ISSN 2229-5518

INVESTIGATION ON FENESTRATION DESIGN FOR A COMMERCIAL BUILDING

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Abstract— **Incorporating energy efficiency and sustainable green design features into a new commercial building has become a top priority in recent years. This study intends addressing the process involved in the delivery of energy efficient building which is not just the result of applying one or more isolated technology. An integrated or whole building design process involves studies of the energy-related impacts and interactions of all building components, including the building location, envelope (walls, windows, doors, and roof), heating, ventilation and air conditioning (HVAC) system, lighting, controls, and equipment. In other words, energy efficient building design can best be achieved by various design features involved in the building energy consumption.**

The objective of this research is to develop energy efficient building through building envelope in order to develop sustainable buildings.

This research primarily focuses on the implementation of energy efficient methodology, life cycle cost analysis of the building, and reduce the carbon emissions to provide a comfortable working environment for the building occupants.

Keywords— **energy efficient building design, life cycle cost analysis, building components.**

I. Introduction

The infrastructure development has been growing in the exponential manner and correspondingly the subject of facility management is gaining considerable importance in the sector of commercial complexes such as office, hospitality structure (hotels and resorts), health units etc. There have always been demands for structures which do not have high expenditure budget on account of energy during the post construction life cycle process. In the concept of green buildings, energy saving takes a very important place. Even in the case of large residential complexes, the facility management is given due attention for reducing the expenditure due to the energy. The architecture for such buildings has been using many materials and material composites for such purpose particularly to moderate the energy flow through the building. The components added for the aesthetics are the ones which perform the energy saving role. A few examples can be modern hazards; glazing and strategically located windows perform such roles. The work presented here investigates the design of such features which are called fenestration elements.

II. Materials

Primarily, glass plays a very important role in the fenestration design for the commercial complexes.

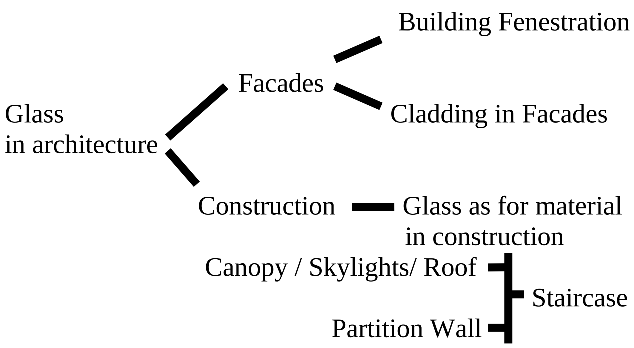

Fig 1 Various Uses of Glass in Construction

Glass is a non-crystalline amorphous solid that is often found transparent and has wide range of applications in day to day lifetime. Found in 500BC, it serves to be the most versatile and oldest material in the construction industry. From its beginnings as a window pane in houses of Pompeii to sophisticated structural members in the new age buildings, its role in the architecture has evolved over the years.

II. A. Types Of Glass

- Float glass
- Tinted glass
- Laminated glass
- Toughened glass
- Double glaze units
- Chromatic glass

II. B. Properties Of Glass

- **Transparency:**
  This property ensures the visual connectivity with the exterior environment. Transparency can be permanently altered by adding admixtures to the initial batch mix.

- **U-value:**
  U-value is the amount of heat that is transferred through the window by conduction. Lower the U-value, it conducts less heat.

ISSN 2229-5518

- **Shading coefficient:**
  It is the fraction of solar incident radiation that enters the building through the window assembly as heat gain.

III. Background Study

The research in building technology has shown many facets of energy saving materials and methods. To trace back the history few of the milestone works are presented below.

R.Saidur (2009) has studied that the air conditioning system shows the major energy user in the office building followed by the lighting system. Use of variable frequency drives (VFD's) in heating, ventilating and air conditioning leads to sustainable energy savings as it allows the machinery at different speed levels by altering the voltage or the frequency of the motor. As there may be a need where not all equipment utilizes the same speed of operation, VFD's are quite helpful. **Luis Perez Lombard et al (2007)** examined that the growth in population, increasing demand for building services and comfort levels, together with the increase in time spent in the buildings assure an upward trend in the energy demand will continue in the future. With the consolidation of demand of thermal comfort, HVAC systems have become an unavoidable asset, accounting for half of the energy consumed in the building. Size, location, design and the level of accounts are the key factors for energy consumption. **Peizheng Ma et al (2015)** have conducted experiments on the window wall ratio of the commercial building. New paradigm of integrated design, proposing a process assumption based design method. It is a two-step design method where important factors are considered. Architectural design plays an important factor as based on which the HVAC equipment can be designed. Desired window wall ratio and required U-value is predicted based on the envelope thermal conductivity and ambient temperature amplitude. This approach takes in account the design of the building and the envelope thermal conductivity in the simulation calculations. Depending on the values, the window area can be proposed. **Nilima N.Kale et al (2016)** have analysed the life cycle cost of the commercial building with the energy efficient approach. The life cycle cost (LCC) analysis can be calculated with the existing condition and proposed energy efficient approach. LCC consists of all cost required for construction, operation, maintenance and end of life costs which includes delivery, installation, replacement, water use and end of life costs. By adopting LCC tool, energy efficient approach requires an initial investment in range of 1.3 to 16%. With minimum initial investment, total cost can be saved over span of 30 years. Energy efficient approach reduces the LCC of the existing building effectively. **Wan Iman Wan Nazi et al (2015)** examined the standard building can be transformed into low energy office by applying heat gain reduction methodologies draws from heat gain balance analysis. It is found that the 75% of the building's heat gain was radiated from lighting system and solar heat gain from the window. Three approaches were chosen to reduce the cooling load. The heat emitted by the lighting system is high, a lamp also emits a radiant and radiant heat promotes heat gain in the building. Building mainly used 36W fluorescent lamps and 70W ceramic discharge metal halide Lamp. Sustainable building does not necessarily induce high cost for the technologies implementation.

IV. Energy

Energy can be classified into two types namely, potential energy and kinetic energy. Potential energy is an inbuilt form of energy whereas kinetic energy is used for the work, if the potential energy which is stored in and gets converted to into kinetic energy needed to perform the certain work. We use energy to do work and make all movements. Work means moving or lifting something or lighting something. Different forms of energy are heat energy, mechanical energy, electrical energy, sound energy, nuclear and atomic energy and so on.

V. Pattern Of Energy Usage In Various Sectors

In many countries buildings consume more energy than transport and manufacturing facilities. Building operation is responsible for about 30% of greenhouse gas emission and accounted for about 40% of primary energy consumption globally. Space cooling, space heating and lighting system together account for the majority of building energy use in technically advanced countries. Air-conditioning system accounts for 43% of the energy consumed in the commercial and residential building.

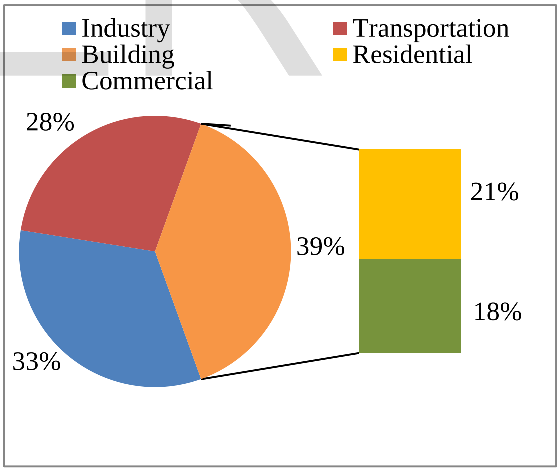

Fig 2 Energy Consumption by Sector

VI. Energy Usage In Various Commercial Buildings

Figure 3 represents the energy usage in various commercial building. At the present stage, there is an upward trend in the energy demand due to increasing demand for building services, comfort levels of the occupants, increase in the population and all together with the rise in the majority of the time spent in the building. Among building services, HVAC is the largest energy use in the commercial buildings followed by the lighting system, which plays an important role in the building. New lighting technologies are many times efficient than traditional technologies and switching over can result in the substantial reduction in net energy use and associated reduction in greenhouse gas emissions. By this process sufficient energy savings can be obtained which will result in considerable energy.

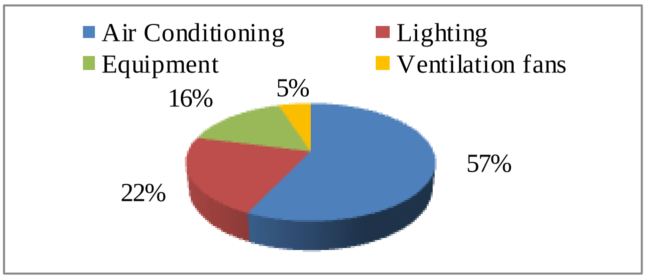

Fig 3 Break-up of Energy Consumption in a Building

VII. Energy Breakup Of Various Building Components

All the materials used in the construction process exhibits properties like thermal conductivity (U-value) but in the case of glass, it exhibits thermal conductivity and the shading coefficient as it is a transparent material. The total solar heat transmittance through transparent and translucent materials is equal to the solar heat that is transmitted through the material directly, plus the total solar heat that is absorbed by the material and then re-emitted in the enclosed space. The second major energy characteristic of the glaze is the ability to control the solar heat gain and it plays a significant role in determining the cooling load of the enclosed space. Heat transfer through glaze by both conduction and radiation.

Heat is generated from the controlled space namely by

- Occupants present in the space.
- Equipment's present in the space.
- Building envelope (materials used in construction)
- Lighting system in the space.

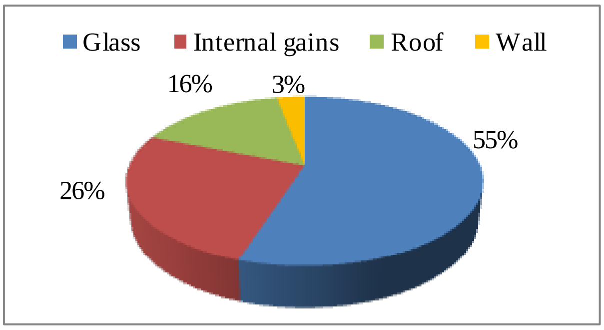

Fig 4 Heat gain through various building components

VIII. Research Methodology

1. Develop The Design Of The Base Building

The selected building was a commercial building and the design of the building was drafted based on the past studies, the proper orientation, the weather conditions and the needs of the regular commercial building.

2. Study The Energy Saving Methodologies

HVAC system plays an important role as the research work is mainly based on the energy efficient methodologies. As the energy consumption by HVAC system is the most, when compared to other equipment's, highly efficient HVAC system and its additional equipment's were proposed in the design.

3. Develop The Alternative Design Of The Building

Glaze plays a major role in the energy consumption of the building. Taking into account the two important properties of the glaze and the proposed window wall ratio, having a base case option, three variations were designed and the energy consumption was simulated and the best suited for the conditions was chosen.

4. Calculate the cooling load summary and the energy requirements of the building

Cooling load is the rate at which a cooling system or process must remove heat from a conditioned zone to maintain it at a constant dry bulb temperature and humidity. The cooling load of the specified spaces was calculated from the Hourly Analysis Program 4.30 and the LPD values were derived from ECBC standard.

5. Life cycle cost analysis of the building

Life cycle cost of the building was estimated considering the life span of the building as 50 years. LCC includes the capital investment, maintenance cost and the running cost for the equipment and services of the building.

IX. Results, Analysis And Discussions

A commercial building having a basement, ground floor and 7 floors with each plate area approximately measuring 2000 m^2 is located in Chennai, India. All the four sides of the building are constructed with fly ash brick walls and concrete slabs in case of the ceiling and floors. The outer elevation has the double glazed unit and aluminium composite panelling.

In order to achieve energy efficient building design, the building was designed by altering the properties of glaze and the window wall ratio in order to develop sustainable buildings.

Table 1: Case options

Case	Options
1	High Window Wall Ratio and High Shading Coefficient
2	High Window Wall Ratio and Low Shading Coefficient
3	Low Window Wall Ratio and High Shading Coefficient
4	Low Window Wall Ratio and Low Shading Coefficient

The high WWR is 51% whereas the low WWR is 31%. The high and low shading coefficient (SC) and the thermal conductivity values of glass which has the direct impact of the energy consumption are shown in the table.

Table 2: Glazing properties

Product Name	U-value (W/m^2K)	SC
Sparkling Ice	2.8	0.64
Iris	1.6	0.26

IX.A. Energy Simulation Summary

The cooling load summary of the building is obtained from Hourly Analysis Program 4.30. The weather properties, the material and the internal properties values of the space was given as input and the cooling load in terms of tonnage of refrigeration was obtained. The energy cost per year of the HVAC system is estimated and the values obtained for each case are shown in the table.

Table 3: Cooling capacity and running cost

Case	Cooling load (TR)	HVAC Energy cost / year (INR) in Crore
HWWR and HSC	505.5	1.78
HWWR and LSC	497.2	1.72
LWWR and HSC	471.4	1.60
LWWR and LSC	459.5	1.58

HWWR= High Window Wall Ratio

LWWR= Low Window Wall Ratio

HSC = High Shading Coefficient

LSC= Low Shading Coefficient

IX. B. Estimation Of The Cost

The cost details of each case are divided into various components namely the initial investment, maintenance cost and the running cost. The maintenance cost and running cost of the HVAC system is taken into account as it is the major contributor of the energy consumption of the building. In order to calculate the recurring expenditure in the account of operational energy consumption, the cost summary is estimated from the energy simulation depicted in the table. As the service life of the building is considered to be 50 years, the maintenance cost summary for every year is estimated. Cost analysis for the 10 years for the case 1 is depicted in the following table.

Table 4: Life cycle cost of the base case

Year	Capital cost (INR) in Crores	Maintenance cost (INR) in Crores	Running cost (INR) in Crores	Cumulative total cost (INR) in Crores
2016	12.78	0.13	1.78	14.68
2017		0.14	1.78	16.60
2018		0.15	1.78	18.53
2019		0.17	1.78	20.48
2020		0.19	1.78	22.45
2021		0.20	1.78	24.43
2022		0.22	1.78	26.43
2023		0.25	1.78	28.46
2024		0.27	1.78	30.51
2025		0.30	1.78	32.59

Table 5: Life cycle cost of all the four cases

HWWR and HSC (Base Case) Cumulative cost (INR)	HWWR and LSC Cumulative cost (INR)	LWWR and HSC Cumulative cost (INR)	LWWR and LSC Cumulative cost (INR)
14.7	15.0	15.1	15.2
16.6	16.9	16.8	16.9
18.5	18.7	18.6	18.7
20.5	20.6	20.3	20.4
22.4	22.5	22.1	22.1
24.4	24.4	23.9	23.9
26.4	26.4	25.7	25.6
28.5	28.3	27.5	27.4
30.5	30.3	29.4	29.3
32.6	32.3	31.2	31.1

The values of the cost are in Crores.

The life cycle cost analysis of the building is calculated and the cumulative cost details of the three cases are compared with the base case option.

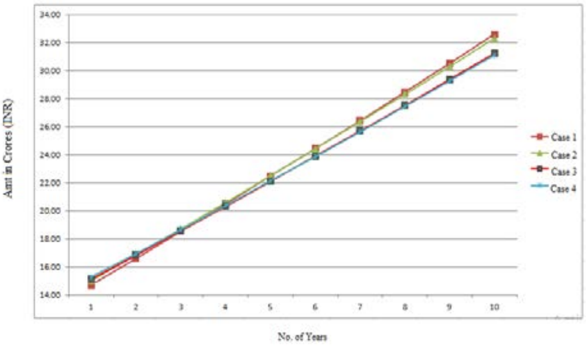

Fig 5 Comparison of the four cases

IX. C. CONCLUSION

In the present research an attempt has been made to make an energy efficient building design from the viewpoint of energy and cost. The window wall ratio of 51% and high shading coefficient of 0.64 is considered as the baseline option. Three other options with different combinations of window wall ratio and shading coefficient are also considered and compared with the baseline.

In order to evaluate the energy performance of the different cases, the cost summaries for the considered cases are calculated over the base case option.

Finally after comparing all the value added design, the third case having the low window wall ratio and high shading coefficient is considered the best choice. Even though when compared with the base case, the case three and four show the cumulative total cost less than the base case in the same year, the case three can be considered best as the capital investment of the case three is less than the case four.

ACKNOWLEDGEMENT

The authors wish to acknowledge with thanks, the encouragement given by Dr.K.S.Babai, Secterary of the institution and Dr.P.K.Suresh, Principal of the institution. The support given by Professor R.Arivazhagan is gratefully acknowledged.
The first author wishes to thank Mr.Regobert (Senior Engineer), ADES, Chetpet, Chennai for his substantial contribution throughout my work.

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