Energy Analysis of P.G. Block of Mar Athanasius College of Engineering, Kothamangalam

Aiswarya K.B.[1], Akash Paul Thampi[2], Krutika S.[3], Shamsiya C.S.[4], Prof. Jaleen George[5]

[1]*B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India* [2]*B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India* [3]*B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India* [4]*B.Tech Student, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India* [5]*Professor, Dept. of Civil Engineering, Mar Athanasius College of Engineering, Kerala, India*

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Abstract – *Energy resources being non-renewable, have to be preserved for the future. Buildings are one of the largest consumers of energy. Reducing the energy consumption and increasing building performance major challenges. This project focuses on different environmental themes, such as energy consumption, daylight availability and acoustic comfort, with objectives such as limitation in energy consumption, minimum daylight levels, adequate reverberation time, etc. The project aims at analyzing the energy performance of the 'Post Graduate Block' or 'P.G. Block' of the college, using the energy analysis software 'Autodesk Ecotect' and devising methods to increase the energy efficiency of the building based on the above mentioned criteria. The project intends to create a 3D model of the building and using different sophisticated tools analyze the methods to make the building more energy efficient.*

Key Words: Energy Analysis, Energy Consumption, Daylight, Acoustics, 3D model, P.G. Block, Thermal

1. INTRODUCTION

With the advent of newer and more innovative technologies over the century, the life pattern of people all over the world has been changing. With the exchange of ideas, ideologies and technologies, the demand for services in various fields has been rising. This demand has not spared the building services too, leading to an increase in the demand for energy. Construction of net zero energy buildings is now being considered as one of the main approaches towards achieving sustainability in the built environment and enhance an economic way of living.

Advanced calculation procedures like the computation of daylight levels in a room when a building is overshadowed by surrounding obstructions are complicated tasks that necessitate the use of computer simulation. *'Autodesk Ecotect Analysis Software'* is a concept-to-detail sustainable design analysis software that helps measure the impact of environmental factors on a building's performance and web-based technology for whole building analysis.

2. METHODOLOGY

The project involves creating a model of the P.G. Block and analyzing it using BIM software. Building Information Modeling (BIM) is a process involving the generation and management of digital representations of physical and functional features of buildings. Autodesk Revit is a building information modeling software that allows users to design a building and structure its components in 3D, annotate the building with 2D drafting elements and access building information from the building model's database. Revit's rendering engine can be used to make a more realistic image of what is otherwise a diagrammatic model. In this project, the software Revit Architecture has been used to create a model of the P.G. Block. Autodesk Ecotect is used for the energy analysis of the same. The reason for this choice is that it involves a combination of analysis functions and an interactive display that presents analytical results directly within the context of the building model. The analysis results in improved building performance, lower project costs as well as lower the total cost of ownership over time.

3. CASE STUDY

The Post Graduate Building of Mar Athanasius College of Engineering is one of the most important buildings of the college. The P.G. block houses the classrooms for PG students and 2nd and 3rd year B.Tech students, machinery and computer labs and a water management facility room. It has a total of five floors, four laboratories, two computer laboratories, 45 classrooms, and 9 bathrooms. Hence, upon closer inspection, we can infer that the building is probably one of the highest consumers of energy and hence it is to be properly analyzed and computed in order to create an efficient energy consumption environment and reduce unwanted wastage. This project is primarily aimed at analyzing the energy consumption of the PG block. As a result of the analysis, the secondary aim of suggesting methods to make the PG block more energy efficient would also be achieved.

4. INPUT DATA

Following data were required for modelling in Revit Architecture:

1. The dimensions required for construction of the plan.
2. Specification of the materials required for construction.
    - Wall: Brick masonry (24cm thick)
      Heat transfer coefficient= 2.1920 W/m^2K Thermal Resistance= $0.4562m^2K/W$ Thermal Mass= 29.63kJ/K Absorptance= 0.7 Roughness=3
    - Window: Wooden window with glass panel (size:1220x1220mm)
      Visual Light Transmittance= 0.9
      Solar Heat Gain Coefficient= 0.78
      Heat Transfer Coefficient= $3.69W/m^2K$
      Thermal Resistance= $0.2711m^2K/W$
    - Door: Wooden Door Single Flush (Size 915x2032mm)
      Visual Light transmittance= 0
      Thermal Resistance= $0.2701m^2K/W$
      Solar Heat Gain Coefficient= 0
      Heat Transfer Coefficient= $3.7021W/m^2K$
    - Shutter: Horizontal Panel Garage Shutter (size: 2270x2050mm)
      Visual Light transmittance= 0
      Solar Heat Gain Coefficient= 0
      Heat Transfer coefficient= $3.7021W/m^2K$
    - Floor: Mosaic
      Heat Transfer Coefficient= $120W/m^2K$ Thermal Resistance= $0.0083m^2K/W$ Thermal Mass= 1.58kJ/K Absorptance= 0.7 Roughness= 3
    - Roof: G.I Sheet
      Heat Transfer Coefficient= $0.1129W/m^2K$ Thermal Resistance= $8.8575m^2K/W$ Thermal Mass= 3.58kJ/K
      Absorptance= 0.7
      Roughness= 3

Following data were required for energy analysis using Ecotect:

1. Weather and Location Data: The location and orientation of the model or its site is important for many calculations in Ecotect. The location requires three values: a *latitude*, *longitude* and a *time-zone* value.
    - *Latitude:* Defines the latitude of the site for the building. These values are always in degrees, positive for the northern latitudes, negative for southern. The latitude the of P.G. Block is 10.051801 N.
    - *Longitude:* Defines the longitude of the site for the building. These values are always in degrees, taken relative to Greenwich, England. The longitude of the P.G. Block is 76.619512 E.
    - *Time zone:* This selector sets the time zone of the location. The time zone is relative to GMT. The time zone under which the P.G. Block falls is (00+5.30) hours.

   The weather data was input by specifying the site location in the website www.energyplus.net/weather and downloading the weather data in (.epw) extension file. The file is then opened and resaved as (.wea) file in Autodesk Ecotect.

   With the completed model of the block and the above collected data, the project proceeded on to the energy analysis of the block.
2. The 3D model from Revit Architecture was exported to Ecotect as a gbXmL file.

5. OUTPUT DATA

The following are the output data obtained from the 'Autodesk Ecotect' software for the analysis of the building:

5.1 Daylight Factor Analysis

Following analysis chart was obtained during the daylight factor analysis of one of the floors of the building.

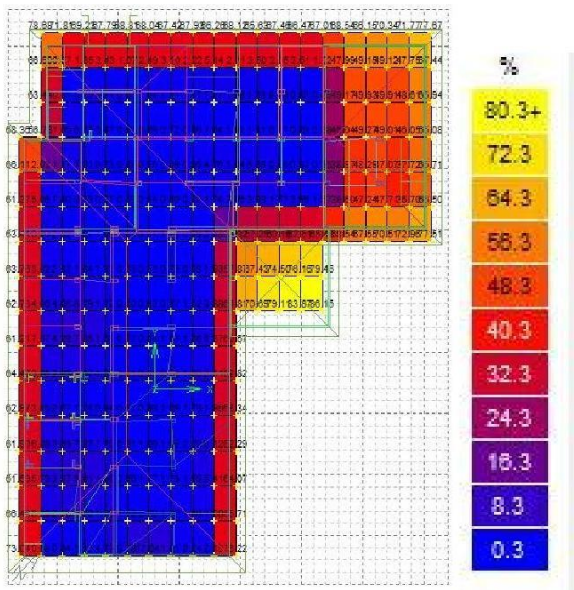

Chart-1: Day Light Factor analysis chart

From the above chart it can be inferred that the level of illumination by natural light is only 0.3% during the day and the building demands artificial lighting throughout the day Similarly, all floors were analysed using the software.

5.2 Sun Path Diagram and Shadow of Building

The following are the sun path and overshadow diagrams of the building obtained from the software.

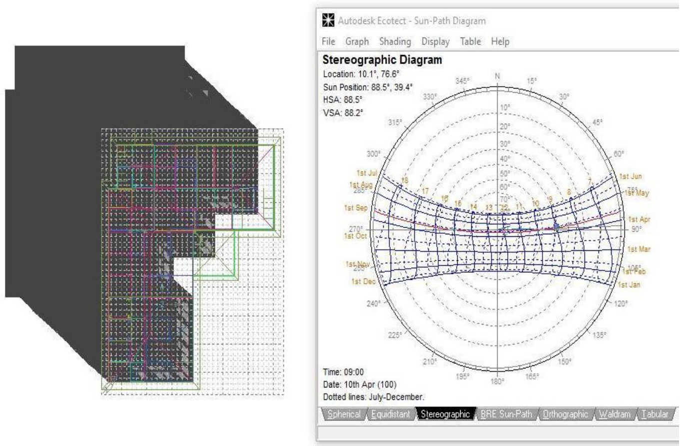

Fig-1: Sun path and overshadow diagram at 10th April, 2016, 09:00 am

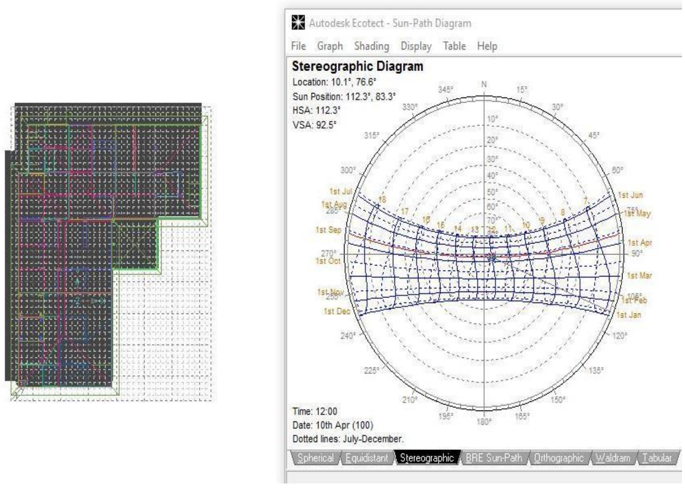

Fig-2: Sun path and overshadow diagram at 10th April, 2016, 12:00 pm

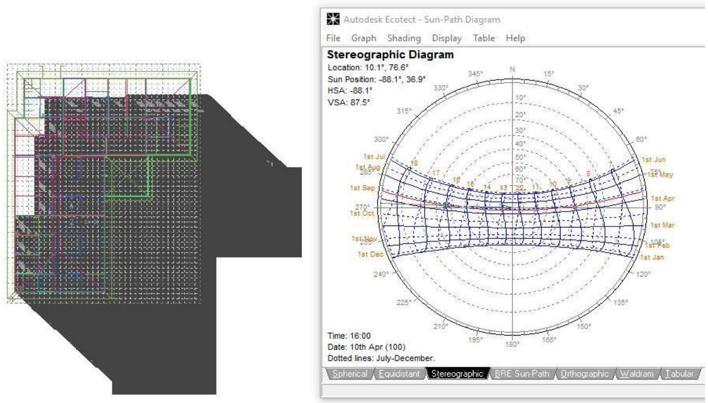

Fig-3: Sun path and overshadow diagram at 10th April 2016, 04:00 pm

From the above figures, it can be inferred that the sun lies on the east side of the building during most of the daytime.

5.3 Thermal Analysis

The following is the output data for the thermal analysis done for the P.G. Block on 10th April 2016 for the room P.G. 209.

HOURLY TEMPERATURES - Sunday 10th April 2016
Zone: PG209 Room
Avg. Temperature: 28.4 C (Ground 26.8 C)
Total Surface Area: 202.831 m^2 (515.6% floor area).
Total Exposed Area: 208.076 m^2 (529.0% floor area).
Total South Window: 0.000 m^2 (0.0% floor area).
Total Window Area: 2.300 m^2 (5.8% floor area).
Total Conductance (AU): 309 W/°K
Total Admittance (AY): 759 W/°K
Response Factor: 2.45

Table-1: Thermal analysis chart of P.G. 209 on 10th April 2016

HOUR	INSIDE	OUTSIDE	TEMP.DIF
	(C)	(C)	(C)
0	42.9	24.1	18.8
1	42.8	24.4	18.4
2	42.1	23.7	18.4
3	41.8	24	17.8
4	41.4	22.4	19
5	41.5	22.4	19.1
6	41.3	23.5	17.8
7	41.4	25.4	16
8	41.2	28	13.2
9	41.2	30.3	10.9
10	41.5	32.2	9.3
11	42	33.3	8.7
12	42.6	34.1	8.5
13	43.2	34.6	8.6
14	43.7	35.2	8.5
15	44	35.4	8.6
16	44.2	35.2	9
17	44.3	34	10.3
18	44.4	32.1	12.3
19	44.4	29.8	14.6
20	44.3	27.8	16.5
21	44	26.3	17.7
22	43.5	25.6	17.9
23	43	25.2	17.8

Similarly, thermal analysis was carried out for all rooms. From the above output, it can be inferred that the internal temperature is greater than the temperature outside.

5.4 Reverberation Time Analysis

The following is the output obtained for the reverberation time analysis from the Ecotect software.

Volume= 137.430 m^3
Surface Area= 171.104
m^2 Occupancy= 32
Optimum Reverberation time (500Hz speech) = 0.54 sec
Optimum Reverberation time (500Hz music) = 1.06 sec
Volume per seat= 4.295 m^3
Minimum (speech)= 4.303 m^3
Minimum (music)= 8.169 m^3

Table-2: Output Chart for reverberation time

	TOTAL	SABINE	NOR-ER	MIL-SE
FREQ.	**ABSPT.**	**RT(60)**	**RT(60)**	**RT(60)**
63Hz:	24.096	0.8	0.78	0.71
125Hz:	19.306	0.95	0.95	0.87
250Hz:	11.192	1.06	1	1.04
500Hz:	3.29	1.59	1.62	1.58
1kHz:	2.796	1.23	1.27	1.23
2kHz:	4.493	0.82	0.86	0.81
4kHz:	7.463	0.55	0.58	0.54

The average value of Reverberation time for the building is obtained as 1 second. This provides a clear articulation of speech and is suitable for lecture halls and speech. However, the desired Reverberation time is 1.5 seconds.

6. SUGGESIONS FOR IMPROVEMENT

For reducing the energy consumptions by the building and to improve its performance, the following methods could be implemented.

1. *Light transport systems*: These are systems that collect sunlight and transport it over long distances inside a building via fibre optics or light pipes.
2. *Light Shelves*: These constitute a daylighting system that can shade and reflect light on their top surfaces and shield glare from the sky. These are mounted horizontally across a window (inside or outside), dividing the window into a lower part with a view and upper clerestory above. These can increase the proportion of light that comes from high angles in the sky where sky luminance is greater.
3. *Louvers*: These are designed principally for control of direct sunlight. They reflect off the high altitude sunlight and increase the interior daylight levels.
4. *Blinds*: Standard venetian blinds provide moderate light distribution. Inverted and silvered blinds increase daylight levels if the slats are horizontal. Automated blinds can also be used in synchronisation with dimmable fluorescent lighting.
5. *Anidolic Ceiling*: It is an exterior sky oriented collection device that has been shown to increase the daylight factor considerably. It requires a blind to be arranged on the collection device to control sunlight on very sunny days.
6. *Laser cut panels*: These increase light levels by 10%-20% particularly in sunny climates. High levels are achieved when the panel is tilted. Tilting the panel also reduces the glare factor.
7. *Sun directing glass*: This system increases illumination levels within a room with reference to the incident angles of the sun and is best used in temperate climates.
8. *Reflective indoor coatings*: These reflect light and perform better than normal paints thus maximising the feeling of space and illumination.
9. *High reflectance and durable outdoor coatings*: These reflect sunlight both in the visible and infrared regions of the spectrum when applied to roofs and walls and reduces its temperature and as a result the heating of spaces underneath the roof and inside the walls.
10. *Phase Change Materials*: When these are used in interior walls and ceilings, the thermal inertia of the inside temperature is reduced.
11. *Advanced insulation foams*: These allow significant energy savings and are versatile to variations in the configurations of different buildings. These include various techniques such as insulation in wall cavities using materials such as spray polyurethylane, external insulation using thermal mesh, using vacuum insulation panel modules etc.
12. *Low emissivity glass*: This is a special kind of glass that has a microscopically thin transparent coating that reflects long wave infrared energy. This is specially designed to dramatically reduce heat transfer and thus the heat fluctuations.
13. *Materials that improve acoustic performance in buildings*- Sustainable materials such as industrial tea leaf fibre, rubber granules, used paper, jute, coir fibre etc. are found to be efficient in improving the acoustic properties of buildings. The recent improvement in coating technology improves the sound absorption properties of common porous materials. Panels coated with nano-fibrous membranes improve acoustic performance at low and middle frequencies.
14. *Solar Panels*: Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating.

When the suggested improvements were provided in the 3D model of the P.G. Block and analyzed in the Ecotect software the following results were obtained:

1. By providing low emissivity windows in the model, the daylight factor was increased by 60%, thus decreasing the need for artificial lighting and energy consumption. The following figure shows the Daylight Factor Analysis chart for one of the floors of P.G. Block.

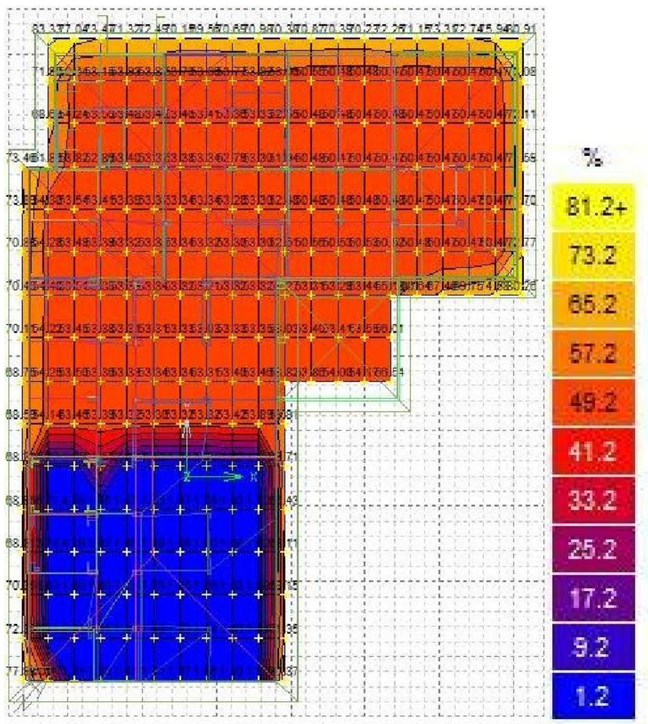

Fig-4: Daylight Factor Analysis Chart after improvements were made

2. By analyzing the position of the sun during the day, we can infer the solar panels can be arranged facing east. Thus the building can produce its own energy and bec-ome self-sustainable.
3. By the use of phase change materials, the thermal inertia can be reduced. The output for of the Ecotect software for thermal analysis by Ecotect software after providing the improvement techniques in the model is shown below

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Total Conductance (AU): 309 W/°K
Total Admittance (AY): 759 W/°K
Response Factor: 2.45

Table-3: Thermal analysis chart of P.G. 209 on 10th April 2016 after improvements were applied

HOUR	INSIDE	OUTSIDE	TEMP.DIF
	(C)	(C)	(C)
0	23.1	24.1	1
1	23.8	24.4	0.6
2	22.1	23.7	1.6
3	23.8	24	0.2
4	21.4	22.4	1
5	21.5	22.4	0.9
6	22.3	23.5	1.2
7	24.4	25.4	1
8	27.2	28	0.8
9	27.2	30.3	3.1
10	27.5	32.2	5
11	30	33.3	3.3
12	30.6	34.1	3.5
13	30.2	34.6	4.4
14	28.7	35.2	6.5
15	30	35.4	5.4
16	28.2	35.2	7
17	30.3	34	3.7
18	28.4	32.1	3.7
19	27.4	29.8	2.4
20	26.3	27.8	1.5
21	25	26.3	1.3
22	23.5	25.6	2.1
23	25	25.2	0.2

CONCLUSIONS

From the study, it can be concluded that the P.G. Block building of Mar Athanasius College of Engineering, Kothamangalam is a highly energy demanding building for the occupants and functioning of the building.

From the output data it can be inferred that, the features of the building such as day light factor, thermal characteristics, acoustics etc. which were originally below desired limits can be improved by modifying the building. Depending on the orientation of the building, sustainable energy sources such as solar panels can be retrofitted so that the building becomes self sustainable.

Hence, by providing the necessary improvements and modifications, the P.G. Block of Mar Athanasius College of Engineering, Kothamangalam is guaranteed to be an energy efficient building.

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