Analysis on the Influence of Building Envelope to Public Buildings Energy Consumption Based on DeST Simulation

Junsheng Hu*, Jing Wu

*School of Municipal and Environmental Engineering, Shenyang Jianzhu University, 9 Hunnan Road, Shenyang 110168, China

Abstract

In order to analyses the influence of building energy consumption with different thermal property building envelope, this paper took a public building where in Beijing as the research object with DeST-c software, and analyzed the influence of exterior walls, roof, exterior windows and the whole building envelop with different thermal property respectively. The simulation changed the single envelop thermal property while kept the whole building envelop thermal property constant, and pointed out that how energy saving redevelopment affected building energy after energy calculation. The results show that the transfer coefficients of the outside windows have largest effect on indoor thermal load, the roof is secondary, and exterior walls are weakest. Thus, the thermal performance of the building envelope and energy efficiency have a great relationship.

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1. Introduction

The envelope are the important channel of building inside and outside exchange thermal, it's have a huge impact on building [4]. With the continuous improvement of living standards, people are increasingly high demand for the indoor environment, the corresponding building energy consumption is also growing, which has caused a lot of pressure to energy supply and environmental protection. At the same time operating conditions of building environmental control systems must also be changed accordingly with the construction environment constantly to achieve meet comfort and other requirements of the built environment. The building environment change is a complex process which is determined by many factors, therefore, only through a computer simulation method can

* Corresponding author. +86-13307726058; fax: +86-24-24692695
Email address: 568632267@qq.com
effectively predict the build environmental factors which may occur whether there is environmental control systems or not [1]. If we can identify the main factors affecting the building energy consumption, it means finding a critical point of energy saving, which is very useful for energy conservation. Therefore, Tsinghua University School of architecture building science and Technology Department of building environment and equipment research institute has developed a software platform—Designer’s Simulation Toolkit (DeST), the software is used for analysis on the building thermal environment design simulation [2]. A special energy simulation software: DeST-c for public buildings has been developed based on the DeST. In 2005, a public building energy efficiency design standards issued by the Ministry of Construction have defined: From north to south, envelope structure shares saving rate of about 25% to 13%, which means that new public buildings in the envelope structure design must consider the energy requirements and meet basic indicators.

Beijing as a typical hot summer and cold winter area, whose building energy consumption is very significant, then how the envelope structure thermal performance affects on the public buildings in the region on earth? DeST-c is used to analysis on the Influence of Building Envelope to public buildings energy consumption [3].

2. Methods

DeST combines the periodic characteristics of actual design process in the development process. The simulation is divided into five stages: building thermal characteristics analysis, system analysis program, AHU program analysis, wind network simulation, and cold and heat source simulation. Provide accurate and practical analysis results for different stages of design, for example, simulation of the thermal characteristics of the building to provide architectural body thermal data. DeST treats AutoCAD as the development platform, users can complete the project modeling and simulation of various energy systems and other functions in the AutoCAD interface. Therefore some AutoCAD commands are also functional in DeST.

2.1. Establish architectural models

Selecting the office buildings in Beijing as objects of simulation. The office is public buildings which is made of single frame structure, it's 3.6m each story and the total construction area of air conditioning is 1496.25m². Each room is mainly used as classroom. The buildings are all facing to south and north. Text and not supplied separately. Below is an example which the authors may find useful.

2.2. Draw of building base map

Must draw the underlay before using DEST building energy simulation software. We can make this work to be carried out both in CAD and DEST, the main steps are as follows: Along the centerline of the wall draw the outline of each floor, expressed windows walls and centerline of doors using different colors in different layers. After drawing done the underlay you have to edit the layer according to different floors. Setting a layer each floor. The standard layer can just set one layer. If drawn the outline map using CAD, copy the outline to the DEST software, set up a new DEST layer, open the underlay in DEST. Select the menu bar “Building Description” in the “new construction” button, input the name of building in the command line.

2.3. Draw windows and doors

Open doors on the straight wall, Click on “Building Description” in the “straight wall to open the door” or directly click on the toolbar. Input tall and wide of door according to point in the command bar, finally choose the location of doors. Users can continuously add door until click the right side of mouse.

Setting windows on the straight wall, click on “Building Description” in the “straight wall window”, or directly click on the toolbar, at this time the task bar will appear, “given the size of the (F)”, “With the wall automatically adjust (A)”, “Given window to wall ratio (R)”, three kinds of way to draw it. Input the given letter and press Enter, the command bar window will point different parameters.
2.4. The computing Pretreatment of construction

Implement of “simulation in the “Construction Computing pretreatment” command, the entire building can be checked, determine the integrity of the building and the doors and windows are arranged rationality, and remove some divergent envelope automatically, and join the room to identify and thermal disturbance automatically. The implementation of the proposed multi-save “Construction Computing pretreatment” command to check the building envelope should establish a relatively complex construction in the correctness. (Note: If you encounter in the course of a number of variable parameters occurs not show, May be due to pre-treatment is not carried out due to construction budget). In the next building simulation, when changing any parameter stage to be simulated, construction computing pretreatment must be carried out. The method is click on the menu bar of the “simulation” in the “Construction Computing pretreatment”.

2.5. Room ventilation

Click “Automatically added to Ventilation flag” under “Building description”, or directly click on the toolbar [5]. Users can ventilated “between the room and the room” of the prompts to select the command bar, “Between the room and the outside world”, the external ventilation, or both of them. Then the DeST will be automatically added to meet the requirements of all ventilation. You can also manually add their own ventilation. Ventilation automatic ventilation in the room and the room does not include ventilation between floors, so we need to add manual. Add another room ventilation required after the buildings “architecture computing pretreatment”, at this point, you can get the building model plan.

At this point, you can get the building model plan that shown in Figure 1:

![Building Model Plan](image)

Fig. 1. Building Model Plan.

2.6. Condition of building simulation

Considering the diversity and complexity of influencing factors, with respect to the experimental test purposes, computer simulation is more convenient and fast. Simulation by using DeST-c energy software for whole year. Study energy-saving potential of a retaining structure. Consider the temperature characteristics of Beijing, In the heating and air-conditioning season setting, Scheduled heating season from 15 November to next March 15, and air-conditioning season is from June 1 to August 30. Indoor temperature are set as 18 °C and 26 °C. Air conditioning time is 0, and non-air conditioning time is 0.5 time/day. Energy efficiency heating equipment and air conditioning equipment energy efficiency using software default data are 1.9 and 2.3.
In order to effectively analyze the energy saving potential of the building envelope, using individual analysis and portfolio analysis one by one and use research methods. In the case of other containment structure remains unchanged, only change the characteristics of the object of study envelope. Analysis of their impact on building energy consumption, at the same time, the building energy consumption under different combinations of simulated envelope. Study the energy saving potential of the overall envelope.

2.7. Simulation step

On the basis of the establishment of good architectural model, describing the buildings, and the main parameters of buildings. Name the building, name the room, location, bearing, experience conduction. The main component of the buildings: outdoor wall, indoor wall, floor, roof, door and window. Name the building: click on “Building Edit” in the “Edit Building”, or see the building name in the Name field under the toolbar. Name the room: click on “Activities Floor Control” toolbar “show room”, and you can show or hide room logo, the logo of this room is automatically assigned room. To automatically renamed by the system, then click on the “System Description” and “the system automatically renames the room”. Location: click “Show” in the “Display Browser Window”, and selected sites button and click on “City” option in the figure, optional city building and finally click “OK”. This option is very important. Because different cities there will be no weather conditions, calculated according to the selected city DeST local calls meteorological data generation program annual hourly meteorological parameters. Room features: in commercial buildings, room features are different from situations of its internal personnel, lighting, equipment, systems which will affect the final load in the room is largely. Therefore, the “function room” is a very important parameter. Click “Show” in the “Display Browser Window” or click directly on the toolbar, select the desired room, select “Basic property” in the top of the Properties toolbar. Then click “function room”, select the type of room in the pop-up toolbar room. Total Office Edition to build more rooms, shopping centers, toilets, empty room several room types to choose from. Building components: select building components within the room floor. If the current floor is the first floor, then specify the building to substitute its room floor. If the current layer is the top room, then assign roof member as specific components. Choose interior walls, exterior walls, floors, roofs, floor, the doors, windows and other building components of a unified interface dialog. Pr ess the “display” in the “Display Browser Window”, then selected building elements in the figures. In the Properties toolbar, click on the member number pops up all member types to choose from. First, the selection of members to be selected using the category, and you can also select all categories. All available members of the class should display its name in the list, while its members the right to its legend pagination. When the currently selected member of its list items and cases were highlighted, and press the OK button to confirm after selecting components used in the “browser window”.

2.8. Building global settings

Global settings mainly include the building global setting, air conditioning system global setting, air handling equipment global settings, and cold and heat source global settings et al. If a parameter from the building or systems has the same settings, you can use the above global setting functions to overall modify the parameter. “Building Global Setting” can overall set every parameter of the construction, such as building location, room function, ventilation settings, window-wall ratio setting, and each envelope parameters. If a parameter of the building has the same setting such as facade elements using the same material, then you can set corresponding parameters by “Building Global Settings” conveniently and efficiently. After setting, all the parameters of the building will be changed to the parameters that “Building Global Settings” has set.

2.9. Analog computation

The main function of analog computation menu is to detailedly simulate and calculate the building load, the performance of natural light, air conditioning system load and cold and heat source, fans and pumps, and energy consumption of transmission and distribution systems, etc., based on user input, and then could output and view the journal sheet. Analog computation can obtain load analysis table of the construction. The results can be viewed via the “output journal sheet” button to be outputted in EXCEL. Due to the large amount of data is calculated, and in
order to better meet the needs of users, DeST offers several different options, by which users can selectively take out data and continue to process the data according to their own needs. However, “architecture computing pretreatment” for the buildings is needed before performing the simulation.

3. Results

3.1. The impactions of building energy consumption due to the Changes of the heat transfer coefficient of the exterior wall.

Keeping building envelope coefficient of the benchmark Building and other envelope unchanged, sequentially changing the Exterior wall heat transfer coefficient: 0.199, 0.256, 0.297, 0.418, 0.466, and 0.591. Using DEST software Simulation calculation, the calculation results are shown in the Table 1:

Table 1. Exterior walls in different condition simpact of building energy consumption

| heat transfer coefficient k/[W.(m².K)-1] | 0.199   | 0.256   | 0.297   | 0.418   | 0.466   | 0.591   |
|----------------------------------------|---------|---------|---------|---------|---------|---------|
| Total annual heat load(Kw.h)           | 181862.92 | 182073.24 | 183176.92 | 183724.92 | 184386.14 | 185283.73 |
| Total annual cooling load(Kw.h)        | 65651.46  | 65663.35  | 65698.97  | 65690.63  | 65621.29  | 65553.15  |
| Annual cumulative total load(Kw.h)     | 247514.382 | 247636.59 | 248875.892 | 249415.55 | 250007.429 | 250836.883 |

According to the value of simulation, we can draw a histogram help us to analyze changes in energy consumption, the results are shown in the Figure 2:

Fig. 2. Exterior walls in different condition simpact of building energy consumption

3.2. The impactions of building energy consumption due to the Changes of the heat transfer coefficient of the roof.

Keeping building envelope coefficient of the benchmark Building and other envelope unchanged. Sequentially changing the roof heat transfer coefficient: 0.075, 0.145, 0.269, 0.359, 0.437, 0.531. Using DEST software Simulation calculation, the calculation results are shown in the Table 2:
Table 2. Roof in different condition impact of building energy consumption

| heat transfer coefficient k/[W.(m².K)-1] | 0.075  | 0.145  | 0.269  | 0.359  | 0.437  | 0.531  |
|------------------------------------------|--------|--------|--------|--------|--------|--------|
| Total annual heat load(Kw.h)             | 181862.92 | 185378.22 | 190128.33 | 194681.58 | 201565.38 | 205341.22 |
| Total annual cooling load(Kw.h)          | 65651.46  | 65837.38  | 64734.24  | 65072.86  | 65205.90  | 68464.79  |
| Annual cumulative total load(Kw.h)       | 247514.3818 | 251215.605 | 254862.5716 | 259754.448 | 266771.2868 | 273806.0036 |

According to the value of simulation, we can draw a histogram help us to analyze changes in energy consumption, the results are shown in the Figure 3:

3.3. The impacts of building energy consumption due to the Changes of the heat transfer coefficient of the exterior window.

Keeping building envelope coefficient of the benchmark Building and other envelope unchanged. Sequentially changing the exterior window heat transfer coefficient: 1.0, 1.4, 2.0, 2.4, 2.7, and 3.0. Using DEST software Simulation calculation, the calculation results are shown in the Table 3:

Table 3. Exterior window in different condition impact of building energy consumption

| heat transfer coefficient k/[W.(m².K)-1] | 1   | 1.4 | 2   | 2.4 | 2.7 | 3   |
|------------------------------------------|-----|-----|-----|-----|-----|-----|
| Total annual heat load(Kw.h)             | 181862.92 | 186597.74 | 195191.54 | 202330.96 | 212374.10 | 222054.23 |
| Total annual cooling load(Kw.h)          | 65651.46  | 66043.63  | 67022.31  | 66280.18  | 63322.12  | 64428.72  |
| Annual cumulative total load(Kw.h)       | 247514.3818 | 252641.366 | 262213.8578 | 268611.143 | 275696.224 | 286482.95 |

According to the value of simulation, we can draw a histogram help us to analyze changes in energy consumption, the results are shown in the Figure 4:
Now we analyze the simulation results based on the Figure2 to 4: Annual total building heat load increases to a lesser extent with the exterior wall heat transfer coefficient increases; Total annual cooling load received little impact by change the heat transfer coefficient of exterior wall; For the roof, Annual total building heat load the magnitude of the increase is more significant with the heat transfer coefficient of the roof increases; Total annual cooling load change with increasing heat transfer coefficient is smaller roof; For exterior windows, Annual total building heat load increases slightly larger magnitude than the roof with the heat transfer coefficient increases, but cooling load changes to a lesser extent by heat transfer coefficient increases with the outside window. This shows that, in the Beijing area, in order to more effectively promote energy conservation, the roof, Exterior windows to improve the thermal performance of the building is very necessary. If the building envelope heat transfer coefficient is smaller working conditions the smaller the amount of the annual total building load and the building energy-saving rate is higher. Through simulation is easy to see Annual total building heat load is the larger the magnitude of the increase with the heat transfer coefficient increases and the total annual cooling load has little effect by the heat transfer coefficient.

4. DISCUSSION

Model established in this study has been simplified to the actual situation, such as office work schedules according to the national festival, the provisions of the holiday, the building is fully insulated roof, the building without external shading measures. Therefore differ from the actual energy consumption. Heat loss through exterior windows accounted for 35% to 45% of building energy consumption, visible outside the window of the building envelope is relatively weak parts. Outside the window sash materials, glass shade varieties and whether the measures will significantly affect its thermal performance. Therefore, the use of new energy-saving insulation outside the window. Outside the window should try to choose insulating glass, heat-absorbing glass, and reflective glass. Currently better thermal performance outside the window using double-lumen Shuangbo hollow filled with inert gas (thickness 40mm) glass, aluminum window frames for thermal break Profiles Bridge.

5. Conclusions

The stages study by DEST, we have the preliminary master software for DEST, the initial simulated for the building envelope impact on building energy consumption. Building energy efficiency is directly related to the country's resources strategic, sustainable development and environmental protection, while achieving the expansion of domestic demand, stimulating economic growth and improving people's living standards. Building envelope energy efficiency is a long-term thing and benefits the country, focusing on the development of energy-efficient building envelope is to develop suitable for different climatic conditions, various energy-saving walls, roofs and
windows. Today, energy has become shortage understand building energy-saving potential will undoubtedly provide a strong guarantee for the future of architectural design. The study results can be obtained as follows:

The building envelope thermal performance is better, the building energy-saving effect is better. Roofing and exterior windows energy saving potential is large, exterior wall energy-saving potential is smaller. Beijing area annual total building heat load increases the amplitude greater, followed by the roof, there are less affected by exterior wall the heat transfer coefficient. Total annual cooling load of the building of small magnitude of change with the building envelope heat transfer coefficient increases.

Overall, annual total building cooling load affected building envelope thermal performance is not obvious. For the Beijing area, improving the building envelope thermal performance, the air conditioning heating season can be better, in air conditioning and refrigeration quarter ineffective.

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References

[1] M. Fátima., S. Pedro., P Casimiro, Size fractionated aerosol composition at roadside and background environments in the Madrid urban atmosphere, Atmos. Res. 138 (2014) 278-292.
[2] W. Qian,, Y Zhu,, S Tang, Reconstructed index of summer monsoon dry-wet modes in East Asia for the last millennium, Chinese. Sci. Bull. 56 (2011) 3019-3027.
[3] V Liao., C Chio, Modeling human health risks of airborne endotoxin in homes during the winter and summer seasons, Sci. Total. Environ. 408 (2010) 1530-1537.
[4] X Su, X Zhang, Environmental performance optimization of window–wall ratio for different window type in hot summer and cold winter zone in China based on life cycle assessment, Energ. Buildings. 42 (2010) 198-202.
[5] Y. Li, Effects of Seasonal Folivory and Frugivory on Ranging Patterns in Rhinopithecus roxellana, Int. J. Primatol. 31 (2010) 609-626.