Evaluating the Energy Efficiency of Horizontal Light Transmitting System in Office Buildings

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Abstract - *The study evaluates the integration of horizontal light transmitting systems in high-rise, glazed office buildings to enhance energy efficiency and daylight utilization. It focuses on regions without overcast skies and minimum day illuminance. Methodology includes literature review, case studies, and comparative analysis between traditional lighting systems and horizontal light pipes. The study finds that horizontal light transmitting systems can save up to 38% of lighting energy and 24% of overall energy consumption in office buildings. The proposed model indicates a payback period of 3 years, making the investment economically viable. Limitations include applicability to only high-rise, glazed office buildings and potential variations in effectiveness based on different climates and daylight hours. Long-term performance and future lighting advancements are not fully addressed in the study.*

***Key Words*:** **Daylighting, Energy Efficiency, Horizontal light pipes, Office Building**

1. INTRODUCTION

Assessing innovative daylighting solutions in workspaces is vital for enhancing natural lighting utilization and cutting down on electricity consumption. This evaluation focuses on their impact on reducing energy usage and advancing sustainable architecture.

1.1 Aim and Objective

The aim of the study is to assess and demonstrate the effectiveness of integrating horizontal light transmitting system as a daylighting solution in office buildings to enhance energy efficiency. The objectives of the study are;
Identify - To evaluate the current energy consumption patterns in typical office buildings, identifying areas where lighting systems play a significant role
Analyse - To analyse the design principles and technical specifications of horizontal light transmitting system to understand their potential for harnessing natural light and enhancing daylight utilization
Evaluate - To study the financial feasibility and assess the return on investment for the implementation of these horizontal light transmitting system

1.2 Scope and Limitations

The study focuses on high-rise, glazed office buildings prone to issues like glare and thermal comfort. It considers new construction in regions with minimal overcast skies and adequate daylight. A speculative model is created using simulation to optimize energy efficiency and to calculate the implementation costs, energy savings, and payback period.

Limitations include the study's applicability only to high-rise, glazed office buildings and its variability in effectiveness depending on regional climate conditions and daylight hours. It does not consider long-term performance or future advancements in lighting technology.

2. METHODOLOGY

The methodology followed for the study was, firstly, a literature study was done to understand the need for daylighting, energy efficiency, theoretical aspects, types and the components of these horizontal light transmitting system. Next, a comparative study was conducted between traditional lighting systems and horizontal light pipes in terms of energy efficiency, lighting distribution, electricity consumption. This is done through an experiment where a simulation model is set up for a hypothetically said situation. The abstract costing was be done to learn the costing aspect of the proposed model. Lastly, cost of implementation and payback analysis was done to understand the potential return on investment.

3. LITERATURE REVIEW

Among the electrical energy consuming services lighting energy contributes to almost 30%.[1] In a glazed building conditions the area next to the glazing gets maximum amount of natural light compared to the other deeper region. But the amount of glare provided by this glazing system is causing visual discomfort.[2] Hence by introducing innovative daylighting technology along with controls we can get daylight into deeper office spaces and also reduce electrical energy consumption.[3]

There are two types of providing daylighting: Stepped and Diming. Stepped gives more energy efficiency but when analysed w.r.t various climatic aspects dimming is a more effective system.[4] By introducing these daylighting strategies along with artificial light it increase the energy performance of that building. Also the thermal load of the building is decreased in turn reducing the HVAC loading and the total energy consumption.[5]

The application of tubular daylighting devices provides the means of introducing daylight into poorly lit environments, which has a huge potential for electric energy saving.[6] Light pipes will possess high quality when the bends are designed by a thorough analysis. Also the inner materials for the light transmitting pipe should have very high reflectance.[7] An experiment done shows that light pipe technology can be adopted to utilize the natural lighting into deeper areas of the building and it also helps in energy savings. [8]

Various experiments done on these horizontal light transmitting systems. An experiment in an open office plan says that by orienting the collector towards south we can achieve more distribution of lighting into deeper office space and for longer time of the day.[9] Another study on educational building shows that the system of daylighting and the reflectance of the film used places a very important role. [10]

The implementation of daylighting require a substantially greater capital investment than normal electrical lighting system. But these tubular daylighting systems have shown to be economic over the long term.[11] By integrating daylight systems one can reduce this electric energy consumption and also the return on investment is acceptable.[12] The horizontal light pipe system not only get in more lux levels in office space but also provide uniform lighting almost throughout the year.[13] The design of daylighting requires a through macro and micro level analysis. Understanding these variables can be a key to successful daylighting system.[14] For more efficiency aluminium foil is the best material that can be used to increase the overall transmission of daylighting into inner spaces.[15]

4. Simulation

4.1 Proposed Building Prototype

For the proposed prototype simulation the location is chosen to be Chennai. The building orientation is North-South, where as the daylighting is south facing. Number of floors is ground + 8 floor and floor to floor height taken is 3.6m. The average floor area taken is 980 Sqm and total floor area is 11,150 Sqm for the envelope glazing type chosen is Aluminum frame with 6mm reflected glass structural glazing.

Working hours was taken from 9 am to 6 pm and 6 days per week. The HVAC system type is variable refrigerant volume (VRV) system. The lighting type is LED lights with 10 h per day of lighting load.

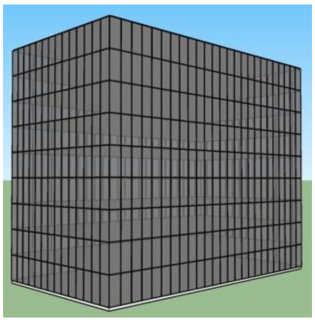

Fig -1: Proposed building prototype

4.2 Proposed Daylight Prototype

Dome or Collector
Located on the roof or façade level, this component collects sunlight from the outside. It is usually a transparent or translucent dome-shaped structure made of polycarbonate, acrylic or glass designed to capture sunlight from various angles.

Light Pipe or Tube
This is a highly reflective tube that extends from the collector down to the interior of the building. It is designed to transport and distribute sunlight without significant loss of intensity. Light pipes are typically made of highly reflective materials such as polished aluminum or silver-coated surfaces to maximize light transmission.

Diffuser or Fixture
The light pipe terminates in a diffuser or fixture located within the interior space of the building. This component disperses the natural light into the room, providing even illumination. The diffuser is made of either acrylic polycarbonate prismatic or textured glass and may be a simple opening or a more complex fixture designed to spread the light in a specific pattern.

5. RESULTS

5.1 For Daylight Distribution

A Lighting Simulation was conducted in Rhino-Climatestudio and following results were obtained. From the above figures it is seen that only 50% of the office floor area is receiving daylight without the use of proposed daylighting system (figure-2). Whereas in the proposed horizontal light pipes system of daylighting there is almost 100% distribution of daylight throughout the daytime (figure-3).

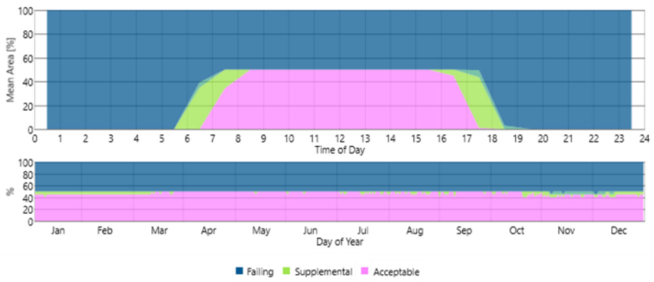

Fig -2: Daylight Distribution without Daylighting System

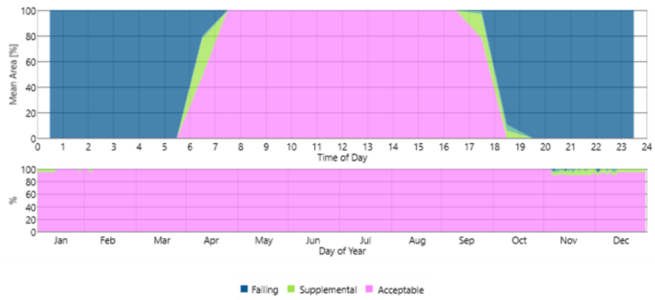

Fig -3: Daylight Distribution with Daylighting System

5.2 For Energy Performance

An energy simulation was conducted in EnergyPlus-Openstudio. In without daylight system scenario the total energy consumption was seen to be 10,92,960 kWh and lighting energy consumption was 1,19,454kWh. When the daylighting system was implemented the total energy consumption was seen to be 8,28,355 kWh and lighting energy consumption was 75,450 kWh.

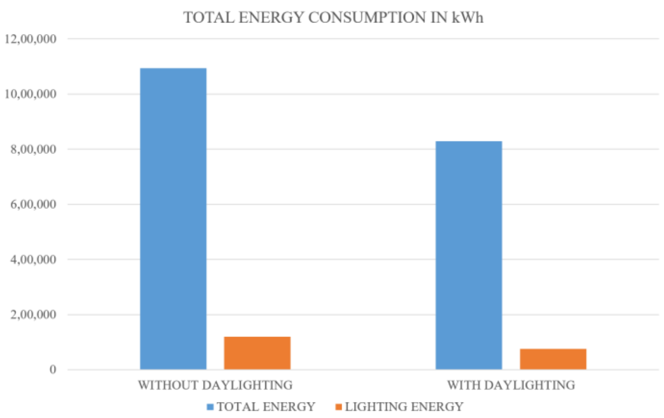

Chart -1: Energy Consumption without and with Daylighting System

The total energy savings was 2,64,561 kWh and lighting energy saving was 45,004 kWh, which is 24% and 38% of savings respectively.

6. COST OF INSTALLATION AND PAYBACK

Total cost of installation of 120 HLP (20 in each floor into 6 upper floor) is rupees **67,57,440** and the details is mentioned in the table below.

Table -1: Cost of Installation

Component	Material	Cost per sqm
Collector	92% Light Capturing White Acrylic Sheets	Rs. 602
Transmitter	95% Reflective Aluminum bent to profile	Rs. 1938
Diffuser	6mm Clear Glasss	Rs. 915
Cost of Installing 1 HSP of length 15m and 0.6 dia		Rs.56,312
Total cost of installation of 120 HLP (20 in each floor into 6 upper floor)		**Rs. 67,57,440**

For the payback calculation following data is followed,
Energy savings done : 2,64,561 kwh
Cost of electricity : 8.70 rs/ kwh
Total Cost savings per year : **Rs. 23,01,680**
Total Investment Cost : **Rs. 67,57,440**

Hence payback is given by,

$$Payback = \frac{Initial\ Investment}{Annual\ inflows}$$

$$Payback = \frac{67{,}57{,}440}{23{,}01{,}680}$$

$$= \underline{\mathbf{3\ years}}$$

The payback for the investment done can be withdrawn within **3 years**.

6. DISCUSSION

From the above results we can see that the horizontal light transmitting system placed in an office building can save up to 38% of lighting energy and 24% of overall energy consumption. This shows that there is significant reduction in energy consumption patterns in the office building.

Even though the cost of installation is comparatively high we can see that in the proposed model for office building the payback period is derived as 3 years indicating that the investment is viable.

7. CONCLUSION

Utilizing daylight through horizontal light transmitting systems improves thermal and visual comfort in office environments. This approach greatly reduces reliance on artificial lighting, leading to significant electricity cost savings. Additionally, by lessening the need for artificial lighting, these systems also decrease HVAC expenses, enhancing overall energy efficiency. Incorporating horizontal light transmitting systems into building designs promotes sustainable architecture and environmental responsibility.

Research indicates that implementing these systems in office buildings can save up to 38% of lighting energy. Moreover, these systems can reduce overall energy consumption by up to 24%, demonstrating their effectiveness and potential impact. The proposed model shows a payback period of just 3 years, making the investment in horizontal light transmitting systems both viable and economically advantageous

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