DESIGN AND ANALYSIS OF GREEN HIGH-RISE BUILDING USING RECYCLED MATERIALS

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Abstract- This project deals with the design and analysis of high-rise building by using eco-friendly building materials. The locally developed building materials from recycled waste were used as concrete and bricks. A ten-story high-rise building was designed using the software ETABS. The concrete comprised of 10% partial replacement of cement by red brick powder (RBP) and the bricks contained 25% mass of clay replaced by the RBP. These materials were cast and their properties were determined as per ASTM standards. The characteristics were incorporated in the software and the building was designed and analyzed. The designed building was compared with that containing conventional concrete and bricks. It was found that the design having waste materials resulted in the saving of 160 tons of cement, and 440 cubic meters of fertile clay. This will avoid a Carbon emission of 144 tons to the atmosphere and a significant saving in energy required to manufacture cement. The building containing waste materials is also PKR. 5.67 million less in cost than that containing conventional materials.

Keywords- Green Design, High-rise Buildings, Recycling, Waste, Environmental Impact, Cost.

1 Introduction

In daily construction activities, it is observed that the concrete is made up of three main constituents i.e. cement, sand and aggregates. Cement being the main constituent, significantly affects the environment as well as sustainability. Cement while its production causes severe environmental impacts such as CO_2 emission which causes the global warming, production of cement requires a high temperature around 1400°C which is primarily done by igniting fossil fuels which are also decreasing day by day and its production is causing resource depletion and air pollution (emission of Nitrogen oxides & Sulphur oxides). It is required to reduce these effects to make the construction practices sustainable and reduce the environmental impact of concrete

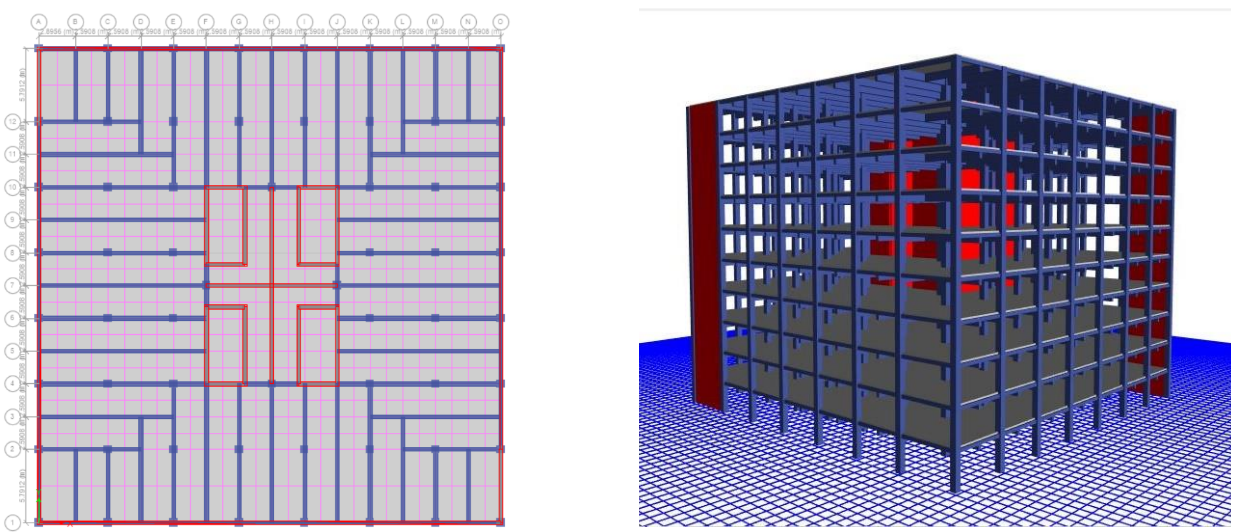
Red brick powder is a local material and has been used in a variety of ways in the archeological sites of the sub-continent. Locally, it is known as "surkhi" [1], [2]. Arif et al. studied the effect of red brick powder (RBP) as a partial substitute of cement in concrete [3]. The results showed that for the replacement of 10% of cement provided improved mechanical properties and work ability due to its particle shape and size, and improves compressive, flexural, and tensile strengths due to its pozzolanic properties. It also improves the compressive strength and durability of concrete. On the other hand, it causes reduction of carbon and energy consumption in cement production and recycling of construction waste [3]. Riaz et examined the effect of red brick powder on the properties of clayey bricks. The study found that incorporating RBP increased brick porosity, making them suitable for moderate weather resistance and insulation, but decreased unit weight, leading to lighter and more economical structures. Moreover, compressive strength reduced with RBP addition but remained adequate for second-class bricks up to 15% RBP. Flexural strength also remained satisfactory even with 25% RBP. RBP incorporated in the production of clayey bricks saved 25% of fertile clay, leading to environmentally friendly construction [4]. Shah et studied the harnessing of red brick powder as a sustainable cement alternative. The findings revealed that RBP was a viable alternative to cement, enhancing the compressive strength of the concrete, particularly at an optimal dosage of 15%, which resulted in a 9% increase in strength at 28 days compared to the control mix. Moreover, the split tensile strength also saw a 15% improvement with 15% RBP substitution. Overall, incorporating RBP into concrete not only improved its structural integrity but also promoted sustainable waste management and cost efficiency [5].

This work deals with the design and analysis of an RCC high-rise building. In the design, concrete containing 10% RBP as a partial replacement of cement was used. Additionally, the partition walls were made of red bricks, in which 25% fertile clay was replaced by the RBP. The aim was to design a sustainable building based on the materials previously developed in our research group. The benefits of using locally developed materials were assessed by designing an actual RCC structure and comparing it with the conventional building in terms of environmental and cost. This work aims to provide the benefits of a green building in terms of waste reduction and utilization in accordance with the sustainable development goals of UNO [6]. A 10-story building was chosen as a test case. The design and analysis were carried out using ETABS. The benefits of green building are presented in the form of reduction in greenhouse gas emission, the use of natural resources, energy and cost.

2 Research Methodology

2.1 Dimensions of the proposed building:

The proposed plan for the high-raised building is shown in Figure 1. It has dimensions of 37m x 36.57m with a height of 32m including ground floor. In this design, four shear walls were provided as per recommendations of ASCE 7-17 [7].



a) b)

Figure 1: Two- & Three-Dimensional Plan of proposed model

One shear wall each was provided along the longer side and two central shear walls were provided in the middle along the shorter side. The building was subjected to dead, live, wind and earthquake as per Universal Building Codes 97 [8].

2.2 Analysis and Design:

The proposed building was modeled using ETABS, and properties of the materials resulting from past researches were assigned to the components of the building, i.e., slabs, columns, beams, walls, etc. The material properties used in the design are shown in Table 1.

Table 1 Properties of green materials used

Materials	Compressive Strength (MPa)	Density (kg/m^3)	Poisson's Ratio	Modulus of Elasticity (GPa)
Conventional concrete	27.5	2402.8	0.2	24.55
10% RBP in Concrete	30.3	2324.76	0.2	25.871
Conventional brick	9.13	2162	0.2	12.4
25% RBP in Bricks	5.95	1274.65	0.2	11.5

3 Results

After designing the model in ETABS, the dimensions of different components of green building (i.e. slabs, beams, columns and walls) for all stories were obtained and are described in Table 2:

Table 2 Dimensions obtained from design

Components	Width (mm)	Depth (mm)
Slabs	-	175
Beams	300	750
	300	300
Columns	560	560
Shear Walls	300	-
Perimeter Walls	228	-

After analyzing the model, the parameters were checked by the given ACI code (i.e. ACI-318-14) [9] using ETABS. The International Building Code (IBC) (for earthquake as load) specify a maximum story drift of 0.015-0.02 whereas it is 0.00016 & 0.000031 in x and y direction respectively, and a story displacement of 45-60 mm for a story height of 3 m [10] whereas it results in 4.06mm and 4.01mm, respectively. Moreover, the overturning moments was obtained as -540 KN-m, which normally depends on foundation soil conditions. This implies that the given structure is within the safe limits. The comparison of different parameters that are linked with sustainability are given in Table 3:

Table 3: Sustainability Parameters

Parameters	Conventional Building	Green Building	Savings	Cost Effectiveness
Cement (tons)	1088.222	927.924	160.398	4.65154 Million Rupees
Carbon Dioxide (tons) [11]	979.399	835.04	144.358	-
Electricity (kWh)[12]	119704.403	102060.6	17643.803	0.70575 Million Rupees
Clay (m^3)	1761.822	1321.36	440.46	0.308319 Million Rupees
Structure weight (MN)	169.22	142.36	26.86	-
			Total saving in Rs. Million	**5.67**

The Table 3 indicates that use of eco-friendly materials is a cost-effective sustainable solution: it provides savings in the use of cement, the emission of greenhouse gases, and the energy requirements. Additionally, the use of 25% RBP provides an economy of 440 m^3 of fertile clay. Nevertheless, the structure is also lighter than that consisting of the conventional materials.

4 Conclusions

This work deals with the design of a 10-story RCC building using green materials, developed in the lab. Based upon the simulations, the following conclusions are withdrawn:

1. The designed building provides a saving of 160.39 tons of cement, and 440 m^3 of fertile clay.
2. The saving in cement corresponds to a reduction of 144 tons of CO_2 to the atmosphere, and an energy conservation of 17.64 MWh.
3. The proposed green design assures a cost reduction of 5.67 million PKRs.
4. The building incorporating waste materials is 16% lighter than that containing conventional materials.

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