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PERFORMANCE EVALUATION OF BUILDING ENVELOPE RETROFITTING MEASURES IN A HOSPITAL BUILDING FOR ENERGY CONSERVATION

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ABSTRACT

Energy conservation in hospital buildings is essential to minimize operational costs, reduce environmental impact, and ensure sustainable healthcare infrastructure. The environment is greatly influenced by the emission of carbon dioxide and plays a very large part in global warming issues. A significant large amount of energy is consumed in hospital buildings for cooling, heating; ventilation and lighting to create desirable thermal comfort conditions. So, energy conservation is required for these buildings. Enhancing the energy efficiency of buildings is commonly achieved by insulating their exterior walls, a recognized strategy given the ongoing rise in global energy prices and the commitment to support worldwide initiatives for climate improvement. Energy retrofitting of healthcare buildings is crucial for reducing energy consumption and improving sustainability. Various types of materials can be utilized for this purpose, each offering unique benefits and challenges. This paper explores the potential of different materials for energy retrofitting in healthcare buildings, including insulation materials, window glazing, roofing material. It presents ways for the enhancement of energy efficiency in healthcare buildings (i.e. Nutema multispecialty hospital, in Meerut) by applying sustainable materials like Polyurethane spray and Composite Panel (ETICS) for thermal insulation on roof and outer surface of the wall. The Energy Performance Index of existing building is evaluated by using Rhino 7 and Climate Studio software. Different cases have been taken and compared. It is found that at the time retrofitting, use of sustainable materials like Polyurethane spray, External Thermal Insulation Composite Panel (ETICS), etc. for roof and wall insulation and double-glazed windows prove to be efficient for energy conservation.

Keywords: Energy Performance Index, Building Energy Simulation, Assessment Tool, Building Envelope, Healthcare Architecture

1. INTRODUCTION

Energy is a fundamental necessity for the economic development of all key sectors of the Indian economy, including agriculture, industry, transport, commercial, and residential sector[1]. Over the past three decades, developing nations have faced a significant energy crisis during the summer season, primarily driven by the escalating cooling load demands of buildings. This heightened energy consumption has contributed to environmental pollution, leading to global warming and depletion of the ozone layer. The improving standards of life and increasing world population has led to increase in energy consumption and it is further expected to increase [2][3]. The global population which is rising continuously is expected to rise from 7.7 billion in 2019 to 9.7 billion in 2050 and will probably reach 10.9 billion or more by the end of this century. The environment is greatly influenced by the emission of carbon dioxide and plays a very large part in global warming issues. CO2 is the largest environmental concern in building and construction industries. Thus, research has been prompted for developing new building systems and technologies in order to mitigate the green-house gases, which are continuously depleting the ozone layer [4].

The growing global population will drive higher demands for water, energy, and natural resources, resulting in an overburdening of biological systems. This, in turn, will progressively degrade the environment by escalating energy

consumption, ultimately impacting the built environment [5][6]. Consequently, the energy efficiency and conservation of existing buildings play a crucial role in mitigating global carbon emissions.

For energy conservation, sustainable materials (like the roof insulation, window roof and external wall of the building) can be used at the time of retrofitting of existing buildings. Potential options can be adding thermal insulation for external walls and roofs. Polyurethane spray (U-value is 0.579 W/m2K) is used for thermal insulation for external roofs. And for wall, External Thermal Insulation Composite Panel (ETICS) (U-value is .252 W/m2K) is used and then replaced all windows with Double low E 3mm, 13mm air gap windows (U-value is 1.53 W/m2K) and extra projection to the windows are added.

Simulation models of the all cases are built and then compared to make out the most viable one, which provides maximum energy efficiency.

In this research work, investigate the energy consumption of the hospital by evaluating the Energy Performance Index (EPI) and then all potentials options are considered.

Section II presents the Literature review and case study of the existing system and section III presents the methodology. Section IV reflects the results and discussions. Section V shows the conclusion.

2. LITERATURE REVIEW

Maintaining the economy in its best possible state has several angles to it. Energy conservation and energy efficiency are the prime factors that play a key role in building the economy. For the research onenergy conservation of the buildings, existing and new buildings should be under focus to be discussed [7][8].In the design of energy efficient buildings, it is necessary to optimize building construction and energy utilization. Currently, buildings consume about 31% of the total energy produced as per reports of Energy Audit Studies. Around 9% of the total energy consumption is by commercial sector. The Healthcare industry is the prime focus of energy consumption because they are operational throughout the day. For the renovation of existing buildings, focus should be on many aspects such as building structural reinforcement, building insulation performance improvement, renewable energy use, etc. Opting for energy-saving transformations on the outer skin of a building is the most convenient and relatively affordable method for building renovation projects. This approach minimizes the impact on the existing functions of the building. The transformation of the building envelope and the transformation of the building windows are the two aspects of the energy-saving transformation and improvement of the building skin[9]. About 31% electricity consumption in India is due to building sector. It has been revealed in Energy Audit Studies that there is a savings potential of 40% in lighting, cooling, ventilation, refrigeration, etc. Estimates reveal that built-up area will increase by 66% in the commercial sector by 2030 that will lead to enormous consumption of energy. In commercial properties, 56% and 21% energy are consumed by air conditioning and lighting systems [10]. This energy consumption can be reduced through energy conservation in commercial buildings.

In the present scenario of ongoing global energy price hikes and the commitment to enhance climate conditions, a recognized approach to boost the energy efficiency of buildings involves insulating their exterior walls. These study shares findings on improving energy efficiency in collective residential buildings, including an analysis of the freezing point shift in the external wall structure with additional insulation applied to its outer surface [11].

During the year 2000-2006 there has been an increase of 67.6% of hospital building in the country and it will continue to grow until 2030 to meets its population's healthcare demands (Central Bureau of Health Intelligence, India, 2010). A large share of energy consumption in healthcare facilities is by HVAC systems due to long operating periods [12].

Retrofitting in hospital is necessary because renovation instead of construction is efficient to be adopted [13]. The disruption to patients and healthcare providers are potential challenges for hospital construction projects. In the growing trends of Indian health care sector Energy efficiency improvements in hospitals can play a significant role in reducing energy consumption [14]. Implementing energy conservation measures (ECMs) in retrofit projects for healthcare facilities can enhance the substantial rate of energy consumption improvement [13]. Retrofitting of buildings has both direct and indirect benefits. As an illustration, tangible economic advantages include decreased expenses for building heating and cooling. Meanwhile, intangible benefits encompass heightened property value or rental rates for existing buildings and an elevated comfort level of living [15].

Some of the methods implemented in these hospitals were: Replaced old elevator machinery with variable frequency device, Installation of solar heat panels and optimizing indoor and street lighting, CFL were replaced with electronic chokes for lighting, all desktop PCs have a screensaver of 2 minutes.

Dynamic facade systems, such as electrochromic windows and smart glazing technologies, offer adaptive control over daylighting and solar heat gain. The effectiveness of dynamic facades in hospitals can be seen in how they optimize natural lighting and minimize solar heat gain and thus contribute to energy savings and occupant comfort [18][19].

PCM-enhanced building materials have gained attention for their ability to store and release thermal energy, thereby reducing heating and cooling loads. The application of PCMs based retrofitting in hospitals effectively regulate indoor temperature and reduce HVAC energy consumption, particularly in climates with temperature fluctuations [16].

Thus, it was found that most of the methods used were normal techniques, however the sustainable materials can be used at the time of retrofitting of existing buildings such as: Polyurethane spray and Composite Panel (ETICS) are used for thermal insulation for external roofs and wall. Also, all windows are replaced by double glazed windows [2][11].

Polyurethane spray foam insulation is frequently applied in building retrofits owing to its excellent thermal resistance and ability to seal air leaks. Research indicates that integrating polyurethane spray insulation into hospital structures can lead to notable reductions in energy usage by mitigating heat loss across walls, ceilings, and floors.

External Thermal Insulation Composite Systems (ETICS) encompass the application of insulation panels onto a building's exterior walls. These panels, commonly crafted from sustainable materials like expanded polystyrene (EPS) or mineral wool, boast superior thermal properties. ETICS have been found in various studies to bolster the energy efficiency of hospital structures through enhanced insulation and diminished thermal bridging.

3. METHODOLOGY

This section includes the case study of existing system, then energy evaluation of existing system and then retrofitting the base or existing system or base model of hospital. The flowchart showing the method of retrofitting or optimizing the energy or energy conservation for existing building is shown in Fig.1.

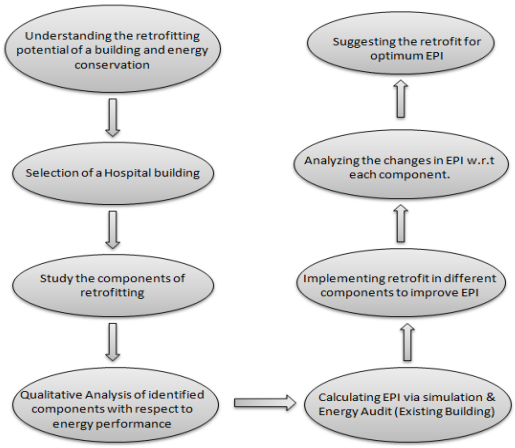

Figure1: Flowchart showing methods of retrofitting for energy optimization in the existing building

1. CASE STUDY

This research includes a careful analysis along with an investigation of Nutema Hospital is a multispecialty hospital, in Meerut. The total ground floor area is 1968 sqm and the total built area is around 7872 sqm. It is a four storied building G+2 and 1 basement.

Figure 2: Demonstration of the Ground floor plan

The numbers mentioned in the figure are indicative of the following:

1- Reception
2- Pharmacy
3- Back Office
4- Sample collection
5- V.I.P. Room
6- Consultant
7- OPD Waiting area
8- X-Ray view/Reporting/Radiologist
9- Lift Lobby
10- Lift
11- Dialysis
12- ISO
13- CMO
14- Reception waiting area
15- Minor O.T/ Plaster procedure
16- Eye exam
17- Eye exam waiting
18- Triage/ Observation
19- CT
20- DU
21- CU
22- Toilet
23- Handicap toilet
24- USG
25- Console
26- X-Ray
27- X-Ray TMT/ Echo
28- Dark room
29- RO
30- Wash
31- Drinking water
32- Corridor

The outer wall is 230 mm thick using clay brick and has both sides plaster, U-value is 2.13W/m2K with aluminum cladding panels and the roof is a flat concrete slab with thick brick tilling over it, U-value is 2.07 W/m2K.

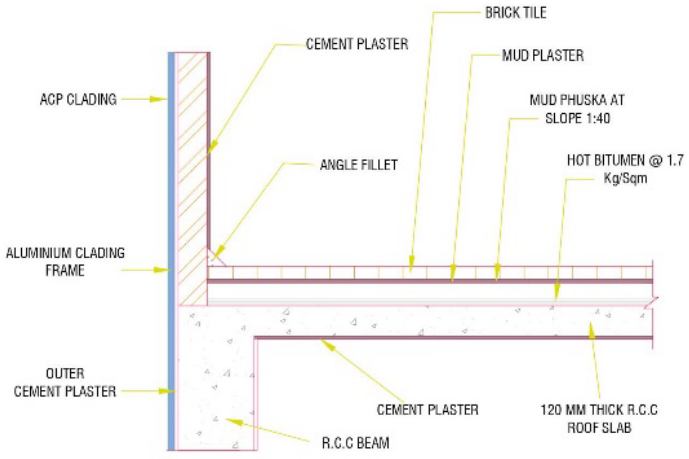

Figure 3: Terrace Section

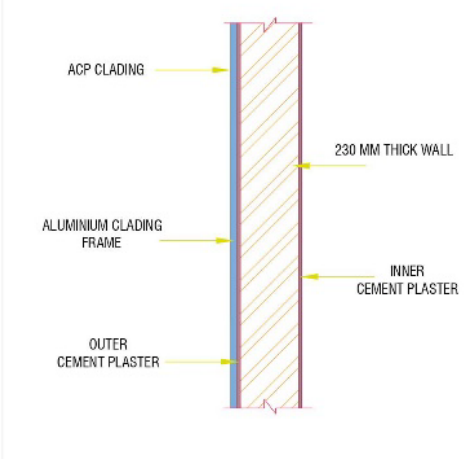

Figure 4: Section through exterior wall

Windows are 10mm thick single glass and have an aluminum frame (U-value is 7.1 W/m2K).

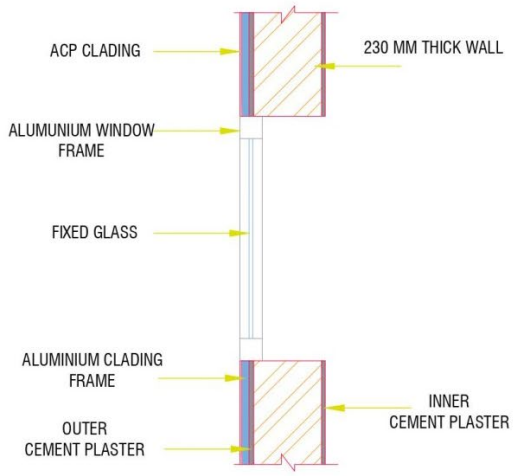

Figure 5: Section window Type 1

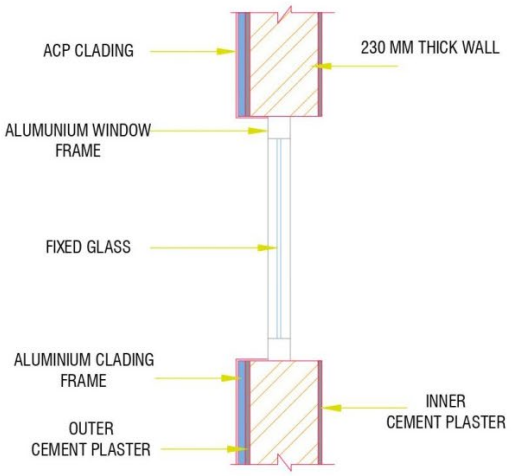

Figure 6: Section window Type 2

2. ENERGY EVALUATION

Primarily energy analysis is to be performed to get an idea of the total consumption of energy in the hospital. For energy evaluation, a simulation model using Rhino 7 and Climate Studio 1.9 is built with the present specifications of the building and then determine the Energy Performance Index (EPI) of the hospital.

Basically, Energy Performance Index (EPI) is an excellent tool to track and compare the performance of energy consumption in buildings. EPI is related to the size of the building because the energy used is calculated based on total floor space. After this extensive data collection and detailed evaluation, using some technical input a base plan is prepared which is to be acted upon to bridge the gaps that were identified.

3. SUSTAINABLE MATERIALS FOR RETROFITTING:

Several retrofitting options for different features like the roof insulation, window roof and external wall of the building are identified. Potential options can be adding thermal insulation for external walls and roofs. Polyurethane spray (U-value is 0.579 W/m^2K) is used for thermal insulation for external roofs.

For wall, External Thermal Insulation Composite Panel (ETICS) (U-value is .252 W/m2K) is used and then replaced all windows with Double low E 3mm, 13mm air gap windows (U-value is 1.53 W/m2K) and extra projection to the windows are added.

Simulation models of the all cases are built and then compared to make out the most viable one, which provides maximum energy efficiency.

4. RESULTS AND DISCUSSION

1. BASE CASE:

A base model is prepared for simulation, and it has the following specification:

- The outer wall is 230 mm thick and made by clay brick and having both side plaster, and having U-value of 2.13 W/m2K.
- The roof is flat concrete slab thick brick tilling over it and its U-value is 2.07 W/m2K.
- Windows are 10mm thick single glass and have an aluminum frame and having U-value of 7.1 W/m2K.

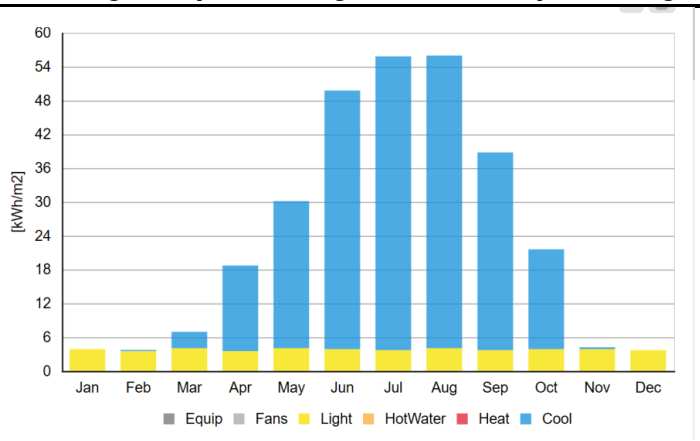

Figure 7: EPI for existing or base model

- Simulation result shown in Figure 7. It is calculated from the Figure4 that the EPI for existing system or EPI of base model is found to be 293 KWh/M2/Yr.

2. BASE CASE WITH ROOF INSULATION

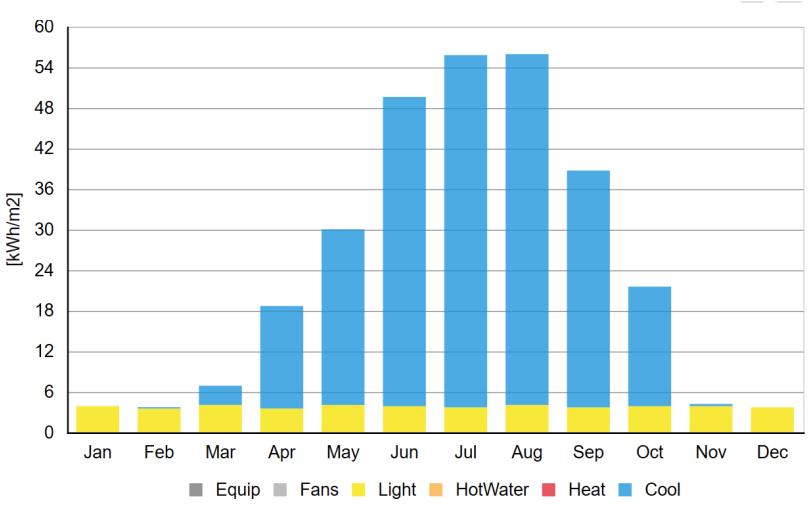

Figure 8: EPI for existing building with roof insulation

Figure 8 shows the simulation results of the existing building having insulated roofs and Polyurethane spray having U-value is 0.579 W/m2Kis used. After observation and calculation, it is found that EPI for this case is 293 kWh / m2 / year and EPI is not saved

(EPI saved = 293-293=0kWh / m2 / year)

3. BASE CASE WITH ROOF INSULATION AND OUTER WALL INSULATION:

Figure 9 shows the simulation result for the existing building having both roof and wall insulation is added. The External Thermal Insulation Composite System ETICS used in this research having U-value of 0.252 W/m^{2}K. The calculated EPI for this case is found to be 257 kWh / m2 / year. It is observed from the result that the EPI is 36 kWh / m2 / year saved (EPI saved: 293-257= 36 kWh / m2 / year).

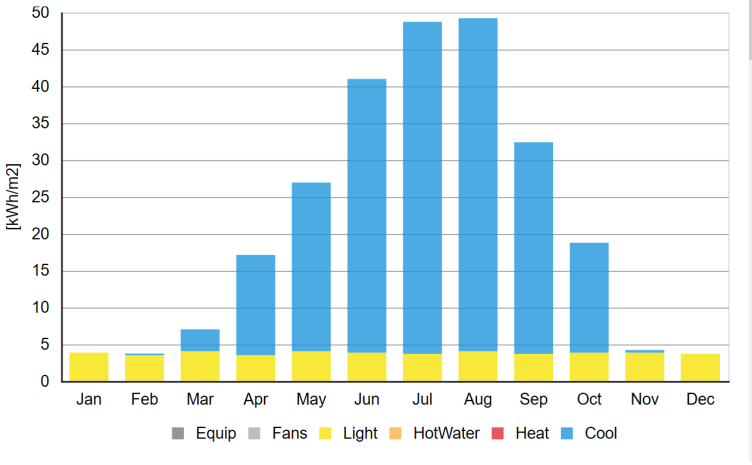

Figure 9: EPI for existing building with roof and outer wall insulation

4. BASE CASE WITH ROOF INSULATION AND OUTER WALL INSULATION AND REPLACING WINDOWS:

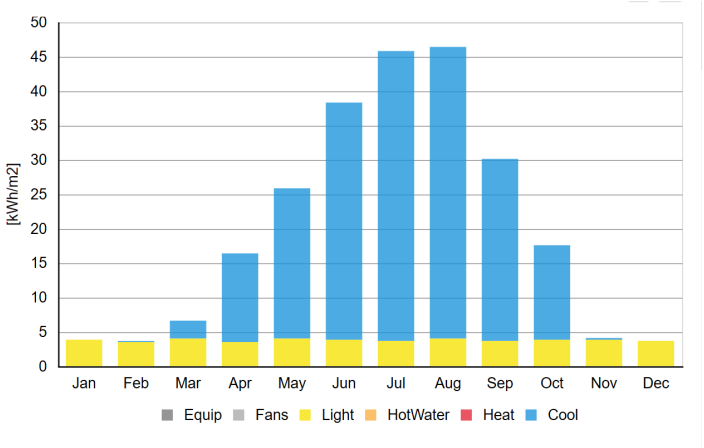

Figure 10: EPI for existing building with roof and outer wall insulation and replacing windows

Double Glazing windows of 0.579 W/m2K U-value are replaced with existing windows in the base model. From the simulation results as shown in Figure 10, it can be calculated that EPI for this case is 243 kWh / m2 / year and 50 kWh / m2 / year energy is saved (EPI Saved: 293-243= 50 kWh / m2 / year).

5. CONCLUSIONS

In conclusion, the paper provides a comprehensive investigation into the energy conservation measures for hospital buildings, crucial for reducing operational costs, minimizing environmental impact, and ensuring sustainable healthcare infrastructure. The escalating energy consumption in buildings, particularly in the healthcare sector, poses significant challenges, exacerbated by the global population growth and rising energy demands. Addressing these challenges requires the adoption of innovative building systems and technologies to mitigate greenhouse gas emissions and protect the ozone layer.

Through a detailed literature review and case study of Nutema Hospital in Meerut, India, the paper highlights the importance of retrofitting existing buildings with sustainable materials to enhance energy efficiency. Polyurethane spray foam insulation and External Thermal Insulation Composite Systems (ETICS) are identified as effective solutions for improving insulation and reducing thermal bridging in hospital buildings. Additionally, replacing windows with double-glazed alternatives further contributes to energy conservation.

The methodology section outlines the energy evaluation process using simulation models and the calculation of Energy Performance Index (EPI) to assess the effectiveness of retrofitting measures. The results demonstrate significant energy savings achieved through the implementation of sustainable materials, with EPI reductions ranging from 13% to 19%.

Overall, the study underscores the importance of adopting energy-efficient building practices in healthcare facilities to mitigate environmental impact, reduce energy consumption, and enhance operational efficiency. By leveraging sustainable retrofitting strategies, hospitals can contribute to global efforts to combat climate change while ensuring the delivery of quality healthcare services.

CONFLICT OF INTERESTS

None

ACKNOWLEDGMENTS

None

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