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Impact of Civil Envelope on Energy Consumption Based on EnergyPlus

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Abstract

In this paper, a rural residential model located in Shenyang is established by simulation software DesignBuilder. Simulation process is divided into the following conditions, variety of thermal performance walls, roofs and windows. Building energy consumption was simulated through EnergyPlus under different conditions. The information of EnergyPlus and modelling process are referred. Impact of envelope heat consumption for various thermal performance and the energy saving potential are analysed. This research provides technical support and theoretical guidance for new energy efficient building and renovation projects.

Keywords: Thermal performance, Building envelope, Energyplus, Energy simulatio ;

1. Introduction

1.1. Development of building energy consumption calculation

The building energy consumption analysis development can be summarized as a process. It is from original rough manual work which is a steady-state heat transfer method of energy analysis to existing delicate cyber-work which is a dynamic-state heat transfer method of energy analysis. Steady-state analysis of energy consumption ignores building envelope structure thermal storage. Such methods include response factor method, finite difference method

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and the state space method.

1.2. Basic principles of building energy simulation

Building energy consumption simulation objects are new buildings and existing buildings. New building energy simulation is to compare the most optimized design to meet the design requirements. Meanwhile users can get economic analysis. Typically researchers simulate by forward modelling approach. Existing building energy simulation is to analyse energy-saving programs and cost savings by inverse simulation method.

Energy consumption simulation process consists of three parts. (1) Input variables: control variables and uncontrollable variables. (Such as indoor temperature and humidity control, required fresh air, weather parameters, location); (2) building structure and system characteristics: modelling building construction system (such as thermal performance of the building envelope, the air conditioning system and equipment parameters); (3) output variables: systematic feedback (such as cooling and heating load, energy consumption).

Forward modelling approach is to input variables, structures and systematic characteristics. Then researchers can gain output variable prediction. The reverse simulation method is to input variables and to preset energy consumption data. Then we can estimate the system parameters and build the system form.

1.3. Application of EnergyPlus

EnergyPlus is new generation energy consumption analysis software instead of BLAST and DOE-2. Users need to input the location, weather, the basic information of the building envelope, internal usage (including personnel, lighting, and equipment), the basic form of HVAC operating conditions, and cold or heat source parameters. Then building energy simulation analysis can be carried out throughout the year for the entire building by EnergyPlus.

The heat transfer into room through windows due to the combined effects of indoor and outdoor temperature and solar radiation. Sun light on window. A part is transmitted. A part as short-wave through the window come into house. It became the heat form. EnergyPlus ignores shifty heat capacity in the heat balance equation. It assumes that heat transfer is one-dimensional. And it assumes that the inner and outer surface of the glass is an isothermal surface. Meanwhile absorbed shortwave radiation is assigned by proportion to the inner and outer surfaces. The heat transferring into room can be divided into conduction heat gain, solar radiation heat gain, people heat gain, equipment heat gain, air infiltration heat gain and fresh air heat gain. EnergyPlus calculates cooling and heating using the heat balance module. It includes the room envelope surface heat balance model and the room air heat balance model [1].

Users need to input the relevant building information in IDF editor, such as housing construction, people，equipment and HVAC system. Data from dataset in IDF editor can be copied in the input file. Users can create a new object in the module corresponding to the information bar. Then we select the added data, fill in name and the specific values. But the user interface of EnergyPlus is extremely unfriendly, poor visibility, complicated operability. Editing the input file is time-consuming. So the information must be absolutely accurate. Users run the EP-Launch after the input file completely edited. Users need view the error file and modify repeatedly. Therefore an experienced operator is necessary for editing the input file.

The modelling process using EnergyPlus is as follows. (1) Setting Information: User need make some preparation before editing the input files. We need get building location and weather information. Then an overall description of building need to be described, including building size, exterior walls, interior walls, roof, windows, doors, floors, ceilings and other various parameters. And then we set lighting equipment and people. Then we can input regional temperature and humidity control. Finally, work schedule is set and air conditioning system operating parameters are set. (2) Building Zoning: Various Surface building elements constitute an overall architectural model. They are divided into heat transfer surfaces and thermal storage surfaces. The partition is not a geometric concept, but a thermodynamic concept. Therefore, two close regions using a set of air-conditioning can be zoned in different space due to different orientations. Identically, two regions which locate in different areas in space also can be designated as a hot zone due to same design temperature. The principle of zoning is using function, setting temperature and solar radiation heat gain. EnergyPlus required to maintain same setting temperature in every hour, every day and each zone during calculation. As the foundation of the software is based on heat balance of the partitions. So

building can be divided into one heat zone to estimate its load. Because the magnitude is identical relative to real load. Then researcher zones the building in exact partitions. (3) Modelling the Building Construction: After zoning the construction, researcher classifies the building surfaces according to the temperature control. Then direct sunshine and wind exposed portion need be defined. We can reduce the number and complexity of the surfaces in input files by defining the equivalent surfaces. All the same constructed surfaces can be defined as an equivalent surface in a hot zone. Its size is equal to the size of all the heat storage surfaces. Windows and shading also follow the same principle. Also it can greatly simplify modelling difficulty through stitching complex surfaces into basic geometry. Then we make a more detailed description of building by setting envelope styles and materials. BLAST, DOE-2 and other software need a library of construction materials, schedules and other aspects of building simulation. In EnergyPlus, the simulation data files can be used in the IDF editor. These basic building information root in ASHRAE Guide guidelines. (4) Editing interior space data: Indoor load can be affected by staff, lighting, equipment, air infiltration and ventilation form. Load can be described by design load, peak load and the corresponding timetable in EnergyPlus. In the absence of the set value, these can be set with reference to the relevant specifications. (5) Inputting an Air-conditioning System: It is difficult to input air conditioning system. Modeller need to understand the knowledge of air conditioning. Although some third-party software have friendly and easy-operation interface, they are lack of complete air conditioning system data. Researcher need to add more details in IDF editor after basic model establishment. (6) Setting Economic Factor: EnergyPlus can calculate not only building energy consumption but also using cost after entering the energy rates. Energy rates need to be set according to the actual situation, including the monthly service fees, energy costs, basic cost, power factor cost, block fees and other charges.

The third-party interface program developed with the maturity of EnergyPlus. Graphical user interface can be introduced to the building and air-conditioning systems modelling process through the development of a third-party program's interface. It can greatly simplify the user's workload. EnergyPlus friendly interface has been developed such as DesignBuilder and OpenStudio. OpenStudio is a plug-in to edit input file in Google SketchUp. The study was modelling by DesignBuilder in order to avoiding error report and saving time. Then generated input file and Weather file run calculations in EP-Launch.

DesignBuilder was selected to build the model about a rural residential pilot experiment building in Shenyang. Simulation process is divided into the following conditions, variety of thermal performance walls, roofs and windows. Building energy consumption was simulated through EnergyPlus V8-1 under different conditions.

1.4. The third-party interface DesignBuilder

DesignBuilder is currently the most comprehensive user-friendly EnergyPlus interface. It provides a three-dimensional architectural modelling tool, and it has an ability to easily input various parameters. It is convenient for this software to view a variety of output reports [2]. It contains all the EnergyPlus building construction and lighting data but also all of the material implanted database. But DesignBuilder is lack of some sophisticated air conditioning system with respect to IDF editor. So users need to deal with this part of the project further by the IDF editor after applying DesignBuilder build your model.

DesignBuilder adopts OpenGL solid modeler which is easy to operate. User can establish block by stretching, shearing and other production in 3D space. It completes visual editing for construction model. You can also import CAD files or scans to construct three-dimensional building on this basis and add EnergyPlus EPW weather files. The time intervals of running period can be divided a year, a month, a day, an hour or smaller. Results reveal building energy consumption across the consumption of fuel or electricity. We can get heating and cooling design load, output of CO_2 and so on. Output files can provide rendering and animation relevant to architecture including the effect of building envelope materials, sunshine shadows and shading effects.

2. Methods

2.1. Description of the simulated building

It is a rural residential pilot experiment energy-saving building in Shenyang. The building lays north to south with 3m story height. Slope degree of the pitch roof is 30%. Construction area is 198.27m². Windows, long 2m, high 1.8m. Doors, wide 1.2m, height 1.85m. Wall, high 3m. The building is divided to different functional area, including bedroom, kitchen, bathroom, hall, equipment room, and corridor. Author selected range of heat transfer coefficient on the envelope according to "rural residential building energy efficiency design standards GB / T 50824-2013", and then set several different conditions. The plan view is shown in Fig. 1.
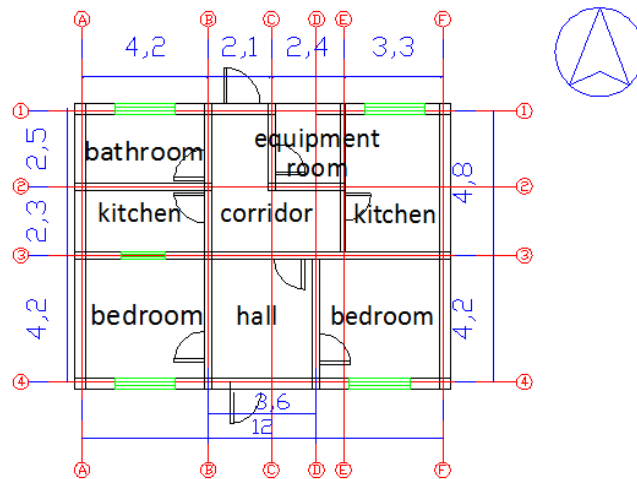

Fig. 1. The plan view.

2.2. Architectural modelling and parameter settings

Fig. 2. Architectural model.

The building three-dimensional model was established according to CAD base map in DesignBuilder. Then every parameter was set. User will get an input file which can run in EnergyPlus. The specific input parameters of this study are as follows.

First, the building is divided by eight areas due to different function. Second, set indoor environmental parameters. The indoor temperature is 18 ℃ and the feedback temperature is 12 ℃ in winter. The indoor temperature is 25 ℃ and the feedback temperature is 28 ℃ in summer. Humidity control is between in 10% and 90%. Next, people, light, schedule, electrical equipment and others were set [3]. People density is 0.04 people / m2. Staff coefficient is 0.9. Lighting power is 5W / m2 • 100lux. Equipment power is 3.58W / m2. The schedule to different room is set according to different residential buildings personnel schedule. At last, building envelope is set to several different conditions. The heat transfer coefficient of exterior wall is set to 0.5, 0.4, 0.3, and 0.2. The heat transfer coefficient of outside window is set to 2.7, 2.5, 2.2, and 2. The heat transfer coefficient of roof is set to 0.4, 0.3, 0.2, and 0.1. The architectural model is shown in Fig. 2.

3. Results

The simulation period is one year. The heat balance algorithm is used to calculate load without considering the coupled heat and moisture transfer within the building porous materials. The CTF (Conduction Transfer Function) is used to calculate the value of the wall heat transfer [4]. Calculation step is 15min. The main results of the analysis include the variation degree of building energy consumption due to the thermal performance of external wall, outside window, roof.

External wall insulation structure is key aspects of building energy efficiency. Currently, designers make use of two ways to increase wall insulation thermal performance. One is to improve the insulation properties of material, and the other method is to increase the thickness of the insulation layer. The second way is the more widespread form in practical engineering applications. Researcher can find better economy way for thermal performance of the wall across analysis software. Total construction costs get to minimum [1]. The variation degree of building energy consumption due to the thermal performance of external wall is shown in Fig. 3.
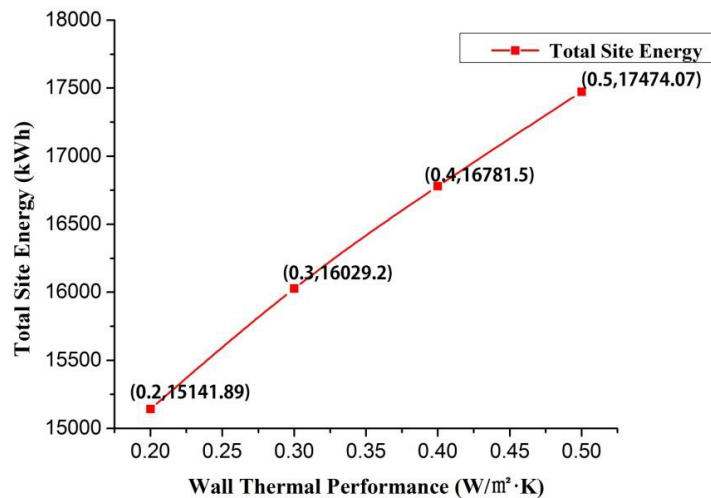

Fig.3. The variation degree of building energy consumption due to the thermal performance of external wall.

The window is an important component of building envelope. It is also the weakest link in insulation measures. The energy consumption per unit area is the largest. But, it will certainly affect the sunshine and indoor lighting if window-wall ratio is be decreased separately. It will not only increase the indoor electric energy but also influence room comfort. It will be greatly reduced energy consumption by selecting good thermal performance of materials. Currently, research on energy-saving glass material has great breakthrough. Then the attendant problem construction cost will increase. So it is a significant research to find the most economic and energy-saving potential of the window. The variation degree of building energy consumption due to the thermal performance of external window is shown in Fig. 4.
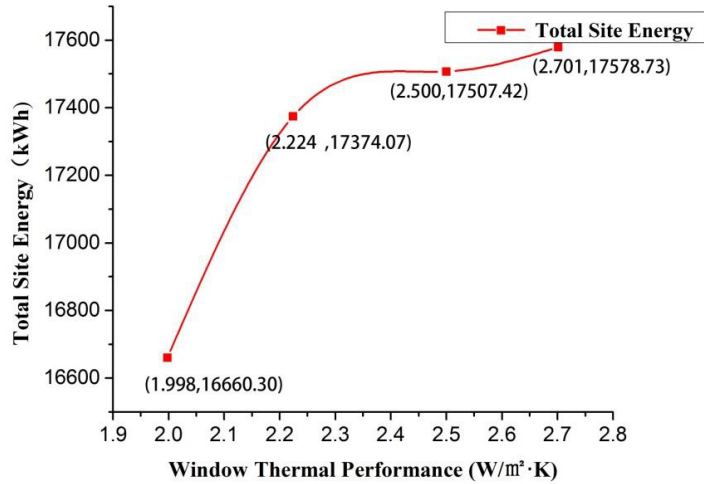

Fig.4. The variation degree of building energy consumption due to the thermal performance of external window.

In addition to walls and windows, the roof is a large proportion of total energy consumption in the building envelope. Its special location makes that it accept the maximum probability of solar radiation in architectural construction. Therefore it is also an important channel of energy exchange between top room and outside [5]. The variation degree of building energy consumption due to the thermal performance of external roof is shown in Fig. 5.
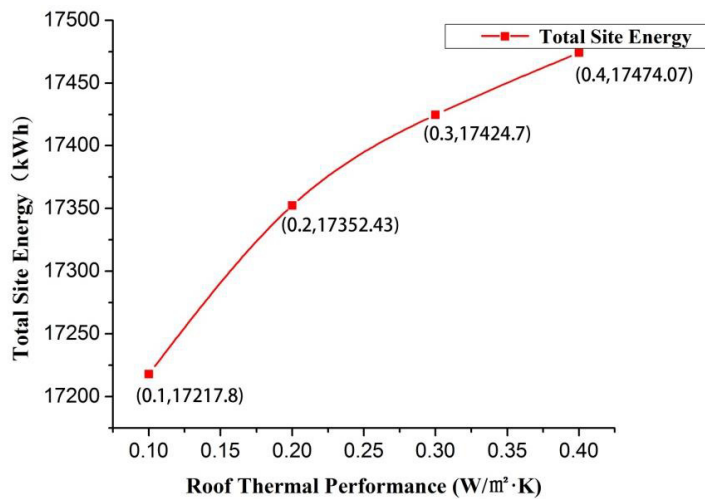
Fig.5. The variation degree of building energy consumption due to the thermal performance of external roof

4. Discussion

The smaller building envelope heat transfer coefficient is, the smaller the building energy consumption is across the simulation of analysis. With the decrease of the heat transfer coefficient of the external walls, the range of decrease for the building energy is increasing slightly. Magnitude of the energy reduction is the most significant. For exterior windows, the heat transfer coefficient decreases, meanwhile the amplitude of energy consumption reducing increases obviously. The energy consumption reduction is inferior to the wall extent. For roof, the heat transfer coefficient decreasing and the amplitude of energy consumption reducing increases. The energy consumption reduction is minimum comparing with wall and window.

5. Conclusions

By application and learning for EnergyPlus, we can find that EnergyPlus is a powerful energy consumption simulation analysis software with potential and development space comparing with other software. But now the prominent problem is unfriendly interface and output result. Therefore, DesignBuilder is the best third-party interface for EnergyPlus to make up for EnergyPlus difficult reading obstacles after comprehensive comparing.

Now energy issues are outstanding. Series of energy analysis software like EnergyPlus have wide application prospects. We can get some conclusions through simulating building energy consumption under different thermotechnical conditions. The better building envelope thermal performance is, the smaller building energy consumption is. Energy-saving potential of the wall is the largest in terms of these aspects. The performance of windows is smaller. The roof is minimized. It is necessary to improve the thermal performance of exterior walls and windows in order to promote energy-efficient building design and renovation.

Acknowledgement

References

[1] H. Wang, Thermal property of composite wall and analysis of energy consumption, Ph.D. Thesis, Harbin Institute of Technology, China, 2007, 77-78 pages.
[2] J. Feng., Y. Ding, H.W. Wu, EnergyPlus energy simulation software and its applied tools, Build Energ Efficiency, 1 (2012) 67.
[3] ASHRAE, ANSI/ASHRAE Standard 55-2010, Thermal Environmental Conditions for Human Occupancy, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Atlanta, 2010.
[4] Y. Pan, G. Wu, and H. Volker, Building energy analysis software EnergyPlus and its applications, HVAC, 9 (2014) 3-4.
[5] C. Wu, Analyze and practice of resident building envelope energy efficiency. Master Thesis, Chongqing University, China, 2005, 81-85 pages.