Optimizing Natural Daylight for School Building

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Abstract

In developing country such as Indonesia, low cost school are peoples dream. But it seems that condition remains a utopia. In truth, parents still need lots of money so their children can enter school. One of many factors that causes high schooling cost is none other than a very high school operational cost. Most of school operational budget is allocated for paying electrical bill. And most of school electrical consumption comes from light bulbs.

For educational fascilities such as schools, lighting quality becomes main factor which can support the whole school activities. Lighting quality for classrooms need to be adequate so that students can concentrate when studying. Libraries must adequately lit so readers can read with enough light. Others like laboratories, sports hall, teacher's lounge, cafeteria, and so on also need suitable amount of lighting for users' comfort sake.

Although lighting quality does become a considerable factor in most of school designs, but practically lighting quality still becomes a forgetable factor which can be solved with mere artificial light. Architects and designers seem putting less priority for lighting quality and focusing more on ordering forms and spaces, creating facades, arranging hierarchies, and so on. As results, we still find lots of dark classrooms, labs, or libraries that need to be lit with artificial lights even on a day.

The best daylighting source comes from the sun, that known as daylight or skylight. Imagine if classrooms, labs, libraries, and sports hall are adequately lit only with daylight, how much electricity savings we can do? This will positively affects in reducing school operational cost directly.

Keywords: *Schools, daylighting quality, energy savings.*

1. Introduction

School is a place of study. A place where students undergoing various processes of activities with the hope that knowledge learned at school can be beneficial to their lives later on.

The process of student activities in a variety of schools, such as receiving the subject matter of teachers in the classroom, lab science lab, reading or study independently at the library, carrying out PE in the gym, eat in the cafeteria, and so on.

The question is, can all the above activities performing well with no lighting? All activities at the school absolutely needs enough space with good lighting. That is, the existing lighting levels shall meet applicable standards. The standard requires that minimum lighting for classrooms is 250 lux, 500 lux for laboratory, library 300 lux, 200 lux for cafeteria, computer room 350 lux, and much more.

2. Natural lighting vs artificial lighting

Generally, school activities carried out from morning till noon. There are also schools which started its activities from noon until evening. In fact, there are a few schools that carry out activities from morning to evening. However, regardless of when the activities started, all have in common: "School activities take place when the sun is still shining". With the existence of natural light during the day, it would be very good if that light source can be used as a primary lighting source.

However, often found many spaces in the school can not take advantage of natural lighting during the day so the lighting for these spaces still to be assisted by artificial lighting. This course is an unwise action from the point of view of energy saving.

3. Ecotect analysis: it's origin, description, and features

The original Ecotect software was written as a demonstration of some of the ideas presented in PhD thesis by Dr. Andrew Marsh at the School of Architecture and Fine Arts at The University of Western Australia. The fundamental theme of this thesis was that building performance concerns are best addressed by architects at the most conceptual stages of design, not at the very end of the process.

Figure 1. Dr. Andrew Marsh (source: andrewmarsh.com)

Autodesk Ecotect Analysis is an environmental analysis tool that allows designers to simulate building performance right from the earliest stages of conceptual design. It combines a wide array of detailed analysis functions with a highly visual and interactive display that presents analytical results directly within the context of the building model, enabling it to communicate complex concepts and extensive datasets in surprisingly intuitive and effective ways.

The most significant feature of Ecotect is its interactive approach to analysis. Change the type of carpet on the floor and compare changes in the room's acoustic response, its reverberation time, light levels and internal temperatures. Add a new window and immediately see its thermal effect, weighing that up against changes in daylight factor, incident solar radiation and overall building cost. Spray sound particles around an enclosure and watch the wavefronts reflect and slowly decay in 3D. Ecotect is also the only application of its kind to include comfort, greenhouse gas emissions and embodied energy analysis alongside capital and running costs for direct comparison.

The software has undergone some major changes since then. Version 2.5 was the first commercial release in 1996, followed by version 3.0 in 1998, version 4.0 in 2000 version 5.0 in June 2002 and version 5.50 in September 2006 - with version 5.60 in June 2010 building significantly on the functionality of previous versions introducing a range of new analysis functions and real-time hidden line and sketch visualisation. It also refines some of the major algorithms such as the thermal and daylight factor calculations.

The most important news is that Ecotect was acquired by Autodesk, hence the release of Autodesk Ecotect 2009 in January 2009, Autodesk Ecotect Analysis 2010 in March 2009 and Autodesk Ecotect Analysis 2011 in April 2010.

Another major part of Ecotect was the development of its innovative 3D interface. A traditional geometric CAD system is actually not that appropriate for early design development, being far too onerous and specific in its input requirements - forcing a designer to think mathematically at a time when they are only really thinking intuitively. Thus, a flexible and intuitive relational 3D construction system has been designed that exploits a surprisingly simple set of inherent relationships between building elements to greatly simplify the creation of even the most complex geometry, and to vastly increase its ongoing editability.

One can use Ecotect to do the following:

- Display and animate complex shadows and reflections,
- Generate interactive sun-path diagrams for instant overshadowing analysis,
- Calculate the incident solar radiation on any surface and its percentage shading,
- Work out daylight factors and artificial lighting levels either spatially or at any point,
- Calculate monthly heat loads and hourly temperature graphs for any zone,
- Generate full schedules of material costs and environmental impact,
- Trace the paths of acoustic particles and rays within any enclosures of any shape,
- Spray sound particles around an enclosure and watch the rate of decay,
- Quickly calculate statistical and raytraced reverberation times in any space,
- Export to VRML for interactive visualisation and presentation to clients,
- Export to the RADIANCE Lighting Program for physically accurate lighting analysis,
- Read and write a wide range of CAD and analysis file formats,
- And much more.

Figure 2. Ecotect User Interface (source :Ecotect 2011 Help)

4. Case study: alfacentauri school, bandung

The case study was conducted to determine the quality of lighting in a school, especially to find out if there are spaces in the schools are still using artificial lighting during the day. In addition, the case study was conducted as a means to try Ecotect Analysis software which has been described previously.

The selected schools are elementary and junior high school of the Alpha Centauri, Palasari, Bandung. The school is owned by Sony Sugema Foundation.

In this case study, there are four main things to do, namely:

1. Documentation, to determine the actual condition of every room, especially in terms of quality of illumination
2. Measurement, to determine the dimensions (length, width, and height) of existing spaces, as well as to know the positions and openings (doors and windows) in each room.
3. Remodeling, ie re-create 3-D models are schematically based on the results of measurements. Here is the result of modeling along with some photo documentation:

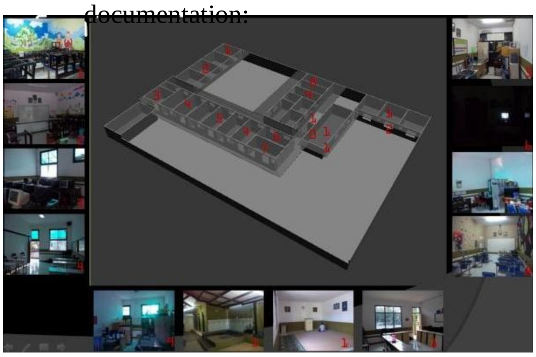

Figure 3. 3-D model,scheme anddocumentationof Alfa Centauri School (source: private document)

4. Testing the software, importing 3-D models into Ecotect for daylighting analysis with the following results:

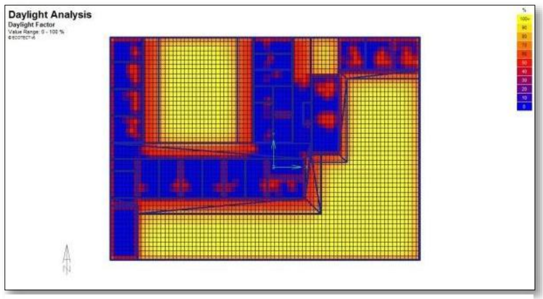

Figure 4. Spectrum test result displaying natural lighting quality in Alfa Centauri School (source :private document)

Based on the analysis of natural lighting, it appears that in the primary and secondary lighting Alfa Centauri was still require assistance at any time during the day light. In other words, the quality of natural lighting in the school is not good.

5. Ideal concept

Designing the school in accordance with the standards is a must. However, designing schools that rely on natural lighting during the day is a value-added. This idea was tested to be realized in this study. The goal is at least 75% of the total area of the existing spaces at the school did not use lights when daylight or simply rely on natural lighting through openings.

There are two things to be done to realize this idea, namely:

1. Incorporating natural lighting in every room through a window opening.
2. Neutralize a nuisance lighting glare from the sun with sun-shading.

6. Design process i: field survey

The design of the school will be built on an area of approximately 2.8 hectares, which lies at 6:57 ° LS - 107.37 ° E, at an altitude of 689 meters above sea level. Orientation of land facing east-west line which is the sunrise and sunset. Meanwhile, the land toward the north at an angle of 14 ° to the northeast.

This phase was conducted to determine the condition of the buildings around the area, especially the average height of the building.

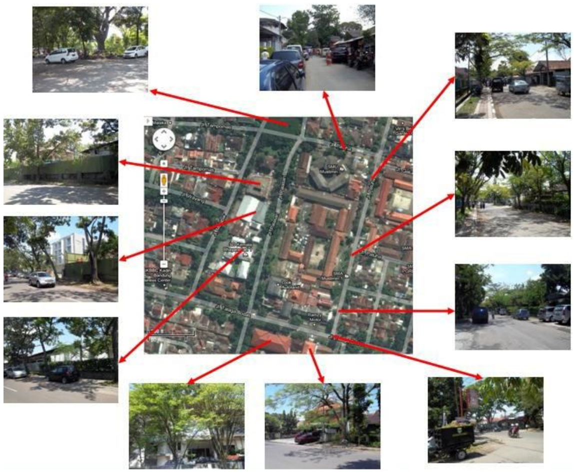

Figure 5. Site situation
(source: private document)

Figure 7. Natural lighting quality
(source: private document)

Based on the survey, it can be seen the average building height around the land. In the north and east, around the building has a height of 2 floors or an average of 8 meters. To the west, the building has a height of about 4 floors or have an average height of 16 meters. While in the south, around the height of the building is 2 floors but there is also a building with a height of 5 floors.

Figure 6. Height of building surrounding
(source: private document)

From the height of the building, it can be seen the quality of natural light coming into the land, where the natural light coming from the north, east, and the natural light coming from most of the south is better than coming in from the west and the south are blocked by a five-story building.

7. Design Process II: Schematic Plan

Schematic sketch was made with reference to the space program that had been developed previously. The schematic sketch was made by following the magnitude BCR, FAR, border and required number of floors.

In short, this stage is characterized by preparing, laying, and classifying spaces in such a way that would later form a unity building.

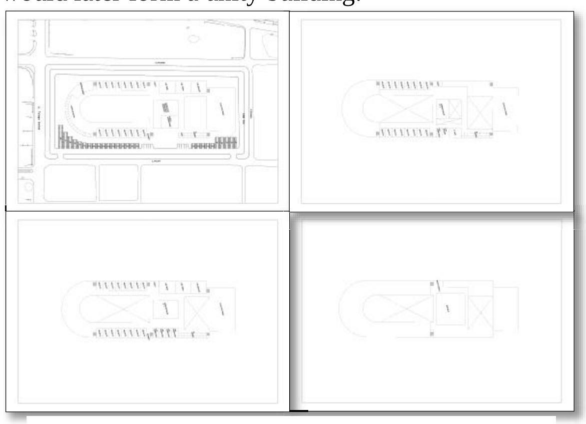

Figure 8. Schematic Design
(source: private document)

8. Design Process III: Counting the dimensions of room openings.

Performed by the method of calculating the value of the minimum sky factor (FLmin) on the main measuring points (TUU) and side measuring point (TUS). This calculation is done manually for each room in school buildings, especially for spaces located on the east and west sides of buildings where natural light will be entered from both the directions.

The purpose of this phase is to calculate the area of effective aperture of a room so the light can enter the room reaches the required minimum illumination quality. This calculation is performed by taking into account the position of the room, the position of the wall where the openings will be installed, and the height of surrounding buildings that may block the entry of natural light into the room.

Although it has been attempted to calculate the dimensions of each room opening to the method of calculating the value of the minimum sky factor, there are several rooms that can not be determined by these methods, like the spaces in the center of the building and the spaces in the south. For these spaces, the method of trial and error used in determining the dimensions of the openings.

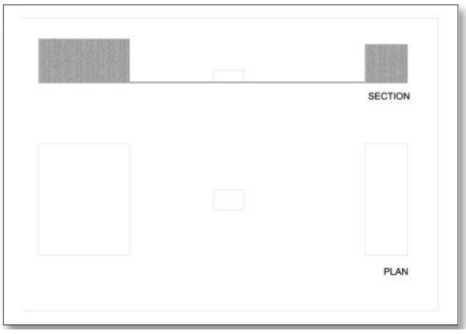

Figure 9. Plan and section of the classroom (source: private document)

PERHITUNGAN LUAS BUKAAN EFEKTIF

Tipe Ruang : Kelas 1 SMP

Dimensi : 7.20 x 10.80 m (lihat denah dan potongan)

L = 10.80 D = 3.60

1. FL min pada TUU = 0.35 L

   = 0.35 x 10.80

   = 3.78 %

2. Koreksi untuk kusen + 30% --------> 1.3 x 3.78 % = 4.9 %
3. Dari tabel didapat :

H/D	L/D
0.9	1.0

H/D = 0.9 L/D = 1.0

H/3,60 = 0.9 L/3.60 = 1.0

H = 3.24 m L = 3.60 m

Luas = 11.66 m²

4. Terdapat penghalang berupa bangunan dengan ketinggian rata-rata 8 m, jarak 36 m dari dinding, sehingga:

   H/D = 6.65/39.6 = 0.16

   tidak dapat dilalui cahaya, maka perlu dilakukan koreksi luas bukaan menjadi:

   1.16 x 11.66 = 13.52 m² -----→ H = 2.60 m L = 5.15 m

5. Bukaan dinaikkan 65 cm untuk privasi kelas, sehingga dimensi bukaan menjadi

   H = 1.95 m L = 5.15 m

   dengan ketinggian 1.2 m dari permukaan lantai

Figure 10. Part of the natural lighting calculation (source: private document)

9. Design Process IV: 3-D Modeling Scheme andNatural Lighting Analysis

3D model of the space that has been created using the calculated dimensions Graphisoft ArchiCAD 15. 3-D models of these spaces are made in accordance with the orientation of the original, complete with the location and size of openings in accordance with the calculation in the previous stage (also opening spaces instead of the calculation). At design also made the simulated barrier wall as the building across a barrier of entry of natural light into the room.

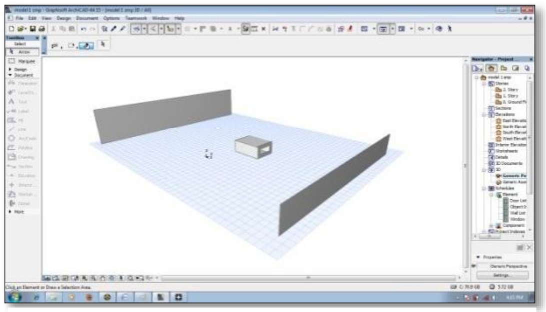

Figure 11. 3-D model of the room being analyzed (source: private document)

Models of 3-D is then imported into Ecotect Analysis software for the analysis of natural lighting. Dilakukian analysis to determine the quality of natural lighting in every room. The room will be considered to have the qualities of natural light if the spectrum of colors indicate the level of 5 to 10 (orange to yellow), and will be judged less good if the level of the color spectrum is less than 5 (purple to blue). Spectrum in the rendering process Ecotect program itself takes 30 minutes to 1 hour for each 3-D models.

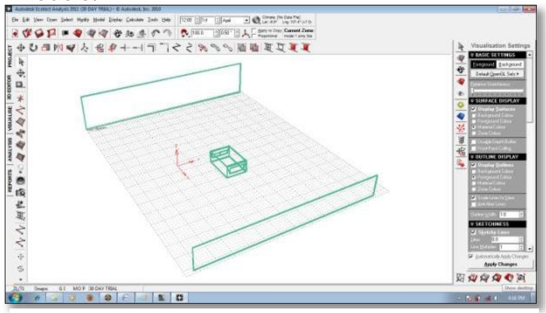

Figure 12. 3D model, after being exported to Ecotech (source: private document)

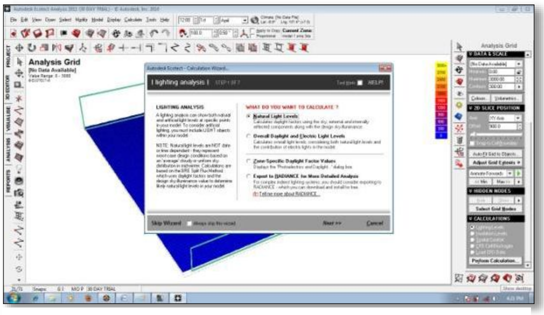

Figure 13. Process before spectrum test on Ecotech (source: private document)

Specifically for 3-D models of spaces facing east and west as well as for indoor sports hall canteen, openings equipped with shading devices in response to direct sunlight. In this case, the desired conditions where direct sunlight should not enter into the room through the openings from 9 am to 2:30 pm. shading dimensional of each aperture is calculated with the help of Solar Tool, software that participated was installed along with Ecotect Analysis. After that daylighting analysis performed on models 3-D..

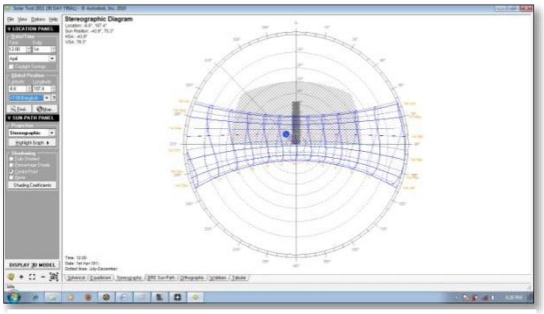

Figure 14. Solar Tool determining Sun Shading dimension
(source: private document)

Sometimes, some daylighting analysis showed that the results have not been satisfactory. Recalculation and change the location of a daylighting analysis performed to achieve the desired results.

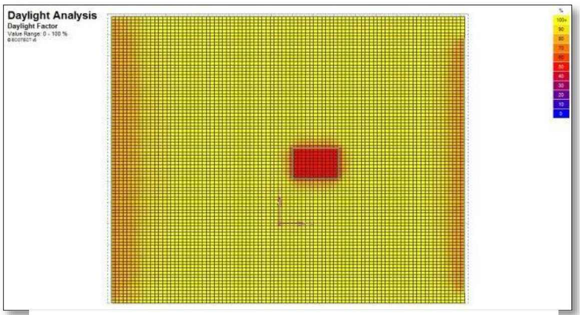

Figure 15. The result of spectrum final test on classroom sample
(source: private document)

10. Design Process V: Design Development

After the analysis of natural lighting throughout the school halls showed satisfactory results, the design process was resumed.

From this point, the design gradually perfected. The images work to be started. Structural logics already implemented into the design. Material had been applied to the design, as well as other things that had long been abandoned due to manual calculation and analysis process of natural lighting which is quite time consuming.

11. Final Design

Integrated Secondary School is designed with specific parameters aimed to get efficient lighting. Although more focused on the quality of natural lighting, the building is still designed without forgetting the design standards for school buildings.

Room lighting during the day is using optimal natural light. The light is entering each room through a window opening. The size of the windows is based on manual calculations and analysis with the help of Ecotect Analysis illumination, where the results of the calculation and analysis of the different types of rooms with one other room types. As a result, the window size for each type of room would be different from each other

In addition to optimizing natural lighting, glare problems stemming from direct sunlight. To block direct sunlight from entering the room at the desired time, The sun shading is used whose size obtained with the help of Solar Tool. Sun shading is applied at every opening in the outer wall of the building. It is clear that shading sun directly affects overall form of the building façade

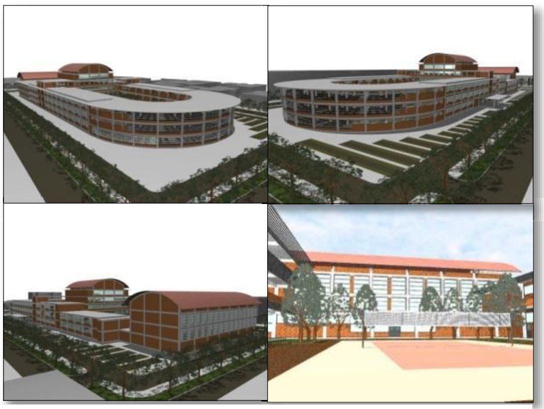

Figure 16. Computer model of the school
(source: private document)

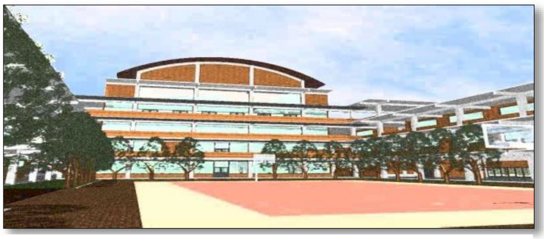

Figure 17. Computer model of the school
(source: private document)
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