Evaluation of Energy Performance of a High-Rise Building

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ABSTRACT

Energy conservation of building is a measure to tackle climate change and design the buildings. It is achieved through proper usage of natural renewable sources of day lighting, ventilation and other energy saving measures. A building's location and surroundings play a key role in regulating its temperature. It is important to know how well a building is insulated from the external weather conditions for achieving comfort conditions. It needs the evaluation of energy performance of a building in terms of heating, cooling loads and various heat gains. The assessment helps in knowing the positive approach to design buildings with respect to the surrounding environment. The conservation strategies are applied and based on that a typical high rise building in Chennai is taken for the evaluation purpose which has multiple floor plan of usage as shop, restaurant and office. The project study involves site location, surrounding environmental and climatic conditions. Ecotect Analysis was done. Based on that, energy performance such as heat gains, incident solar radiation, thermal loads were analyzed.

Keywords: Energy performance, heat gain, ECOTECT ANALYSIS

1. INTRODUCTION

Energy has become the prime resource of development of a country to improve living standards and reduce poverty. The trio consists of energy consumption, population and economic growth forms a strong interconnection. According to International Energy Agency, the growth of energy use in India has been increased to 91% from 1990 to 2008. In 2001 census, India ranks sixth in world in terms of energy demand.

Out of various sectors contributing to energy consumption, building sector plays an important role in energy expansion. Construction industry is growing at a point higher than population growth, especially in India. After industry and agriculture, buildings consume more energy. India, which is diverse in climate, needs both heating and cooling. Both residential and commercial buildings accounts for increase in energy consumption. There are different means through energy is consumed, where residential buildings are through fans and lighting, and commercial buildings have large consumption from lighting and air-conditioning. More comfortable style of living and growing electrification have been the main cause.

Mohamed Krem *et al.* [1] suggested that for different types of climate there exists an optimal building morphology, consisting of floor plan geometry and placement of structural system. The results predicted were presented in terms of annual sensible heating and cooling loads. Jinghua Yu *et al.* [2], showed that design parameters of building envelope alters the energy performance. In cooling season, shading coefficient and Window to Wall ratio are the most vital factors and in heating season, wall heat-transfer coefficient and shape coefficients have crucial effects. Niki Papadaki *et al.* [3], made a parametric study on the energy performance of double-skin facades. Ventilation rate, the shading requirements and the cavity dimensions are taken as parameters and showed the lack of adequate ventilation increases the cooling demands and deteriorates the double skin façade's effectiveness.

From the various studies, it is noted that a building energy performance is determined from the factors such as geometrical dimensions of building elements, material properties, weather data and building usage data. Thermal loads such as heating and cooling loads are the major root of energy heat gains and losses. For Indian tropical climate, buildings generate cooling loads i.e., direct solar gain, infiltration and ventilation gain, heat transmission through envelope and internal heat gains due to people, lighting and equipment. Different simulation tools have been used from the past to analyze energy performance of a building.

2. OBJECTIVE

Calculation of thermal energy performance of a high-rise building using *ecotect analysis.* A typical building in *Chennai* is taken for the evaluation purpose. The building is to be developed for commercial purposes in two phases – the first phase shall consist of a commercial complex comprising of retail area at lower levels and office spaces at higher levels, the second phase of development shall be of 3/4 Star type**.** The study mainly focuses on the first phase alone. The building is located at 13°05'24"N and 80°16'12"E and the orientation is towards northeast direction. The floor area increases with respect to floor levels from bottom to top.

3. BUILDING MODELLING

The analysis of energy performance of the building is carried out using *ecotect analysis.* The process of evaluation follows varies steps as:

1. Modelling in Revit Architecture
2. Creating rooms (around 28 rooms are created)

3. Exporting as gbXML file
4. Import in Ecotect
5. Zone separation of the building
6. Assigning materials for each zone
7. Loading weather file and providing project information
8. Performing various calculations

Building is designed using *Revit Architecture* software. Building has G+7 floors. Three different occupancies are accommodated in different floors. Hyper market and shops are accommodated in the ground floor. The second floor occupancy is restaurant and the remaining is for office space. A typical floor plan is presented in the Figure 1.

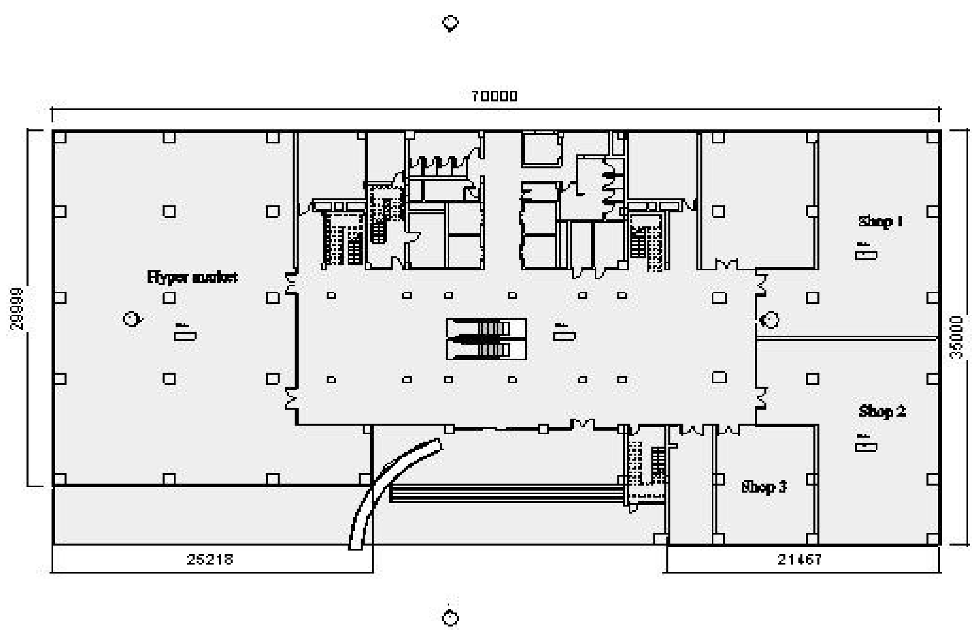

Figure 1 Retail area floor plan

4. MODELLING ASSUMPTIONS

For the purpose of study, several assumptions were made as: (a) Only building part is taken for evaluation leaving out surroundings, (b) All sides of the building envelope is of glazing, (c) *Chennai* climate is taken based on Department of Energy, United States, (d) Interior walls constitutes of thickness 230mm brick masonry, 115mm brick masonry and partitioned glazing wall.

Energy consumption of building fully depends on occupancy and use of interior space. Autodesk's *Ecotect* energy simulation tool was used for analyzing energy performance for the building. After designing the building model in Revit, and it is exported to Ecotect as gbXML file. Rooms, which are created during modelling, exist as volumes or zones. Since there are three types of occupancies, zone settings differ accordingly. One room is identified for analysis in each zone. Comparison of heat gains for various zones is made and results are discussed. The zone properties of different floors are given in Table 1:

FLOOR	GENERAL PROPERTIES	THERMAL PROPERTIES
Ground Floor & First Floor	Clothing - 1.00 clo Lighting - 600 lux Occupancy - Walking high (220 W)	Full Air-conditioning Hours of operation Weekdays = 09-22 Hrs. Weekends = 08-23 Hrs.
Second Floor	Clothing - 1.00 clo Lighting - 400 lux Occupancy – Walking slow (115 W)	Full Air-conditioning Hours of operation Weekdays = 09-22 Hrs. Weekends = 08-23 Hrs.
Third Floor to Seventh Floor	Clothing - 1.00 clo Lighting - 300 lux Occupancy – Reading, Typing (70 W)	Full Air-conditioning Hours of operation Weekdays = 09-19 Hrs. Weekends = 10-15 Hrs.

Table 1 Zone properties

Thermal Analysis

For the building, *Ecotect* performs energy analysis which includes: (a) Solar radiation, (b) Heat gains break down, and (c) Hourly gains. The process is carried out for three zones considering one room in each. The building in *Ecotect* is presented in Figure 2.

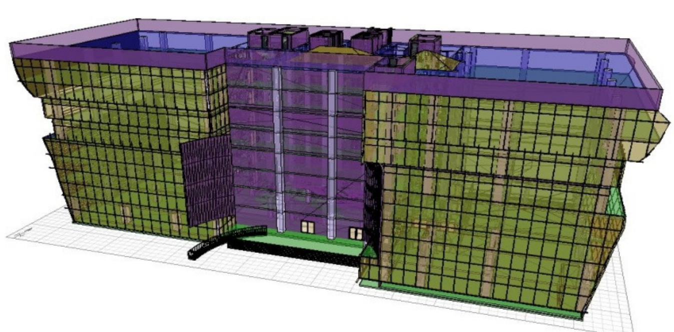

Figure 2 Building in Ecotect

5. RESULTS

a) Incident solar radiation (Insolation) – Average daily

Figure 3 shows the variation of incident solar radiation for the year 2013. On an average, the insolation value during mid-day is 388.73 W/m^2. Since the building is oriented towards northeast, there is maximum exposure towards sun. March and April months have higher insolation value that accounts for 14% and 17.5% more than the yearly average. Winter months did not differ widely. December receives 15.4% lesser than the average value.

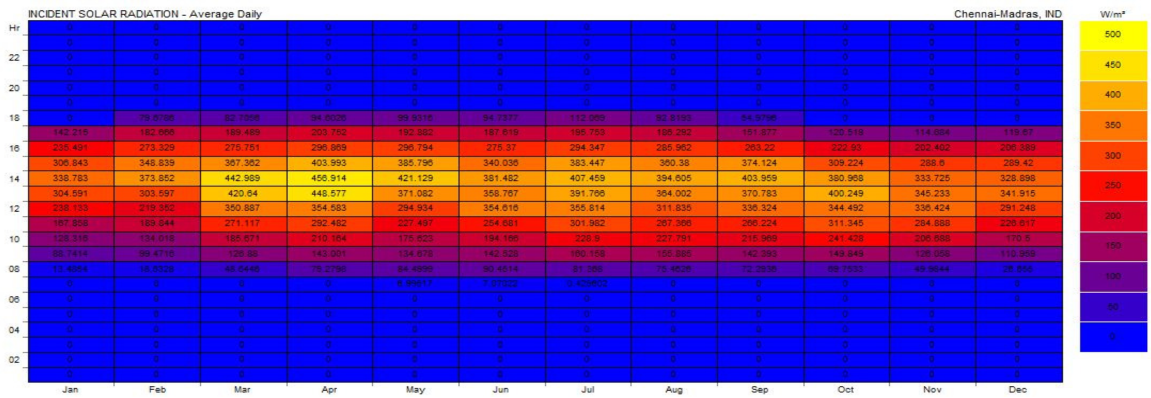

Figure 3 Incident solar radiation

b) Heat gains breakdown

Figure 4 shows the range of heat gains and losses in terms of Wh/m^2 from different sources over the period from 1st January to 31st December, 2013. For a building in hot climate, heat gains are more predominant than losses.

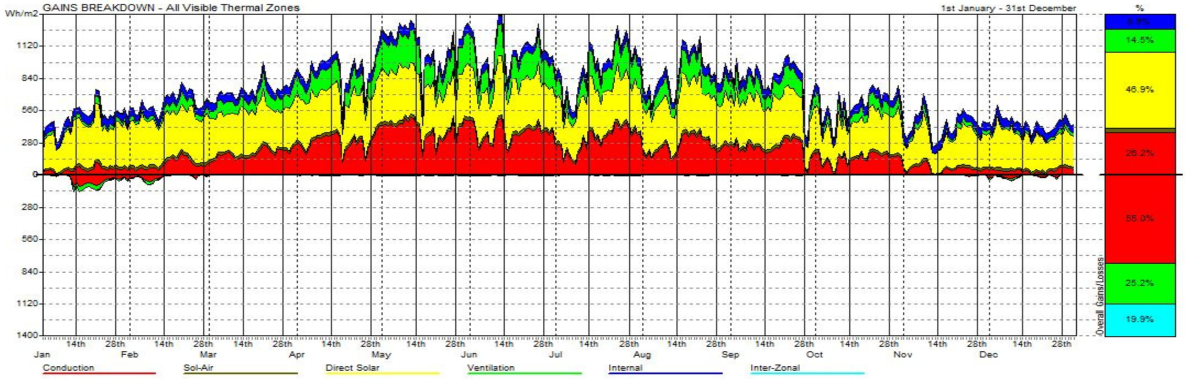

Figure 4 Gains breakdown

- Only conductive and ventilation losses exist with maximum during mid of January and minimum during November-December.
- Gains from conduction (red) reaches maximum during summer months closer to 500 Wh/m^2 and gradually decreases during winter months.
- Direct solar heat gains (yellow) is same throughout the year irrespective of months.
- Similarly, internal heat gains (blue) has same range of value but differs in duration, thicker in winter and thinner during summer.
- Ventilation heat gains (green) have variety of values insignificant during November to January, meagre during March, April, September and October and significant during May to July.

c) Hourly gains

Hourly breakdown of heat gains from HVAC, Direct solar and Conduction for two representative days winter solstice (23rd December) and summer solstice (16th May) are represented in Figures 5 and 6:

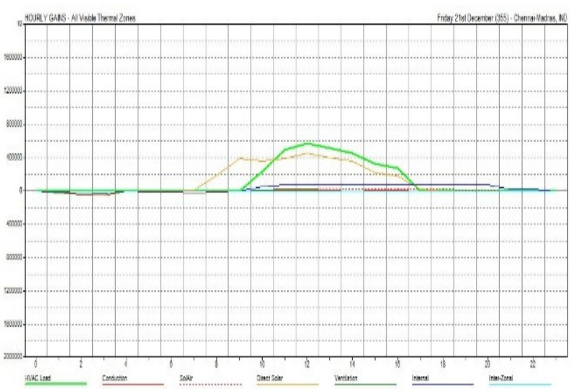

Figure 5 Winter solstice hourly heat gain

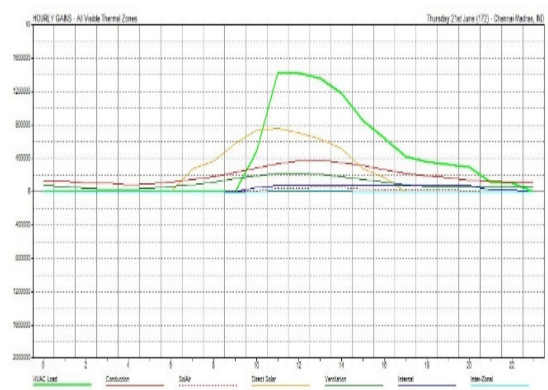

Figure 6 Summer solstice hourly heat gain

- From the above Figures, the gains from HVAC and Direct solar exist over second half of the day during summer solstice, whereas it stops around 4pm during winter solstice.
- On summer solstice, contribution of heat gain from HVAC and Direct solar are 150% and 75% higher than during winter solstice respectively.

6. CONCLUSION

- For a building having different occupancies, the heat gain from different sources varies. The following conclusions are made:
- Considering all the heat gains, Direct solar gain produces a maximum of 46.9% and a Conduction of 26.2%

- Irrespective of occupancy level, the months of March and April receives higher insolation of about 15% than the yearly average.
- Retail occupancy area produces 68.7% more ventilation heat gain than restaurant and office areas.
- Internal heat gain and conduction heat gain is maximum from office occupancy of about 22% and 19% higher than retail area respectively.
- Losses are similar in all occupancies.
- For the cooling load requirement, office area needs higher than restaurant and retail areas.
- HVAC produces heat gain which is twice that of direct solar gain during summer solstice as compared to winter solstice.

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[4] Information on http://wiki.naturalfrequency.com/wiki/Ecotect_Tutorials

[5] Information on http://energy.gov/eere/office-energy-efficiency-renewable-energy