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Comparative Analysis of Energy Consumption of Multistorey Residential Building – A Case Study of using Conventional Burnt Clay Bricks Vs Innovative Cellular Light Weight Concrete (CLC) Blocks

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ABSTRACT

The global building construction consumes a major part of energy productions along with generating a fair some portion of carbon footprint. Although human efforts to create sustainable environment have yielded benefits in achieving comfort for betterment in life but high energy consumption pattens in building is becoming a matter of concern for current sustainable developments. With an increasing the interest on sustainable design and energy efficiency, professionals as well researchers are constantly seeking ways to efficiently analyse and evaluate energy performance of buildings throughout the design process. The current work investigates the impact of building envelop constructed of two different construction materials, conventional clay burnt bricks and innovative Cellular Light Weight Concrete (CLC) blocks, on energy levels of multistorey residential building. Building Information Modelling (BIM) has been used to develop the virtual model of the case study in a 3D environment using Revit. The energy analysis was performed using INSIGHT. The conventional construction with bricks achieved energy consumption of 465 kWh/m²/yr whereas CLC blocks achieved 405 kWh/m²/yr. The results show that the CLC blocks have lowered the energy level by 12.90% in light of ASHREA 90.1 standard.

KEYWORDS: Cellular Light weight Concrete (CLC), Energy Analysis, BIM

1 INTRODUCTION

As human communities are expanding, the construction industry is rapidly advancing. The different operations are involved in the practice of construction have an enormous impact on the use of energy and material worldwide [1]. The construction industry is always changing and getting better with new materials and technologies that are introduced to make things more energy efficient and sustainable. Energy conservation is the effort made to reduce the consumption of energy. Reduction of the demand of the natural resources of the earth and controlling the use of energy are major reasons that drive towards the construction of energy conserving structures [2]. The use of innovative blocks in energy analysis creates a more collaborative approach to sustainable building design. These blocks offer a simplified and efficient means of evaluating and optimizing energy performance in the buildings. On the other hand, clay burnt bricks caused smoked when manufactured and cause of CO_2 in atmosphere. By utilizing these innovative blocks, engineers can simulate different design options and assess their impact on energy performance.

These innovative blocks provide an accurate means of calculating energy consumption, thermal performance and others factors that influence the sustainability of the buildings. Innovative blocks are able to gain valuable insights into the energy consumption patterns, identify areas for improvement and ultimately create more sustainable and energy efficient buildings. Cellular lightweight concrete (CLC) blocks having foaming agents that induced inside them that make them more sustainable and environmentally friendly.

Concerns have been raised over the energy use that has grown rapidly in recent times. The size of building, use of building and more importantly the type of use extracted from the service are the paramount factors that determine the quantity of energy required. The conventional materials offer a potential for improved sustainability, energy efficiency and cost-effectiveness in residential building construction. As a result, there is a need for comprehensive cost comparative analyses to evaluate the innovative materials versus traditional options [3].

2 LITERATURE REVIEW

The construction industry plays an important role in economic growth and development. It is not only responsible for building infrastructure and structures but also for generating substantial employment opportunities and creating business activities. However, this sector experiences various challenges and issues that create a barrier in smooth functioning. These challenges may include cost escalation, environmental impact, safety factor and other complex issues. Besides other challenges, the construction industry imparts serious impacts on our environment. It plays a major role in the generation of greenhouse gas emissions, mainly due to construction processes and the operation of buildings that consume vast amounts of energy. This includes manufacturing construction materials, transportation and on-site energy consumption. Thus, construction activities release various pollutants into the air and soil which impart negative effects on air quality and soil health [4]. Construction materials are one of the prime concerns that contribute in carbon footprint and energy consumption patterns of the buildings. About 36% of carbon dioxide emissions are attributed to construction sector [5]. Many researchers have explored and discussed various aspects of construction materials to manage the environmental challenges. According to material management is a critical aspect involving the efficient planning, procurement, storage and utilization. Effective material management minimizes construction waste in addition to cost overruns and schedules. It also has reported that alternative materials and substitutes play a significant role by which offering innovative and sustainable options to reduce environmental impact and enhance project performance [6]. These benefits may be in terms of energy efficiency, carbon footprint, durability and cost-effectiveness. The research explored use of substitutes like bamboo, recycled materials and green concrete that can lead to improved sustainability and reduced construction waste. Besides these materials, the benefits of alternate materials like cross-laminated timber (CLT) [7], Enhanced Concrete with Graphene [8], Thermal Insulation with Aerogel [9], Energy-Efficient Windows with Transparent wood [10] have been explored from time to time.

Most recently, the Cellular Lightweight Concrete (CLC) blocks have received a great attention of the industry professionals and researchers due to their low density and thermal insulation properties. They have been considered ideal for walls construction (internal and external), providing good acoustic insulation and reducing overall construction costs. Their light weight property makes them easy to work with and manage desired sizes using regular tools, this offering a cost-effective and efficient solution for flexible interior spaces [11]. Besides, their thermal insulation properties also make them suitable for energy-efficient construction. lower thermal conductivity helps to reduce heat transfer through walls and improves energy efficiency in buildings. Ultimately leading to reduced heating and cooling costs [12]. There are numbers of benefits used of innovative blocks that have explored by researchers, table 1.

Table 1: Previous research works pertinent to innovative blocks

Authors	Observations
Pisello, Castaldo [13]	CLC block are environmentally friendly.
Amran, El-Zeadani [14]	CLC blocks improve thermal performance and structural integrity of residential buildings. Also reduce construction costs and environmental impact
Blumberga, Vanaga [15]	high-performance concrete blocks and insulated concrete forms (ICFs) make building more resilient and energy efficient.
Kirschke and Sietko [16]	CLC block which are lightweight that reduce cost and environmental impact.
Ma, Sheikholeslami [17]	Innovative blocks make significant contributions achieving sustainable and modern practices in construction industry.
Pawar and Kushwah [18]	Innovative materials are lightweight and environmentally friendly
Khan, Khan [19]	CLC Blocks are great thermal insulator as compare to bricks which save the energy in cooling and hot season and save the cost.

3 METHODOLOGY

In the residential sector, the use of energy is far stretched at the present time. For energy planning, management, and conservation, building energy consumption prediction is essential. Figure 1, details the flowchart adopted for the current work.

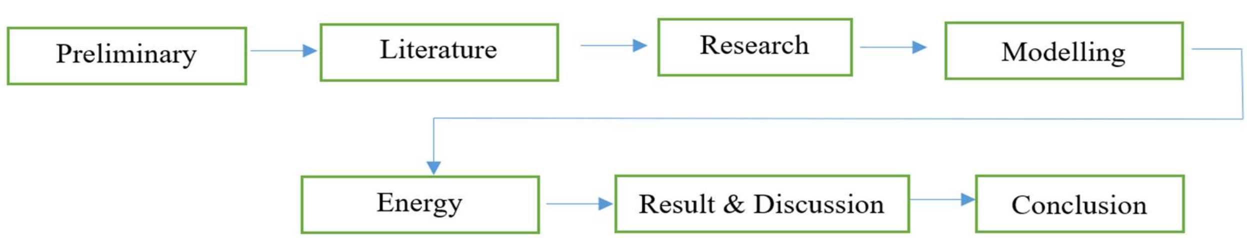

Figure 1: Paradigm of Research Design

Current work adopts case study paradigm, a five-story residential building proposed to be constructed in city of Islamabad. The building is a RCC frame structure with a ground covered area of almost 2250 sft. It is expected to accommodate 10 residential units each having almost 1000 sft of covered area.

3.1 Building Information Modelling (BIM)

Building information modelling (BIM) is a process which involves creation and management of digital models with the help of different tools and technologies. These models are prepared to demonstrate the functional and physical characteristics of places. Building information models (BIMs) are computer files that can be extracted and exchanged in the process of decision making. The relevant design data was acquired for the research work from concerned authority. Using REVIT, a 3D virtual model of the case study has been developed, figure 2.

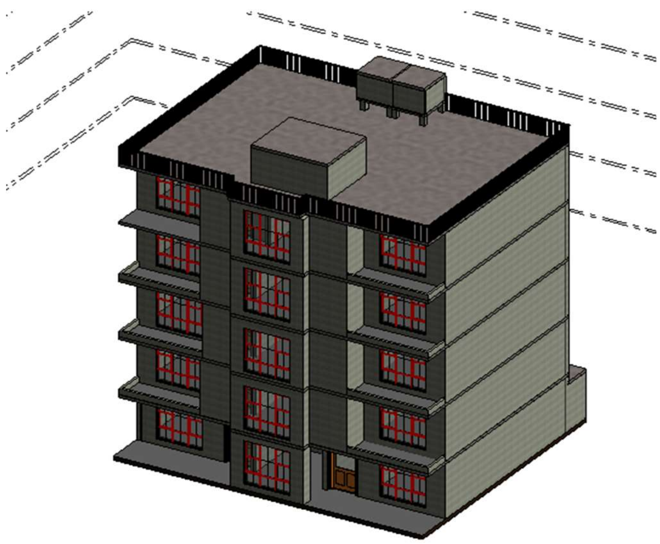

Figure 2: 3D Virtual Model of the case study

3.2 Building Energy Modelling (BEM)

After development of BIM model, the next step is to conduct the energy analysis. Using INSIGHT, the developed BIM model was transformed into BEM. Building Energy Modelling (BEM) can be defined as a process that utilize a simulation software and performs a detailed analysis on the energy consumed by a system. Figure 3 provide a graphical view of steps to achieve energy analysis.

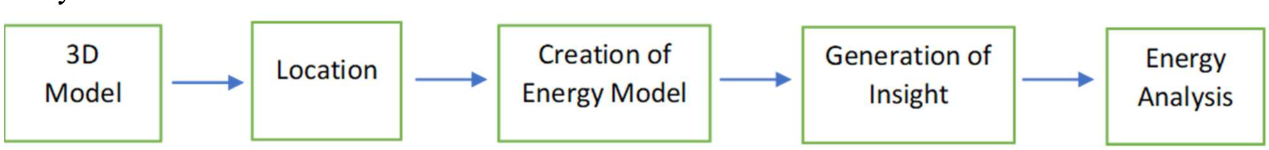

Figure 3: Steps to achieve energy analysis

In order to achieve the objective, a virtual duplicate of an existing building is created and a simulation is performed by subjecting the building to the weather conditions that exist throughout the year.

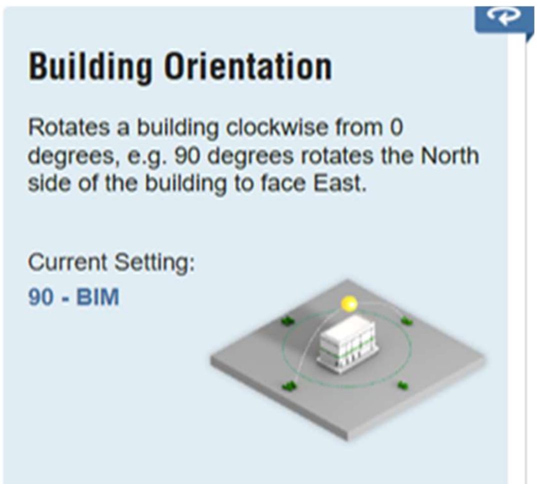

Figure 4: Building Orientation

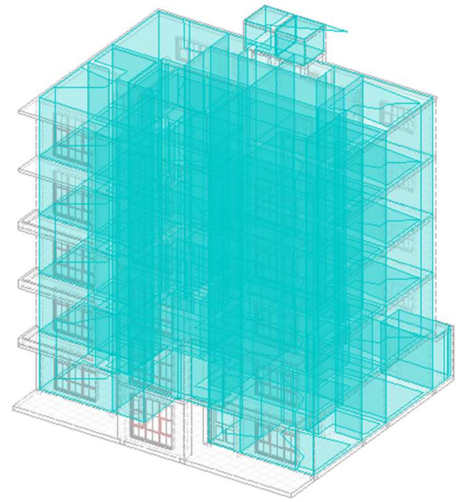

Figure 5: Energy Model

The orientation of building with respect to true North is an important parameter while studying the energy consumption of building. This property determines the energy (heating and cooling energy) that will be consumed within the building. The orientation selected for the current work is being shown in figure 4 whereas based on these parameter, Figure 5 presents the BEM model for our case study.

4 RESULTS AND ANALYSIS

In order to assess the comparative energy levels, only the impact of wall construction has been evaluated. Two materials, conventional clay burnt bricks and Cellular Light weight Concrete (CLC) blocks have considered.

4.1 Burnt Clay Brick

The results are presented as yearly energy consumption in kWh per m² area of the wall. When applied at all the walls, energy analysis demonstrates that the total consumption comes out to be 465 kWh/m²/yr. Lower limit of energy consumption was 161 kWh/m²/yr. and upper limit was 1294 kWh/m²/yr. Figure 6 shows the results of energy analysis with burnt clay bricks.

Figure 6: Energy Consumption for Conventional Clay Burnt Bricks

4.2 Cellular Lightweight Concrete Blocks

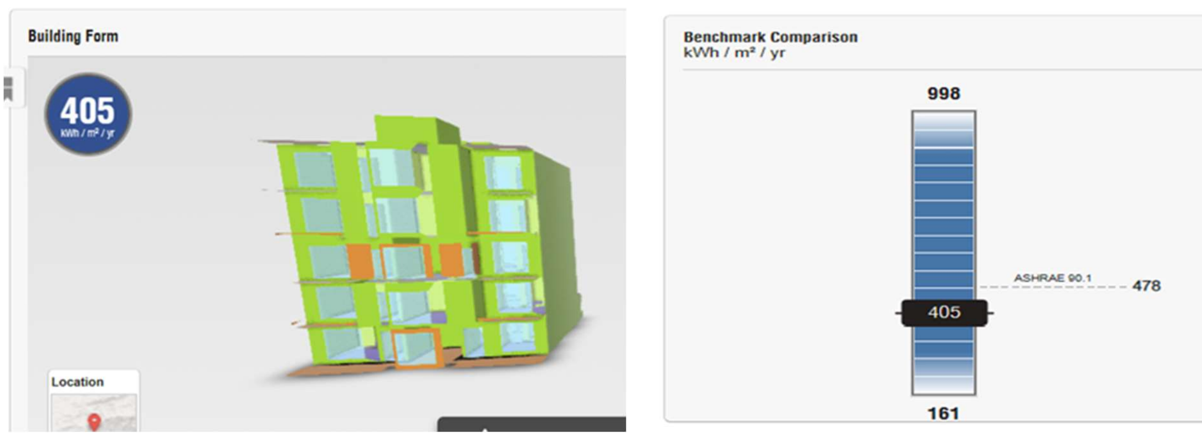

Figure 7: Energy Consumption for Cellular Light weight Concrete (CLC) Block

Results of energy analysis with the cellular lightweight concrete blocks applied are shown in Figure 7. The results are presented as yearly energy consumption in kWh per m² area of the wall. In this part, when CLC Blocks was applied at all the walls, the energy consumption decreases by 60 kWh/m²/yr. and was estimated to be 405 kWh/m²/yr. Upper limit being 998 kWh/m²/yr. and lower limit being 161 kWh/m²/yr.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Cellular Lightweight Concrete Blocks

Use The energy analysis gives a measure of the energy conservation potential of the building in the form of energy consumption for an area of 1 m². After performing energy analysis on the two models, energy consumption value of 465 kWh/m²/yr. was obtained for the model with burnt clay bricks and a value of 405 kWh/m²/yr. with CLC Blocks. Int means the utilization of CLC blocks have lowered the consumption level by 12.90 % per year, table 2.

Table 2: Energy comparison

Conventional Burnt Clay Bricks	Cellular Lightweight Concrete Blocks
465 kWh/m²/yr.	405 kWh/m²/yr.

5.2 Cellular Lightweight Concrete Blocks

Based upon the current work, the following recommendations are put forward:

- As the cellular lightweight concrete block have energy saving properties, it is advisable to promote these materials in construction practices.
- CLC blocks are lightweight, thus with energy saving these can also enhance the speed of construction when compared to conventional brick work. This will lead in saving precious time as well.

Besides energy saving and speedy construction attributes, cost of materials is one of major concerns in construction industry. A careful consideration should also be to the economical solutions when comparing innovative construction materials.

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