Experimental Investigation on Workability and Density of Medium-Range Foam Concrete with Hybrid Fibers

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Abstract: As the unit weight of conventional concrete ranges from 2200-2400 kg/m^3. But, foam concrete unit weight ranges from 350-1900 kg/m^3. Today the foam concrete becomes popular due to easily workable, low density and economical when compared to conventional concrete. The foam concrete is considered as sustainable construction material as it having low thermal conductivity and sound insulation. This investigation involves the preparation of foam concrete with a density of 1000 kg/m^3 and mixed with hybrid fibers such as polypropylene fibers and Nylon fibers to reinforce the mix. This investigation studies the mechanical properties such as compressive and tensile strength at different volume fractions of Polypropylene fibers that is at 0%,0.5%, 0.75% and 1% also with a combination of hybrid fibers fraction such as (0.75% of PF + 0.25% of NF), (0.25% of PF + 0.75% of NF) and 1% of nylon fibers were used. The foam concrete was mixed with designed proportions and thereafter tested for flow ability that is workability, plastic density, dry density against standard specimens.

1 Introduction

At the moment there is a large demand for foam concrete in the construction industry due to its lightweight and easy preparation. In general, the density of conventional concrete ranges from 2200 kg/m^3 – 2400 kg/m^3 but the foam concrete the density ranges from 350 – 1900 kg/m^3. Therefore, the dry density of foam concrete is 20% - 80% lighter than conventional concrete. The lower density concrete can be achieved by introducing air bubbles/voids in the concrete. The foam concrete is classified into different forms based on their densities – low-density foam concrete 300-600 kg/m^3 which is commonly used for insulation and filling purpose and whereas medium-density foam concrete 800-1200 kg/m^3 which is commonly used for non-loading bearing structures and high-density foam concrete 1200-1800 kg/m^3 used for load-bearing structures. Amritha Raj et al.. [1-2] reviewed the physical properties such as the workability and densities of foam concrete. Shibi Varghese et al. [3] studied the role of various foaming agents and their performance in foam generation. Anju P Rajan and Aneeta Anna Raju, [4] explained through experimental studies Strength of foamed concrete will vary with volume of foam content. In foam concrete the usage of aggregates can be eliminated partially, in addition to this filler materials such as Fly ash, silica fume, etc; can be used which gives better flow ability and plastic density properties. In fact with a decrease in the density of concrete ultimately strength of the concrete also decreases. Many investigators studied [5-7] and reported fresh state, physical and mechanical properties of foam concrete. Ashfaque Ahmed [8-10] et al. concluded that plastic and dry densities of foamed concrete are enhanced with fibres. Satyanarayana, G.V.V., and Chaitanya, B.K. [11] studied the durability of M 60 grade concrete for sustainability. So that in this investigation additives such as hybrid fibers such as Polypropylene and Nylon fibers were used in the foam concrete to study workability and plastic and dry densities of Medium-Range Foam Concrete with Hybrid Fibers. The foam concrete mix designed as per I.S. codal provisions [12].

2 Materials

The materials utilized in the preparation of foam concrete were OPC 53 grade cement, Fly ash, water, Foaming agent to prepare Foam and Polypropylene and Nylon fibers.

2.1 Ordinary Portland cement

In this investigation OPC 53 grade cement was used for the preparation of all foam concrete mixes. Fresh and no lumps were found in the cement. Cement was tested as per IS 12269-1987 and confirmed its utility.

Table 1. Characteristics of Cement

CHARACTERISTICS	OBSERVED VALUES
Normal consistency	30%
Initial setting time	55 min
Specific gravity	3.159
Compressive strength at 28 days	58 MPa

2.2 Fly ash

Fly ash was used in foam concrete as a replacement of sand. The usage of sand fails the foam concrete against density and specific gravity. Fine fly ash was used in the preparation of foam concrete. The Physical properties of Fly ash obtained from the supplier.

Table 2. Physical Properties of Fly ash

CHARACTERISTICS	VALUES
Specific gravity	2.07
Fineness	290 m^2/kg
Bulk density	1100-1200 kg/m^3
Colour	Light grey

2.2.1 Chemical Composition of Flyash

Table 3. Chemical Properties of Fly ash

COMPONENTS	VALUES (%)
CaO	12.34
SiO_2	72.08
Al_2O_3	5.15
Fe_2O_3	0.57
MgO	4.04
Loss of Ignition	0.76

2.3 WATER

Water used in this investigation for preparation of foam concrete confirmed as potable having PH 7. Water does not have any organic contamination which affects the quality of foam (especially for synthetic foaming agents). The Water /cement ratio is suggested by earlier researchers ranging between 0.4 to1.25. If the water/cement ratio is low which results in stiff mix and it draws water from the foam which leads to breakage of bubbles and the mix will be crumble.

2.4 Foam

The Foam was prepared with the help of the foam generator. In this foaming agent was filled after dilution with water in the ratio 1:20. By this process, proper foam will generate. The pre-foaming solution was expanded to foam in the presence of air at constant air movement of 2-3 MPa. The foam bubbles were stable and able to resist the physical and chemical forces imposed during pumping, placing and curing of concrete. The stability of bubbles depends on the quality of the foaming agent and the density of foam produced.

2.4.1 Foaming Agents

There are two types of foaming agents. These are

1. Synthetic foaming agent.
2. Protein based foaming agent.

In this investigation Synthetic foaming agent that is Sodium Laureth Sulfate (**SLES**) was used. The density of the synthetic foaming agent is around 1041g/litre. The synthetic foaming agent was obtained from the soap manufacturing industries and the recommended dosage ranges from 20-30ml per litre of water. The Physical properties of Sodium Laureth Sulfate obtained from the supplier.

Fig. 1. Sodium Laureth Sulfate (SLES)

Table 4. Properties of Foaming Agent

CHARACTERISTICS	VALUES
Specific gravity	1.047
Colour	Colourless (Transparent)
Ph	≥7
Density of foam	66-85 kg/m^3

Fig. 2. Experimental setup for production of foam

2.5 Hybrid Fibers

Hybrid fibers such as Polypropylene and Nylon fibers were added to the foam concrete to improve the physical and mechanical of the foam concrete

2.5.1 Polypropylene Fibers

Table 5. Properties of Polypropylene Fibers

CHARACTERISTICS	VALUES
Fiber length	12mm
Specific gravity	0.91
Melting point	165-175^{0}C
Tensile strength	350-400 MPa
Colour	white
Chemical Resistance	Very good

2.5.2 Nylon Fibers

Table 6. Properties of Polypropylene Fibers

CHARACTERISTICS	VALUES
Fiber length	12mm
Specific gravity	0.91
Melting point	165-175^{0}C
Tensile strength	350-400 Mpa
Colour	white
Chemical Resistance	Very good

3 Methodology

The foaming agent Sodium Laureth Sulfate (SLES) was diluted with water in the ratio 1:20 and poured into the foam generator, through which constant air is passed about 2- 3MPa using an air compressor and the foam produced from the foam lance. Investigation work procedure starts with batching of all materials as per design quantity for each mix and add required quantity fibers at different volume fraction such as at 0%, 0.5%, 0.75% and 1% and also combined hybrid fiber fraction of 0.75% of PF + 0.25% of NF and 0.25% of PF + 0.75% of NF of nylon fibers were mixed in the mixer. Now add a designed amount of water and generated foam was added in the mixer. Hence the foam concrete was formed. Before pouring into the mould check the wet density of foam concrete. If the density is higher than the target density then add additional pre-foam to the mix and if the density lower than the target density add cement motor to the mix. Then foam concrete poured in moulds of size 150mm×150mm×150mm and the specimens were de-moulded after 24hours. And all the samples put for water curing for 7, 14 and 28 days thereafter dry density and compressive strength were determined.

4 EXPERIMENTAL INVESTIGATIONS

For conventional concrete mix design technique is utilised in various nations are mostly dependent on the empirical relationships, charts, and graphs created from extensive trail examinations. But in foam concrete, there are no standard methods for proportioning the quantities of foam concrete. With available literatures, we came to know that density is the primary factor to be considered. So, density should be used for mix designing. So the first stage of mix design is Target Density rather than target mean strength in conventional concrete.

4.1 Mix Proportions for Foam Concrete

Assuming a target density (D, kg/m^3), cement content (C, kg/m^3), Fly ash content (F, kg/m^3), water /cement ratio (w/c), sand/cement ratio (s/c) and total water content (W, kg/m^3),Specific gravity of cement(s_c),Specific gravity of water (s_w), Specific gravity of Fly ash (s_f).

Target density, D = Cement content (C) + fly ash content (F)+ Water content (W)

Volume of Foam to be added is given by

V (m^{3}of concrete) = V_f (foam) + V (cement) +

V(water) + V (fly ash)

$$\text{For 1 m}^3 = V_f(\text{foam}) + \frac{weightofcement}{ScXDw} + \frac{weightofwater}{SwXDw} + \frac{weight\ of\ Flyash}{Sf\ X\ Dw}$$

4.2 Mix Proportions For The Target Density 1000 Kg/M^3

Target density foam concrete = 1000 kg/m^3

Water / cement ratio is taken based on different trail mixes w/c = 0.8

Flyash/cement ratio is also considered based on different trail mixes f/c= 2

1000 kg/m3 = C + 2.0C + 0.8C

Cement content (C) = 263.15 kg/m^3

flyash content (s) = 526.35 kg/m^3

Water content (W) = 210.52 kg/m^3

$$\text{The volume of foam } (V_f) = 1-\left(\frac{263.15}{3.14\ X\ 1000} + \frac{526.35}{2.07\ X\ 1000} + \frac{210.52}{1\ X\ 1000}\right)$$

V_F = 0.425 m^3

4.2.1 Mix-1 (0% PF+ 0% NF + Cement + Fly ash+ Water)

Table 7. Foam Concrete Mix-1

MATERIALS	VALUES
Cement	263.15 Kg/m^3
Flyash	526.35 Kg/m^3
Water Content	210.52 Kg/m^3

4.2.2 Mix-2 (0.5% PF+ 0% NF + Cement + Fly ash+ Water)

Quantity of fiber is added based on the total volume of concrete.

Table 8. Foam Concrete Mix-2

MATERIALS	VALUES
Cement	263.15 Kg/m^3
Flyash	526.35 Kg/m^3
Water Content	210.52 Kg/m^3
PF (0.5%)	61.425 g

4.2.3 Mix-3 (0.75%PF+ 0%Nf+ Cement + Fly ash+ Water)

Table 9. Foam Concrete Mix-3

MATERIALS	VALUES
Cement	263.15 Kg/m^3
Flyash	526.35 Kg/m^3
Water Content	210.52 Kg/m^3
PF (0.75%)	92.1 g

4.2.4 Mix-4 (1% PF+ 0%NF +Cement + Fly ash+ Water)

Table 10. Foam Concrete Mix-4

MATERIALS	VALUES
Cement	263.15 Kg/m^3
Flyash	526.35 Kg/m^3
Water Content	210.52 Kg/m^3
PF (1%)	122.8 g

4.2.5 Mix-5 (0.75% PF+ 0.25% NF + Cement + Fly ash+ Water)

Table 11. Foam Concrete Mix-5

MATERIALS	VALUES
Cement	263.15 Kg/m^3
Flyash	526.35 Kg/m^3
Water Content	210.52 Kg/m^3
PF(0.75%)	92.1 g
NF (0.25%)	39.15 g

4.2.6 Mix-6 (0.25% PF+ 0.75% NF + Cement + Fly ash+ Water)

Table 12. Foam Concrete Mix-6

MATERIALS	VALUES
Cement	263.15 Kg/m^3
Flyash	526.35 Kg/m^3
Water Content	210.52 Kg/m^3
PF (0.25%)	30.71 g
NF (0.75%)	117.45 g

4.2.7 Mix-7 (0%PF+ 1% NF+ Cement + Fly ash+ Water)

Table 13. Foam Concrete Mix-7

MATERIALS	VALUES
Cement	263.15 Kg/m^3
Flyash	526.35 Kg/m^3
Water Content	210.52 Kg/m^3
NF(1%)	156 g

4.3 Casting and De-moulding

The mould of size 150mm×150mm×150mm was used in the preparation of foam concrete cubes. Cubes are prepared for all the mixes and de-moulded after 24hrs.

4.4 Curing

Before placing the cubes for curing, ensure that target density is reached. Then cubes are placed in potable water for 28 days for complete heat hydration.

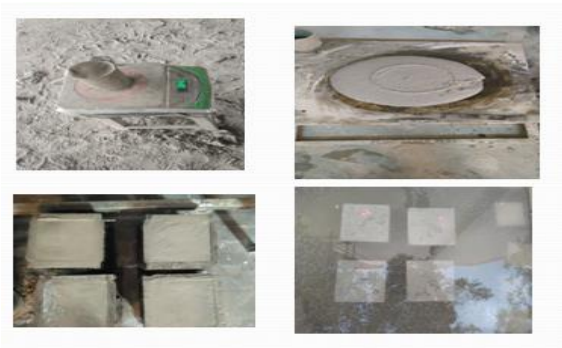

Fig. 3. Preparation of Moulds and Curing

5 TEST RESULTS

5.1 Workability of Foam concrete

Flow table test/ flow test is the method to determine the workability/consistency of foam concrete.

Table 13. Flow Table Test Values

MIX PROPORTIONS	AVERAGE FLOW IN (mm)
Mix-1	420
Mix-2	340
Mix-3	335
Mix-4	332
MIX-5	327
MIX-6	350
MIX-7	355

5.2 Dry Density

All the cubes are dried to a constant mass. Before calculating the density, cubes are kept in the oven and approximately lOO^0 C temperature is maintained. After cooling the blocks to room temperature, the dimensions of each block shall be measured and the overall volume computed. The blocks shall be weighted (to the nearest 10 g). And the average density of each mix is computed.

Density Kg/m^3 $=\frac{weight of cube}{volume of cube}$

Table 13. Densities

Mix Proportion	Plastic Density Kg/m^3	Dry Density Kg/m^3
Mix-1	1035	998
Mix-2	1041	1000.3
Mix-3	1045	1002.1
Mix-4	1050	1002.6
Mix-5	1054	999.5
Mix-6	1049	1000.4
Mix-7	1046	1001.2

6 CONCLUSIONS

Below are the conclusions that made from the inquiry are:

1. The overall workability of foam concrete was decreased when fibres were add but free from balling effect.
2. The consistency of foam concrete decreases with the addition of hybrid fibers
3. The plastic density of foam concrete was marginally increased from 0.6 to 1.8 % with fibres.
4. Maximum percentage of plastic density increased in Mis-5 and minimum in Mix-2.
5. More or less the dry density of foam concrete is similar with and without fibres.
6. The target density was achieved due to the quality of the foaming agent and also dense foam produced from the foam generator by maintaining constant air pressure as per previous literature.

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