Abstract

The paper describes the daylight simulation of Y-house for the competition of Solar Decathlon 2011, USA. Daylight factors and daylight illumination levels in the paper are of great importance to analyze the interior daylight environment of Y-house. Through detail description in the text, the proceeding steps for the analysis of daylight report the simulation method systematically. With the software, the data of daylight simulation is described in 3D model clearly and directly. The suggestions from the result of analysis enable designers and engineers to make a comparatively reasonable decision for the renewal of architecture design and lighting design. With the assistance of software, the design for house, especially the lighting design, and the calculation of daylight factor and daylight illumination levels will support the achievements of the projects, not only Y-house.

Keywords: Daylight, Daylight Factor, Daylight Illumination Level, Lighting Design, Daylight Simulation

1. Introduction

Light environment is one important aspect of building indoor environment. Daylight design and analysis is one of the two parts of the indoor light environment. It is of great significant for realizing human comfort, zero energy cost, and subjective satisfaction in the field of building science and technology. Y-house is the design work for the competition of Solar Decathlon 2011, USA. It aims at realizing less energy consumption for a residential house by using solar energy as the only source of power supply. Daylight design and analysis for this house is stated in this paper.

Light environment is generally designed as the experience of designers or the favor of customers without scientific analysis for actual outcome and rational data. It is not reasonable to waste additional time and energy to rebuild the building because of the insufficient daylight inside. The lighting design depends on the light from windows to build light environment inside to satisfy with the users, so the designer can only visit the actual rooms to make out his plan after the indoor space design, especially the place of windows or partitions, is fixed in house.

Daylight simulation is based on the daylight design and analysis to work out the daylight factor or daylight illumination levels for the evaluation of architecture design and the interior lighting design at the platform of Autodesk Ecotect, which is the main analysis tool.

Under the simulation of software, designers can analyze the daylight distribution correctly and the arrangement of lights possibly. The modification for architecture design can be made before building and the suggestion can be given according to the result of simulation, if the daylight data does not meet the national standard or the real demand of designer and users.

The paper will detail the simulation processes in design strategy, analysis condition, and analysis and discussion, which are the main parts of all description contents. At last, the conclusion for daylight analysis will give the research value according to sufficiently analyzing the present data and point out the factual relationship.

2. Design Strategy

Design strategy is made by analyzing of the architectural design, environment, location and other factors related to daylight. In this paper, the daylight simulation of Y-house selects the “autumn” pattern of passive solar equipment design (figure 4), since the competition will be held in October, 2011.

Figure 2-1 shows the branches of Y house in are kitchen, bedroom, bathroom, living room, dinner centre, and equipment room.
Figure 2-2 shows the framework of Solar Container is depicted by designers in.

Figure 2-3 shows Passive solar equipment design and is the combination of thin film modules and facade louvers and the panels would regulate the angles in 4 seasons if necessary.

3. Analysis Conditions

According to the schedule of competition, the season is autumn, which the angles of the passive solar panels would be regulated.

Autodesk Ecotect, the software we use for daylight analysis, is an industry leading building analysis program that finally allows designers to work easily in 3D and apply all the tools necessary for an energy efficient and sustainable future. It features a designer-friendly 3D modeling interface fully integrated with a wide range of performance analysis and simulation functions.

Figure 3-1 is the summary of analysis settings. The value of design sky illuminance is 7000lx, derived from the latitude of location. And the setting of sky luminance distribution model is CIE Over Sky Condition, which determines how available natural light is distributed over the sky doom. Window cleanliness in Ecotect, the likely cleanliness of Y house windows and the corresponding reduction in transmittance, is Average (x0.90).

Figure 3-2 is the Analysis Grid for Y House, simply a grid of points used as the basis for spatial calculations in Ecotect. Number of Cells defines the number of individual cells in the grid over each of the major axis. The greater the number the greater the accuracy of the grid calculation, but the longer it will take.

The offset, equal to the working plane, is 750.0 mm, according to “GB/T 50033-2001 Standard for Daylighting Design of Buildings”.

Figure 3-1 the summary of analysis settings
4. Analysis and Discussion

After the design is made, software simulation and results analysis have been done, in order to make sure the design outcome is fit to the strategy and comply with the related standards. Most natural lighting calculations are based on daylight factors. The Daylight Factor is simply a ratio of the daylight illuminance at a particular point within an enclosure to the simultaneous unobstructed outdoor illuminance, expressed as a percentage. Thus an unobstructed view of the sky would result in a 100% daylight factor. Daylight factors include the contribution of both internal and external reflections. Daylight Illumination Levels are simply estimated illumination levels calculated by multiplying the daylight factor (%) by the current Design Sky value (lx).

Figure 4-1 shows the perspective daylight analysis of daylight factor. The difference of colors means the difference of factor values, as well as the height. Thus we can directly know the distribution of daylight from the 3D model.

Figure 4-2 shows the plan for the daylight analysis of daylight factor. The connection of different colors in different rooms of Y House describes the variation of daylight factor.

Figure 4-3 shows perspective for the daylight analysis of daylight levels. The values are simply calculated by multiplying the daylight factor (%) by the design sky value (7000lx in Washington D.C).

Figure 4-4 shows the plan for the daylight analysis of daylight levels, which is similar with Figure 4-3.
Figure 4-4 Plan for the daylight analysis of daylight levels

Table 4-1 is the calculation results of daylight for Y-house, the Minimum value of daylight factor $C_{\text{min}}$(%) and Critical illuminance of interior daylight $E_1$(lx), as the table 4-2 depicted in GB/T 50033-2001 Standard for daylighting design of buildings.

Table 4-2 is standard of daylight design in China. According to 《Standard of daylighting design of buildings GB/T 50033-2001》, Standard value of daylight factor of residential building is stated to assess the result of Y-house.

Table 4-1 Value of Daylight Factor of Y House

<table>
<thead>
<tr>
<th>Daylight level</th>
<th>Room</th>
<th>$C_{\text{min}}$(%)</th>
<th>$E_1$(lx)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bedroom</td>
<td>2.23</td>
<td>156.1</td>
</tr>
<tr>
<td></td>
<td>Living Room</td>
<td>2.53</td>
<td>177.1</td>
</tr>
<tr>
<td>IV</td>
<td>Equipment Room</td>
<td>2.63</td>
<td>184.1</td>
</tr>
<tr>
<td></td>
<td>Kitchen</td>
<td>4.50</td>
<td>315.0</td>
</tr>
</tbody>
</table>

$C_{\text{min}}$(%) : Minimum value of daylight factor  
$E_1$(lx) : Critical illuminance of interior daylight

Table 4-2 Standard Value of Daylight Factor of Residential Building

<table>
<thead>
<tr>
<th>Daylight Level</th>
<th>ROOM</th>
<th>Siding daylighting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Living room</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>bedroom</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Study</td>
<td></td>
</tr>
</tbody>
</table>

Discussion:

- $C_{\text{min}} > 1\%$ and $E_1 > 50$ lx in bedroom living room, equipment room and kitchen, all the rooms of level IV, which satisfy the GB in table 4-2.
- $C_{\text{min}} > 0.5\%$ and $E_1 > 25$ lx in dining room and bathroom, all the rooms of level V, which satisfy the GB in table 4-2.

The most significant result that can be drawn from the data in figure 4-1 to 4-4 concerns the daylight inside house has comparatively uniform distribution according to the similar colors in the pictures. What’s more, the daylight will be more sufficient between the wall and passive solar equipment panels, which is described by the color meaning high values. And from table 4-1 and 4-2 concerns all the factors meet the requirement of design strategy as well as related standard and codes for building daylight. So the daylight design for Y-house is good idea.

5. Conclusion

It is concluded that by software simulation and results analysis, the design result is proved to be good for application, and analysis process is necessary for architectural design. By a good daylight design, it is easy to create a comfortable light environment for room users.

The analysis of daylight is completed with the direction of detail knowledge under the autumn mode of passive solar equipment design, but the ones of another 3 modes, winter, spring, and summer, are not given in this paper. The limitation of the analysis is the surrounding of Y-house, which is supposed to be no high buildings and trees to affect the daylight of Y-house.

The simulation of daylight distribution is a fairly new method to evaluate the architecture design, especially the daylight design and the theory on this knowledge is published rarely with systematical discussion and study. It is through Autodesk Ecotect that the analysis of daylight is achieved quantitatively and intuitively, which displays the results of colorful pictures with color grade and accurate numbers.
6. Reference


[5] Christopher S. Pechacek, Marilyne Andersen, Steven W. Lockley. COMBINING ANNUAL DAYLIGHT SIMULATION WITH PHOTOBIOLOGY DATA.


