COST EFFECTIVENESS TO RESIDENTIAL BUILDING USING GREEN BUILDING APPROACH

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Key words: Terracotta, Neutral Axis, Green Building, Flyash and Quarry dust

ABSTRACT The present study deals with developing a technique to replace the conventional solid concrete slab with hollow terracotta block slab. The objectives include development of an eco-friendly concrete slab with partial replacement of cement with fly ash and natural sand with quarry dust. The first task identified in this study deals with placing of terracotta hollow blocks below the neutral axis of the solid slab concrete portion towards reducing the volume of concrete (about 50%), since the volume of concrete below the neutral axis is ineffective, contributing nothing to the bending strength of the slab. The second task deals with the partial replacement of cement with fly ash, quarry dust and 6 mm chips above the neutral axis of the concrete slab. This paper presents the feasibility of the usage of by product materials like fly ash, quarry dust and 6 mm chips and to study the economic viability of the material and found that the cost has been lowered. From the above methodology it is possible to reduce the CO2 emission in atmosphere towards eco friendly construction technique. The use of fly ash in concrete contributes the reduction of greenhouse emissions with negative impacts on the economy. Tests were conducted on cubes and beams to study the strength of concrete for various combinations of fly ash and quarry dust.

1 Introduction

The consumption of cement workability, compressive strength and cost of concrete made with fly ash and quarry rock dust were studied by researchers, Pattanaik et al. [1], IS 10262-1982. [2] reported moderate increase in compressive strength, modulus of rupture and split tensile strength when 30 percent of cement is replaced by fly in concrete. Dan Ravina and Mehta. [3], reported that increase in compressive strength by using 30%fly ash in concrete. CII, India and CANMET, Canada. [4], Indian Standard [5], Babu, K.K., et al.[6], Nagaraj T.S. and ZahidaBanu [7] and Narasimahan et al[8]. The mix design proposed by Nagaraj et al [7] shows the possibilities of ensuring the workability by wise combination of rock dust and sand, use of super plasticizer and optimum water content using generalized Iyse Rule. Sahu A.K et al [9] reported significant increase in compressive strength, modulus of rupture and split tensile strength when 40 percent of sand is replaced by quarry rock dust in concrete. IlangoVand and Nagamani [10] reported that natural sand with quarry dust as full replacement in concrete as possible with proper treatment of quarry dust before utilization. The utilization of quarry rock dust which can be called as manufactured sand has been accepted as a building material in the
industrially advanced countries of the west for the past three decades [11]. This paper presents feasibility of the usage of the materials such as fly ash, quarry dust and 6 mm stone chips. It deals with the partial replacement of cement with 30% fly ash, natural sand with 50% quarry dust and coarse aggregates with 20% 6 mm chips obtained from quarry dust. In this project interlocking hollow blocks were introduced as i. and ii. The interlocking TC roof block and TC joist block (beam) provided makes excellent interlocking and rigid bonding between the blocks. These interlocking TC roof block having grooves helps to convert to hold rigidly. These TC roof blocks are placed in the tension zone of the solid concrete slab. Feasibility study was carried out that the usage of TC blocks, fly ash, quarry dust and 6 mm stone chips because co₂ emission less and eco friendly construction techniques.

2 Material used

2.1 Fly ash

They are generally finer than cement and consist mainly of glassy spherical particles as well as residues of hematite and magnetite, char, and some crystalline phase formed during cooling. Fly ash is a finally divided residue resulting from the combustion of bituminous coal or lignite in a thermal power plant. Indian coals have on an average 45% ash content. Every year 87 to 100 million tonne of fly ash is generated from coal based thermal power station in India. In addition to economics and ecological and economic benefits, the use of ash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali-aggregate reaction, and enhances sulfate resistance. In term of public good, the greater use of fly ash in concrete contributes to reduced greenhouse gas (GHGs) emission without negative impacts on the economy. The overall quantity of CO₂ emission will be reduced in one important sector of the economy without affecting it.

2.2 Quarrydust

Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete Industry needs to be found. In such a situation the quarry rock dust can be an economic alternative to the river sand. Quarry rock dust can be defined as residue, tailing or other non-voluble waste material after the extraction and progressing of rocks to form fine particles less than 4.75 mm. Use of quarry rock dust as a fine aggregate in concrete draws serious attention of researchers and investigators.

2.3 Fine aggregate

Natural river sand having density of 1460 kg/m³ and finess modulus (FM) of 2.51 was used. The specific gravity was found to be 2.6.

2.4 Coarse aggregate

Natural granite aggregate having density of 2700 kg/m³ and finess modulus (FM) of 6.80 was used. The specific gravity was found to be 2.60 and water absorption as 0.45%.

2.5 Terracotta

Hollow blocks that are made using terracotta or burnt clay are called terracotta hollow bricks (TC). Extracted from the mother earth clay products are essentially eco-friendly and made use of in the production of these tiles and make a healthy and reliable environment. The weight of this particular TC blocks is 60% lesser than the cement block of the same size. Of that excellent thermal insulation and sound insulation, water absorption less than 20%, reduction in dead load, and it is faster in construction, good fire resistant. Heel cracks will not be formed by the usage of terracotta floor. Medically proved material for health, etc they are light in weight, rigid, and economical inconstruction. TC blocks are provided with grooves on the top and bottom and sides of the blocks, which provides rigid joints and serves as a key to bonding the concrete. The specification of TC blocks are Density: 700 – 750 kg / m³, U-Value: ~ 1.1 W/m²K, Efflorescence: nil, Compressive Strength: > 3.5 N/mm². The cavities in hollow bricks should not exceed 25% of the total mass.
Methodology

It is seen that in solid slab a portion of concrete below the neutral axis, remains ineffective and contributing to no strength. It is, therefore, possible to eliminate concrete from such tensile zones thereby reducing the dead weight of the slab without affecting its structural stability. Such a slab (with concrete removed) has an appearance of ‘T’ beam and slab construction. A series of small TC joist (137.5 mm x 250 mm x 100 mm) are closely placed at 500 mm c/c. To obtain a plain ceiling effects, the space between terracotta channels ribs are filled with TC roof blocks of size (362.5 mm x 250 mm x 100 mm).

Design calculation - problem

Consider a one way ribbed floor of effective span 3.3m (11’) and 1m wide, and TC joist beams are spaced at 500 mm c/c. Live load of 2.0 kN/m², Floor finish 0.75 kN/m². Use M20 and Fe415. Design constant: \( f_{ck} = 20 \) N/m²; \( f_y = 415 \) N/mm². Analyze the floor slab by using limit state design for solid slab concrete and THB slab concrete, Estimate the quantity requirement such as steel and cement and compare their results.

4.1 Design of ribbed slab

Load acting per square meter area on ribbed area.
Self wt of slab 0.05 x 20 =1.0 kN/m²; Total load = (1.0 + 0.75+ 2.0 = 3.75 kN/m²)
Max limit. moment(3.75 x 0.5² / 10)1.5 =0.175 kN-m Cover to slab = 20mm.
\( \frac{Mu}{bd^2} = \frac{(0.175 x 10^6 ÷ 1000 x 30^2)}{0.87 (415) (0.8) (110)} = 222 \) mm²
Provide minimum reinforcements 0.12 % BD = 0.12 x 1000 x 50 = 180 mm²
Provide D6 100 mm c/c.( main); Provide distribution steel as D4 at 150 mm c/c.

4.2 Design of terracotta beam or channels

Load per meter length of channel; load from slab = 3.75 kN/m² x 0.5 = 1.875 kN/m; Self wt. of THB beam + THB = [(80 N+ 316 N) ÷ (1000 ÷250) ] =1.58kN/m . Total Load=1.875+1.584=3.46 kN/m; Effective span = 3.30 m; Max BM required for flexure = (3.46x3.3² ÷ 8) x 1.5 = 7.06 kN-m. Moment available by the ‘T’ beam (Assume \( X_d = D_f \) ) =0.36 \( f_y b_d (d-0.416 D_f) \) [18]  Moment available = 0.36 (20) (500) (50) [ 105 – 0.416 50] = 15.16 kN-m. Area of reinforcement = 7.06 x 10⁶ ÷ 0.87 (415) (0.8) (110) = 222 mm² Steel consumption per sq. meter area = (2.2+0.65+4.34)=7.19 kg/m²

4.3 Design of solid slab & steel utilization calculation

Load per square meter area; self weight. 0.15 x 24 = 3.6 kN/m²; F.L + L.L=2.75 kN/m² ; Total load = 6.35 kN/m².
Max limit.BM = (6.35 x 3.3² / 8) x 1.5= 12.97kN-m.Use D10 at 150 mm c/c as main bar D8 mm at150 mm c/c as distributor. Steel consumption per sq. meter area=4.11+2.6+6.71+25% top reinforcement =8.39 kg /m²Steel saving for both slab{(8.39-7.19) - 7.19) *100=16.7%.

5 Mix Design & Test Procedure

No standard method of designing concrete mixes incorporating Fly ash, Quarry dust and 6mm chips. The procedure of mix proportioning is to produce the required properties in both plastic and hardened concrete by working out a combination of available material with various economic and practical standards. As per Indian Standard for M20 grade mix design will be taken as 1:1.48:2.72. The 150 mm size concrete cubes, concrete beams of size 100 x 100 x 500 mm and cylinder of size 150 mm dia and 300 mm height were used to determine (i) compressive strength (ii) splitting tensile strength (iii) flexural strength. The specimens were cost for M20 grade with different combinations.

5.1 Sample A :

OPC with F.A (natural sand) C.A (20 mm)
5.2 Sample B

OPC 75% + fly ash 25% + 50% natural sand F.A + 50% Quarry dust + 20% 6 mm C.A + 80% C.A (20 mm).

5.3 Sample C

OPC 70% + fly ash 30% + 50% natural sand as F.A + 50% Quarry dust + 30% 6 mm C.A + 70% C.A (20 mm).

5.4 Sample D

OPC 60% + fly ash 40% + 60% natural sand as F.A + 40% Quarry dust + 30% 6 mm C.A + 60% C.A (20 mm.)

Table 1. M20 (Mix ratio 1:1.48:2.72) by weight

<table>
<thead>
<tr>
<th>Ref</th>
<th>Grade of concrete</th>
<th>Combination</th>
<th>W/C ratio</th>
<th>Comp strength @ 28 days MPa</th>
<th>Flexure strength MPa</th>
<th>Split tensile MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>M20</td>
<td>100 - 100 - 100 - 0.4</td>
<td>55</td>
<td>24.40</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>M20</td>
<td>75 25 50 50 80 20 0.45</td>
<td>56</td>
<td>23.40</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>M20</td>
<td>70 30 580 50 70 30 0.43</td>
<td>57</td>
<td>22.60</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>M20</td>
<td>60 40 50 50 60 40 0.48</td>
<td>53</td>
<td>21.60</td>
<td>6.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Cost comparison per 10 square metre floor area,

( rate adopted in Chennai city, Tamil Nadu state, India a on 24 – 09 -2011)

<table>
<thead>
<tr>
<th>Material</th>
<th>Solid slab concrete</th>
<th>THB slab concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Qty</td>
<td>Rate per RS.</td>
</tr>
<tr>
<td>Concrete M20</td>
<td>1.5 m³</td>
<td>3250/m³</td>
</tr>
<tr>
<td>Fly ash concrete</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ceiling plaster 1:3, 12mm thk</td>
<td>10 m²</td>
<td>2500/10m²</td>
</tr>
<tr>
<td>Centering</td>
<td>10 m²</td>
<td>2000/10m²</td>
</tr>
<tr>
<td>Steel</td>
<td>84 kg</td>
<td>35/kg</td>
</tr>
<tr>
<td>Steel fabrication charges</td>
<td>10 m²</td>
<td>60/m²</td>
</tr>
<tr>
<td>Cost of THB block set</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fab. Charge for THB beam</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
6 Construction technique

Fourteen THB- Beams are stocked in series one after the other for a given span 3.3 m. THB- Beam have three semi circular cavity portion for placing the reinforcement as two were located at bottom and one at the top as shown in figure. Further the designed reinforcement was placed in the bottom with 2 numbers (12 mm \(\phi\)). Also one number of 8 mm \(\phi\) in top for better bonding with concrete and it doesn’t require any design calculation. The cavity portions were filled by the mix proportion of 1 cement and 2 quarry dust. It was allowed for three day wet curing. Centering was prepared for the floor slab to hold THB-beam & blocks. The THB beams were spaced @ 500 mm c/c. THB blocks were filled the gaps between THB beams. Reinforcements were placed over the THB slab. The designed fly ash concrete were poured.

7 Result and Discussions

Mix proportions weredesigned by trial casting techniques towards achieving the better strength. The mix proportion ratios were arrived with 70 % cement + 30 % fly ash + 50 % natural sand + 50 % quarry dust & 80 % coarse aggregate + 20 % of 6mm stone chips obtained from quarry dust. The above combinations revealed an equal/better or acceptable value in terms of compressive strength, flexural strength and split tensile strength. The results were compared with conventional concrete using cement, natural sand and course aggregate.

7.1 Fly ash

In this project 30 % of fly ash is used as a replacement for cement in the proposed mix. The greatest challenge before the concrete technologists is to serve the need of the human society, namely the protection of the environment. The use of fly ash will lead us to reduce the air pollution in turn reflecting lesser emission of green house gases like CO\(_2\). Recent amendment from the Government of India (ISS: 455 - 2000) permits the usage of fly ash from 15 % to 35 % instead earlier value 25%. Hence utilization of fly ash can be achieved only by making strict enforcements by the Government.
7.2 Quarry Dust

The study reveals that the 50% use of quarry dusts lead to the reduction of natural sand usage. And it will minimize the acute shortage of river sand and lower down the cost. Large-scale natural resource depletion through mining of natural river sand can be minimized towards conserving the resources.

7.3 Terracotta hollow block (THB)

Partial replacements of concrete portions with THB slab were proved in reducing the dead load. Further THB acts as an excellent thermal and sound insulator. Medically proved materials for health were used in floor slab.

7.4 Quantity Comparison

It has been proved in the construction of floor slab that the following material savings could be possible (i) cement with 70% (ii) CA with 75% (iii) Natural sand with 80% and (iv) steel with 14%.

7.5 Cost Comparison

The cost of the solid slab concrete and THB slab were compared with Chennai schedule of rates and found 20% lower for the proposed slab construction.
Conclusion

It is seen that the replacement of concrete portion below the neutral axis by terracotta blocks helps to reduce the dead load of the structure. Further it leads to minimize the project cost. It is concluded that the usage of terracotta blocks in buildings are the favorable choice of environmentalist and eco friendly. This study reveals the relative performance of concrete, by cement with 30% fly ash, natural sand with 50% quarry dust and coarse aggregates with 20% 6mm stone chips. It is concluded that the partial replacement of main constituents of concrete is possible with fly ash, quarry dust and 6mm stone chips and attained better strength. This study project also concluded that the usage of by product materials such as fly ash, quarry dust and 6mm stone chips is economic viability and cost reduction factor to the project. The usage of fly ash in concrete contributes the reduction of green house emission.

References:

[17] All India seminar on fly ash utilization & disposal on 11th& 12th oct, 2003 – The Institution Of Engineers ( India)