CONFERENCE PROCEEDINGS

5th INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

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PLACES AND TECHNOLOGIES 2018

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ENERGY REFURBISHMENT OF A PUBLIC BUILDING IN BELGRADE

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ABSTRACT

Statistics show that about 8% of overall EU building sector belongs to Sports and Recreation Building Stock, that represents about one and a half million of these kinds of buildings. It's been estimated that out of whole building sector these public buildings are accounting up to 10% of total annual energy consumption. Considering that in 2008 overall energy use was about 1,768 [Mtoe], there is the potential to reduce energy consumption of about 21 [Mtoe] on a yearly base in the EU Sport Facility Building Stock which is far away of insignificant (SportE^2, 2018).

Most of the buildings of this kind were built from 1960 to 1980. At the time of construction, energy efficiency was not taken into consideration, and even if it was taken into account, the equipment and fabrics installed at that time are not efficient now as at the time of installation. Energy sources are mostly traditional, fossil fuel based. Since regulations on energy efficiency are more stringent, these facilities must be renovated and then well maintained in terms of energy consumption. Sport buildings are mostly very well postured to adopt RES technologies, as active features, having in mind large open spaces and large outdoor surfaces. However, this paper investigates use of Passive House technologies in these manmade structures that may be productive in energy saving. The case study includes sport centre built in 1974 in Belgrade, Serbia. Different Passive House measures applied on the building structure and benefits in the sense of reducing total annual energy consumption for space heating, as well as conditions related to the comfort of the indoor environment were simulated in software package Integrated Environmental Solutions Virtual Environment, IES VE 2016, that is approved by USGBC, ASHRAE, CIBSE and U.S. Department of Energy.

Keywords: Public buildings, Sport facilities, Belgrade, Energy refurbishment, Passive House technologies

Introduction

Number of sports facilities has grown in all European countries in the last years of twentieth century. In some countries there was a strong policy „sport for all" that resulted to the increase of sports buildings. The situation was the same in Serbia. Most of the sports centres were built in that period, from 1960 to 1980. Sports centres in Belgrade are located in city area and their overall characteristics are mostly similar. Within the building there is a main sport hall area and a number of other additional facilities. Main sport hall is universal, designed for several sports, including basketball, volleyball, handball and other indoor team games. Generally, sports centres consist of few groups of spaces: group intended to public, group intended to players, management and technical equipment and group for TV and press (Ilić, 1998).

Energy consumption in these types of buildings significantly differs based on location, area and applied structural materials. It includes thermal energy used for space and water heating and electrical energy for the operation of equipment, air conditioning, ventilation and lightning. Energy consumption notably depends of climate conditions. The average total energy consumption for large scale sports buildings in the Mediterranean type of climate for effective area amounts to 260 kWh/m^2 and 490 kWh/m^2 for continental type of climate (IECCU, 1994).

Energy consumption is mostly effected by the required comfort that need to be suitable for different groups of users, the public and players, as well as the services and all other activities offered within the centre. Conditions concerning indoor environment for sports facilities are very complex. Existing sports buildings are not fulfilling standards regulated in accordance with today's environmental requirements. Comfort within sports buildings has to be considered in two ways, from the perspective of spectators and players. There is a need to achieve level of comfort for both groups. In this article the subject of the consideration is the improvement of the energy performance of the envelope of the sports centre Šumice, in Belgrade. Given the difference in the comfort conditions, the main sports hall is considered as a separate thermal zone, while the rest of the building as other zone.

Research methodology

The sports centre Šumice in Belgrade was selected for in-depth analysis of different interventions for improvement of indoor comfort and decrease of energy consumption. After analysing existing building concerning location, structural elements and thermal envelope performances, two scenarios of building improvement were created. Scenario 1 refers to the application of different refurbishment measures on the thermal envelope of the building without the main hall, while in the Scenario 2 the application of measures is only to the main sports hall.

Methodological approach includes following steps:

- Assessment of the existing building model.
- Identification of elements of a thermal envelope requiring refurbishment - priorities are determined based on the highest value of transmission losses (based on the height of the transmission losses).
- Defining measures for energy improvement of selected elements of thermal envelope - architectural refurbishment actions that fulfil conditions regulated by EnerPHit/EnerPHit+[1] (Passive House Certificate for retrofits) - Creation of Scenario 1 and Scenario 2.
- Analysis of effects of the applied measures; Parameters according to which the suitability of the applied measures is estimated are final energy $Q_{h, nd}$ [kWh/m^2a] and obtained comfort conditions. The improvement effects were considered for each measure individually and then cumulatively.
- A comparative analysis of Scenario 1 and Scenario 2, as well as Scenario 1+2.

Case study – Energy refurbishment of Sport Centre Šumice in Belgrade, Serbia

The sports centre Šumice is located in the peripheral zone of the central area of Belgrade, in the southeast direction, at a distance of about 4 km from the downtown. The position of the building is at the edge of the forest area. Building layout and the appearance/design of the exterior and interior parts are shown in the Figure 1.

1 EnerPHIt Certification for retrofits is applied for retrofits of the existing buildings where there is no possibility to satisfy passive house requirements. EnerPHit+i is applied for buildings where more than 25% of existing non transparent area of the building is covered with internal insulation.

Figure1: Building layout (left - A+D+S-the building without main hall, H-main hall), south façade of the Sport Centre Šumice (middle) and interior of the main sports hall (right). Source: Original project documentation, 1974. Archive of Vozdovac Municipality. Photos taken by Authors.

Some structural and architectural characteristics of the building that are important for further analysis are that the building has three stories, including basement, 1,250 seats in the main sport hall and that the area of the facade is 4,164.2 m^2 – out of which 25.7% is glazed. The structural system is rainforced concrete skeleton for the building without the main sport hall and for the main sports hall concrete frame, with brick walls as infill. Other important characteristics concerning working hours and HVAC system that exist in the building are shown in Table 1.

Table 1: Operating profile and HVAC characteristics of the Sport Centre Šumice, Belgrade, Serbia (Source: Authors)

Basic characteristics	**Building without main sports hall**	**Main sports hall**
Operating profile	Administration: from 8am till 16pm, except weekends and holidays. Two administrative workers in the office.	From 8am to 23pm, every day except 1st of January. Official games during the weekends have 500 spectators.
HVAC	Central space heating system for the whole building. Boiler room is located in the basement of the building. There are radiators in each room Termik 808-IV, 480-IV of different size based on situation. Boiler for hot water is 2000 l. Sport hall is not naturally ventilated.	
Lighting	Lighting of the foyer by fluorescent lamps 60 W each. Offices have incadescent lamps of 100 W.	Main sports hall has 30+ halide lamps of 1000 W.

Thermal envelope of the Sport Centre Šumice in Belgrade

Structural elements of thermal envelope of the Sport Centre are shown in Table 2.

Table 2: Thermal envelope of the Sport Centre, existing condition (Source: Authors)

Thermal envelope, selected positions	**Existing building before implementation of proposed energy efficiency measures**					
	Layers - from outside to inside	**Thermal transmittance U W/m²K**	**Area** A (m²)	**Fx**	**UxAxFx**	**%**
Building without main sports hall						
External wall of the building	Ceramic tiles 8mm Concrete 120mm Expanded polystirene 75mm Gypsum plasterboard 12.5mm	0.368	1,789.56	1.0	658.56	19.82

External wall, basement of the building	Gravel 150mm Half brick as protection Bitumen layer 5mm Cast concrete 250mm Gypsum plastering 12.5mm	1.159	933.26	0.6	648.99	19.53
Glazed surfaces of the building facade	Clear float 6mm Cavity 12mm Clear float 6mm	Uf with frame = 3.201 Ug glass only = 3.201 g EN 410= 0,707	947.74	0.7	663.42	19.91
	Aluminium doors with clear float glass 6mm	Uf with frame= 3,201 Ug glass only= 3.201 g EN 410= 0.707		0.7		
Flat roof	Stone chippings Waterproof roof covering Polyurethan insulation 40mm Vapour control layer Screed 40mm Reinforced concrete 150mm Dense plaster 12,5mm	0.467	2,631.29	1.0	1,228.81	36.99
Ground floor	Gravel 150mm Reinforced Concrete 150mm Bitumen layer Cast concrete 60mm Screed 30mm Clay tile 22mm	1.291	2,631.29	0.5	1,698.49	51.12
Main sports hall						
External wall, Sport Hall	Face brick 380 Plaster (lightweight) 12.5mm	1.858	1,051.52	1.0	1,953.72	58.81
Glazed surfaces of the main sport hall facade	Pilkington 6mm Cavity 12mm Pilkington 6mm	Uf with frame = 2.857 Ug glass only = 2.856 g EN 410= 0.608	121.88	0.7	243.79	7.33
	Wooden door	2.194	45.0	1.0	98.73	
Pitched roof	Felt bitumen layers with vulkapren in Al colour 15mm Polyurethan board 40mm Roofing felt 0.5mm Syporex 150mm Cavity average height 22000mm Oak 20mm	0.302	1,784.69	1.0	538.98	15.15
Ground floor	Gravel 150mm Reinforced Concrete 150mm Bitumen layer Cast concrete 60mm Elastic layer Timber on 100mm joist Oak 22mm	0.509	1,784.69	0.5	454.20	13.67

Fx- correction factor, UxAxFx- transmission losses, %- percentage of transmission losses

Simulated conditions

Energy performances of existing building and models – Scenario 1, 2 and 1+2 after applying various energy efficiency measures, are simulated in software package Integrated Environmental Solutions Virtual Environment 2017, IES VE. Model of the case study is created in

SketchUp 2016 and transferred in IES VE 2017., as shown in Figure 2. Total floor area of the heated space of sport centre is 6,790.5 m^2. Total heated volume of the building is 30,995.51 m^3.

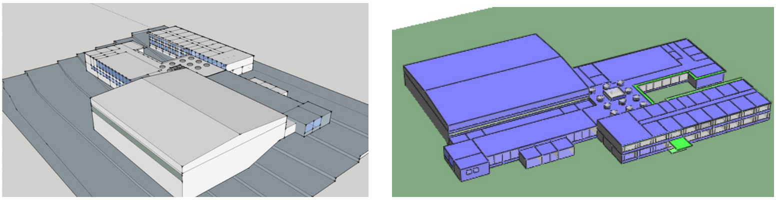

Figure 2: Model of Sport Centre Šumice, existing situation, model in SketchUp 2016 (left), module ModelIT, IES VE 2017 (right).

Operating hours summarized in Table 1 are different for main sport hall and other part of the building. These two parts are treated as two thermal zones based on different thermal requirements. For the simulation of the existing situation infiltration rate was taken as 0.2 ACH. Regarding air exchange there is no natural ventilation in main sport hall but it exists in other parts of the building.

Simulated indoor air temperature during the heating period (from mid-October to mid-March) is taken as 16°C for main sports hall (it goes from 12°C to 18°C for the sports activities) and 20°C for the rest of the building (range for achieved thermal comfort is 24°C for the locker rooms and 26°C for administration) (CIBSE Guide A, 2006). During the period from mid-May to mid-October the simulated indoor air temperature is set at 20°C for the main sports hall and 26°C for all other spaces according to the Rule book on the Energy Efficiency of Buildings (Official Gazette of RS, No. 61/2011). However, regarding European standards, thermal comfort during summer should not be more than 10 % of the occupancy hours over 25 °C in the given year (Passive House Requirements, 2017).

Concerning internal thermal gains in the main sport hall the following sources are present: sports arena lights, sports arena occupancy, sports arena equipment, computers in the administration area, lights and people.

Measures for improvement of elements of thermal envelope - passive measures

Strategy of initial improvement implies upgrading of thermal insulation in terms of material type and thickness. Improving or applying thermal insulation is one of the most effective individual energy efficiency improvement measures. It can be applied as internal or external. In this case study increase in thickness of thermal insulation (applying rock wool or XPS of 15cm on the inner side of the thermal envelope) and improvement of the glazed area (Low-E Triple Glazing SC=0.2) are defined based on the requirements set by EnerPHit/EnerPHit+certification (Passive House Institute, 2017) that shows maximum values of thermal transmittance of different parts of thermal envelope. U values are presented in the Table 3.

Analyse of effects of the proposed refurbishment measures

Results of simulation of energy performances before and after refurbishment are presented for Scenario 1 - Sports Centre-building without main sport hall in Table 3 and for Scenario 2 – Main sport hall in Table 4. For each proposed intervention heating energy $Q_{h, nd}$ [kWh/m^2a] is calculated.

Table 3: Refurbishment interventions and estimated annual energy consumption for Scenario 1

Sports Centre- building without main sport hall (Scenario 1)					
Positions of thermal envelope	Existing situation before implementation of energy efficiency measures				After applying proposed measures
	U	U_{max}	A	Hts	A1
	W/m²K	W/m²K	m²	W/K	Rock wool (15cm) U W/m²K
External wall, first story, office	0.37	0.15	1,789.56	658.56	0.14
Fulfilled condition of thermal comfort , office		13.4% when occupied comfort index is 6 8[2]			13.4% when occupied comfort index is 6 8
Q_{hnd} kWh/m²		1,037.5			1,010.2
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E[3]			$Q_{h,nd,rel}$= 167.7% E
Energy saving					2.6%
External wall, basement, office -1	1.19	0.35	933.26	648.99	Rock wool (15cm) U W/m²K 0.2
Fulfilled condition of thermal comfort in the office		18% when occupied comfort index is 6 8			18% when occupied comfort index is 6 8
Q_{hnd} kWh/m²		1,037.5			1,014.7
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 168.6% E
Energy saving [%]					2.2%
Floor	1.32	0.15	2,631.29	1,698.49	XPS (15cm) U W/m²K 0.15
Achieved thermal comfort in the building		13.4% when occupied comfort index is 6 8			13.6% when occupied comfort index is 6 8
Q_{hnd} kWh/m²		1,037.5			771.1
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 128.1% D
Energy saving [%]					25.7%
Flat roof, stone chippings	0.47	0.15	2,631.29	1,228.81	XPS (15 cm) U W/m²K 0.15
Achieved thermal comfort in the building, office		13.4% when occupied comfort index is 6-8			14% when occupied comfort index is 6-8
Q_{hnd} kWh/m²		1,037.5			957.5
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 159% E
Energy saving [%]					7.7%
Glazed area	3.210	0.85	1,069.6	663.42	Al U W/m²K 1.3 glass only 0.8
Achieved thermal comfort in the building [°C]		13.4% when occupied comfort index is 6-8			14.3% when occupied comfort index is 6 8
Q_{hnd} kWh/m²		1,037.5			998.4
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 165.8% E
Energy saving [%]					3.8%
Scenario 1, cumulative measures					
Achieved thermal comfort in the building [°C], existing 13.4%					15.8% when occupied comfort index is 6 8
Q_{hnd} existing 1037,5 kWh/m²					541.5
Energy grade $Q_{h,nd,rel}$=172.3% E					$Q_{h,nd,rel}$= 89.8% C
Energy saving [%]					47.8%

AL- glazed area- Triplex thermo insulation glass, Low-E Triple Glazing SC=0.2

[2]Comfort index values are taken from IES VE, Integrated Environmental Solutions Virtual Environment.

[3]Qh, nd [kWh/m2a] for the existing building, without any intervention is as follows:
$Q_{h,nd}$ = 1,037.54 MWh total heating energy $q_{h,nd} = Q_{h,nd}/A_f$ = 1,037.54/6,790.5 MWh/m2a = 155.1 kWh/m2a

$Q_{h,nd,rel}$ = (155.1/90)x100= 172.3%

$Q_{h,nd,rel} \le 180$ for existing sports buildings and presents E energy level

For Sport Centre Šumice - building without main sport hall, energy saving of almost 50% is achieved by implementation of refurbishment measures proposed in Scenario 1. With the same Scenario percentage of comfort index from 6-8 (comfortable) is increased from 13.4% to 15.8% when the analysed space is occupied. After applying measures proposed in Scenario 1 building is upgraded from E to C energy level.

Table 4: Refurbishment interventions and estimated annual energy consumption for Scenario 2

Main sports hall (Scenario 2)					
Positions of thermal envelope	Existing situation before implementation of energy efficiency measures				After applying proposed measures
	U	U_{max}	A	Hts	A1
	W/m²K	W/m²K	m²	W/K	Rock wool (15cm) U W/m²K
External wall, in the contact with external air	1.9	0.15	1,051.5	1,953.7	0.2
Fulfilled condition of thermal comfort , main sports hall		23.8% when occupied comfort index is 6 8			22.6% when occupied comfort index is 6 8
$Q_{h,nd}$ kWh/m²		1,037.5			939.3
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 156% E
Energy saving					9.5%
External wall (towards heated part of the building)	1.8	0.35	303.98	428.9	Rock wool (15cm) U W/m²K 0.2
Fulfilled condition of thermal comfort in the office		23.8% when occupied comfort index is 6 8			24% when occupied comfort index is 6 8
$Q_{h,nd}$ kWh/m²		1,037.5			1,036.8
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 172.1% E
Energy saving [%]					0.07%
Floor of the playground area	0.51	0.15	1,784.7	454.2	XPS (15cm) U W/m²K 0.15
Achieved thermal comfort in the building [°C]		23.8% when occupied comfort index is 6-8			23% when occupied comfort index is 6-8
$Q_{h,nd}$ kWh/m²		1,037.5			1,018.3
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 169.4% E
Energy saving [%]					25.7%
Roof of the main sport hall	0.3	0.15	1,784.7	538.9	XPS (15 cm) U W/m²K 0.13
Achieved thermal comfort in the building, office		23.8% when occupied comfort index is 6-8			24.1% when occupied comfort index is 6-8
$Q_{h,nd}$ kWh/m²		1,037.5			1,028.6
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 170.7% E
Energy saving [%]					0.9%
Glazed area	2.9	0.85	121.9	243.8	Al¹ U W/m²K 1.3 glass only 0.8
Achieved thermal comfort in the building [°C]		23.8% when occupied comfort index is 6-8			23.8% when occupied comfort index is 6 8
$Q_{h,nd}$ kWh/m²		1,037.5			1,034.9
Energy grade $Q_{h,nd,rel}$		$Q_{h,nd,rel}$= 172.3% E			$Q_{h,nd,rel}$= 171.9% E
Energy saving [%]					0.3%
Scenario 2, cumulative measures					
Achieved thermal comfort in the building , existing 23.8%					21.6% when occupied comfort index is 6-8
$Q_{h,nd}$ existing 1,037.5 kWh/m²					899.4
Energy grade $Q_{h,nd,rel}$=172.3% E					$Q_{h,nd,rel}$= 148.7% E
Energy saving [%]					13.6%

For main sports hall, energy saving of 13.6% is achieved by implementation of refurbishment measures proposed in Scenario 2. With the same Scenario percentage of comfort index from 6-8 (comfortable) is decreased from 23.8% to 21.6% when the main sports hall is occupied. After applying measures proposed in Scenario 2 building cannot be upgraded from E energy level. Decreasing of percentage of level of comfort shows that in the space of main sport hall installed HVAC system and its operational level are essential for achieving desired comfort.

Comparative analysis of Scenario 1, Scenario 2 and Scenario 1+2

Comparative analysis of Scenario 1, 2 and consolidated Scenario 1+2 is given in the Table 5 and Figure 3. If Scenario 1 is united with Scenario 2, when the whole building is refurbished, 62.2% of energy saving is achieved. Building is upgraded from E to C energy level (same as with Scenario 1).

Table 5: Comparison of results of energy simulations for Scenario 1, Scenario 2 and Scenario 1+2

Results of the simulations	Existing	Scenario1	Scenario 2	Scenario 1+2
Q_{hnd} [MWh]	1,037.5	541.5	899.4	392.27
Energy level $Q_{h, nd, rel}$	E	C	E	C
Energy saving after package of measures [%]		47.8%	13.6%	62.2%
Office- Comfort index, when occupied 6-8	13.4%	15.8%	-	14.6%
Main sport hall- Comfort index, 6-8	23.8%	-	21.6%	22.1%

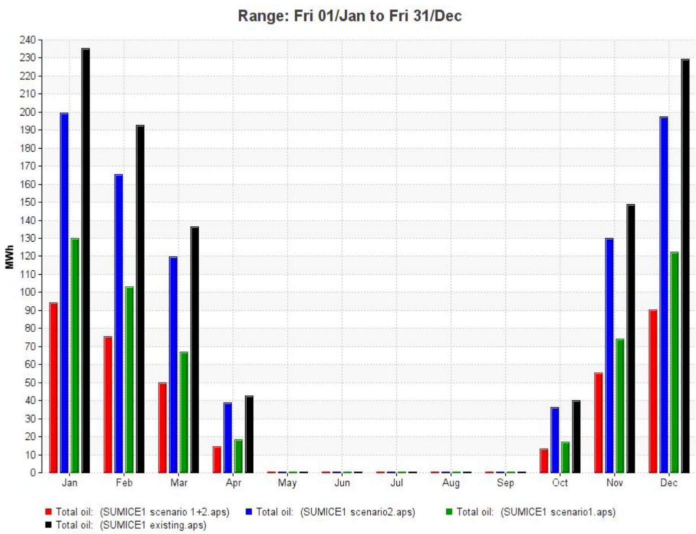

Figure3: Comparison of total oil consumption (heating energy) for Scenarios 1, 2 and 1+2, Apache Module, Vista Pro, IES VE 2017.

Conclusions

Energy consumption for space heating is significantly reduced by implementation of defined refurbishment measures, which includes improvement of thermal performance of the transparent and non-transparent parts of the thermal envelope proposed in the different scenarios. By applying of Scenario 1, improvement of building without taking into account the main sport hall, comfort is improved by 15% for the overall occupation of the office space. Estimated energy savings for space heating is 47.8%. In Scenario 2, by improving the thermal envelope of the main sport hall, 13.6% energy savings for heating were achieved. In terms of amount of energy for space heating, 138,1 MWh is saved, which is considered to be remarkable savings. But, concerning comfort in the main sport hall percentage of comfortable hours during the occupancy period is reduced. That can be explained by existing of two groups of occupants in the same space with different comfort requirements - spectators and players, sedentary and hard work (sports activities are considered as hard work). In order to solve the situation for both groups of users, it is necessary to install and improve the HVAC system within the building, especially for the main sports hall. By consolidating both scenarios, a savings of 62.2% of the energy for space heating is estimated. The conclusion of this research approach is that if the aim is to improve the energy class, it is only necessary to apply scenario 1 - the effect is the same as the implementation of the 1+2 scenario.

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