DAYLIGHTING SIMULATIONS: *A Case Study of the University of the Philippines College of Architecture Library*

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Abstract

This paper reports on the use of lighting models to simulate daylight conditions in building spaces. The case study was conducted for the College of Architecture Library, University of the Philippines Diliman (at that time, under construction). The study intended to test the effectiveness of two (2) daylighting design elements that were to be incorporated in the library, namely the sunshade devices protecting the exterior windows and skylight. Also, it investigated the sufficiency of light levels for specific tasks inside the library compared to established local standards.

A daylighting model was constructed with finishes matching the existing conditions as close as possible. Testing was done through simulating the lighting model with a light meter attached during critical days within the year (equinox and solstices) and specific times of the day. Light level readings at particular areas of the lighting model were obtained.

The results showed that base measurements exceeded the local light level standards and produced harmful glare. The solution taken was controlling the amount of light entering the library by simulating overcast conditions to distribute light evenly throughout the spaces. Interventions on the lighting model were simulated and tested, resulting in favorable light levels. These were used as basis in the design and construction of the actual library space.

Keywords: daylighting model, simulation, task coordinate, skylight, design manipulated

I. Introduction

The study of daylighting in tropical climates, particularly in the Philippines, appears to be sorely lacking. Considering the rising cost of fuel and electricity, daylighting can help in energy cost cutting. It is considered as a cost-efficient way of lighting design as it enables a building to be free from full reliance on electric lighting.

One building type that requires huge lighting expense is the library. In particular, the University of the Philippines has over 30 libraries. Most of them are not designed with daylighting as the primary source of light. If these libraries were to rely on daylighting, significant saving in power costs can be achieved.

Based on this notion, the study looked at how effective daylighting design can be applied in a library space by simulating daylight conditions using two (2) daylighting elements that were 'design-manipulated' to produce desired light levels. It aimed to determine the validity of the two elements by applying variety of design set-ups. The best set up producing the desired light levels for the specific tasks inside a library space was identified and adopted in its actual design and construction. The study selected the College of Architecture Library as the subject building for this experiment. The researchers believed there was no better example to start with than this library because it was to be re-constructed when this study proposal was taking shape. The original building was razed by fire. Major re-planning of spaces and retrofitting were done to fit the requirements for space of the UPCA when it moved in 2005 from the old Melchor Hall Building to the place where it is now.

II. The UP College of Architecture Library

The University of the Philippines College of Architecture (UPCA) Library is located at the northern part of the UPCA Building 2 (at the lower right side as shown on Figure 1). Figure 2 illustrates the spatial layout of the library, with the yellow rectangle enclosure emphasizing the area which was the focus of this daylighting study. It is divided between the public area that includes the circulation, reading and the multi-media room areas; and the private area, which includes the offices and the reserved section.

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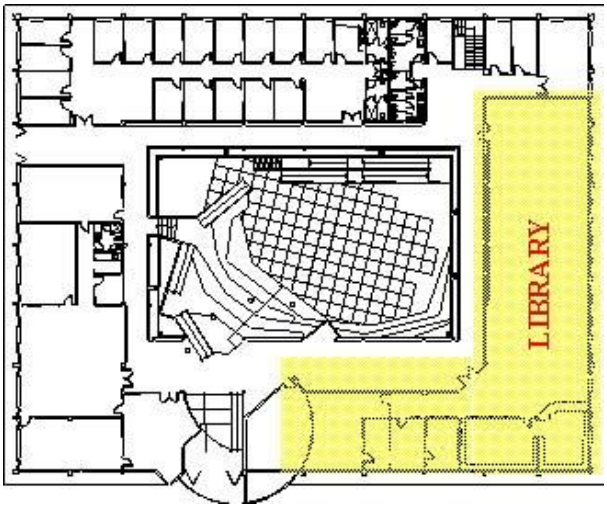

Figure 1. Layout of UP College of Architecture Building 2.
Source: Office of the Campus Architect, UP Diliman.

The chosen section of study in the library is the circulation and reading area where most of the visual activities are located. The daylight sources for this section are the main windows (exterior side), the clerestory windows (interior side), and the skylight. The main windows are specified to be of powder coated framed clear glass awning and fixed windows that provide spaces for the installation of window type air-conditioned units (ACU's). The clerestory windows are jalousie glass strips for additional lighting at the book stacks area. The skylight has alternating louvers and fixed clear glass panels to let heat escape through the opening above.

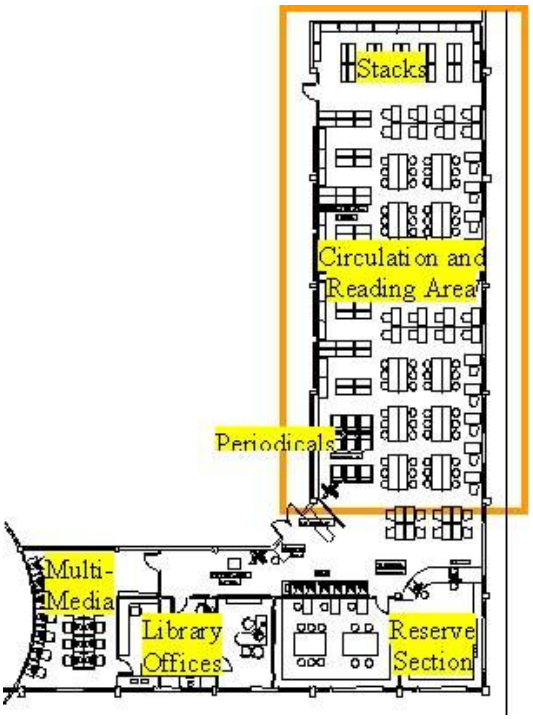

Figure 2. Layout of UP College of Architecture Library.
Source: Office of the Campus Architect, UP Diliman.

Along the exterior side of the building, sunshades were installed at five panels per bay. These were constructed using 6.3mm thick fiber-cement boards anchored together using angular steel bars. These sunshade devices serve not only as light dampers but also as main aesthetic elements that characterize the design of the reconstructed building.

The following methodology description shows how the determination of the validity of the two design elements was carried out. The determination of this validity was primarily hinged on finding the most desirable light levels for the specific tasks in the library spaces that can be obtained, and in doing so, various set-up manipulations of the daylighting elements were explored.

III. Methodology

Figure 3 shows the flow of procedures in carrying out the study. The first step in the testing phase was the identification of the parameters and the variables to be used. The daylight model was manipulated based on these parameters and variables. Three different tests were done: (a) the existing conditions of the library; (b) the manipulated conditions playing with the variables; and (c) the proposed solutions to meet the desired results.

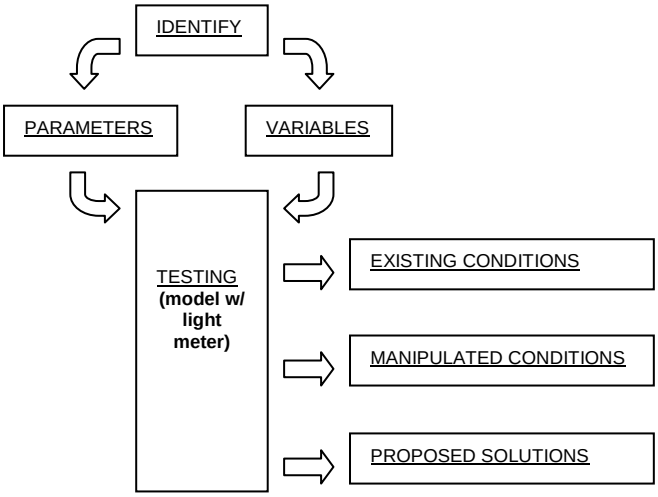

Figure 3. Flow of Study.

A. Parameters

The following parameters were used as basis in determining the desirability of the lighting conditions produced by the set-ups. The first one, *illuminance,* is a quantifiable parameter which was measured using the light meter. Glare, being a non-quantifiable factor however, was qualitatively evaluated through pictographic manifestation on the library space in each set-up trial.

1) Illuminance – is the density (concentration) of luminous flux incident on a surface (Moore, 1991). Simply, it is the amount of light that falls on an area, in this case, per square meter. Measured in lux, the amount of light should be sufficient for specified tasks in a library, such as reading and browsing.

2) Glare – is the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eye is adapted to cause annoyance, discomfort, or loss in visual performance and visibility (Moore, 1991). Simply, it is the high intensity of light markedly different from its surroundings that produces discomfort. While glare is hard to quantify, its intensity will be detected visually through the photographs that will accompany each test.

B. Variables

The following light sources (fenestration elements) were identified as the elements that supplied the variables of light getting into the library spaces when 'design manipulated':

1) Main windows (exterior side) with or without the sunshades;
2) Clerestory windows (interior side); and
3) Skylight.

The term 'design manipulated' refers to the simulated condition when the two (2) main elements, sunshades and skylight, were made *present* or *absent* in the design set-up. This also includes the process of modifying the model to reach overcast condition in the inside, and the control of light levels by applying opacity to the openings through the use of overlapping tracing paper sheets.

C. Daylight Model

Figure 4 shows the daylighting model that was constructed using a scale of 1:50 meters.

Figure 4. Daylight Model exterior.

The scaled model included only the portion of the library where the skylight is present. It was made of mostly foam core and illustration board to represent the walls, floor, ceiling and sunshades. The color and details of finishes were approximated to actual library conditions. Clear acetate was used to represent glass windows. Appropriate furniture, including tables, chairs, carrels and bookshelves were also constructed. Cut-outs of people, appropriately sized, were inserted to simulate actual use conditions. A peephole was located at one end of the model for the digital camera to be inserted. The wires for the sensors were placed underneath the model leading to the daylight meter. The meter used was the Megatron Architectural Model Daylight factor meter.

The following daylight conditions were tested on the following dates:

1) March 21 (Equinox) - <9am, 12noon, 3pm>
2) June 22 (Summer Solstice) - <9am, 12noon, 3pm>
3) December 22 (Winter Solstice) - <9am, 12noon, 3pm>

A digital photograph for each date and time was also taken to detect the presence of glare.

IV. Test Results and Analysis

Table 1 shows a summary of the test procedures and the corresponding results of the different test set ups that were carried out.

Test	Variables	Results
First	• Benchmark conditions • With sunshades • With skylight • Under normal conditions	• exceeded (1000++ lux) the recommended levels (750 lux) for all dates • glare present
Second	• Benchmark conditions • With sunshades • Without skylight	• exceeded (1000++ lux) the recommended levels (750 lux) for all dates • glare present • unlighted areas present
Third	• Overcast conditions • With skylight and sunshades	• matched recommended light levels • light from skylight diffused • glare from windows minimized
Fourth	• Normal conditions • With skylight and sunshades • With opaque windows	• matched recommended light levels with exceptions • glare from windows minimized

Table 1. Summary of test procedures and results.

The First and Second tests were both of benchmark conditions and used a set up each with the sunshades in place. The First test had the skylight installed as well but the Second test did not. The results show that both set up had a reading of more than 1000 lux, clearly exceeding the recommended illuminance level (IIEE-ELI, 2002) of 750 lux. Glare was present in both the First test and Second test set ups, with unlighted areas within the library space manifested also in the Second test.

The Third and Fourth tests both had the sunshades and skylight in place, but were different in the aspect of having started with overcast and normal conditions, respectively.

The two set ups produced the desirable conditions of having met the recommended illuminance level of 750 lux. Glare in both set ups was minimized. The Third test set up had the light from skylight diffused. On the other hand, the Fourth test set up had the windows made opaque by using layers of tracing paper. This set up met the recommended illuminance level, but with exceptions to specific times and dates.

The first test conducted on March 3, 2005 at 3:00 in the afternoon was made to establish the benchmark conditions inside the library. The results showed that light levels exceeded the recommended levels. As seen on the photograph in Figure 5, glare was present on the floor space. It was also reflected on the surface of some furniture.

Figure 5. First Test (March 3:00 PM).

In the second test (Figure 6), the skylight was removed from the equation. But it only produced uneven light levels as shown by the pockets of light reflection on various points inside the library.

Figure 6. Second Test (June 9:00 AM).

The third test (Figure 7) was to simulate the effect of overcast conditions inside the library. The results matched the recommended light levels of 750 lux (IIEE, 2002) for all dates. Light from the skylight was effectively diffused to the space below. In this set-up, the direct glare from the windows was minimized.

Figure 7. Third Test (typical for all dates and times).

Since the overcast conditions were ideal, the model was modified, specifically the openings to reach the same conditions. Control of light levels was achieved by applying opacity to the openings through the use of overlapping tracing paper sheets. The fourth test (Figure 8) showed results matching those of overcast conditions with exceptions to specific times and dates.

Figure 8. Fourth Test (typical for all dates and times).

To verify the accuracy of the readings taken with the daylight model, actual testing was done in the existing College of Architecture Library. Readings were taken with a handheld daylight meter on March 31, 2005 at 3:00 in the afternoon to verify light meter values on the following three areas: the table, the carrel in the middle, and the carrel near the side windows.

In turn, these readings were calibrated on the basis of the transmissivity property of the different materials used in the research – the float glass in the actual building and the acetate and tracing paper in the daylighting model. This was done to ensure closeness of the simulated lighting condition with that of the actual library.

Figures 9, 10 & 11 below show the effects of modification made on the windows by putting layers of tracing papers to attain a condition of opacity. This modification was done in the Fourth Test set up with measurements done on 9:00 am, 12:00 nn and 3:00 pm, respectively.

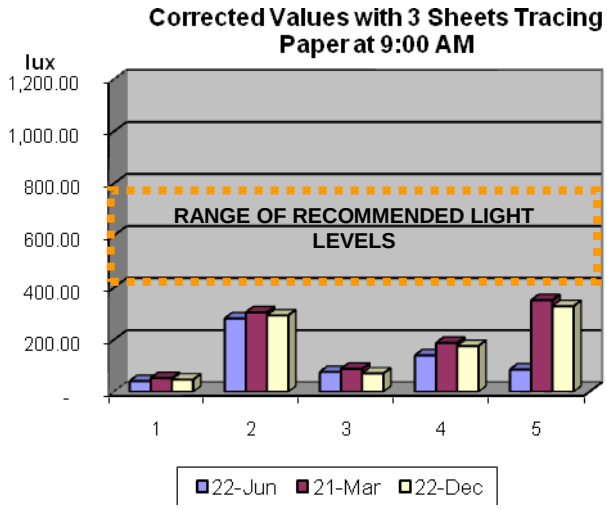

Figure 9. Corrected Values (Fourth Test) for 9:00 AM.

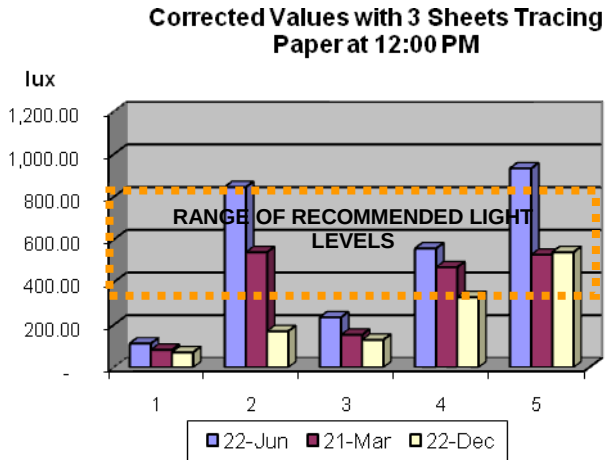

Figure 10. Corrected Values (Fourth Test) for 12:00 NN.

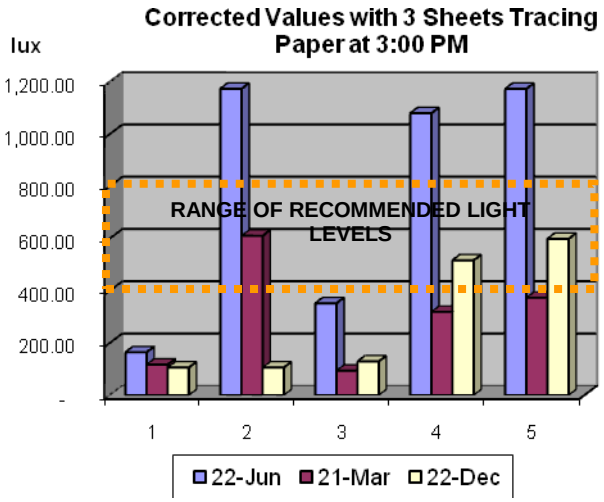

Figure 11. Corrected Values (Fourth Test) for 3:00 PM.

The test suggested that for mornings, since light levels barely meet the recommended, no opacity is recommended for the light sources. Specifically for March afternoons, increased opacity is recommended to reduce the high light levels. However, these may also cause significant glare.

V. Conclusion and Recommendations

The simulation done in the University of the Philippines College of Architecture Library has led to the adoption of two (2) daylighting elements in the actual design: the sunshades and the skylight. These have been tested and shown compliant with the recommended level of illuminance for library spaces. Modifications have been effected, particularly that of modifying window openings through the application of opacity, to achieve the desired lighting condition.

The results show that in order to produce sufficient light levels and to reduce the amount of glare inside the library, the best solution is to simulate overcast conditions. It is recommended as well to apply a material over the windows that can control the amount of light coming in. This material may be a film that may be applied on the glass itself or any washable cloth that has a desired opacity. It is also suggested that retractable cloth blinds that may be easily rolled up will be used in cases where the outdoor conditions are overcast. These may be installed in layers to control the opacity of the windows. Less opacity will be required during the summer months and in the mornings, while more opacity will be required during June and in the afternoons.

The case study has delved on the testing of application of two (2) daylighting elements and has established desirable lighting conditions that are compliant with the recommended lighting rate. However, the actual determination whether the design has led to an actual reduction of power consumption in the use of library space has not been carried out yet. Consequently, further study is therefore recommended in order to define empirical proofs that would show that daylighting techniques, such as the ones applied in the study, would really lead to energy saving.

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