A PARAMETRIC ANALYSIS PROCESS FOR DAYLIGHT ILLUMINANCE

The Influence of Perforated Façade Panels on the Indoor Illuminance

YI HE1, MARC AUREL SCHNABEL2, RONG CHEN3 and NING WANG4
1,2 Victoria University of Wellington, New Zealand
1,2 {harry.he|marcaurel.schnabel}@vuw.ac.nz
3,4 Changjiang Survey Planning Design and Research Co., Ltd., China
3,4 {rongchen|ningwang}@cjwsjy.com.cn

Abstract. BIM modelling systems and graph-based modelling systems have been widely used in the architecture design process recently. Based on the systems, an alternative approach to study the influence of perforated façade panels on the indoor illuminance by using a parametric performance analysis in a practical architectural project is proposed. The workflow we developed makes the modelling process faster, more accurate, and easier to modify. From the circulation of modelling-to-analysis process, the performance can be compared, feedback can be generated. Accordingly, optimized design can be concluded. This study suggests an analysis method to evaluate the indoor illuminance performance in the early design stages. The simulation is not a conventional typical in-depth one, but a practical method to immediately evaluate the performance for each design alternative and provide guidelines for design modification. Moreover, the first generation of digital modeling programs allow designers to conceive new forms, and allow these forms to be controlled and realized. It reacts to the conference theme by presenting a protocol for a digital workflow in the early stage of the design development.

Keywords. Daylight illuminance; BIM; parametric sustainability; parametric modelling; façade panels.

1. Introduction

Nowadays, BIM modelling systems and graph-based modelling systems have been widely used in the architecture design process (Eastman et al. 2009). Meanwhile,
as sustainability has received attention continually in recent years, relative analysis is sometime needed in the early stage in design process. The previous sustainable analysis may require the establishment of new models because of the software environments. The simulation time are usually long and models are hard to be modified in some platforms. Therefore, this can be complicated and time consuming, which affects the efficiency of architecture design process. In our study, we propose an alternative approach to study the influence of perforated facade panels on the indoor illuminance by using a parametric performance analysis based on graphic and associated models.

The study is part of a practical architecture design project. This design is for a real project of a Natatorium in the city of Wuhan, China. The Natatorium is located west of the Huangpu Hall, an auditorium on the Huangpu Road in Jiang’an District. The investment for this project is about CNY22 Mio giving the project a very tight budget. The Natatorium has three levels with an architectural area of ca. 6,250 square meters. It is designed for 400 people to use. The number includes swimmers, audiences, and staffs. The swimming pool has ten 50 meters standard lanes. The main body of the Natatorium can be divided to the auxiliary part and swim hall. The auxiliary part has a three level high structure associated with the swimming hall. The swimming hall is a large-span space, using the steel-grid roof.

For the design of facade, perforated aluminium and ceramic panels are used. It is a double-skin facade with ordinary cement walls inside and perforated aluminium panels installed as the outer layer (He et al. 2012). In this work, the method for the façade will be present. Parametric modeling is developed for daylighting simulation. The main objective of the process and algorithm is to evaluate the illuminance performance of the façade, composed of a series of perforated openings that actuate in response to dynamic daylighting.

![Figure 1. The 3D model of the natatorium. The major part of the modelling of the Natatorium has been done in Revit. The model is divided into several child models which are connected to the main model.](image)

2. Sustainable Design

For this project, we use BIM and parametric modelling methodologies paired with a simplified illuminance calculation method to assist our design (figure 2). This is not the first time we make use of this methodology in such architectural projects (He & Schnabel 2016a). From our previous experience, this methodology not only offers benefits during the design phase, but also further down the track during construction and management (He & Schnabel 2016b).
From the beginning, aspects of sustainability have been taken into consideration (Huang et al. 2004). Information about local climate, existing circumstance of the site and architectural standards especially the Green Building Standard are included in the initial analysis. In communication with clients, requirements, detailed functions and expected performance are determined to guide the initial design phase. During this, several analysis models have been generated.

3. The Modelling Process

In this section, we present the modelling process which includes the natatorium and its facade. Software tools of Autodesk Revit, Rhinoceros 3D and Grasshopper3D are applied in this project. In the case of complex application such as sustainable analysis, conversion processes are often involved in the modelling.

3.1. THE MODELLING OF THE NATATORIUM

The major part of the modelling of the Natatorium has been done in Revit. The model is divided into several child models which are connected to the main model. Several parts of the design are developed by different departments of the architectural firm. Then the parts are all assembled into a complete 3D model the natatorium. For the illuminance analysis, it is mainly done in the software environment of Rhino and its plug-ins. So we convert the BIM models to the format that can be edited in Rhino. Before import, the models are simplified to reduce the computing needs of the software. The models are modified further in Rhino to fit the analysis environment. The reasons of doing so are: first, this can improve the analysis efficiency; second, in this case of illuminance analysis, physical and graphical information are the major part needed from the BIM models.

3.2. THE PARAMETRIC MODELLING OF THE FACADE

The modelling of the facade can be done in the environment of Rhino and Grasshopper. For the generation of the openings of small holes on the panels, using the parametric method is efficient and suitable for comparative research (Schnabel 2007).

Our idea is to generate the single facade panel first, and then assemble them together. For the perforated panel modelling, the main strategy is to create the arrangement of points to locate the positions of openings. Then the shape of the openings can be defined by using certain algorithm before attaching them to the lo-
cation (figure 3). In Grasshopper, we can use the array algorithm to create a group of points. The horizontal and vertical number of the points can be defined by the inputs related to integer parameters. As the openings are in the shape of circle in this project, the circle component is introduced to create the round holes on the panels. Then we use the move command to duplicate the holes by attaching the circles to the array of location points. The generation process at this stage is not complicated, but it has the advantage in adjustments of the openings arrangement, which is suitable for iteration simulations and analysis. For example, by changing the parameters, the radius and the arrays of the round holes can be adjusted accordingly. The perforated density and arrangement of the panels can be modified in this way.

Moreover, this method can provide the big potentials that allow us to create complex facades and analyse them further by modifying the algorithm adopting different modules. This will be discussed in the following sections.

Figure 3. The perforated aluminium sheet model generated by parametric modelling. In Grasshopper, the array algorithm has been used to create a group of points. The circle component is introduced to create the round holes on the panels. Then the move command has been used to duplicate the holes by attaching the circles to the array of location points.

4. The Illuminance Analysis Based on Parametric Modelling

In this section, we explain the illuminance analysis process.

First, for the illuminance performance, we need the criterions to guide our optimization. In this case, for indoor illuminance evaluation, the criterions comes from the standards formulated by relate institutions in China. For example, in ‘Code for design of civil buildings (GB50352-2005)’, ‘Standard for daylighting design of building (GB50033-2013)’, there are requirements for different indoor environments according to their functions. It has been defined the lighting coefficient and natural illuminance of the facade in the criterions.

Second, for analysis, the software tool DIVA is introduced. It is an optimized daylighting and energy modelling plug-in for the Rhino. The plug-in was initially developed at the Graduate School of Design at Harvard University and is now distributed and developed by Solemma LLC. DIVA allows users to carry out a series of environmental performance evaluations of individual buildings and urban landscapes. The simulation core of DIVA comes from the well-known software tools Radiance, which has been widely recognized as a suite of programs for the
A PARAMETRIC ANALYSIS PROCESS FOR DAYLIGHT ILLUMINANCE

analysis and visualization of lighting in design.

After the parametric generation of the panels, their performance can be tested and compared. In our study, the variable parameters include the horizontal numbers, vertical numbers and the radius of the round openings, which can be defined in different sizes. For comparative study, we can set two parameters unchanged at first, and adjust the last parameter. A series of simulation for the panels can be done one by one. After this, the tendency of the results can be analysed. Then different parameters is chosen to be adjusted for repeating the analysis. This preliminary iteration study can help to locate the relative available parameters of the facade panels. Base on this, we can select the subjects for further study. In our case, for example, the panels with vertical number of 100, horizontal number of 8, and holes of radius of 30mm (“V100-H8-R30”-panel), as well as the other panels are analysed (figure 4).

To study the influence from the facade to the indoor illuminance further, the simulation is done for the interior environment. DIVA is used to complete the visualization analysis under the natural illuminance situations from January to December. In a series of analysis, we set the simulation time at 3:00 PM on 15th day in every month, as three o’clock in the afternoon is usually the time that the natatorium is occupied most according to the common situations. All simulations are set in a fixed view angle that results can be compared conveniently. The visualization simulation can help to better understand the natural illuminance in realistic environment in every month all over the year. References can be set up for architects to evaluate their design.
5. Results and Discussion

For the selected subjects after the initial filtration study of the facade panels, our illuminance simulation concludes they can meet the requirements. The results of the illuminance intensity distribution on the different facade panels have been compared.

![Diagram of panel parameters and illuminance requirements](image)

**Figure 5.** Left: The definition of the panel parameters. Right: The panels that have been studied and the panels that meet the illuminance requirements.

In our case, a series of panels with certain parameters has been analysed. As it is shown in figure 6, the calculation results of panels with vertical number of 100, horizontal number of 8, and holes of radius of 30mm ("V100-H8-R30"-panel), as well as the panel with vertical number of 100, horizontal number of 8, and holes of radius of 40mm ("V100-H8-R40"-panel), vertical number of 100, horizontal number of 9, and holes of radius of 40mm ("V100-H9-R40"-panel), vertical number of 160, horizontal number of 9, and holes of radius of 40mm ("V160-H9-R40"-panel), vertical number of 160, horizontal number of 9, and holes of radius of 30mm ("V160-H9-R30"-panel), and vertical number of 200, horizontal number of 11, and holes of radius of 30mm ("V200-H11-R30"-panels) have been presented. Specifically, figure 5 has shown the panels that have been studied. For the radius of the openings, the situations with the radii of 30mm and 40mm have been concerned. The panels that meet the illuminance requirements have been presented in figure 5. The value differences on specific positions of the panels are of an acceptable small range. For the average illuminance on the selected panels, they are almost the same. We find that these samples all meet the requirements of the building-code. But the opening size should be considered for good appearance, the manufacture simplicity and the production economy of the facade panels. In this case, the panel with specific parameters (V160-H10-R30) is recommended. This allowed us to develop guidelines for the facade panel manufacturer to produce the aluminium panels.

To improve the illuminance performance further, we can modify the generation algorithm to change the opening sizes in a defined range. This leads to letting more
or less daylight into the indoor space by controlling the parameters. Our strategy is to create interference geometries first. Second the distances within openings and geometries can be calculated. Then we can use the values to define the sizes of each opening through the scale components. As the Figure 4 has illustrated, the sizes of the openings change gradually according to the position of the interference geometries we created parametrically.

6. Conclusion

This study suggests an analysis method to evaluate the indoor illuminance performance. The simulation is not a conventional in-depth one, but a practical method to immediately evaluate the performance for each design alternatives and provide guidelines and instant results for modification on the early stage. Our simulation approach is based on both the associative and graph-based models. In sum, the contribution can be summarized as follows:

(1) Our study has developed an alternative approach to study the influence of perforated façade panels on the indoor illuminance by using a parametric performance analysis. This modelling-to-analysis process can be repeated efficiently in
order to compare the performance of models with different parameters. Based on comparison and circulation, optimized design can be concluded according to the feedback. By setting up the link of graph-based system and associative system, we’ve tried to take the best advantage of the BIM models for multiple use.

(2) The study has attempted to explore a parametric design-analysis workflow in order to determine the advantages of parametric design in studying real-time changes in building design. Compared to conventional workflow, it is easier possible to design a performative-responsive façade using parametric design. As it allows for efficient editing the model in any stage of the design process. With the established relationships between parameters in parametric design, architects have better dominance on the project.

(3) Based on our research outcomes we can give our design guidelines to the facade panel manufacturer who produces the proposed aluminium panels. As the models are developed on a parametric computational platforms can seamlessly be employed to manufacture the facade panels, e.g. industrial robots.

(4) The simulations can improve the understanding of the natural illuminance at any given times during a year allowing architects to evaluate their design during the early design stages.

Acknowledgements

The research is supported by the Changjiang Survey Planning Design and Research Co., Ltd., Project (No. CX2015Z08). The Natatorium has won the Best Green Building Design Award and the 2nd Class Prize of the 3rd BIM Design Competition of Exploration & Design Association of Hubei Province (EDAHB), China in December, 2015.

References