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Mechanical Properties of Foam Concrete

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Abstract: The development of construction industries provides countless benefits to the society and the people. At present scenario construction field all around the world is facing a serious problem with price hike of raw materials. So they are very much concern to reduce the consumption of readily available raw materials.. It is also important for engineers to develop ecofriendly material, as environment is getting affected day by day by the increasing construction activities. Usage of foam concrete is an innovative idea to achieve the requirements. Because of its lightweight, the rate of construction is quick and the installation becomes easy. The benefits of gas concrete are endless, which are lightweight in turn saves foundation cost, high load bearing strength, high durability, easy handling and rapid construction, good in sound absorption, earthquake resistant and so on. The focus of this project is to study the properties of lightweight foam concrete with addition of various binders /fillers such as Fly ash, Micro silica, Sio2 powder, clay and Rice husk ash. The results are discussed elaborately with respect to compressive strength, split tensile strength, and water absorption.

Keywords: *Foam concrete, Clay, Fly Ash, Compressive Strength, Split Tensile Strength.*

1. Introduction

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures. Concrete is used more than any other man made material in the world.

In this way or by substitution for the cemetitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties. The adverse development in the field of concrete has led to the innovation of lightweight concrete materials. The development of lightweight concrete is made with a good achievement of performance in their characteristics. The reason for the need of lightweight concrete is to facilitate the rate of construction and to reduce the cost of construction attaining an economical construction practice. At the same time it is essential to reduce the consumption of raw materials for the production of concrete because it involves use of cement which during production emits large volume of CO2. In lightweight concrete it is possible for us to use cement with partial replacement of some other additives, thereby reducing the usage of cement. There are many types of lightweight concrete such as cellular concrete, foamed concrete, aerated or gas concrete. There are many studies going around the world regarding all types of lightweight concrete. Foam concrete is produced when foam is added to cement-based slurry. The foaming agent is diluted with water and aerated to create the foam. The cement paste or slurry sets around the foam bubbles and when the foam being to degenerate, the paste has sufficient strength to maintain its shape around the voids.The optimal value of foam generation pressure (less than 150 kPa) and SLS concentration of around 2% was studied [1]. A control unit of foamed concrete mixture with ordinary Portland cement and 10% and 20% silica fume was prepared and proved that replacing high proportions of cement with silica fume does not significantly affect the long term compressive strength of well cured foamed concrete [2]. Water absorption by complete immersion are measured for various mixes with different fly ash replacement levels for sand and different foam volume and concluded that the water absorption of foam concrete are lower than the corresponding base mixes [3]. The high performance foamed concrete using Portland cement, ultra-fine granulated blast furnace slag, pulverized fly ash and condensed silica fume by means of pre foaming process. The compressive strength of foamed concrete with oven dried bulk density of 1500 Kg/m3 in appropriate mix proportion and with small amount of super plasticizer reached as high as 44.1 Mpa [4].

Variety of foam concretes are designed using different types of pozzalanic materials and tested for its mechanical strengths and durability aspects to find out its utility in the field of construction whether it would be used for structural or non-structural purposes. The results of all characteristic strength and durability test results are presented and discussed in detail.

1.1. Materials Used

Ordinary pozzolana cement of 53 grade, Ennore sand conforming to grade III of particle size less than 0.5mm (500 microns) and greater than 0.09mm (90 microns) conforming to IS: 383 – 1970, various mineral admixtures like fly ash of class f were used, Micro silica, Rice Husk Ash, Sio_2 powder and clay were also used and Sodium Lauryl Sulphate was used as foam agent for a concentration of 1:15, potable tap water is used.

1.2. Mix Proportion and Casting of Specimens

1. Cement + Fly Ash + Sand
2. Cement + (Fly Ash + Micro Silica + Sio_2 Powder) + Sand
3. Cement + Clay + Sand
4. Cement + Rice Husk Ash + Sand

These mixes were casted under these mix ratios as cement: filler: sand. Table 1 shows the mix proportion and volume of foam added for all mixes

1) 1:1:1
2) 1:0.5:1.5
3) 1:0.5:2
4) 1:0.5:3

Table 1: *Mix design of various foam concrete mixes*

Mix Proportion	Mix Ratio	1:1:1			1:0.5:1.5		
	Foam volume (%)	10	30	50	10	30	50
C: FA: S	FC1	C1	C2	C3	C4	C5	C6
C:FA+MS+Sio2:S	FC2	C13	C14	C15	C16	C17	C18
C: Cl: S	FC3	C25	C26	C27	C28	C29	C30
C: RHA : S	FC4	C37	C38	C39	C40	C41	C42

Mix Proportion	Mix Ratio	1:0.5:2			1:0.5:3		
	Foam volume (%)	10	30	50	10	30	50
C: FA: S	FC1	C7	C8	C9	C10	C11	C12
C:FA+MS+Sio_2:S	FC2	C19	C20	C21	C22	C23	C24
C: Cl: S	FC3	C31	C32	C33	C34	C35	C36
C: RHA : S	FC4	C43	C44	C45	C46	C47	C48

The quantity of slurry required to fill the moulds which are to be casted are calculated first and then the foam volume is taken as 10% of the slurry volume. Similarly the foam concrete with 30% foam and 50% foam was casted for each mix proportion under each mix ratio.
The table above shows the weight proportion of each mix proportion under the mix ratio of 1:1:1 with 10%, 30% and 50% foam volume. The quantity of slurry is calculated for 2 cubes of size 100mm*100mm*100mm and 2 cylinders of size 46mm diameter and 82mm height.

1.3. Tests

The tests comprised of evaluation of physical properties, mechanical properties and structural properties.

1. Evaluation of physical properties
   1.1. Dry density
   1.2. Water absorption
2. Evaluation of mechanical properties
   2.1. Cube compression test
   2.2. Split tensile test

1.4. Test Procedures

1.4.1. Dry density

For the determination of dry density of the cured mortar mixture samples, specimen of size 46mm diameter and 82 mm length were cast and cured for 28 days in water. As per ASTM C 642-97, the cured samples must be free from observable cracks, fissures and shattered edges. The dry density of the sample is calculated as

Dry Density (ρ) = Dry Mass of the Specimen / Volume of the specimen.

1.4.2. Water Absorption

For the determination of water absorption of the cured samples, specimen of size 46mm diameter and 82mm length were used. The mass of water absorbed by the dry mass of specimen gives the capacity of water absorption. It's normally expressed in percentage.

Percentage of Water Absorption = (B-A/A)*100

Where

A = Mass of the oven dried sample.
B = Mass of the saturated sample.

1.4.3. Cube Compression test (f_{cu}) : (ASTM C109/C109M)

For the determination of cube compressive strength of concrete with specimen of size 100 x 100 x 100 mm were cast and cured for 28 days in tap water. After that specimens were dried in open air until constant weight was attained for all specimens, then subjected to cube compression testing. Figure 1 shows cube compression test equipment. The rate of loading was adjusted as 0.5

kN/s.; the cube compressive strength (f_{cu}) was computed from the fundamental principle as

f_{cu}= load at failure / Cross sectional area= P/A_s (N/mm^2)

Where,

P = Load at failure (N)
A = Area of the specimen (mm^2)

***Figure 1:** Cube compression test*

1.4.4. Splitting tensile strength testing

For the determination of splitting tensile strength of mortar, cylinder specimen of diameter to length ratio 1:2 was selected, with diameter 50 mm and the length as 100 mm. Specimens were dried in open air after 28 days water curing until constant weight was attained for all specimens, then subjected to splitting tensile test under universal testing machine., with the rate of loading as 0.11 to 0.023 Mpa/sec as per ASTM standards ASTMC 490-96. While testing the specimen, plywood pieces are placed one a top and the other at the bottom. Figure 2 shows the equipment for split tensile test. The splitting tensile strength (f_{sp}) was computed from the following formula. f_{sp}= 2P/πdl (N/mm^2)

Where

P= Load at Failure (N)
d = diameter of the specimen (mm)
l = length of the specimen (mm)

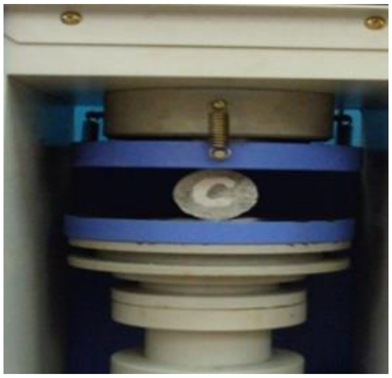

***Figure 2:** Cylinder split tensile test*

2. Results and Discussions

2.1. Dry Density

The fig 3 and 4 shows highest dry density obtained by incorporation of clay and the lowest dry density obtained for the mortar mix made by incorporating rice husk ash .For other mixes which incorporated with fly ash, micro silica , SiO_2 falls in between range. High density of mix uses clay is due to the fact that clay provides high density compared to rice husk ash mix. The fact is that rice husk is low in density, it is also attributed to the fact that rice husk ash has a filler effect with cellular structured material and thus low in density of mortar.

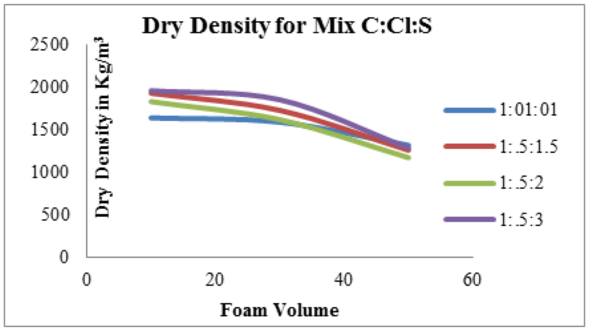

***Figure3:** Dry density for mix C: Cl: S*

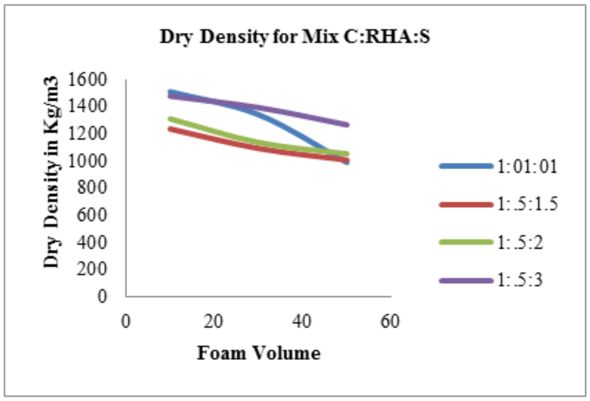

***Figure 4:** Dry density for mix C: RHA: S*

2.2. Water Absorption

Water absorption is carried out for all specimens and found, highest water absorption was found in the material incorporated with rice husk ash mixed mortar and lowest water absorption was obtained for incorporating fly ash mixed mortar. This is due to the fact that rice husk ash is highly porous and cellular structured material and hence it absorbs more water than the fly ash mixed specimens. Water absorption is higher when compared with control mix in all other mixes. . In some cases where rice husk ash is added, the water absorption is 39.28% as against 2.73% for control mix. Fig 5 shows high water absorption for rice hush ash mixed foam concrete and the lowest water absorption for fly ash added foam concrete in fig 6. The highest water absorption is found in both cases for 50% of foam volume. The water absorption was found lower at 10% of foam volume, this is again due to micro structure of foam concrete.

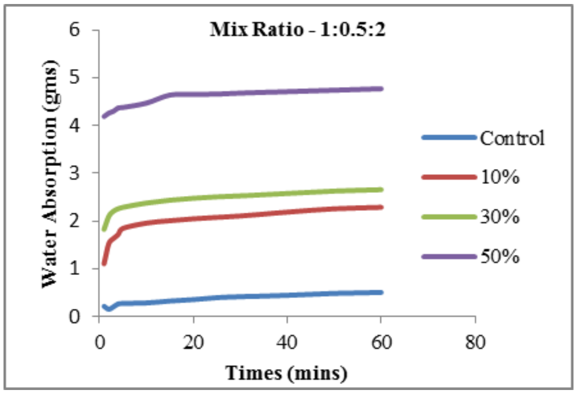

Figure 5: *Water Absorption of the mix C: RHA: S*

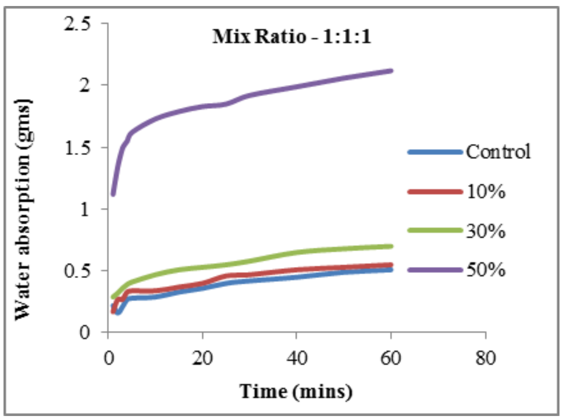

Figure 6: *Water Absorption of the mix C: FA: S*

2.3. Cube compression Test

The cube compression test was carried out for all foam concrete specimens. The fig.7 to 8 shows, the cube compressive strengths measured less for all the foam concrete compared to control mix. The foam concrete made out of fly ash, micro silica and sio_2 powder (fig. 9) proves to be significantly high compressive strength compared to control mix.The increase of this compressive strength is in the range of 25.38 N/mm^2 and 24.2 N/mm^2 which shows that this foam concretes are satisfactorily be used for structural applications or load bearing purposes. The fly ash based foam concretes are fit for structural applications in addition to thermal and sound insulations. Even though the compressive strength are drastically less in case of rice husk ash and clay mixed foam concrete, they are quiet enough to withstand sound and thermal insulation. In particular, rice husk ash mix can be used as a thermal insulating barrier material on roof top to replace weathering course and roof tile. So this area requires further studies. As the foam volume increases the compressive strength decreases drastically. But up to 30% there is no much reduction in strength compared to 10%. However for 50% foam added concrete shows drastic reduction in compressive strength. Therefore it can be found that 30% foam volume is found to be an optimum percentage without compromising on strength.

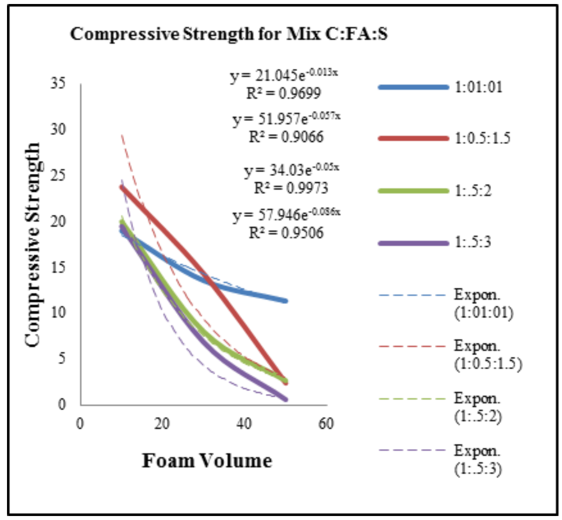

Figure 7: *Compressive Strength for Mix C: FA: S*

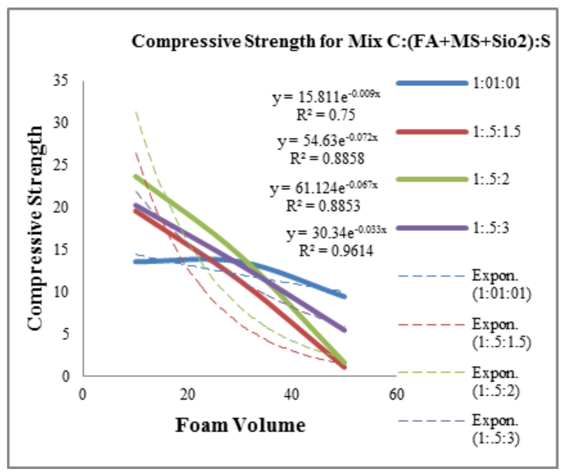

Figure 8: *Compressive Strength for Mix C: (FA+MS+Sio2): S*

2.4. Split Tensile Strength

The fig 9 shows the result of split tensile test carried out for foamed concrete specimen. In common, the split tensile strength of foamed concrete is higher when the foam volume is 10% and for 30% and 50% the strength reduces drastically. The mix incorporated with fly ash foamed concrete, the split tensile value is found to be on high as shown in fig. 9 and the lowest values are found for the mixes incorporated with rice husk ash. When the clay is added in the mix, the split tensile strength found to reduce only 50% as against 10% foam volume mix.

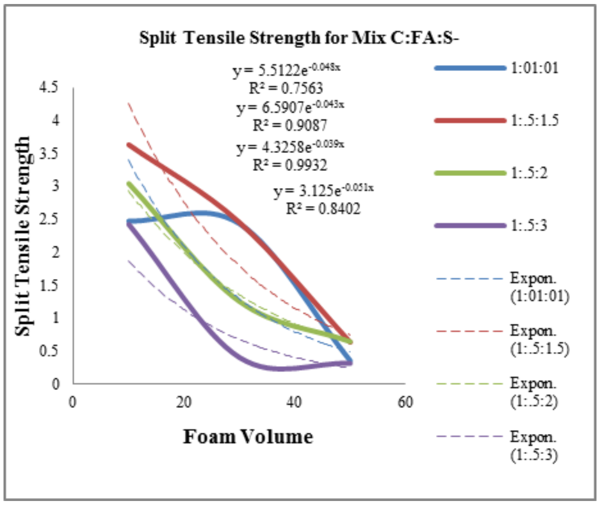

Figure 9: *Compressive Strength for Mix C: FA: S*

3. Conclusion

1. The maximum compressive strength obtained for the mix FC1 – C7 which is equal to 25.38 N/mm^2, in this FC1 category that the mixes incorporating fly ash mixed foam concrete prove to be better than all other mixes, found to be suitable for structural applications. In FC2 category C19 and C22 (10 % of foam added) are found suitable for structural applications. The rest of the mixes found suitable for nonstructural applications. This is attributed to the fact that fly ash undergoes pozzolanic reactivity in spite of addition of foam.
2. Splitting tensile point of view C7 found to be having highest splitting tensile strength is equal to 3.93 N/mm^2.The lowest splitting tensile strength is due to attendance of carbon content in rice husk ash.
3. The results of water absorption shows highest water absorption of 39.28% was obtained for C42 which is for the mix FC4-C45, this is due to the fact , is at high foam content and rice husk ash in the mix. The capillary absorption and absorption by pores as resulted high amount of water absorption and low water absorption observed was found to be FC1-C7 and these is equal to 1.9%, the lowest water absorption due to higher pozzolanic activity of fly ash and low foam volume of 10% in the mix.
4. In common as the foam volume increases, the mechanical strength such as cube compressive strength and split tensile strength are drastically decreased.
5. It can be concluded that there is no signifance strength loss between 10% to 30% foam volumes. From this study FC1-C7, found to be fit in all respect to be used as structural lightweight concrete.

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