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Analysis of Energy Performance and Application of Wall Insulation on an Academic Building using EQUEST

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Abstract—Building sector is one of the major consumers of energy produced in the country. This study was carried out to assess the energy performance of a typical academic building and to analyze the effect of energy efficiency measures on energy consumption for space cooling. EQuest software was used to model the year round energy performance. The simulation results were compared with annual metered energy usage. Moreover, a standard wall insulation was simulated in order to analyze its effect on energy saving. The results showed a considerable energy saving potential.

Keywords— Energy performance, Energy efficiency, academic building, insulation

I. INTRODUCTION

Energy performance is a term use to access the quality of energy usage in buildings [1], [2]. Approaches of building energy assessment can be classified into two major types, i.e. performance-based approach & feature-based approach. In performance based approach, different indicators can be established to compare the performance among buildings like energy utilization index per unit area EUI, carbon dioxide CO_2 emissions etc. While in feature-based assessment credit can be awarded for specific features. Hence, an overall score can be calculated by integrating the above two performances [3]. Performance-based assessment is more preferable as it is easily quantifiable and then comparable. Wang et al [4] divided energy quantification approaches into three types i.e. measurement based approach which uses sub-meters to calculate the energy consumption for specific tasks, calculation based approach which uses simulation techniques to simulate the energy usage while hybrid approach combines the features of above two methods. He also ascertained the importance of energy performance assessment of existing buildings. Different market available simulation tools were used which allowed detailed data input and hence comprehensive results, which proved helpful in assessing the energy performance. Yan et al [5] simplified the energy performance assessment procedure by disintegrating the energy bill into three end-uses and then comparing it with the respective domain-wise simulated energy results. Baig et al [6] modelled the energy performance of a library building using eQuest, one of the available simulation tool. Energy simulation was carried for three consecutive years and later compared with the metered energy usage. Overall simulated energy consumption was accurately in compliance with actual energy usage with only 2% difference. Jinghua et al [7] used eQuest software to analyze factors, thermal insulation of exterior walls, glazing of shades, window to wall ratio, which effect on energy savings of air conditioner. Energy savings of cooling and heating load was recorded and analyzed while changing the thermal insulation envelop configuration [8]. Another study was carried out to determine the effect of heating and cooling load in comparison to the exterior insulations on residential facility [9]. Bolatturk [10] carried out study to analyze the extent of heating & cooling savings with respect to the optimum insulation thickness. Payback period was also calculated to figure out the overall feasibility of this energy efficiency measure. Another approach was carried out by Hasan et al by using overall cost analyzes for optimum insulation thickness [11]. Bokos et al [12] established a comparison between the energy savings before and after the installation of thermal insulation in building's envelop. Mohammad et al [13] analyzed the optimum insulation thickness for building in hot climatic zone. It was also concluded that the maximum heat transfer was due to the solar thermal radiations. Dombayaci et al [14] analyzed the mitigation of environmental impact with thermal insulation installation. Coal was used as energy source while expanded polystyrene as insulation material.

II. METHODOLOGY

This chapter describes the experimental methodology of the research. Following tasks were carried out in chronological order with details.

- Data Collection

- Energy Simulation of Academic Building using eQuest
- Application of Thermal Insulation in eQuest

A. Data Collection

The eQuest is an energy simulation tool used to calculate yearly energy performance of a building by the input of certain required parameters. It is a highly efficient simulation tool also on the recommended by DOE (Department of Energy) [15].The collected data of the actual building parameters is fed into the simulation tool. The data is further processed by eQuest to generate yearly energy performance on the basis of data input. Data regarding the insulation thickness, glass type, door type, wall thickness & ceiling parameters are also taken from the detailed drawings. HVAC data was also collected from the relevant drawings so that installed HVAC can be modelled in eQuest with required accuracy. Internal load other than HVAC, was characterized into three portions i.e. lightning, occupancy load & appliances load. Figure 1 shows the two dimensional layout of the academic building under consideration while Figure 2 shows the building shell in eQuest after collecting the required data.

B. Energy simulation of Academic Building using eQuest

After getting the building envelop configuration from collected data, building was divided into different thermal zones as required. In academic building under consideration, split and window air conditioning units of various models were installed in different thermal zones. EQuest supports designing of the installed system directly as single packaged unit for each respective thermal zone.

Lighting, fan and other installed load were recorded through walk through energy audit and entered in eQuest model. Afterwards, building energy was simulated for the whole year. At the end, simulated energy usage was compared with the metered energy usage of the building, first to validate the energy simulation and as well as to deduce useful deductions in terms of energy efficiency.

C. Application of Thermal Insulation in eQuest

After simulating the energy performance of academic building as present, polystyrene having thickness of 4 in. was incorporated in the walls as thermal insulation in eQuest against the losses occurred during cooling the space.
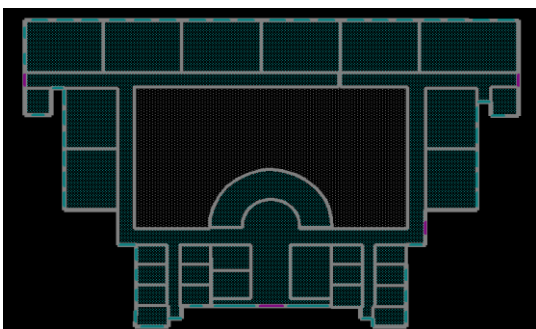

Figure 1: Two-Dimensional Layout of Academic Building in eQuest

As during heating days, natural gas was used in burners instead of electricity, so energy usage for heating was not included in this study. Later, energy usage of cooling space was compared as of before and after the installation of thermal insulation.
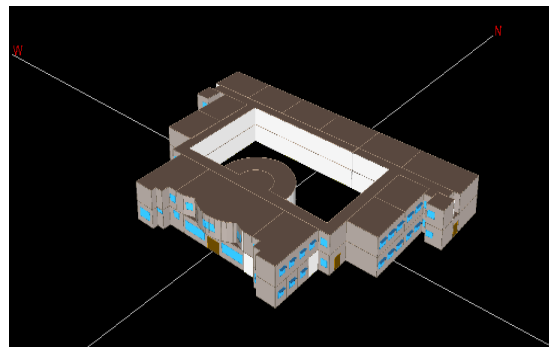

Figure 2: Academic Building Shell in eQuest

III. RESULTS & DISCUSSION

A. Energy Simulation of academic building using eQuest

Energy simulation of academic building situated in Peshawar was carried out using eQuest to determine its yearly energy usage of 2019 electricity by end use & ancess its energy performance. Results show that the building used total of 59.4 MWh of energy during the year 2019. Lighting consumed the maximum portion of load among the subcategories i.e. 27.47 MWh, 45.7% of the total, varing from monthly extremes of 2.41 MWh & 2.11 MWh. . It was also recorded that by the end use, cooling space used the second maximum portion of electricity i.e. 36.7%. Cooling space accounted 22.05 MWh energy usage of that year. Least energy by cooling space was used during the month of February i.e. 2.57 MWh while the maximum was recorded in July i.e. 8.07 MWh. This behavior was recorded as the tmeperatures kept increasing from February till July & then started decreasing subsequently. Apart from the above stated two major subcategories of energy usage, various other usages were recorded and are shown in Figure 3.

B. Comparison between Actual Energy Consumption and Simulated Energy Consumption

Figure 4 establishes a comparison between the yearly energy consumption of academic building under consideration situated in Peshawar, Pakistan. For the first four months of the year, both graphs depict almost same energy consumption. During the cooling season the difference starts increasing with maximum difference being recorded in the month of August. Split ACs were installed in different zones with varying EER (Energy Efficiency Ratio) values. Although overall energy consumption for the period of year 2019 from both graphs shows a mere change of 4.2%.

C. Comparsion of Simulated Energy Results of Cooling Space, before & after the Application of Thermal Insulation

After applying thermal insulation of 4 inch polystyrene with thermal conductivity 0.030W/m·K on all the walls, cooling space load was considerably reduced. Following Figure 5 establishes a comparison of cooling space load before and after the application of polystyrene 4 in. thermal insulation. 22% difference of yearly energy usage of cooling space was recorded before and after the application of energy efficiency measure.
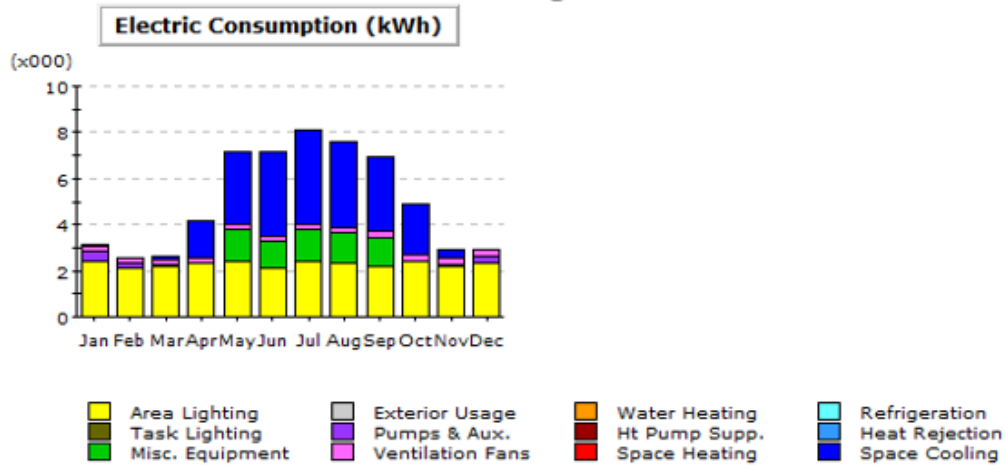

Figure 3: Whole year 2019 energy modelling of Academic building using eQuest
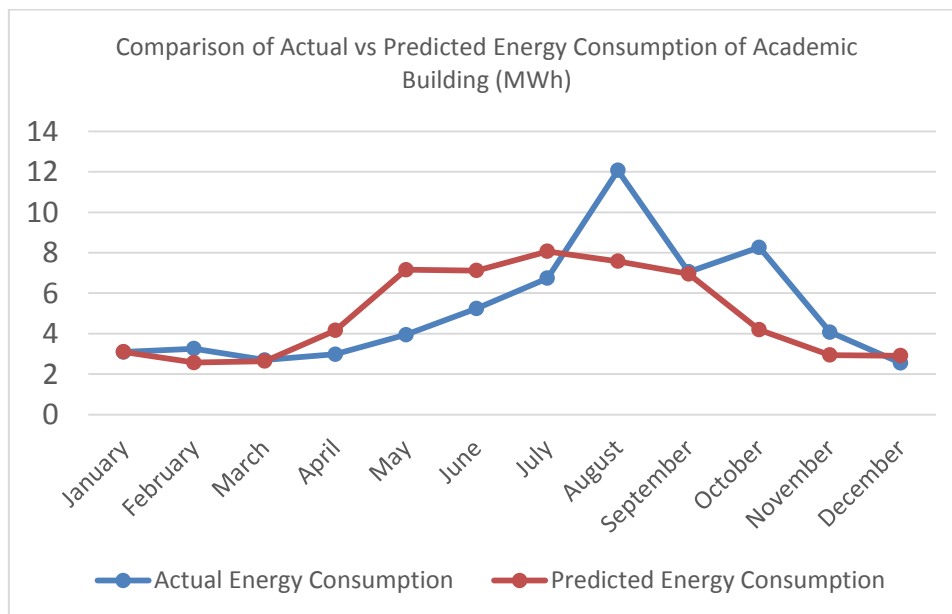

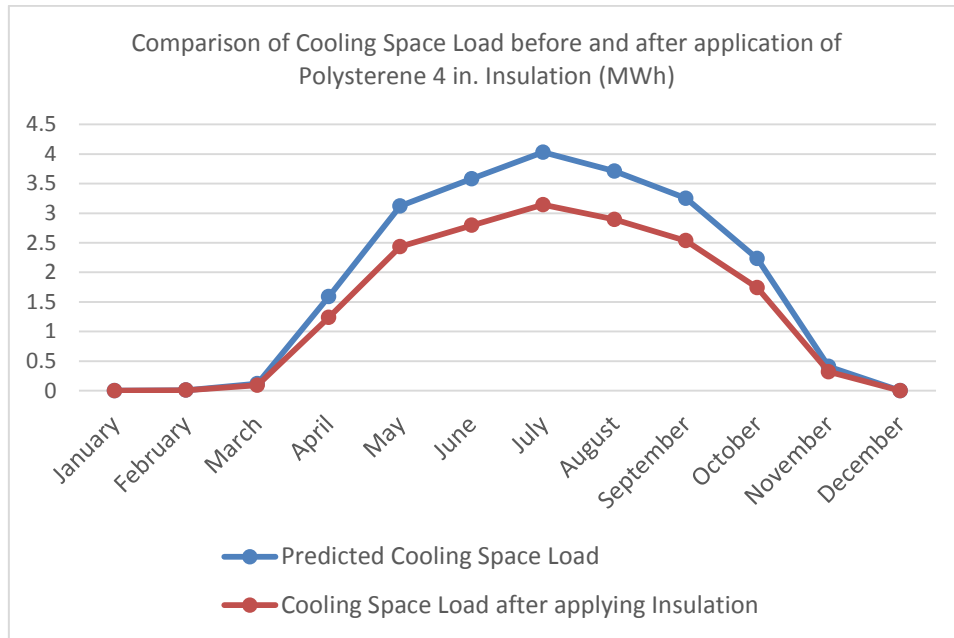Figure 4: Actual & Simulated Energy Consumption Comparison

Figure 5: Cooling Space Load Comparison

CONCLUSIONS

This research was carried out to access an academic building energy performance located in Peshawar, Pakistan.
EQuest was used as a modelling tool to simulate the building energy performance. Actual building was modelled for whole year. The model design was validated by first recording the actual HVAC temperatures of each respective thermal zones. Also, lightning and other load schedules were monitored for the selected period to ensure maximum accuracy. Difference of only 4.2% was recorded while comparing actual metered energy consumption and the modelled energy consumption, thus validating our designed model after simulation. Hence, results show that energy simulation of buildings using eQuest can be used with much accuracy to predict the energy performance, having enough data input, hence getting in a better position for the formulation of energy efficiency measures.

By end use, cooling space used the maximum proportion of electricity. Maximum & minimum monthly values of 8.07 MWh and 2.57 MWh were recorded during the months of July and February respectively. In fact, cooling space accounted for 36.7% of the total energy usage, with no thermal insulation installed, pointing out the effectiveness of any proposed energy efficiency measure regarding thermal insulation.

After simulating the building energy performance and getting the end usage, an energy efficiency measure was proposed by applying a market available thermal wall insulation to lower the energy consumption of cooling space. It can be seen that by installing wall insulation of 4 inch polystyrene, this proposed energy efficiency measure reduced 22% of the overall energy usage of cooling space i.e. 4.85 MWh of energy can be saved yearly.

Different insulation materials can be simulated in future simultaneously using eQuest with varied thickness to get the optimum results. Furthermore, cost benefit analysis can also be performed while incorporating market related constraints.

Overall sustainability of the building needs to be quantified with better understanding to achieve effective results. Future research should also focus on other areas of building's overall sustainability as well i.e. Indoor air quality, onsite renewable energy, transport, etc.

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