilište u Mariboru
Fakultet građevinarstva, prometa i arhitekture
Slovenija – 2000 Maribor, Smetanova ulica 17

vesna.lovec@um.si
miroslav.premrov@um.si
vesna.zegarac@um.si

Original Scientific Paper
https://doi.org/10.31522/p.28.2(60).10
UDC 72.025.4:725.573 (497.4) "19/20"
Technical Sciences / Architecture and Urban Planning
2.01.03. – Architectural Structures, Building Physics, Materials and Building Technology
Article Received / Accepted: 23. 6. 2020. / 16. 12. 2020.

Izvorni znanstveni članak
https://doi.org/10.31522/p.28.2(60).10
UDK 72.025.4:725.573 (497.4) "19/20"
Tehničke znanosti / Arhitektura i urbanizam
2.01.03. – Arhitektonske konstrukcije, fizika zgrade, materijali i tehnologija građenja
Članak primljen / prihvaćen: 23. 6. 2020. / 16. 12. 2020.

Thermal Comfort and Indoor Air Quality after a Partially Energy-efficient Renovation of a Prefabricated Concrete Kindergarten Constructed in 1980's in Slovenia

Toplinska udobnost i unutarnja kvaliteta zraka nakon djelomične energetske obnove prefabriciranog betonskog dječjeg vrtića izgrađenog 1980-ih u Sloveniji

energy-efficient renovation
indoor air quality
kindergartens
Slovenia
thermal comfort

energetska obnova
kvaliteta zraka u interijeru
dječji vrtići
Slovenija
toplinska udobnost

The majority of kindergartens situated in the territory of former Yugoslavia need renovation. Apart from their enhanced energy efficiency, renovated buildings will presumably offer better indoor environmental quality. According to the current case study, children using a classroom with new windows installed are exposed to substantially poorer indoor air quality due to airtightness and improper ventilation, which calls attention to a vital technical issue of the current renovation process.

Većini dječjih vrtića smještenih na teritoriju bivše Jugoslavije potrebna je obnova. Osim naglašene energetske učinkovitosti, obnovljene će zgrade vjerojatno ponuditi i bolju kvalitetu boravka u interijeru. Prema aktualnoj studiji slučaja, djeca u učionicama s instaliranim novim prozorima izložena su osjetno lošijoj kvaliteti zraka u zatvorenom prostoru zbog zračne nepropusnosti i neispravne ventilacije. U središtu pozornosti stoga treba biti tehnička problematika aktualnih procesa obnove.

Introduction

Uvod

In the last two decades, the majority of European countries have been facing the exigency of renovating the existing preschool education buildings constructed in the second half of the 20th century. Despite being relatively small in number compared to residential and non-residential buildings[1], they represent an important part of the building stock calling for particular attention on account of a significant average building age, the need for maintenance and particularly for the reason of their impact on health as well as on well-being of their occupants who are mainly children.

Preschool education in Slovenia comprises 1,026 units in public kindergartens.[2] In Croatia, there are 1,710 relevant institutions[3] while in Serbia the latest census shows 2,464 preschool education buildings.[4] With regard to EU data, more than 95% of children from the age of 4 to school admission age attend institutions offering preschool programmes.[5] In spite of its continuous growth, the number of kindergarten children in the countries that used to be part of former Yugoslavia proves to be far below European average.[6] The data clearly demonstrate a hugely increasing number of children who spend most of their weekdays in preschool education buildings. The above listed facts underline the importance of analysing all aspects regarding the quality of European preschool buildings and their indoor comfort.

Preschool facilities construction within the territory of former Yugoslavia followed the transitions of the society and politics, the progress of technology and demographic changes, in particular. Architectural building expression of the time resulted from the pursuit of optimal solutions to satisfy the requirements of the developing society and from a thorough analysis of pedagogical guidelines and advancement. Preschool building facilities along with other public buildings represent invaluable historical and architectural heritage. Today, most of these buildings need to be renovated and updated, with a primary focus being that of energy efficiency.

In Slovenia, the average age of buildings hosting preschool education is 45 years and above, which is in line with the European average. Preschool building stock is hence rather outdated. In the last twenty years, individual buildings have already seen partial or comprehensive renovation with a view to achieving better energy efficiency. Since energy savings are a primary goal of the energy-efficient renovation, buildings should have a better energy performance in comparison to the pre-renovation state. Unfortunately, contrary to the expected increase of indoor comfort, practice proves it is often not the case as a number of renovated buildings display improper ventilation, poor indoor air quality in inadequate thermal comfort. Energy-efficient renovation is also the only renovation type benefiting from national financial support funds. Moreover, buildings in question also call for functional renovation, i.e. architectural adjustment to modern ways of preschool work and life although the current article does not discuss the mentioned topic.

Architecture of kindergartens in the territory of former Yugoslavia has never been a focal point of architectural discussions in spite of its being an ever-popular topic. Development in architectural typology of kindergartens is nowadays a systematically treated area only in a few former Yugoslavian republics.[7] Moreover, indoor comfort has been a rather unresearched subject despite the fact that children tend to be the most vulnerable group which is extremely sensitive to poor indoor

1 European education facility stock represents only 6% of the entire European building stock (Decarbonising the non-residential building stock).

2 Fabbri, 2013

3 *** 2019d

4 *** 2019b

5 *** 2019c

6 With 82.8% of children aged 4+ who are involved in preschool education, Croatia's statistics on the number of kindergartens and children taking part in preschool programmes places the country behind the rest of the European Union [*** 2019c]. Other countries in the territory of former Yugoslavia mark an even poorer proportion. However, a fact to highlight is the growing number of kindergarten children, which is linked to severe space scarcity in preschool education buildings.

comfort. On the other hand, international studies highlight a substantial impact of various indoor environmental quality [IEQ] parameters exerted on preschool children's development and well-being.[8] The majority of researches carried out so far analyse indoor air quality [IAQ] along with thermal comfort in kindergartens and alert to the increased CO_2 concentration, which is a basic indicator of poor indoor air quality. Numerous studies on indoor air quality in kindergartens encompass measurements of CO_2 concentration. Kindergarten facilities in individual European countries underwent the average CO_2 concentration measurements with the following results: Finland 810 ppm[9], Denmark 1,400 ppm[10], with 640 ppm in Sweden.[11] The average CO_2 concentration in Portuguese kindergartens with poor ventilation amounted to 2,137 ± 368 ppm, and to 1,233 ± 170 ppm[12] in those having efficient ventilation. The results concerning Latvian kindergartens show a maximum CO_2 concentration of up to 1,700 ppm in classrooms with PVC windows, while those with timber windows demonstrate a value of up to 1,450 ppm.[13] Overall, in most cases the measurements point to increased CO_2 concentration levels surpassing the value of 1,000 ppm, with the exception of kindergartens in Finland and Sweden.

Slovenia's contribution to the context of research work within the territory of former Yugoslavia lies in several studies focusing on *in-situ* measurements in preschool facilities. The process of measurement involved only temporary or short time periods and was carried out in a day or a few hours, with multiple repetitions. Accordingly, Slovenian territory based research lacks continuous measuring of IEQ parameters, which is a fact that needs to be underlined. Slovene studies also outline the problems of thermal discomfort and poor indoor air quality. A study encompassing integral assessment of all IEQ parameters in Slovenian kindergartens shows increased air temperature in 37% of the classrooms, air dryness in more than a half of the classrooms analysed, with 80% of the classrooms witnessing a value of CO_2 that mounted over 1,000 ppm.[14] However, there is no available documented research for the territory of former Yugoslavia that would compare IEQ parameters prior to and after the renovation of kindergartens, in order to determine the conditions which children in these facilities are exposed to, before and after energy-efficient renovation.

The purpose of the current research therefore is to assess indoor air quality and thermal comfort in two classrooms of the selected kindergarten, built in 1980, located in Maribor, Slovenia (Fig. 1). Built in prefabricated concrete construction system, the kindergarten belongs to one of the most commonly used architectural typologies applied to building preschool facilities in the territory of the former SFRY republics in the 70s.[15] Partial energy-efficient renovation of the building included window replacement in half of the classrooms, i.e. installation of the new double glazed windows with PVC (polyvinyl chloride) frames, while the other half of the classrooms kept the original timber-framed windows. The analysis comprises typological, architectural and historical analytical aspects of the building along with assessment of individual thermal comfort and indoor air quality parameters based on results obtained from in-situ measurements in two of the kindergarten's classrooms. Hence, the goal of the research is to analyse the parameters of thermal comfort and indoor air quality in one of the classrooms with new windows installed and in one of the classrooms with original windows, for the purpose of answering the following question: Are children using the classroom that underwent energy-efficient renovation procedure, i.e. window replacement carried out with the view of increasing thermal comfort and energy efficiency, indeed exposed to enhanced thermal comfort and a better indoor air quality?

The findings of this research could be of significant importance for both, the users of the already renovated building stock as well as for the scientific and lay public involved in the operation of buildings for which energy-efficient renovation is an unavoidable future step.

Theoretical Framework

Teorijski okvir

The context of constructing preschool facilities in Yugoslavia

Kontekst izgradnje predškolskih ustanova u Jugoslaviji

Historical analysis of constructing preschool education facilities in Yugoslavia is approached in the context of massive residential construction, taking place after World War II. In-

---

7 In the Republic of Serbia the subject matter is dealt with in National Typology of Kindergartens in Serbia [Jovanović-Popović et al., 2018: 186], while in Bosnia and Herzegovina Typology of public buildings in Bosnia and Herzegovina encompasses kindergartens as well.

8 The authors claim that children feel more comfortable at lower temperatures than prescribed. [Yun et al., 2014]

9 Ruotsalainen, 1993

10 Pejtersen et al., 1991

11 Cars et al., 1992

12 Araújo-Martins et al., 2014

13 Borodinecs, Budjko, 2009

14 Pajek et al., 2017

15 *** 2018

tensive construction of housing estates, carefully planned from the viewpoints of urbanism and architecture, in the territory of former Yugoslavia in the 70s, encompassed all areas of creating housing space and building housing estates. The latter was seen in well considered architectural and urbanistic solutions, construction elements, planned industrial construction, economical use of modern materials down to thoughtful consideration of open space design. Urbanist paradigm of the time lay substantial focus on the distance from a home to a school or preschool facility and stressed the importance of having a well-developed network regarding the latter. Therefore, massive residential construction was parallel to building multiple kindergartens amidst large housing estates in Belgrade, Ljubljana, Maribor, Sarajevo, Podgorica, etc.[16]

The post-war period housing policy of former Yugoslavia was oriented towards rapid massive construction of affordable, yet high quality residential units that would satisfy modern lifestyle requirements. The 70s therefore witnessed a situation where numerous construction companies in the territory of former Yugoslavia focused primarily on residential housing and its planning, which was interspersed with experimental attempts at modern construction techniques. The tendencies went towards industrialising the field of civil engineering and enhancing prefabrication which gained ground owing to the need for quick and economical prefabricated construction.[17] Accordingly, a number of light and heavy prefabrication systems were developed within different companies, such as *Jugomont* in Croatia and *Obnova* in Slovenia (whose concrete elements production started in 1965 and was based on the system introduced by *Jugomont*), along with the prefabrication system *Žeželj* originating from Belgrade, Serbia (named after the inventor of the skeletal system – at the Serbian Institute for testing of materials – *IMS Institute*). Apart from residential housing, construction activity encompassed the systems of full or partial prefabrication of other public facilities, with the inclusion of kindergartens. Similar architectural solutions regarding preschool facilities dating from the late 70s can thus be found in many towns and cities of former Yugoslavia (Figs. 2 and 3).

The need for fast-paced construction of a great number of preschool facilities in the territory of former Yugoslavia resulted in the development of numerous modular and prefabricated/partially prefabricated solutions. The idea of prefabrication underwent a process of systematic development through several architectural competitions targeted at modular and prefabricated solutions for buildings, including those to serve as kindergartens. Hence, many of the ensuing systems relied on the idea of permitting for alteration, adjustment and application to different locations.[18] The latter has led to numerous preschool education buildings, whose planning and design reflect a composition of modular and/or prefabricated building elements (Figs. 2 and 3), arising from carefully considered fundamental structural principles, construction techniques and materials. Moreover, these facilities represent architectural heritage of an era marked by massive prefabrication.[19]

Energy-efficient renovation of preschool education buildings and their IEQ

Energetski-učinkovita obnova zgrada za predškolski odgoj i njihov IEQ

Most preschool education buildings constructed before the implementation of stricter regulations on energy efficiency of buildings in the territory of former Yugoslavia require energy-efficient renovation.[20]

In Slovenia, the already renovated building fond surpasses that of other countries in the territory of former Yugoslavia, owing to the necessary conformity with European directives and on account of benefitting from the available European funds, created to support renovation of kindergartens in EU member states. Hence, approximately 80 % of Slovenian kindergartens built in the period from 1960 to 1980 % have already undergone a partial or comprehensive energy-efficient renovation.[21] The most frequent measure of energy-

16 Most intensive purpose-based construction of preschool education buildings in Slovenia took place in the period from 1970 to 1980. [Gregorski, 2017]

17 The population growth marked a considerable increase, with a rate of 30,000 inhabitants per year only in Belgrade, which led to a continuous lack of housing. The most intensive housing construction covered a period extending from the end of the 60s to the beginning of the 70s, when prefabrication rose to its climax all across former Yugoslavia. The beginning of the 70s witnessed the building of 12,000 new residential units per year. [Đukanovic, 2015: 43]

18 Within the scope of different prefabrication systems applied, the system of the Slovenian company Marles was used to build seven Zagreb based kindergartens in 1975/76. [Roth-Čerina, 2017]

19 Kindergartens from the this period are classified as C3 type of buildings according to the National Typology of Kindergartens in Serbia and represent approximately 12 % of the preschool education building stock [Jovanović-Popović et al., 2018: 186]. In addition, there is a number of schools and buildings serving other purposes (non-residential buildings).

20 In Slovenia, the *Rules* on *Efficient Use* of *Energy* in *Buildings* [PURES] came into force in 2002, with the implementation of the Energy efficiency regulations in Croatia in 2012. Moreover, in Serbia the "Правилник о енергетској ефикасности зграда *(Pravilnik o energetskoj efikasnosti zgrada)*" has been legally effective since 2011. In Bosnia and Herzegovina, the relevant laws came into force in

Fig. 2 Kindergarten *Mladi rod*, the unit of *Vetrnica*, Ljubljana 1972, arch. Stanko Kristl

Sl. 2. Dječji vrtić Mladi rod, jedinica u Vetrnici, Ljubljana, 1972., arh. Stanko Kristl

Fig. 3 Kindergarten *Slavuj* in urban block 28, New Belgrade. Behind the kindergarten – in the same urban block – stands a building called “Televizorka” (“TV set building”), designed in the *Žeželj* prefabrication system. A Slovene architect, Ilija Arnautović was part of a larger team who participated in design and construction based preparatory activity prior to the building process of urban block 28 in New Belgrade (1967-71).

Sl. 3. Dječji vrtić Slavuj u urbanom bloku 28, Novi Beograd. Iza dječjeg vrtića u istome urbanom bloku nalazi se zgrada nazvana „Televizorka” (TV zgrada), projektirana u prefabriciranom sustavu Žeželj. Slovenski arhitekt Ilija Arnautović bio je član veće skupine koja je sudjelovala u projektiranju i pripremnim aktivnostima za izgradnju urbanog bloka 28 u Novom Beogradu (1967.-71.).

efficient renovation recorded is window replacement. As far as renovation process is concerned, the fact to highlight is that of absolutely unplanned and non-strategical approach taken by most of the countries in the territory of former Yugoslavia. Energy-efficient renovation often disregards the necessary inclusion of architectural expertise since legislation frequently classifies renovation activity as maintenance works which do not require building permits or project plans. Furthermore, energy-efficient renovation is mainly performed through limited financial resources, with no expert support. Consequently, a poorly planned non-expertise based energy-efficient renovation may have a negative impact on the architectural aspect of buildings as well as on IEQ, which is the subject of the current research.

Indoor comfort has been a subject of discussion only since a few decades ago, with the focus being primarily laid upon energy efficiency of buildings. Indoor comfort in preschool facilities is determined by legislation through laws, regulations, administrative provisions and expert recommendations. The analysis and critical evaluation of past researches, along with standards and legislative directives in force served as a basis to define referential parameters of indoor air quality and thermal comfort in kindergarten classrooms, employed in the current study. The referential point in the current research is determined as acceptable CO_2 concentration in a kindergarten classroom, set at 1,500 ppm[22] with a target concentration of 1,000 ppm.[23] A recommended classroom indoor temperature range is 20 °C do 22 °C.[24] Ideal humidity in rooms where children spend most of their time ranges from 45 to 55 % at the appropriate indoor air temperature of 20 to 22 °C, with the acceptable relative humidity being 30 % to 70 %.[25]

Research Framework

Okvir istraživanja

Description of the case study building

Opis zgrade u studiji slučaja

The kindergarten chosen for the purpose of the current study dates from 1981, with its construction type being concrete prefabricated structure (Fig. 1). The kindergarten was built simultaneously with the housing estate of Nova Vas I in Maribor by the *Konstruktor* construction company.[26] As already mentioned, with the then period of concrete architecture on the rise in the territory of the former SFRY, massive construction of concrete buildings for different purposes was also seen in a great number of prefabricated kindergartens.

The kindergarten facility is a part of urban complexity of the mentioned housing estate in Maribor, Slovenia (with a latitude of 46°33’ and a longitude of 15°38’ E).[27] The ground floor building has a net area of

2017, while in Montenegro new legislation was introduced in 2015.

21 UM-FGPA

22 According to the Representatives of European Heating and Ventilation Associations [REHVA], the acceptable limit for CO_2 levels is 1,500 ppm. [Alfano et al., 2010]

23 According to the American Society of Heating, Refrigeration and Air Conditioning Engineers standards, the limiting value during the occupied period is 700 ppm above outdoor CO_2 levels, i.e. approximately 300-500 ppm, which means acceptable indoor concentration of up to 1,000 ppm. [2019a]

24 The Republic of Slovenia Regulation on ventilation and air-conditioning defines the parameter for thermal comfort of a person in a seated position indoors. Accordingly, the temperature in the heating season is set at the span from 19 °C to 24 °C, with the recommended range from 20 °C do 22 °C.

25 *** 2002

26 The housing estate was under construction from 1978 to 1982. The works were performed by the companies of Konstruktor and Stavbar which applied partial prefabrication since the external walls were made of prefabricated elements. [Škratek, 2018: 206]

27 Maribor’s climate is *moderate continental* and the heating season lasts on average 187 days. There is a deviation as to the length of the heating season and average temperatures observed in different town and cities in the territory of former Yugoslavia.

Fig. 4 Classroom with original windows (A)
Sl. 4. Učionica s izvornim prozorima (A)

Fig. 5 Classroom with windows replaced (B)
Sl. 5. Učionica sa zamijenjenim prozorima (B)

852 m², 7 classrooms in 2 wings of which one is occupied with children aged 2 to 3 while the other serves to 5 to 6-year-olds (Fig. 6). The external building walls are made of prefabricated concrete elements, composed of a concrete loadbearing structure with poro-concrete sheathing. The thickness of walls is 25 cm. A slanting roof has *metal roofing sheets with insulation material in the attic structure. The roof insulation thickness is approximately 10 cm while the floor of the building has a minimal insulation within its screed.*

Table I Basic characteristics of the two selected classrooms
Tabl. I. Osnovne karakteristike dviju odabranih učionica

	Classroom A	**Classroom B**
Technical data of the classroom		
Windows	**Timber / single-glazed**	**PVC / double glazed**
Classroom orientation	South-West	East-South
Shading	Curtains (curtain fabric)	Exterior roller blinds
Ventilation	Natural – window opening	Natural – window opening
Air-conditioning	/	/
Heating	Radiators	Radiators
Classroom floor area [m²]	45	51
Floor area per occupant [m²/occ]	1.875	3.642
Window area [m²]	15.7	13.2
Volume [m³]	170	190
Position in the building	End-of-wing classroom	End-of-wing classroom
No of external walls	2 (1 glazed + 1 concrete)	3 (1 glazed + 2 concrete)
Data on building occupants		
No of children enrolled	24	14
No of kindergarten teachers	2	2
Age of children	5-6 years	2-3 years
Elements of the thermal envelope U [W/m²K] (approximate value)		
External wall	0.90	0.90
Windows	3.30	1.40
Ground floor	0.30	0.30
Pitched roof	0.25	0.25

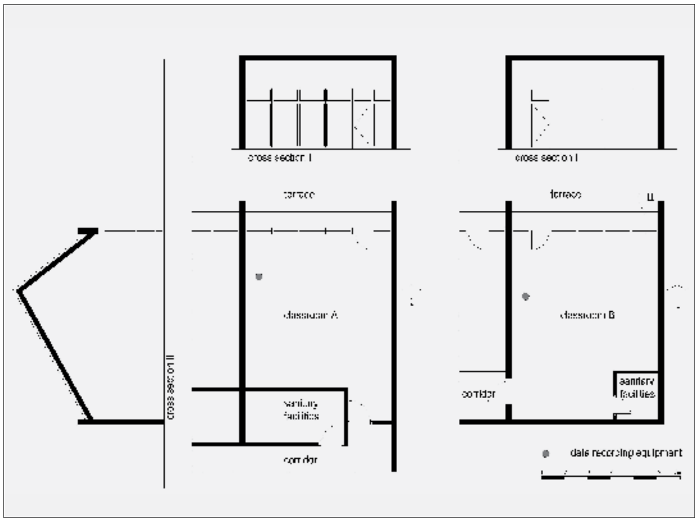
Upon inspecting the building, the findings showed that half of the classrooms had their windows replaced in 2018 (classrooms for 2 to 3-year-olds). The second half of the classrooms have original, single glazed timber-framed windows, which goes for commonly used areas, corridors and auxiliary rooms as well. The roof sheathing has been replaced. No other renovation measures have been performed apart from the listed improvements.

The building chosen for the study case analysis is a specific example as it includes two of the most common cases of kindergarten classrooms today: an end-of-the-70s classroom with its original windows (classroom *A*), and an end-of-the-70s classroom having undergone a partial renovation procedure of window replacement (classroom *B*). Such a specific case allows for *in-situ* measurements in a single building with indoor air quality and thermal comfort comparison relative to two classrooms, of which one has been partially renovated (Figs. 4 and 5). The building has district heating with radiators installed directly below the windows. The temperature of water in the heating system decreases at night-time and on days when the facility is closed (Saturday, Sunday), while the heating remains in use during the heating season. The classrooms have no air-conditioning or ventilation systems, i.e. they utilise natural ventilation by means of window opening.

The selected classrooms[28] are occupied by a maximum number of children – in conformity with the age group standards although not all of them were present on all days of con-

28 A classroom in Slovenian kindergartens is an area where multiple activities are performed according to the educational curriculum, in addition to being a play space, a dining and a resting/sleeping room.

29 Missia et al., 2010



ducting measurements. In view of the latter, a list of the number of children present in classrooms during the measurements was made. Classroom B has a slightly larger floor area and is occupied by a smaller number of children than Classroom A. In addition, Classroom B sanitary facilities are included within its surface. The room volume of both classrooms surpasses average numbers (Fig. 7: Cross section II). A comparison of the classrooms' characteristics is given in the Table I.

Classrooms interior has mostly remained in its original form with built-in furniture mainly dating form 1981, except for a few pieces of movable furniture acquired later. Both classrooms have their original parquet flooring. Original single glazed timber-framed windows have been preserved in Classroom A, while there are new double glazed windows with PVC frames installed in Classroom B. The original window raster on the façade has remained unchanged in the process of window replacement in *Classroom B*. Original windows in both classrooms were fitted in a manner that allows only for the door leading to the external atrium to be opened, which has not been altered at window replacement. With regard to the latter, we can clearly highlight inappropriate dimensioning of windows, a mistake made during the construction process in the 80s, a fault that could have easily been eliminated during the renovation process. Lastly, there are no visible signs of mold or damp in the classrooms.

Measuring *in-situ* methodology

Metodologija mjerenja na terenu

The experimental analysis encompassed continuous *in-situ* measurements of individual thermal comfort and indoor air quality parameters. In the domain of thermal comfort, the measurements carried out examined indoor air temperature T_{ai} [C°] and indoor air relative humidity RH_{ai} [%]. The measured indoor air quality indicator was CO_2 concentration [ppm]. Other IEQ parameters, lighting and acoustics in classrooms are not subject of the current study.

The measurements were conducted in the winter season for the purpose of effective evaluation of thermal comfort in both classrooms along with that of window replacement impact exerted on indoor air temperature in the classroom that underwent partial renovation. The heating season is additionally appropriate time for indoor air quality analysis due to an increased concentration of harmful substances indoors, which results from the building airtightness and a low ventilation rate.[29]

The measurement process was carried out in two kindergarten classrooms in January 2020, continuously in the period of 7 days. All the usual activities of the occupants remained undisturbed as it was requested from the kindergarten teachers not to alter their daily schedule. Records regarding the number of children present in the classrooms and their customary daily activities were kept for each day of performing measurements. An additional record entry included ventilation intervals within the 9-hour span of daily occupation. The classrooms were ventilated for 10 to 30 minutes three times a day, with ventilation dynamics and intensity following a regular rhythm defined by the teachers.

The position of measuring devices in the classrooms was adjusted to the occupants and the specifics of their activities. With respect to the young age of the children, the recording equipment had to be placed in a manner to avoid potential endangering of the occupants, in addition to being secured or

Fig. 6 Floor plan of the selected kindergarten

Sl. 6. Tlocrt odabranog dječjeg vrtića

Fig. 7 Floor plan of the classroom with original timber windows (A) and of the classroom with windows replaced (B), cross section

Sl. 7. Tlocrt učionice s izvornim drvenim prozorima (A) i učionice sa zamijenjenim prozorima (B), poprečni presjek

TABLE II DATA PARAMETERS RECORDED DURING CLASSROOMS OCCUPANCY (CLASSROOM A – ORIGINAL TIMBER-FRAMED WINDOWS, CLASSROOM B – REPLACED PVC WINDOWS)

TABL. II. PARAMETRI ZABILJEŽENI TIJEKOM BORAVKA U UČIONICAMA (UČIONICA A – IZVORNI DRVENI OKVIRI PROZORA, UČIONICA B – ZAMIJENJENI PVC PROZORI)

Classroom	No. of occupants	RH_{ai} [%]		T_{ai} [°C]		CO_2 [ppm]	
		min	max	min	max	min	max
			Day 1 - Wednesday				
A	16+2	19.8	36.6	20.8	24.7	417	2455
B	9+2	32.3	41.5	20.6	21.6	1072	2222
			Day 2 - Thursday				
A	17+2	22.3	34.3	19.5	24.6	422	1773
B	9+2	28.3	43.3	20.6	22.4	730	2530
			Day 3 - Friday				
A	16+2	21.1	37.2	19.4	24.7	414	2628
B	9+2	26.3	42.6	20.1	21.9	473	2245
			Day 4 - Monday				
A	15+2	22.4	35.2	17.9	24.6	413	1927
B	13+2	32.4	38.4	20.3	21.2	773	1578
			Day 5 - Tuesday				
A	18+2	28.7	40.1	21.0	23.2	490	2661
B	10+2	34.3	42.5	20.7	21.3	1111	2422
			AVERAGE VALUES				
A		28.4		22.2		961.8	
B		37.3		21.3		1507.4	

hidden in order not to be tampered with during the measurement process. Furthermore, the position of measuring devices had to be out of the direct heat source exposure (radiators) or sun radiation and out of the zone of the children's breathing (which is set at an approximate height of approximately 0.5 to 0.7), i.e. at a height of h = 1.5 m. The sensor was placed away from the window, at about 0.6 m from the wall, almost in the centre of the room. The position of the data recording equipment is seen in Fig. 7.

The data recording equipment used: the *CL11 rotronic meter (data logger) for the T_{ai}, RH_{ai} and CO_2 measurements and additional volcraft meters for the* T_{ai}, RH_{ai} measurements. The settings enabled measurements at 15-minute intervals.

RESULTS

REZULTATI

The analysis of the results encompasses a comparison of the measured data in *Classrooms A and B*. The measuring period extended during 5 workdays and 2 weekend days. The classrooms were occupied on a daily basis from 7h30 to 16h00 and fully closed until the next morning, with the zero-occupant closing period extended over the weekend. Continuous *in-situ* measurements allowed for data recording after the children left the classrooms and during the weekend.

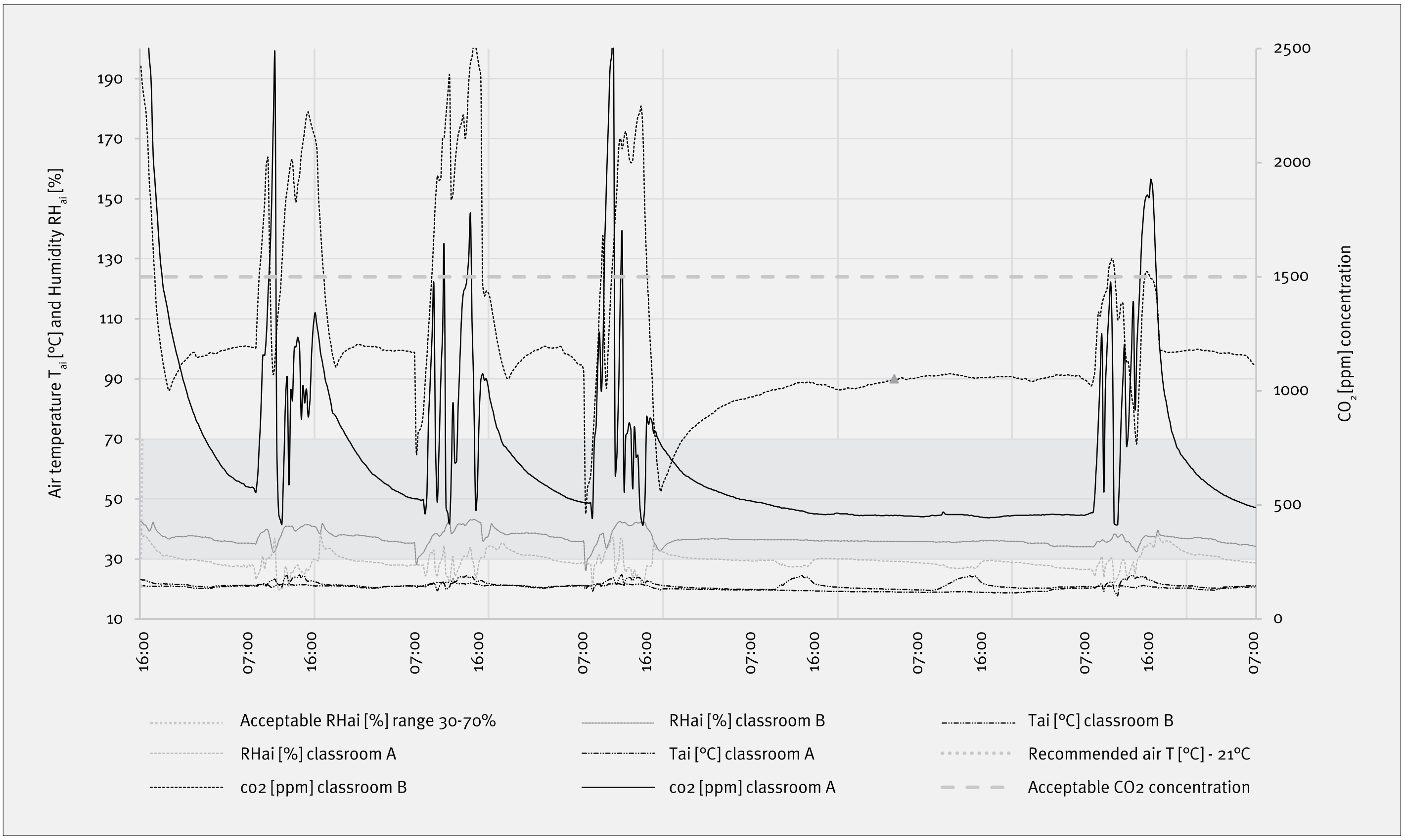
The Table II shows the data recorded during classrooms occupancy: relative air humidity RH_{ai} [%], indoor air temperature T_{ai} [°C] and CO_2 concentration [ppm].

As seen in the table, the maximum daily CO_2 concentration is observed in classroom A where it also attains the minimum daily value recorded. We can therefore conclude that there is a higher CO_2 recorded concentration range in classroom A, while the data obtained point to a more constant CO_2 concentration in classroom B. Similarly, the recorded indoor air temperature variation is more distinct in classroom A and ranges during the room's occupancy from ±1.1 to ±3.4 °C, while that of classroom B ranges only from ±0.3 to ±0.9 °C. Moreover, indoor air humidity data also reveal a substantially higher variation level in the classroom with the original timber-framed windows (A). The above underlined facts are due to better airtightness of the classroom with new windows (B), which is why the room lacks spontaneous air infiltration.

The Table II also displays average recorded parameter values, which represent the average of all measurement points during the kindergarten's occupancy and point to considerable differences in the two classrooms' CO_2 concentration. The average CO_2 concentration recorded during the occupancy period in the classroom with new windows installed (B) surpasses that of the classroom with old timber windows (A) by a third, despite a smaller number of children in the room.

Minimal daily CO_2 concentration is recorded before the arrival of children in the classroom and is always lower in the classroom with original timber-framed windows (A), owing to poorer airtightness of the room and due to spontaneous air infiltration at night-time. Maximum daily CO_2 concentration is recorded at daytime and is directly conditioned by the number of children and the manner of ventilation. With a higher number of children in classrooms along with inadequate room ventilation, the concentration of CO_2 rises exponentially. Considering a relatively steady number of children in individual classrooms, the CO_2 value varies significantly per days, mostly on account of an altered ventilation pattern which takes place on certain days. Ventilation intervals last 10 to 45 minutes.

30 The classrooms are closed even during weekends when CO_2 concentration in the classroom with original timber windows (A) gradually falls for about 50%, owing to a constant airflow via the old poorly airtight windows. On the other hand, in the case of non-occupancy CO_2 concen-



GRAPH I PARAMETERS FOR THE ENTIRE MEASUREMENT PERIOD, RH_{AI} [%], T_{AI} [°C], CO_2 [PPM]

GRAF. I. PARAMETRI ZA CJELOKUPNO RAZDOBLJE MJERENJA, RHAI [%], TAI [°C], CO2 [PPM]

The rooms are usually ventilated for 30 minutes while the children go for a walk, however in the case of bad weather the teachers do not take younger children out, which means lack of conditions for a thorough ventilation. Ten-minute ventilation intervals proved to be ineffective as the room CO_2 concentration hardly showed any decrease, similarly to indoor air temperature and humidity. On the other hand, 30-minute room ventilation significantly decreases CO_2 concentration, while it also lowers indoor air temperature by up to 1°C (Graph I).

Indoor air temperature and CO_2 concentration start rising on a daily basis upon the arrival of children as the windows remain closed while the number of occupants increases. With kindergarten children in the classrooms, CO_2 concentration increases in proportion to the period of time passed since the last ventilation interval. At the end of the workday at 16h, the average CO_2 concentration in the classroom with the original windows (A) amounts to 1,080 ppm, with the value recorded in the classroom with the windows replaced (B) being considerably higher, 2,252 ppm. The time span from the departure of children and their arrival the following day at 7h equals 15 hours. During that time the (A) classroom concentration of CO_2 decreases on average by 62 %, while that of the classroom with new windows (B) shows a reduction by only 39 %, on account of better airtightness. Hence, each new workday in classroom B begins with a strongly elevated CO_2 concentration which gradually increases towards the end of the workday.[30]

Kindergarten children in the classroom with the windows replaced (B) are clearly almost constantly exposed to CO_2 concentration higher than 1,000 ppm. On certain days, the concentration of CO_2 does not fall below 1,000 ppm; what is more, children are frequently exposed to a concentration beyond 1,500 ppm which is present over long time intervals (several hours). Such time intervals, relative to the classroom with original windows (A) lasted for a maximum period of an hour, i.e. until the next ventilation interval and were not observed on a daily basis.

Indoor air temperature recorded in both classrooms had an appropriate range. The average indoor air temperature at occupancy times

tration in the classroom with new PVC windows (B) gradually even increases (relevant literature defines furniture and equipment as a potential pollution source whose combination with the windows closed results in the increase of indoor CO_2 concentration).

was 21.3 °C (classroom B) in 22.2 °C (classroom A). Indoor air temperature in both classrooms was approximately the same at the start of each workday. Both classrooms have the same heating mode. On average, classroom B had a lower indoor air temperature during occupancy hours as its window replacement resulted from a desired temperature increase (the staff complained about coldness in the winter season). The classroom with old timber windows (A) also witnessed a higher temperature increase during weekend days, owing to its southward orientation.

Relative air humidity recorded during occupancy hours in the classroom with new windows (B) showed an average of 37.4 %, with the values generally being within the satisfactory range. However, the classroom with original timber windows (A) proved to be drier with the recorded value of 28.7 %, which means that relative air humidity is below the bottom recommended boundary and varies in accordance with indoor air temperature changes.

Conclusion

Zaključak

Preschool facilities built in the territory of former Yugoslavia after World War II are a reflection of societal development. As to their architectural expression, it arises from the search for optimal solutions to satisfy the needs of the above mentioned development. Thus, it can be claimed that numerous preschool education buildings dating form that period represent invaluable built heritage relying on thoughtfully approached spatial planning, coherence with the context of space, modern spatial design, innovative details, sensible use of materials and carefully considered building design taking into account the requirements and specifics of the children.

A considerable number of preschool education buildings have already been partial or fully renovated while a part of the building stock in former Yugoslavia still needs energy-efficient renovation. Renovation measures must definitely not spoil the architectural concept of a building but should result in a significantly better indoor comfort for the children. As a complex task, such renovation requires a holistic approach.[31] Energy renovation tool and methods have been generally well known, however there is still evidence of non-systematic approach, as seen in the study case, due to either a lack of expertise or to economic obstacles.

Partial renovation measures can bring about a marked deterioration of IEQ experienced by kindergarten children, with the most serious issue being that of indoor air quality. The presented case analysis points out that children using the classroom with new PVC windows (B) suffered a continuous daily exposure to elevated CO_2 concentration, as opposed to occupants of the classroom with the original timber-framed windows (A) whose higher level of CO_2 exposure was of significantly shorter duration.

According to the observed maximum occupancy proportion during the measurements, i.e. 75 % for classroom A and 90 % for classroom B, we can assume that indoor air quality in winter time, with a maximum number of children attending, may even be worse, which is highly concerning. Moreover, the average CO_2 concentration in the classroom with the windows replaced (B) seriously surpasses the mention parameter recorded in other European kindergartens. Exaggerated exposure to increased CO_2 concentration can cause the appearance of different symptoms, such as eye irritation, a cold, dry mucosa, dry skin, headache and weariness, in addition to increased respiratory disease risk in children.

Furthermore, indoor air temperature in the classroom with new windows installed (B) conforms to all relevant recommendations and the same is true of the relative humidity, despite occasionally drier air periods. Daily records of indoor air temperature in the classroom with original timber windows (A) show slightly higher values at daytime, all within the scope of estimated circumstances in European kindergartens, with the air being relatively dry, even somewhat drier in comparison to the existing Europe based researches.

With a view to preventing negative consequences of energy-efficient building renovation seen in deteriorated indoor air quality and thermal comfort, it is vitally important for the users of spaces to be aware of the changes that partial or comprehensive renovation measures bring along and to understand how to use a renovated building. The latter is unfortunately not always true. An important guideline relative to window replacement and energy-efficient building maintenance is to practice regular ventilation in order to enable a healthy indoor comfort. Window re-

31 Žegarac Leskovar, Premrov, 2019

32 **Acknowledgment**: The presented study was conducted within the framework of the research project "*VRTEC+ development of renovation models of preschool education buildings in Slovenia*" which is carried out within the Operational Programme for the Implementation of the EU Cohesion Policy 2014-2020 (research core funding No. OP20.04345). The investment is co-financed by the Republic of Slovenia, Ministry of Education, Science and Sport and the European Union under the European Regional Development Fund. The authors also acknowledge the financial support from the Slovenian Research Agency (research core funding No. P2-0129).

placement namely results in significantly better airtightness, which requires more attention paying to ventilation for the purpose of achieving high indoor comfort levels. Sadly, the users of buildings are mostly unaware of these facts and need proper instructions. In addition to the already stated arguments in the current article, the awareness as to appropriate ventilation of rooms occupied by children is undoubtedly at the forefront of the science of architecture in the context of the present global situation regarding the COVID 19 pandemic proportion and the possibility of the infection spreading. What is more, with a view to solving ventilation issues, it is recommendable to combine window replacement in the classrooms with the installation of a ventilation system, in line with the allowable budget.

The problem area discussed is fairly unknown to a wider population or to expert groups and individuals performing energy-efficient renovation, i.e. predominantly construction companies. Unfortunately, it is currently possible to carry out energy renovation measures without holistic design planning of architects, civil and other engineers. As the majority of states once part of former Yugoslavia have only started the process of energy-efficient renovation, there is room for a strategically well planned approach based on a prior building stock and built heritage analysis, on further architectural knowledge acquisition from the part of architects, building users and constructors. The outcome of the current research can be aligned with a great number of kindergarten and other high-density buildings (e.g. schools) in the Balkans. Accordingly, the study findings could also serve as guidelines to expert and non-professional public (e.g. headmasters, responsible individuals or teams within different institutions or municipalities), in addition to being beneficial to building renovation planning in the territory of former Yugoslavia, and to the maintenance of the already renovated stock.[32]

[Translated by Danijela Žegarac,
dipl. ang. prev. in prof. fran.]

Bibliography

Literatura

1. Alfano, A. [ed.], Bellia, L.; Boerstra, A.; Van Dijken, F.; Ianniello, E.; Lopardo, G.; Minichiello, F.; Romagnoni, P.; Gameiro da Silva M.C. (2010), REHVA – Indoor Environment and Energy Efficiency in Schools – Part 1, REHVA: 1-121, Brussels
2. Araújo-Martins, J.; Carreiro Martins, P.; Viegas, J.; Aelenei, D.; Cano, M.M.; Teixeira, J.P.; Paixão, P.; Papoila, A.L.; Leiria-Pinto, P.; Pedro, C.; Rosado-Pinto, J.; Annesi-Maesano, I.; Neuparth, N. (2014), *Environment and Health in Children Day Care Centres* [*ENVIRH*] *– Study rationale and protocol*, "Pneumologija, Portuguese Journal of Pneumology": 220; https://doi.org/10.1016/j.rppneu.2014.02.006
3. Borodinecs, A.; Budjko, Z. (2009), *Indoor air quality in nursery schools in Latvia,* V: Proceedings of Healthy Buildings 2009, Healthy Buildings 2009: 1-4, Syracuse, NY, USA
4. Cano, M. et al. (2012), *Indoor Air Quality in Portuguese Children Day Care Centers – ENVIRH Project*, in: The Second International Conference on Building Energy and Environment 2012, Topic 3. Indoor and outdoor air quality, thermal comfort and health impact related to build environment: 414-421, 1-4 August 2012, Boulder, Colorado
5. Cars, H.; Petersson, C.; Hakansson, A. (1992), *Infectious diseases and day-care center environment*, "Scandinavian Journal of Infectious Diseases", 24 (4): 525-528; https://doi.org/10.3109/00365549209052639
6. Đukanović, Lj. (2015), *Tipologija i valorizacija stambenih zgrada Beograda sa stanovišta komfora stanovanja,* doktorska disertacija, Univerzitet u Beogradu, Arhitektonski fakultet, Beograd
7. Fabbri, K. (2013), *Thermal comfort evaluation in kindergarten: PMV and PPD measurement through datalogger and questionnaire*, "Building and Environment", 68: 202-214; https://doi.org/10.1016/j.buildenv.2013.07.002
8. Gregorski, M.; Zavišek Hudnik, D.; Nardoni Kovač, Š. (2017), *Pomen evidentiranja in vrednotenja stavb vrtcev v Sloveniji,* "AR", 2: 60-67
9. Jovanović-Popović, M.; Ignjatović, D.; Rajčić, A.; Đukanović, L.; Nedić, M.; Stanković, B.; Ćuković-Ignjatović, N.; Živković, B.; Sretenović, A.; Đurišić, Ž.; Kotur, D. (2018), *National Tipology of Kindergarten Building in Serbia*, Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ] GmbH and University of Belgrade, Faculty of Architecture, Belgrade, Serbia
10. Missia, D.A.; Demetriou, E.; Michael, N.; Tolis, E.I.; Bartzis, J.G. (2010), *Indoor exposure from building materials: A field study*, "Atmospheric Environment", 44 (35): 4388-4395; https://doi.org/10.1016/j.atmosenv.2010.07.049
11. Pajek, L.; Kristal, Ž.; Košir, M.; Kacjan Žgajnar, K.; Dovjak, M. (2017), *Indoor environmental quality* [*IEQ*[*in Slovenian children daycare centres*, Part I: Results of in-situ measurements, "International Journal Sanitary Engeenering Research", 11 (1): 4-19
12. Pejtersen, J.; Clausen, G.; Sorensen, D.; Quistgaard, D.; Iwashita, G.; Zhang, Y.; Fanger, P.O. (1991), *Air pollution sources in kindergartens*, in: *V Proceedings of IAQ, Healthy Buildings:* 221-224, Washington DC, Atlanta, USA
13. Roth-Čerina, M. (2017), *Tipski projekti dječjih vrtića u 1960-im i 1970-im godinama u Zagrebu,* "Prostor", 25 (1 /53/): 20-39, Zagreb; https://doi.org/10.31522/p.25.1(53).2
14. Ruotsalainen, R.; Jaakkola, J.J. (1993), *Ventilation and indoor air quality in Finnish daycare centers*, "Environment International", 19: 109-119; https://doi.org/10.1016/0160-4120(93)90362-L
15. Škratek, G. (2018), *Blokovne stanovanjske soseske v Mariboru: morfološki, funkcijski in socialno-geografski oris,* doktorska disertacija, Univerza v Mariboru, Filozofska fakulteta, Maribor
16. Žegarac Leskovar, V.; Premrov, M. (2019), *Integrative approach to comprehensive building renovations*, Green energy and technology (Print), Cham: Springer Nature; https://doi.org/10.1007/978-3-030-11476-3
17. Yun, H.; Nam, I.; Kim, J.; Yang, J.; Lee, K.; Sohn, J. (2014), *A field study of thermal comfort for kindergarten children in Korea: An assessment of existing models and preferences of children,* "Building and Environment", 75: 182-189; https://doi.org/10.1016/j.buildenv.2014.02.003
18. *** (2002), *Pravilnik o prezračevanju in klimatizaciji stavb,* "Uradni list RS", 42/02, 105/02
19. *** (2018), *Betonska utopija: Jugoslovenska arhitektura od 1948. do 1980.,* BINA-Beogradska nacionalna nedelja arhitekture
20. *** (2019a), ASHRAE Standard 62.1, Ventilation for acceptable indoor air quality, American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta
21. *** (2019b), *Gradovi u statistici – Dječji vrtići i druge pravne osobe koje ostvaruju program predškolskog odgoja, početak pedagoške godine 2019,* Državni zavod za statistiku Republike Hrvatske; https://www.dzs.hr/ [13.1.2020]
22. *** (2019c), *Key Data on Early Childhood Education and Care in Europ 2019 Edition, Eurvdice Report,* Europian Comission, Luxembourg: Publications Office of the European Union; https://doi.org/10.2797/894279
23. *** (2019d), *Ustanove za decu predškolskog uzrasta, 2019,* Zavod za statistiku Republike Srbije; https://www.stat.gov.rs/sr-latn/oblasti/obrazovanje/predskolsko-vaspitanje-i-obrazovanje/ [3.12.2019]

Sources

Izvori

Archive Source

Arhivski izvor

1. Janez Kališnik, Vrtec *Mladi Rod*, Ljubljana, zbirka Muzeja za arhitekturo in oblikovanje [MAO]

Document Source

Dokumentacijski izvor

1. Neobjavljeno gradivo, Znanstveno-raziskovalni projekt: *Razvoj modelov prenove stavb za predšolsko vzgojo in izobraževanje v Sloveniji VR-TEC+,* Univerza v Mariboru, Fakulteta za gradbeništvo, prometno inženirstvo in arhitekturo, Vprašalnik VRTEC+ [UM-FGPA]

Internet Sources

Internetski izvori

1. Predškolska ustanova *'11 April'*, Beograd; http://11april-nbgd.edu.rs/mapa/slavuj/ [14.2.2020]
2. The European Portal for Energy Efficiency in Building, *OVERVIEW | Decarbonising the non-residential building stock*; https://www.buildup.eu/en/news/overview-decarbonising-non-residential-building-stock [8.11.2019]

Illustration and Table Sources

Izvori ilustracija i Tablica

Fig. 1, 4-7	Authors, 2019
Fig. 2	Janez Kališnik, Vrtec Mladi Rod, Ljubljana [MAO]
Fig. 3	Predškolska ustanova '11 April'
Table I, II	Authors, 2020
Graph I	Authors, 2020

Summary

Sažetak

Toplinska udobnost i unutarnja kvaliteta zraka nakon djelomične energetske obnove prefabriciranog betonskog dječjeg vrtića izgrađenog 1980-ih u Sloveniji

U posljednjem desetljeću većina europskih zemalja suočava se s potrebom hitne obnove postojećih zgrada za predškolski odgoj i obrazovanje izgrađenih u drugoj polovici 20. stoljeća. U državama koje su nekad bile dijelom bivše Jugoslavije prosječna je starost zgrada za predškolski odgoj 45 godina i više, što je u skladu s europskim prosjekom. Te su zgrade važan dio građevinskog fonda koji zahtijeva posebnu pozornost zbog značajne prosječne starosti zgrade, potrebe za održavanjem, a posebno zbog njihova utjecaja na zdravlje i dobrobit njihovih korisnika, koji su uglavnom djeca. Povijesnoj analizi izgradnje objekata predškolskog odgoja u Jugoslaviji pristupa se u kontekstu masovne poslijeratne stambene izgradnje, uz istovremenu izgradnju vrtića u brojnim gradovima bivše države. Poslijeratna stambena politika bivše Jugoslavije bila je orijentirana na industrijalizaciju građevinskog sektora i poboljšanje kvalitete prefabricirane gradnje, što je također imalo utjecaja na izgradnju objekata za predškolski odgoj. Kao rezultat toga mnoge su postojeće zgrade projektirane i izgrađene korištenjem prefabriciranih graditeljskih sustava.

Većina vrtića izgrađenih prije primjene strožih propisa o energetskoj učinkovitosti zgrada na području bivše Jugoslavije zahtijeva energetski učinkovitu obnovu. Proces energetske obnove složen je postupak koji vodi k boljem arhitektonskom projektiranju, tj. performansi zgrade, a to je povezano s modernim načinima korištenja vrtića. Ipak, pretpostavlja se da će energetski učinkovita obnova rezultirati boljim energetskim performansama zgrada i povećanom unutarnjom udobnošću. Na žalost, praksa dokazuje suprotno jer brojne obnovljene zgrade imaju nepravilnu ventilaciju, što ima za posljedicu lošu kvalitetu zraka i neadekvatnu toplinsku udobnost. Svrha je ovoga istraživanja procijeniti kvalitetu zraka u unutrašnjosti zgrade i toplinsku udobnost u dvjema prostorijama odabrane betonske zgrade vrtića, izgrađene 1980. godine u Sloveniji. Djelomična energetski učinkovita obnova zgrade uključivala je zamjenu prozora u polovici svih prostorija, tj. ugradnju novih prozora s dvostrukim ostakljenjem s PVC (polivinilkloridnim) okvirima, dok je druga polovica prostorija sačuvala izvorne drvene okvire. Cilj je istraživanja bio analizirati parametre toplinske udobnosti i kvalitete zraka u zatvorenom, i to u prostorijama s instaliranim novim prozorima, ali i u prostorijama s izvornim prozorima. Analiza obuhvaća tipološke, arhitektonske i povijesne analitičke aspekte zgrade zajedno s procjenom individualne toplinske udobnosti i parametara kakvoće zraka u zatvorenom prostoru na temelju rezultata dobivenih mjerenjima na licu mjesta u dvjema prostorijama vrtića.

Povijesnoj analizi izgradnje objekata za predškolski odgoj pristupilo se u kontekstu masovne stambene izgradnje u bivšoj Jugoslaviji. Eksperimentalna analiza obuhvatila je *in situ* kontinuirana mjerenja individualne toplinske udobnosti i parametara kvalitete zraka u zatvorenom. U području toplinske udobnosti provedenim je mjerenjima ispitivana temperatura zraka u zatvorenom Tai [C°] i relativna vlažnost zraka u zatvorenom RHai [%]. Izmjereni pokazatelj kakvoće zraka u zatvorenom bio je koncentracija CO_2 [ppm]. Mjerenja na licu mjesta *(in situ)* provedena u betonskoj zgradi vrtića pokazuju da je prosječna koncentracija CO_2 zabilježena tijekom razdoblja korištenja u prostoriji s novim prozorima (B) bila za trećinu veća nego u prostoriji sa starim drvenim prozorima. Djeca u prostoriji sa zamijenjenim prozorima (B) gotovo su stalno izložena visokoj koncentraciji CO_2 (≥1000 ppm). Štoviše, djeca su često izložena značajno povećanoj koncentraciji CO_2 (≥1500 ppm) koja je prisutna u dužim vremenskim intervalima. Takvi vremenski razmaci, u odnosu na prostoriju s izvornim prozorima (A), trajali su najviše sat vremena, tj. do sljedećeg intervala provjetravanja i nisu svakodnevno bilježeni. Prosječno je unutarnja temperatura zraka tijekom vremena korištenja bila niža u prostoriji B (21,3 °C), gdje je zamjena prozora bila posljedica želje za povećanjem temperature u prostoriji. Može se zaključiti da je prostorija sa starim drvenim prozorima (A) imala povišenu temperaturu zraka u zatvorenom prostoru (22,2 °C) zbog dodatnih čimbenika, ali ponajprije zbog svoje južne orijentacije. U cjelini, zabilježena temperatura zraka u zatvorenom u objema prostorijama kretala se unutar odgovarajućeg raspona. Relativna vlažnost zraka zabilježena tijekom radnog vremena u prostoriji s novim prozorima (B) pokazala je u prosjeku 37,4%, s time da su vrijednosti uglavnom bile unutar zadovoljavajućeg raspona. Međutim, prostorija s izvornim drvenim prozorima (A) pokazala se sušom, s prosječnom zabilježenom vrijednošću od 28,7%, što je ispod donje preporučene granice.

Važna smjernica u vezi sa zamjenom prozora i energetski učinkovitim održavanjem zgrada jest praksa redovitog provjetravanja kako bi se omogućilo zdravo unutarnje okruženje. Zračna nepropusnost zgrade nakon energetski učinkovite obnove uglavnom je znatno poboljšana, što znači da je dotok svježega zraka moguć samo ventilacijom (prirodnom, otvaranjem prozora ili mehaničkom) koja je potrebna da bi se osigurala odgovarajuća kvaliteta zraka u zatvorenom. Kako bi se spriječile negativne posljedice energetski učinkovite obnove zgrada koje se vide u pogoršanoj kvaliteti zraka u zatvorenom i toplinskoj udobnosti, osobito je važno da korisnici i odgovorne strane budu svjesni promjena do kojih dovode takve djelomične ili cjelovite mjere energetske učinkovitosti obnove, te da razumiju kako se koristi obnovljena zgrada. Rezultati ovoga istraživanja mogu se primijeniti na velik broj vrtića i drugih zgrada na Balkanu. U skladu s time, ovi rezultati mogu poslužiti kao smjernice stručnjacima, ali i drugima (npr. ravnateljima, odgovornim pojedincima ili timovima u različitim institucijama ili općinama). Usto, oni će biti od koristi pri planiranju obnove zgrada na teritoriju bivše Jugoslavije i održavanju već obnovljenih zgrada.

Biographies

Biografije

Assist. Ph.D. **Vesna Lovec**, Eng.Arch., has a PhD in architecture awarded by the Faculty of Architecture, University of Belgrade. Her research studies address the vernacular architecture of Serbia, energy efficiency of buildings and kindergartens.

Prof. Ph.D. **Miroslav Premrov**, Civ.Eng., Professor of the study programmes of *Timber construction* and *Concrete construction*.

Assoc. Prof. Ph.D. **Vesna Žegarac Leskovar**, Eng. Arch., Associate Professor of the study programmes of *Architecture and Spatial Planning*.

Dr.sc. **Vesna Lovec**, dipl.ing.arh., asistentica. Doktorirala je na Arhitektonskom fakultetu Sveučilišta u Beogradu. U svojim istraživanjima bavi se vernakularnom arhitekturom Srbije te energetskom učinkovitošću zgrada i dječjih vrtića.

Dr.sc. **Miroslav Premrov**, dipl.ing.građ., profesor na kolegijima „Drvene konstrukcije" i „Betonske konstrukcije".

Dr.sc. **Vesna Žegarac Leskovar**, dipl.ing.arh., izvanredna profesorica na kolegijima „Arhitektura i prostorno planiranje".