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INFLUENCE OF THE TIMESTEP ON RESULTS OF OVERHANG OPTIMIZATION

Abstract: *Overhang placing prevents the direct solar radiation and thus reduces the energy required for cooling of buildings. For optimization of the overhangs Hooke and Jeeves method was used with the help of code GenOpt. For simulation energy behavior of building, EnergyPlus was used. The aim of this study was to investigate an influence of the timestep of EnergyPlus calculation to the results obtained by optimizing of overhangs. The timestep is used in the zone heat balance model calculation as the driving timestep for heat transfer and load calculations. Increasing the timestep has the effect of reducing the results of primary energy consumption for cooling.*
Keywords: timestep, EnergyPlus, optimization of overhang, cooling

1. INTRODUCTION

The building sector requires large amounts of energy both for cooling and heating. The cooling loads due to solar gains represent about half of the global cooling loads for residential and non-residential buildings. The decrement of cooling loads; in order to achieve energy conservation in buildings is very important.

Overhangs are devices that block direct solar radiation from entering a window during certain times of the day or the year. These are desirable for reducing the cooling loads and avoid uncomfortable lighting in perimeter rooms due to excessive contrast. They are more effective on south-facing windows [1]. Cooling load due to solar gains represents about half of the total cooling loads for residential buildings [2]. In research of Raeissi and Taheri, the applying of the overhangs achieved 12.7% energy saving for a cooling [3]. Using overhangs on the south orientation of the buildings in Athena, it achieved energy saving of 7.2% [4]. Also, Kim et al achieved energy saving of 11% using overhangs on south orientation of the building in the length of 1.53 m [5].

In this research the impact of the timestep on the overhangs optimization results is investigated. For energy simulation, EnergyPlus software would be used and for the optimization, Hooke-Jeeves search algorithm. These two programs would be controlled by using GENOPT software.

2. BUILDING DESCRIPTION

The analyzed residential house is a residential family house shown in Figure 1. The residential house is located in Belgrade, Serbia. The building is designed for one family and has a living area of 190.08 m^2. The envelope of the building is made of 0.19m porous brick, 0.05m thermal insulating layer and 0.02m lime mortar. The U-value is 0,57W/(m^2K). The windows are double glazed with U-value of 2.72 W/(m^2K). The overall ratio of glass to the exterior walls is 14%, where the total area of exterior walls is 112 m^2 and area of windows 19 m^2.

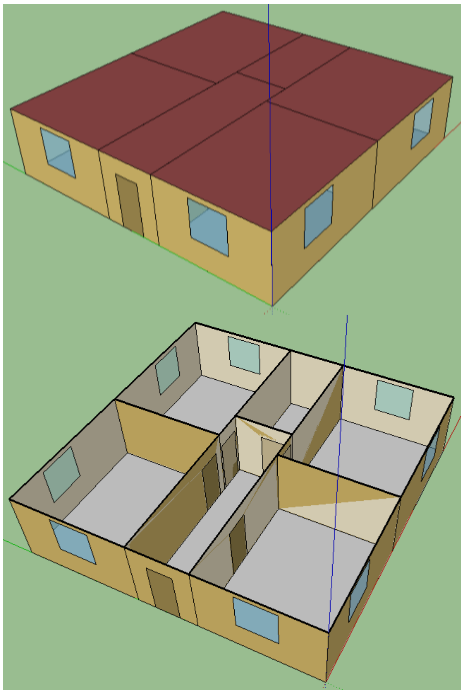

Figure 1. Analyzed residential house

3. MATHEMATICAL MODEL

To simulate a thermal behavior of the building and have accurate calculation results, software EnergyPlus is used. This program is a very useful tool for modeling of energy and environmental behavior of buildings. The program is initially developed by Lawrence Berkeley National Laboratory, U.S. Army Construction Engineering Laboratory, and the University of Illinois [6]. In the software, it is possible to input how people use building during its space heating. In this direction, the complex schedules of heating can be defined together with the schedules for use of lighting, internal energy devices and occupancy in the building.

In this study, the software GenOpt is used to optimize the length of the overhangs. GenOpt is an optimization program for the minimization of a cost function that is evaluated by an external simulation program [7]. It has been developed for optimization problems where the cost function is computationally expensive and its derivatives are not available or may not even exist. The software GenOpt is programmed for the introduction of appropriate objective functions and optimization methods using Hook Jeeves method. Hooke-Jeeves algorithm is a direct search and derivative free optimization algorithm [8]. In Hooke Jeeves algorithm, only the objective functions and the constraint values are used to guide the search strategy.

In the summer mode to maintain proper thermal comfort in rooms the window air conditioners are used. Window air conditioners are powered with electricity. As output parameters after the simulation in EnergyPlus, total electricity consumption of window air conditioners are used $E_{el,c}$, J. Cooling season runs from June 1 to August 31.

3.1 Primary energy consumption of cooling system

The primary energy consumption per cooling season at the investigated residential house is calculated by using the following equation:

$$E_{pry} = E_{el,c}\, R \qquad (1)$$

Here, R stands for the primary energy consumption coefficient. This coefficient is defined as the ratio of the total input energy of energy resources (hydro, coal, oil and natural gas) and the finally generated electric energy. For the Serbian energy mix for electricity production, R = 3.01 [7].

3.2 Embodied energy of applied overhangs

The embodied energy of applied overhangs is calculated by using the following equation:

$$E_{emb}=\rho\ l\ \delta\ h\ S_{emb} / f \quad (2)$$

Here, ρ stands for the specific density of the applied overhangs, *l* stands for the length of the overhangs, δ stands for the thickness of the applied overhangs, h stands for the width of the applied overhangs, S_{emb} stands for the specific embodied energy of the applied overhangs, and *f* stands for the lifecycle of the heating system. The characteristics of the applied overhangs are given in Table 1.

Table 1.The characteristics of the applied overhangs

Characteristics	*Values*
Specific density, ρ	*2150 kg/m*^{3}
Thickness, δ	*0.18 m*
Width, h	*10.8 m*
Lifecycle, f	*30 year*
Specific embodied energy, S_{emb}	*1.92 MJ/kg*

3.3 The total energy consumption of the system

The total energy consumption of the system is the sum of the primary energy consumption by the cooling system and the embodied energy of the applied overhangs. It is given by the following equation:

$$E_{TOT} = E_{pry} + E_{emb} \quad (3)$$

3.4 Timestep

An EnergyPlus simulation covers a certain period of time, such as a day or a year, that is broken down into a series of discrete bins of time that are referred to as timestep. The program marches through time by recalculating model equations at each timestep. The timestep object in EnergyPlus specifies the "basic" time-step for the simulation. The value entered here is usually known as the Zone timestep. This is used in the Zone Heat Balance Model calculation as the driving timestep for heat transfer and load calculations. The value entered here is the number of timesteps to use within an hour. Longer length of time-steps has lower values for number of time-steps per hour.

4. RESULTS AND DISCUSION

Results

In this study, the effect of the timestep on the overhang optimization is investigated. The investigated parameter is the energy consumption of the window air conditioners during a cooling season. In figure 2, the impact of different timesteps on the overhang optimization is shown. Also, for each length of overhangs obtained at the investigated timestep, the annual energy consumption is shown.

Figure 3 shows the energy consumption of the cooling system at different timestep using the optimum overhang length. The figure shows the primary energy consumption, the total energy consumption and the embodied energy of applied overhangs.

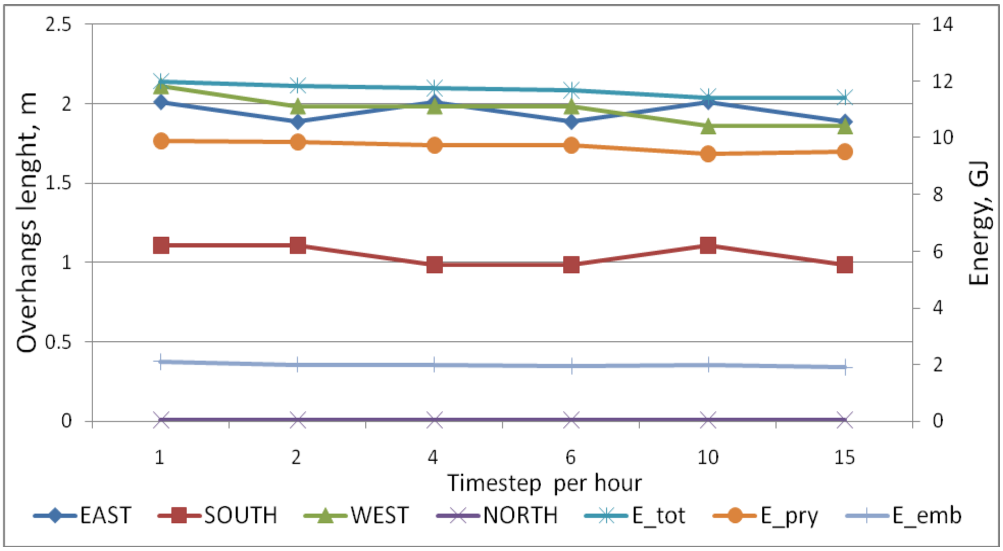

Figure 2. Impact of the timestep on the optimum overhang lengths

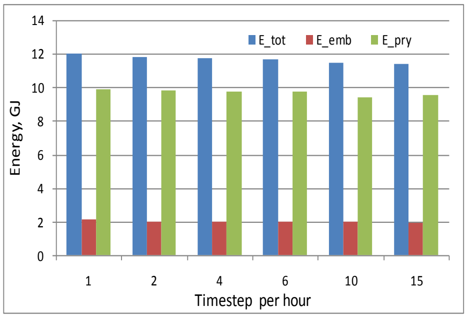

Figure 3 Energy consumption using overhangs at different timestep

Figure 4 shows the energy saving by using optimum overhang lengths at the set timestep.

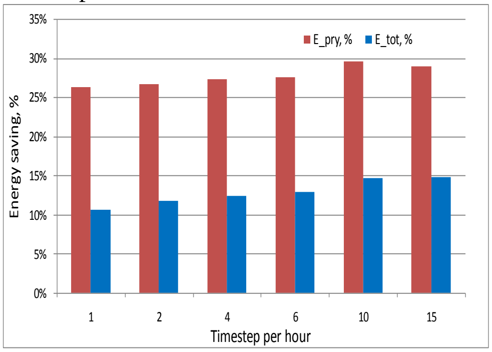

Figure 4. Energy savings using overhangs at different timestep

Discussion

The effect of the timestep on the optimized overhang length is shown in figure 2. The highest values of the overhang lengths are 2.01 m, 1.11 m, and 2.11 m for the east, south and north orientation overhangs, respectively. A minimum values for the overhang lenght are 1.885m, 0.985m and 1.86m for the east, south and north orientation overhangs, respectively. The lengths of the north overhangs were constant (0.01 m) for all values of the timestep.

For the timestep of 1 per hour, the highest total energy consumption was 1.2 GJ. For the timestep of 15 per hour, the minimum value was 1.15 GJ (Figure 3). For the timestep of 15 per hour, the highest total energy savings is achieved of 14.7%. For the timestep of 1 per hour, the lowest energy saving savings is achieved of 10.6%.

5. CONCLUSION

This investigation shows that the values of the timestep could have a significant impact on the results of optimization of the overhang lengths.

(1) There is considerable variation in the energy savings when the timestep is changed from the minimum (one simulation per hour, timestep is 1) to maximum (simulation in every 4 minutes, timestep is 15). Difference between these results is about 4.7%.

(2) Also, there are significant differences for the optimal length of the overhangs optimized by GenOpt software. The highest values of the overhangs length were 2.01 m, 1.11 m, and 2.11 m for the east, south and north orientation overhangs, respectively. A minimum values for the overhangs length were 1.885m, 0.985m and 1.86m for the east, south and north orientation overhangs, respectively.

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