FEASIBILITY STUDY ON CONVENTIONAL CONCRETE AND CELLULAR LIGHT WEIGHT CONCRETE (FOAMED CONCRETE)

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ABSTRACT

Lightweight Concrete is a type of concrete which contains an expanding agent which increases the volume of the mixture while giving additional qualities such as nailbility and reduces the dead weight. It is lighter than the conventional concrete used. Countries like USA, United Kingdom and Sweden has been using lightweight concrete regularly in recent times. Lightweight Foamed Concrete[2] (LWC) has been successfully used and it has gained popularity due to its lower density than conventional concrete. It is created by uniform distribution of air bubbles throughout the mass of concrete. Recently, most studies on LWC concern on the influence of filler type and the particle size of sand on the strength. In this research, the strength of LWC with density 1600 kg/m^3, 1800 kg/m^3 and 2000 kg/m^3 was produced due to different percentage of foam as aggregate replacement by Fly ash[3]. Lightweight Concrete has low density as well as low thermal conductivity. Other advantages include reduction of dead load, faster building rates in construction and lower haulage and handling costs. Lightweight Concrete maintains its large voids also the feature of not forming laitance layers or cement films when placed on the wall. This research is based on the performance analysis of aerated lightweight concrete[4].

INTRODUCTION

Cellular Concrete is a lightweight product mixture of Portland cement, Cement pozzolana, Fine aggregates, Lime-pozzolana or Lime-sand pastes or pastes containing blends of these ingredients and having a homogeneous void or cell structure, attained with gas forming chemicals or foaming agents. For cellular concretes, containing binder ingredients other than or in addition to Portland cement, autoclave curing is usually employed.

Other advantages of foamed concrete are self-compacting, free flowing and pumpable. These concrete can be considered relatively homogeneous when compared to normal concrete, as it does not contain coarse aggregate phase. The type of binder used, methods of pre-foamation and curing plays an important role on properties of these concretes depending upon microstructure and composition. Formerly it has been widely recognized as an insulation material, but now a renewed interest is shown by researchers and agencies working in construction sectors in its structural character exhibits.

As the production involves the materials of low density; a few fillers viz fly ash, quarry dust, GGBS and sludge from paper mills are used. An attempt has been made in the present investigations to produce foamed concrete of desired density 1600 kg/m3 to 1800 kg/m3. Then their strength properties viz compressive strength, flexural strength and the resistance against sulphate attack were investigated and the results are reported.

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1.1 TYPES OF LIGHTWEIGHT CONCRETE

Lightweight concrete can be prepared by two methods viz injecting air in its composition or by omitting the finer sizes of the aggregate or even replacing them by a hollow, cellular or porous aggregate. Particularly, lightweight concrete can be categorized into three groups:

i. No-fines concrete
ii. Lightweight aggregate concrete
iii. Aerated/Foamed concrete

1.2 ADVANTAGES & DISADVANTAGES OF LIGHTWEIGHT CONCRETE

Sr. No.	Advantages	Disadvantages
1.	Fast and relatively simple construction	Very sensitive with water content in the mixtures
2.	Cheap in terms of transportation as well as reduction in manpower	Placing and finishing is difficult because of the porosity and the angularity of the aggregate. In some mixes cement mortar may get separate and float towards the surface
3.	Significant reduction of overall weight results in saving in structural frames, piles or footings.	Takes more time for mixing as compared to Conventional Concrete

1.3 APPLICATIONS OF LIGHTWEIGHT CONCRETE

Lightweight concrete has been used by the Romans since the eighteen centuries. The application on the 'The Pantheon' where it uses pumice aggregate in the construction of cast in-situ concrete is the proof of its usage. Nowadays with the advances in technology, lightweight concrete expands its uses. It is extensively used as loose-fill insulation in masonry construction where it increases fire ratings, reduces noise transmission, does not rot and termite resistant. It is also used for vessels, roof decks and other applications.

1.4 APPLICATIONS OF FOAMING AGENT

Chemical foaming agents are used in a varying range of applications in plastics and rubber processing.

By choosing the right foaming agent system following features can be achieved

i. Weight reduction,
ii. Raw material and cost saving,
iii. Dimensional stability,
iv. Heat insulation,
v. Noise absorption and
vi. Special surface effects

MIX DESIGN

The properties of concrete desired in any application are adequate strength with long term durability and appropriate economy. These essential properties are achieved in any particular set of circumstances by the selection of suitable materials, the choice of mix proportions and the use of proper methods of placement and curing. The main difference lies in the fact that the workability of the mix and the type of maximum size of aggregate as well as strength requirement influence the selection of w/c ratio. The production of high strength concrete requires the suppliers to optimize the three aspects of concrete that affect strength; Cement paste, Aggregate and Cement aggregate bond. To do this it is necessary to play careful attention to all aspects of concrete election of materials, mix design, handling, placing and compaction. The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design.

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2.1 MIX PROPORTION

The mix proportion of the lightweight foamed concrete incorporated with Fly Ash was determined based on trial and error method. Trial mixes with various w/c ratios were carried out. The optimum mix proportion was determined based on density and strength of lightweight foamed concrete incorporated with Fly Ash.

2.2 TRIAL MIX

During the trial mix stage, three types of mix proportion, namely LFC with 100% sand as filler, 10% Fly Ash replacement as part of filler and 20% Fly Ash replacement as part of filler. The water to cement ratio for each type of mix proportion was tried from the range of 0.52 to 0.60 with the increment of 0.02 for each mix. Density for every mix was controlled to 1300 kg/m^3 ± 50 kg/m^3.

2.3 MIXING PROCEDURE

Ordinary Portland cement, Sand and Fly Ash were weighted and mixed in a concrete mixer until the dry mix was uniformly mixed. Next, water was weighted and added into the dry mix. The mix was mixed until the wet mix was uniformly mixed. Followed by that, an amount of foam was weighted and added into the wet mix repeatedly until the desired density, 1300 kg/m^3 ± 50 kg/m^3 was achieved. Lastly, inverted slump test was carried out before fresh lightweight foamed concrete was poured into the mould.

2.4 MIX DESIGN ANALYSIS

Table -1: Mix Design for Grade M20

STIPULATION FOR PROPORTIONING	
a)Grade Designation(M)	**20**
b) Type of cement	OPC 53 grade confirming to IS 12269
c) Type of mineral admixture	Fly ash confirming to IS 3812 (part 1)
d)Maximum nominal size of aggregate	**20 mm**
e) Minimum cement content	**320 kg/m^3**
f) Maximum water-cement ratio	**0.45**
g) Workability	**60-80 mm** Slump
h)Exposure condition	Sever (for reinforced concrete)
i)Method of concrete placing	Pumping
j)Degree of supervision	Good
k)Type of aggregate	Crushed angular aggregate
l) Maximum cement (OPC) content	**450 kg/m^3**
m)Chemical admixture type	Super plasticizer
TEST DATA FOR MATERIALS	
a) Cement used	OPC 53 grade confirming to IS 12269
b) Specific gravity of cement	**3.15**
c) Fly ash	Confirming to IS 3812 (part 1)
d) Specific gravity of fly ash	**2.3**
e)Chemical admixture	Super plasticizer conforming to IS 9103
f) Specific gravity of: Coarse aggregate = **2.74%** Fine aggregate = **2.74%**	
g) Water absorption: Coarse aggregate = **0.5%** Fine aggregate = **1.00%**	
h) Free (surface) moisture: Coarse aggregate = Nil (absorbed moisture also nil) Fine aggregate = Nil	
i) Sieve analysis: Coarse aggregate = Confirming to grading Zone I of Table 4 of IS 383 Fine aggregate = Confirming to grading Zone I of Table 4 of IS 383	

TARGET STRENGTH FOR MIXED PROPORTIONING
fck = fck + 1.65 s Where, fck = target average compressive strength 28 days fck = characteristics compressive strength at 28 days and s = standard deviation From table 1 standard deviation, s = 5 N/mm2 Therefore, target strength = 30+(1.65 x 5) = **38.25 N/mm^2**

SELECTION OF WATER-CEMENT RATIO
From table 5 of IS 456, maximum water-cement ratio(see Note under 4.1) = **0.45** Based on experience, adopt water-cement ratio as **0.40** **0.40 < 0.45**, hence O.K.

SELECTION OF WATER CONTENT	
content for 20mm aggregate from table2, maximum water	**186 Litres** (for 25 to 50 mm slump range)
Estimated water content for 100 mm slump	**197 Litres**
As Superplasticizer is used, the water content up to 30%. Based on trials with Superplasticizer water content reduction of **5.00%** has been achieved. Hence, the arrived water content = 197 litres	

CALCULATION OF CEMENT CONTENT	
Water-cement ratio	**0.40**
Cementitious material cement content	**490 kg/m^3**
Minimum cement content for 'moderate' exposure conditions 490>320 kg/m^3 ok.	**320 kg/m^3**

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT
From Table 3, Volume of coarse corresponding to 20 mm size aggregate and fine aggregate (Zone 1) for water-cement ratio of 0.50 = 0.60. In the present case water-cement ratio is 0.40. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10, the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every = -0.05 change in water-cement ratio). Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.62 Note- In case of coarse aggregate is not angular one, then also volume of coarse aggregate may be required to be increased suitably, based on experience. For pumpable concrete these values should be reduced by 10%. Therefore, volume of coarse aggregate = 0.62 Volume of fine aggregate content = 1-0.62 = 0.38

MIX CALCULATIONS	
The mix calculations per unit volume of concrete shall be as follows :	
a) Volume of concrete	**1 m3**
b) Volume of cement	**0.156 m3**
c) Volume water	**0.197 m3**
d) Volume all in aggregate	**0.647 m3**
g) Mass of coarse aggregate	**1100 kg**
h) Mass of fine aggregate	**674 kg**
Volume	**1000 Litres**

MIX PROPORTIONS FOR TRIAL NUMBER	
Cement	**490 kg**
Water	**197 Lit**
Fine aggregate	**674 kg**
Coarse aggregate	**1100 kg**
Water-cement ratio*	**0.40**
*Aggregates should be used in saturated surface dry condition. If otherwise, when computing the requirement of mixing water, allowance shall be for the free (surface) moisture contributed by the fine and coarse aggregates.	

CONCRETE TEST RESULTS

The Concrete test result includes; Compressive Strength Test, Water Absorption and Concrete Density Test for different trial mix of the lightweight concrete.

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Table -2: Compressive Strength Test Results

Plain Cement Concrete	Foam Concrete		
2300 kg/m^3	**2000 kg/m^3**	**1800 kg/m^3**	**1600 kg/m^3**
Load (KN)			
214	182.3	137	70
234	171.1	120.8	56.6
343	217(Oven Dried)	155.6(Oven Dried)	160.6(Oven Dried)
Displacement (mm)			
1.50	2.63	0.36	1.00
1.83	2.39	1.22	1.01
4.10	2.15	1.05	1.07
Mean Load (KN)			
263.33	190.13	137.80	95.73
Compressive Strength (N/mm^2)			
11.71	8.45	6.12	4.25

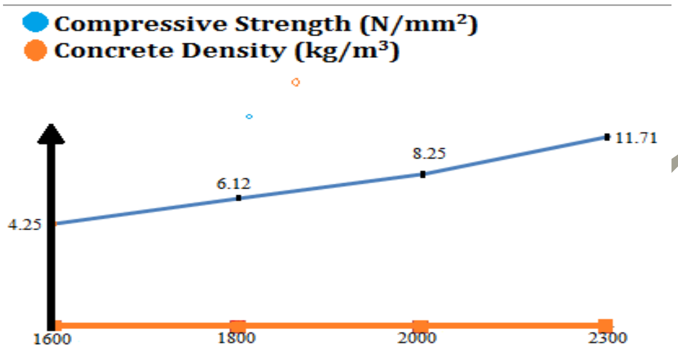

Chart -1: Compressive Strength v/s Concrete Density

Table -3: Water Absorption Test Results

Concrete Densities Kg/m^3	Oven Dry (Dry Wt.) Kgs.	Water Absorption (Wet Wt.) Kgs.	Water Absorbed (%)
Plain Cement Concrete			
2300	4.663	7.82	40
Foam Concrete			
2000	3.871	6.84	43
1800	3.540	6.38	44
1600	3.033	5.54	45

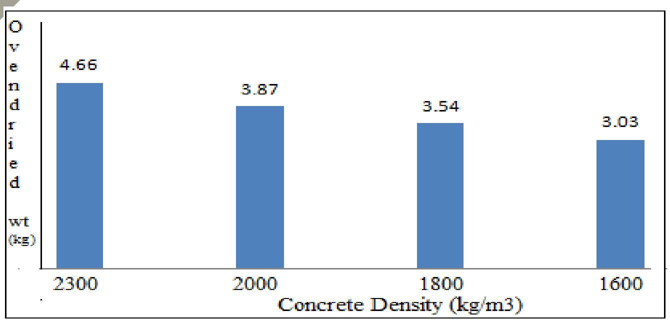

Chart -2: Concrete Density v/s Oven Dried Weight

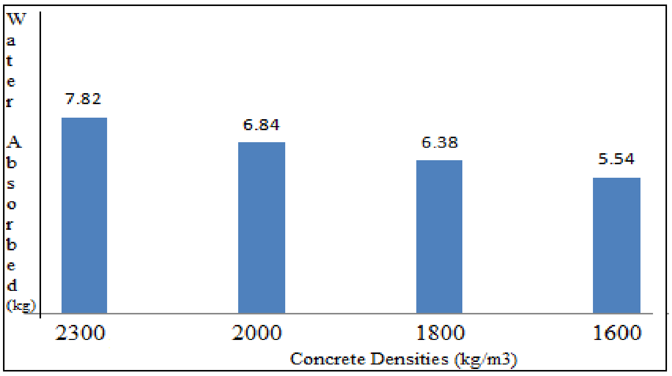

Chart -3: Concrete Density v/s Water Absorption

CONCLUSIONS

- Based on the laboratory results, the following conclusions can be drawn corresponding to the respective objective that are listed out at the beginning of this study.
- The main objective was achieved, by producing Lightweight Foamed Concrete with densities of 1600, 1800 and 2000 kg/m^3. This was achieved by varying percentages of Foaming Agent and it can be concluded that; as the percentage of Foaming Agent increases Density decreases.
- Foam Concrete can be used for constructing structural member and it can be stated that as the results obtained for Conventional Concrete and Foam Concrete for Compression Test were nearly same, so Foam Concrete can be used for constructing structural member and thus structure becomes lightweight.
- Effect of different types of Curing on Compressive Strength of Foam Concrete seen that results obtained shown that concrete cured with Steam Curing gives better results than Conventional Curing.

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