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GREJANJU I HLAĐENJU

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HLAĐENJU I KLIMATIZACIJI

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(Beograd, 6–8.12.2017)

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48. međunarodni kongres i izložba o grejanju, hlađenju i klimatizaciji

Za prilaz zdravim, održivim i rezilijentnim zgradama, naseljima i gradovima nula emisije CO_2

Beograd, 6–8. XII 2017.

Ovogodišnji skup je planiran da bude u duhu tema koje danas obuhvataju aktuelne zadatke svetske energetike i očuvanja životnog prostora i da okupi sve profile učesnika u gradnji zgrada i njihovom energetskom opremanju: energetičare, arhitekte kao i građevince koji ujedinjenim naporima stvaraju objekte, posebno one koji u budućnosti treba da budu nula energije. Rukovodeći se naglašenim potrebama za saradnjom svih učesnika u projektovanju i građenju zgrada, u Organizacionom odboru su predstavnici više struka.

Spisak tema je širok kako bi se podstakle sve institucije, obrazovne, projektantske, montažerske, kao i one administrativno-pravnog profila, da svojim nastupom, svaka u svojoj specijalnost, upotpune celokupnu problematiku energetike koja se odnosi na građevinske objekte. Predviđen je i poseban program za studente visokoškolskih i univerzitetskih institucija.

Kongres i ove godine prati izložba uređaja, sistema, aparata, opreme, koji se ugrađuju i koriste u građevinskim objektima, kao i odgovarajućih instrumenata, materijala i softverskih programa, koji su u vezi sa energetskim potrebama stambenih, javnih i industrijskih zgrada.

U Beogradu, *UREDNIK*
novembra 2017.

Sadržaj

UŠTEDA ENERGIJE U SRPSKOJ PORODIČNOJ KUĆI SA HORIZONTALNIM NADSTREŠNICAMA

ENERGY SAVING IN SERBIAN FAMILY HOUSE WITH HORIZONTAL OVERHANGS

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U ovom radu određivane su dimenzije horizontalnih betonskih nadstrešnica da bi se minimizovala godišnja potrošnja primarne energije za grejanje, hlađenje i rasvetu u porodičnoj zgradi. Takođe je proračunom uzeta u obzir i energija utrošena za izgradnju samih nadstrešnica (sopstvena energija). Simulacije su sprovedene za zgradu lociranu u Beogradu, Srbija, tokom cele godine. Nadstrešnice su postavljene horizontalno, tako da zasenče sve spoljne zidove i prozore zgrade. Da bi se napravio model zgrade, korišćen je softverski paket za energetske simulacije zgrada EnergyPlus. Veličina nadstrešnice je optimizovana pomoću HookeJeeves algoritma i GenOpt programa.

Simulacioni rezultati pokazuju da kuća sa optimalnom veličinom nadstršnica troši 5.2 % manje primarne energije za grejanje, hlađenje i osvetljavanje u poređenju sa kućom bez nadstrešnica.

Ključne reči: *nadstresnica, primarna energija, zgrada, simulacija, optimizacija*

In this paper, dimensions of concrete horizontal roof overhangs were determined in order to minimize the annual consumption of primary energy for heating, cooling, and lighting in a residential building. Also, the energy used for building overhangs (embodied energy) was taken into account in the calculation. The simulations were carried out for the building located in Belgrade, Serbia, throughout the year. The overhangs were placed horizontally to provide shading for all exterior walls and windows of the building. To create the model, the building energy simulation software package EnergyPlus was used. The overhang size optimization was performed by using HookeJeeves algorithm and plug-in GenOpt program.

The simulation results show that the house with optimally sized overhangs consumed 5.20% of primary energy less for heating, cooling, and lighting than the building without overhangs.

Key words: *roof overhangs, primary energy, building, simulation, optimization*

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1. Introduction

Today, question of energy security and stability has become the cardinal question of the entire world economy, economic and social system. EU in addition to its high level of development and evolution of its own relationship to the energy efficiency and energy security, are also faced with a problem of reducing the global warming due to the growing use of fossil fuels. In the energy sector, the most important mechanisms for the fight against climate change are generally known - increasing energy efficiency and the introduction of renewable energy sources in the production, transmission, distribution and satisfying energy needs.

Nowadays, building sector consumes about 40 % of the consumed energy. In Serbia, building sector consumes more than 50 % of the consumed energy. In total building energy consumption, more than three-quarters of the energy is spent on heating, cooling and lighting, while the rest is spent on household electrical equipment. The cooling loads due to solar heat gains represent about a half of the cooling loads for residential and non-residential buildings. It is very important to decrease cooling loads in order to conserve energy. Role of the heat gains in the energy balance of a building is becoming more and more important. The advances in buildings' constructions, which greatly reduce thermal losses and air infiltrations, increase the thermal losses.

In this paper, the effect of shadowing by horizontal roof overhangs was investigated on the primary energy consumption for heating, cooling and lighting at the Serbian family house, through the year. Optimization is performed with the simultaneous operation of the program EnergyPlus and GenOpt to determine the optimal size of horizontal roof overhangs placed over all four walls (east, west, north and south). This is performed with respect to the primary energy consumption for heating, cooling and lighting, and at the same time takes into account the energy spent for the construction of concrete horizontal roof overhangs (embodied energy) [1].

2. House Model in EnergyPlus Software

An investigated one-store family house had the total floor area of 92 m^2, of which 86 m^2 were air-conditioned, heated and lighting. The model of the house in EnergyPlus software is shown in Fig. 1.

To ensure adequate thermal comfort in winter, electric heaters was used. Heating thermostat is used to set the appropriate temperature in winter mode. In summer mode to maintain proper thermal comfort in rooms is used room air conditioners with the appropriate thermostat. Room air conditioners are also supplied with electricity. To maintain an appropriate light level the combined impact of daylight and electric lighting, using Day Lighting Controls function (this function is implemented in EnergyPlus), which is available by entering the appropriate parameters set dimmer room in a given time interval [2].

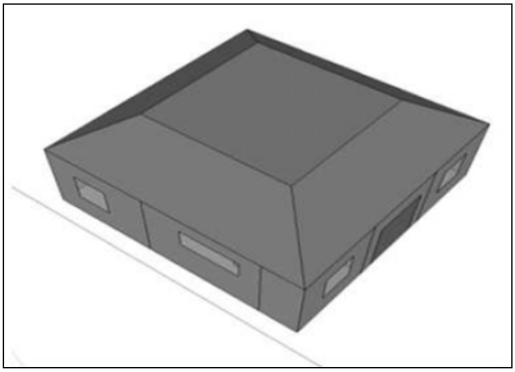

Figure 1. Modeled house in EnergyPlus software

3. Location and Climate

Investigated house is located in Kragujevac, Serbia. The time zone for Kragujevac is GMT + 1.0 h. In the city of Kragujevac summers are very warm and humid, with temperatures as high as 37^0C. The winters are cool, and snowy, with temperatures as low as -12 ^{0}C. The EnergyPlus uses weather data from its own database file, which contains data (hourly or half-hourly) for a lot of parameters (pressure, air temperature, relative air humidity, direct solar radiation, diffuse solar radiation, wind speed…) and, also, for percipitations. Figure 2 shows the weather data (average minimum and maximum air temperature and relative humidity) for Kragujevac, obtained from EnergyPlus weather file [3].

Building energy consumption depends on the building location. Input file in EnergyPlus contains a large variety of parameters for solar radiation calculating for every day in the year. Daily average solar radiation for Serbia is different in different parts of country – it is about 1,1 kWh/m^2 at the north of Serbia and 1,7 kWh/m^2 at the south of Serbia in January; in July it is about 5,9 kWh/m^2 at the north and 6,6 kWh/m^2 at the south of Serbia. Annually average solar radiation in Serbia is from 1 200 kWh/m^2 for north-west to 1 800 kWh/m^2 at the south of Serbia, while in Central Serbia, where the analyzed house is located, this value is 1550 kWh/m^2 [3]. Solar radiation doesn`t depend only on latitude and longitude, it is also depends on climate and relief.

Figure 3 represents average values of solar radiation (direct, diffuse and global) by month for Kragujevac, obtained from EnergyPlus own weather file [3].

4. Energy Consumption and Energy Saving

4.1. Primary energy consumption

Primary energy consumption of the analyzed object is calculated by the following equation:

$$E_{prim} = (E_{ac} + E_{eh} + E_{eq} + E_{el}) K_{ec} \qquad (1)$$

where:

E_{ac} –stand for electricity consumption in the indoor air conditioners,

E_{eh} –electricity consumption of the electric heating,

E_{eq} –electricity consumption for the electric equipment,

E_{el} –electricity consumption for lighting and

K_{ec} –primary energy factor (PEF).

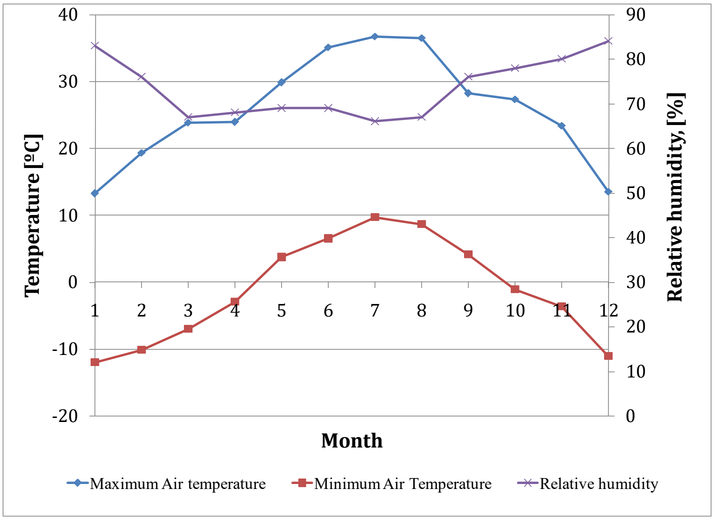

Figure 2. Monthly weather data for Kragujevac, from EnergyPlus weather file

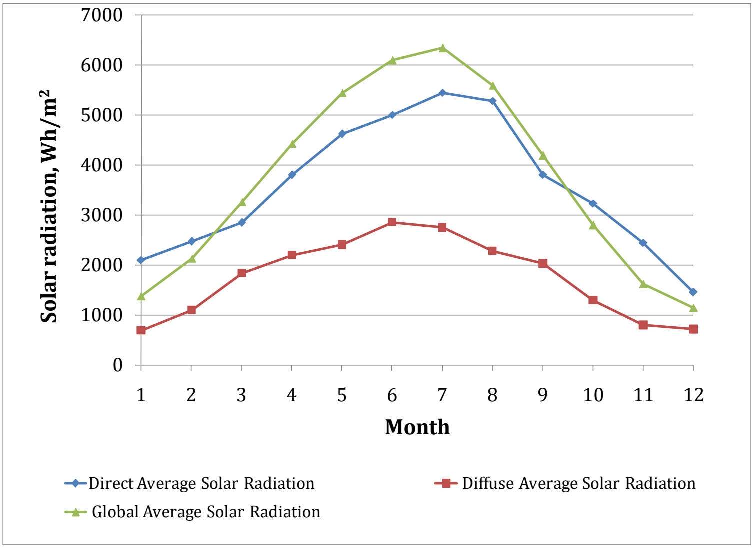

Figure 3. Solar radiation for Kragujevac, from EnergyPlus weather file

Primary energy factor is defined as the ratio of total primary energy consumption by energy sources (hydro, coal, oil, heavy oil and natural gas) and the total supplied electricity when not taking into account the imported electricity. For Serbia, the value of manufactured and supplied electricity amounts Kec= 3.04 [4] (this value varies from year to year and depends on the season hydrological situation)

4.2. Embodied energy

Embodied energy for horizontal roof overhangs depends on size and type of material, given in the next equation

$$AEE = \rho\ \delta\ l\ h s_{ec}/f_n \tag{2}$$

The optimization was performed in respect to the length of the exhaust horizontal roof overhangs h, where ρ stand for material density for roof overhangs (concrete, ρ = 2150 kg/m^3), l stand for the width of the roof overhangs that relies on the buildings wall (10.8 m), δ thick of roof overhangs (0.18 m), h length of roof overhangs, s_{ec} roof overhangs specific embodied energy (1.924 MJ/kg) [5], f_n roof overhangs lifecycle (20 years) [6].

4.3. Primary energy consumption

The total energy consumption is equal to the sum of the primary energy and embodied energy as shown in Equation (3)

$$E_{tot} = E_{prim} + AEE \tag{3}$$

This equation is the objective function for optimization in GenOpt.

4.4. The achieved energy saving

Realized savings of primary energy for heating, cooling and lighting is calculated for the house with the roof overhangs set in relation to an object without roof overhangs [7].

$$e_{psav} = 100\ (E_{p0} - E_{p,min})\ /E_{p0} \tag{4}$$

where

e_{psav} – achieved primary operating energy savings in %,

E_{pmin} – primary operating energy consumed in house after installation the roof overhangs,

E_{p0} – primary operating energy consumed in a facility without roof overhangs.

5. Results

5.1. Case 1 – house without overhangs

Annual energy balance for the house without overhangs is shown in Fig 4 and Table 1.

Results show that in the house without overhangs, electricity consumption of the electric heating is 25.59 MJ, electricity consumption in the indoor air conditioners is 23.28 MJ, electricity consumption for lighting is 8.91 MJ and electricity consumption for the electric equipment is 18.46 MJ annually. Total energy consumption in the house without overhangs is 86.02 MJ and total primary energy consumption is 261.49 MJ.

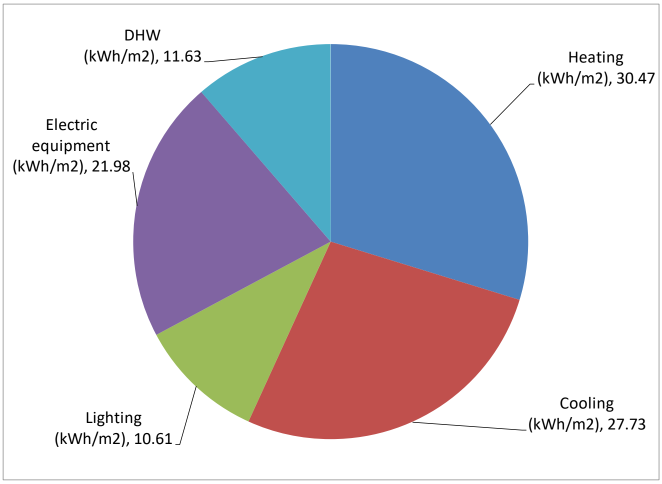

Figure 4. Energy balance for the house without overhangs

Table 1. Annual energy balance for the house without overhangs

	E_{eh} [MJ]	E_{ac} [MJ]	E_{el} [MJ]	E_{eq} [MJ]	E_{ws} [MJ]	E_{sum} [MJ]	E_p [MJ]
Case 1	25.59	23.28	8.91	18.46	9.77	86.02	261.49
	kWh	kWh	kWh	kWh	kWh	kWh	kWh
	7109.0	6467.8	2475.6	5128.2	2713.0	23893.6	72636.6

5.2. Case 2 – House with horizontal overhangs

When taking into account the impact of the energy for heating, cooling and lighting, the optimal depths of the horizontal overhangs are shown in Table 2.

Table 2. Depth of horizontal overhangs

Case 2	Depth of horizontal roof overhangs			
	East (h_E) [m]	South (h_S) [m]	West (h_W) [m]	North (h_N) [m]
Roof overhangs	2.1	0.95	1.9	0.2
Balcony overhangs	2.6	0.7	2.4	0.4

Annual energy balance for the house with overhangs is shown in Table 3 and Fig 5.

Table 3. Annual energy balance for variant 2

	E_{eh} [MJ]	E_{ac} [MJ]	E_{el} [MJ]	E_{eq} [MJ]	E_{ws} [MJ]	E_{sum} [MJ]	E_p [MJ]
Case 2	32.28	11.67	9.36	18.46	9.77	81.54	247.90
	kWh	kWh	kWh	kWh	kWh	kWh	kWh
	8968.0	3242.3	2599.8	5128.3	2713.0	22651.3	68859.8
e_{psav}[%]	-26.14	49.87	-5.05	0.00	0.00	5.21	5.20

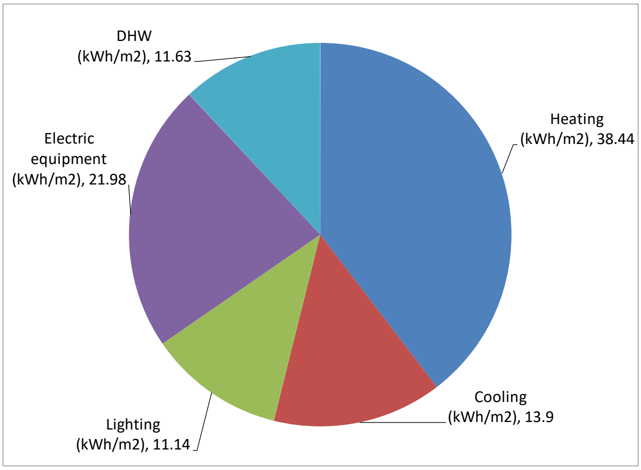

Figure 5. Energy balance for Case 2 – house with horizontal overhangs

Results show that in the house without overhangs, electricity consumption of the electric heating is 32.28 MJ, electricity consumption in the indoor air conditioners is 11.67 MJ, electricity consumption for lighting is 9.36 MJ and electricity consumption for the electric equipment is 18.46 MJ annually. Total energy consumption in the house with optimized horizontal overhangs is 81.54 MJ and total primary energy consumption is 247.9 MJ, annually.

In all calculations, the intensity of infiltration and ventilation in the house was 0.7 air changes per hour.

When we consider the influence of shadowing by horizontal roof overhangs, the primary energy consumption for heating, cooling and lighting decreased 5.20 % compared to the primary energy consumption of the house without overhangs. Then, the house reduced energy consumption for cooling by 49.87 %, while the energy consumption for heating increased by 26.14%, and the energy consumption for lighting increased by 5.05%.

The horizontal roof overhangs reduce solar radiation that passes through the windows for a 48% annually.

6. Conclusion

By placing the horizontal roof overhangs reduces the influence of solar radiation that passes through the windows by 48% per annum, given that the effect is much less pronounced in winter than in summer in the geographical area of Kragujevac. Optimal marquee dimensions are: eastern 2.01 m, southern 0.61 m, western 2.11 m and north 0.51 m. By reducing the heat gains due to solar radiation, reduces the energy consumption for cooling for 49.87 %, while increasing the consumption of energy for heating and lighting is 26.14 % and 5.05 %, respectively. Total primary energy consumption is reduced by 5.2 %.

Acknowledgments

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