Analysis on Factors Affecting the Solar Irradiation of High-rise Buildings Form

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Abstract. This paper aims to explore the relationship between solar irradiation and high-rise building form through parametric design process and simulation, and proposes performance-based building form design recommendations. In this paper, based on the High-rise building form design data, the parametric model of building form is modeled by Grasshopper and Rhino platform, integrating Ladybug and Honeybee to evaluate the building envelope solar heat gains in summer and winter respectively. Finally, correlation and influence trend analysis show that the P-parameter has the least influence on the heat gain of solar irradiation, and the B-parameter has the most significant effect on the heat gain of solar irradiation, what’s, they relationship are inversely proportional.

1. Introduction

The number of high-rise buildings is increasing rapidly, and the solar irradiation acts on the building envelope, which has a significant contribution to energy consumption. Therefore, the influence of high-rise building forms on the heat gains of solar irradiation is studied, and the design strategy is summarized to assist the energy-saving design of the building form. With the development of computers, more and more research combines building parametric model and building performance simulation methods to analyze the accurate numerical quantitative relationship between building design parameters and building performance, to improve the efficiency of building energy-saving design¹²³⁴⁵. Based on the parametric modeling platform Grasshopper and Rhino, and uses Ladybug and Honeybee to calculate solar radiation heat gains. Finally, through the correlation analysis and influence tendency analysis, the correlation between building design and building performance and its influence trend are obtained.

2. Building modeling

2.1. Building Basic Design Data

The investigation results of high-rise buildings show that regular floor shape such as square and rectangle are more often used in high-rise building plan design. as shown in Figure 1. This is closely related to its stable structural properties, structured space, and fine economic. And as the number of layers increases, the frequency at the square floor shape appears is higher, as shown in Figure 2. Finally,
this paper selects square shape as the basic floor shape to modeling.

![Figure 1. Statistics of Floor Shape Proportion](image1)

![Figure 2. Floor Shape Number Trend](image2)

![Figure 3. Floor shape design parameters](image3)

![Figure 4. Section shape design parameters](image4)

![Figure 5. Details of parameters](image5)

### 2.2. Building Design Parametric and Model

Building design parameters can be divided into several levels according to their influence degree of the building form. For example, low-level building form design parameters such as layer number, depth, bay, and other single shape control type. The second is a higher level of building form design parameters such as the bay-depth ratio, which can control two low level parameters at the same time. Finally, high-level building form design parameters such as shape coefficient, perimeter coefficient, aspect ratio, and so on, more parameters can be controlled. Therefore, selecting a high-level control parameter can control building form more efficient, avoiding the redundant workload due to the ineffective connection between low-level parameters, which need to be adjusted repeatedly. Based on the above principles, the study selects several design parameters to control the building form as shown in figure 3 and figure 4. The detailed parameter information and building model form are shown in Figure 5.
3. Simulation

3.1. Input Building Form and Environmental Information
The simulation results of building performance are closely related to the environment in which it is located. The building environment information includes two aspects. One is the local climate data. This paper selects the typical meteorological year data epw file and CIE sky as the climate data. The second is the site information of the building. In this paper, the parameterization modeling of the site information is carried out in the north direction of the site with +y.

3.2. Analysis Grid
The smaller the value of the analysis grid, the more accurate the value of the solar radiation calculated, and the longer the calculation is needed. In this paper, the simulation calculation time is considered on the basis of not affecting the accuracy of solar radiation heating results. Finally, the calculation grid of 1m*1m is selected, and the simulation point is offset by 0.01m of the outer perimeter of the building.

3.3. Simulation Time
The performance evaluation indexes of solar radiation by this paper are the solar irradiation in the summer of per square meter of building envelope and the heat generated by the solar radiation in winter. Therefore, the calculation of the total solar radiation is divided into two time periods, during 7.1 -9.30 and 12.1-2.29. Every morning from 8:00 am to 18:00 pm.

4. Results and Discussion

4.1. The Correlation Analysis Between Building Design Parameters and Performance
As shown in Figure 6, the correlation between the parameters about C/A/B/R/ /S is related significant to the heat gain of solar irradiation in summer and winter. The difference is that there is only parameter-R has positive correlation with solar irradiation. and the remaining design parameters were negatively correlated with solar radiation. In addition, the relationship between the parameter-P and the solar irradiation heat gain from the summer and winter is weakly, thus remove the P-parameter.

4.2. The Influence Trend Between Design Parameters and Performance
As shown in Figure 7, the first type of variables in parameters C have a proportional relationship with solar irradiation, but the second type of variables has an inverse relationship to the solar irradiation; as the value of parameters A and B increases, the solar radiation is decreasing. Finally, the parameters-R has a cyclical upward trend. For S, its influence on the solar radiation is increasing within a certain range, when it exceeds this range, it tends to decrease gradually. The overall trend is cyclical with the change of the S value range.
Figure 6. Details of Parameters
Figure 7. Details of Parameters
5. Conclusion
In summary, in the high-rise building design strategy, the correlation between B-parameter and solar irradiation is the highest, the R-parameter correlation is the smallest, and the P-parameter correlation is lowest, in the design, it can be ignored when considering solar irradiation. The influence trend analysis of the parameters of group C/A/B/R/S with high correlation with the heat gain of sunshine radiation can be concluded as follows:

- Increasing the value of C1 and parameters-R will increase the heat gain of solar irradiation.
- Increasing the value of C2 and parameters-B will cause the solar irradiation to decrease.
- When the parameter-A2 is selected, the envelope solar radiation heat gain value will be the maximum. When the A4-parameter is selected, the envelope solar irradiation heat gain will be minimized, and the envelope solar irradiation heat gain of the parameter-A3 is less than the parameter-A1.
- When applying the design parameter R for building form design, when the value range is R3-R6/R1-R2/R8-R9, as the R value increase, the envelope solar irradiation heat gains is decrease; When the value range is R2-R3/R7-R8, as the value of R increase, the envelope solar irradiation heat gain is increase.

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