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Effect of Fly Ash as a Replacement of Sand on Glass Fibre Foam Concrete

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***Abstract*—: In the present study the effects of fly ash as a replacement of sand in a foam concrete along with addition of glass fibre on physical and mechanical properties of foam concrete is investigated. Three different density of foam concrete as 1000kg/m^3, 1300kg/m^3, and 1600kg/m^3 is prepared. The synthetic foaming agent is used to generate the foam. The results of the experiment show that addition of glass fibre helps in improving flexural strength of foam concrete. The higher density of concrete shows higher compressive and flexural strength. From experimental study it is also observed that the relation between flexural and compressive strength as per Indian Standard is not same. Incorporation of glass fibre not affect on porosity and water absorption of foam concrete.**

Keywords- Foam Concrete, Glass fibre, Porosity, Water absorption, Compressive strength, and Flexural strength.

I. INTRODUCTION

Foam concrete is the one which does not contain large aggregates, only fine sand and with light weight materials, containing cement, water, and foam. The voids can be produced by air or by gas. Because a foaming agent introduces the air, the concrete produced is called foam concrete. Foamed concrete is a light weight concrete, and has properties as free flowing, self-leveling, and self compacting [1,2]. The properties of foamed concrete depend on the microstructure and composition, which are influenced by the type of binders used, methods of pre-foamation and curing. The properties of foamed concrete can vary widely, so it can be used in a wide variety of applications. For heat insulation, thermal acoustic application, void filling, roof-deck insulation application etc. [3].

From the literatures it is obtained that there is a tremendous work in the area of generation of foam concrete. But there is less work in the area of fibre reinforced concrete and not much understood. Present investigation focus on physical and mechanical properties of fibre reinforced foam concrete with varying percentage of fibre.

II. MATERIALS AND METHODOLOGY

A. Materials

Synthetic foaming agent was used to prepare the required density of foam. The foam agent was diluted with potable water in a ratio of 1:5 by weight, there after foam was produced by aerating to a density of 40kg/m^3. Ordinary Portland Cement of 43 grade [4] and Class F Fly ash were used. The physical properties of cement and fly ash are presented in Table 1 and 2 respectively. The physical properties of Glass fibre is presented in Table 3 [5]. The potable tap water was used for to prepare foam concrete.

TABLE 1: PHYSICAL PROPERTIES OF CEMENT

Particulars	Test result	Standard results
Fineness (m^2/kg)	264	225
Soundness		
By Le chatelier(mm)	1.00	10
By Autoclave (%)	0.16	0.8 maximum
Setting time (minutes)		
Initial set	110	30
Final set	280	600

TABLE 2: PHYSICAL PROPERTIES OF FLY ASH

Specific gravity	2.2
Density	2300 kg/m^3
Colour	Blackish gray

TABLE 3: PHYSICAL PROPERTIES OF GLASS FIBRE

Modulus of elasticity	72GPa
Specific gravity	2.67
Length of fibre	12mm
Aspect ratio	850
Number of fibres per kg	213millions

B. Mix Proportion

In the present investigation three different density of foam concrete were prepared. The densities were targeted as 1000kg/m^3, 1300kg/m^3, and 1600kg/m^3. To find out the effect of glass fibre on mechanical properties of foam concrete, glass fibre of different dosages 0.5 to 1.5% were used at an interval of 0.5%. Mix proportion has been done based on previous study and by various trials [1]. Mix proportions for various densities were adopted are as shown in Table 4.

TABLE 4: MIX PROPORTION FOR M3 OF CONCRETE

Description	Density of foam concrete (kg/m^3)		
	1000	1300	1600
Foam (by % volume)	70	60	50
Cement (kg)	250	325	400
Fly ash (kg)	250	325	400
Water (lit.)	200	240	280
Foam (kg)	45	37	18
water/cement	0.4	0.37	0.35
Fibre dosage % by weight of cement			
0.5 (kg)	1.95	2.51	3.1
1.0 (kg)	3.90	5.03	6.2
1.5 (kg)	5.85	7.54	9.3

C. *Foam Preparation*

The density of foam plays important role in getting the perfect microstructure of foam. To get the suitable density of foam the various dosages of foam with water was evaluated. For foam preparation various proportion of foam agent with water was considered. For foam generation rotary blade type mixer were used as shown in Fig.1. Table 5 shows the results of foam density for various foam proportions. In the present study 1:5 proportion is adopted, which gives a density of 40 gms/litre.

Fig. 1 Foam generation setup

TABLE 5: FOAM PROPORTIONS

Foam Proportion	1:30	1:20	1:10	1:5
Foam density gms/litre	20	25	30	40

D. *Methodology*

For the mixing of materials was done by using mortar mixer. Cement, fly ash and glass fibre were mixed initially to avoid the lumps formation in the mixture. Then calculated amount of water was added and mixed the mixture thoroughly. The foam was added in the wet mixture and mixing was done till uniform air void distribution is obtained. After mixing the concrete was poured into moulds. The specimens of cube size 150 mm and flexural specimens of size 500 mm × 100mm × 100 mm size were cast. For smooth demoulding of concrete, the mould has been oiled. The top surface of specimen is levelled to get smooth finish. After 24 hours the specimens were demoulded and were kept for curing for 7 and 28 days.

After 28 days curing, the specimens were taken out wipe out the surface water with cotton. Then a saturated weight of specimen (M_{sat}), were then taken the submersed weight of specimen (M_{sub}), and then specimen were wipe out and kept it in oven at 100˚C for 8hours. Then specimens were removed from the oven and taken the dry weight of specimen (M_{dry}). Equations 2.1 were used to determine the porosity and equation 2.2 for water absorption. The compressive and flexural strength tests were carried out in accordance with IS 516: 1959. [7]

Porosity [P] = $\frac{Msat - Mdry}{Msat - Msub} \times 100$…………………2.1

Water absorption [W]=$\frac{Msat - Mdry}{Mdry} \times 100$………..2.2

Where,
M_{sat},=Surface saturated weight of specimen,
M_{sub}=Submerged weight of specimen,
M_{dry}=Oven dried weight of specimen,
W=Water absorption in %, P= Porosity in %

III. RESULTS AND DISCUSSION

A. *Porosity, Water absorption, and Density*

The variation in porosity with respect to fibres for various densities is shown Fig. 2 Porosity is observed in the foam concrete is due to presence of air voids and voids in the paste. From Fig. 2 it is observed that, there is large variation in porosity of foam concrete for various density of concrete. The porosity of concrete is increases as the density of foam concrete increases. For higher density of 1300kg/m^3 to 1600kg/m^3 foam concrete, steep decrease in porosity is observed with addition of fibre content in concrete. The trend is not similar for lower density of 1000kg/m^3 to 1300kg/m^3 foam concrete. The porosity of lower densities is independent of fibre content.

The variation of targeted density and obtained density for foam concrete is shown in Fig. 3. Figure 4 illustrate that, obtained density is nearly equal to targeted density.The variation in water absorption with density is presented in Fig. 5. From Fig. 3 and Fig. 5 it is observed that water absorption is directly proportional to porosity, as porosity increases, water absorption is also increases. From Fig.4 it is observed that, at 1000kg/m^3, 1300kg/m^3 and 1600kg/m^3 density of foam concrete water absorption is around 33%, 26% and 5% respectively for all fibre content concrete.

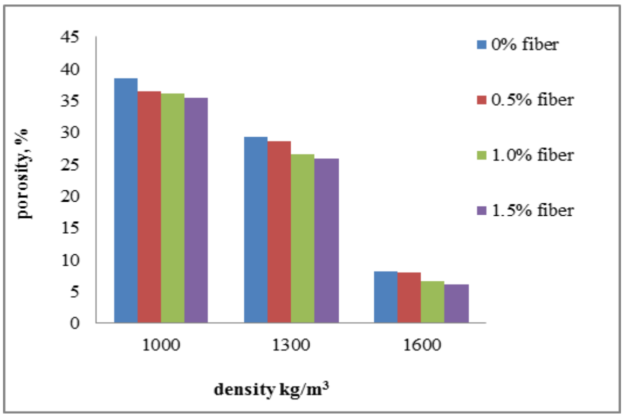

Fig.2 variation of porosity with density

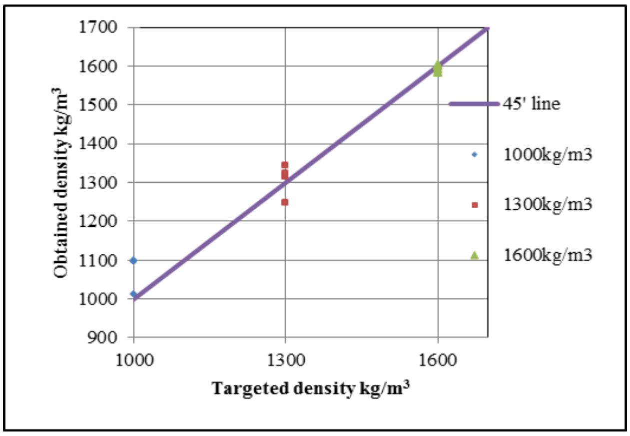

Fig.3 Variation of Targeted and Obtained density

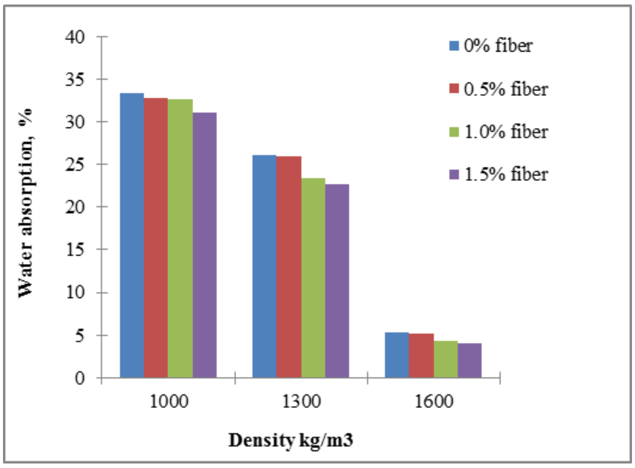

Fig. 4 Variation of water absorption with densities

B. Compressive strength

Table 6 shows the results of 7 days and 28 days compressive strength of glass fibre foam concrete. Figure 5 shows variation in 28 days compressive strength with density of foam concrete. The increase in compressive strength of foam concrete is observed with increase in density and fibre content in foam concrete. Compressive strength of glass fibre foam concrete for density 1000kg/m^3, 1300 kg/m^3 and 1600kg/m^3 with the fibre content is 30%, 35% and 45% observed. Among all three densities of foam concrete, 1600 kg/m3 density concrete shows significant increase in strength as compared with non fibred foam concrete. From Fig 5 it is observed that, compressive strength of foam concrete increases with the increase in density of concrete. From 1000kg/m^3 to 1600kg/m^3 density non fibred foam concrete 28 days compressive strength increase to 40.0%. Whereas for 1.5% fibred foam concrete 28 days compressive strength increase to 43.4% from 1000kg/m^3 to 1600kg/m^3 density concrete.

TABLE 6: RESULTS OF COMPRESSIVE STRENGTH

Density (kg/m^3)	Fibre content (%)	7 day compressive strength (MPa)	28 day compressive strength (MPa)
1000	0	1.92	3.55
	0.5	1.92	3.77
	1.0	2.36	4.22
	1.5	2.66	4.88
1300	0	2.81	7.56
	0.5	3.25	7.70
	1.0	3.25	9.03
	1.5	3.55	9.92
1600	0	5.03	14.52
	0.5	6.07	16.14
	1.0	6.51	17.03
	1.5	7.11	21.18

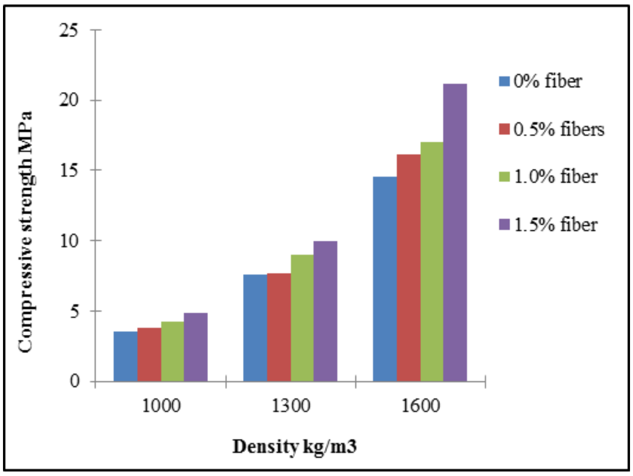

Fig. 5 Variation of compressive strength with respect to density

C. Comparison of 7 day and 28 day compressive strength

The relation between 7days and 28 days compressive strength for glass fibre foam concrete is presented in Fig. 6. The strength development with age from 7 days to 28 days in glass fibre foam concrete is compared with the equation given for normal strength concrete in IS 456:2000 [8]. From the Fig. 6 it is observed that the strength development with age for glass fibre concrete is not follow the same trend presented in IS 456: 2000 [8]. The comparative results of 7 days and 28 days foam concrete in comparable with the results reported by K. C. Brady et al. [3]. In the present study the attempt has been made to propose a relation between 7 days and 28 days glass fibre compressive strength by regression analysis. The equation 3.1 gives the relation between 7 days and 28 days glass fibre compressive strength. The percentage error in prediction of compressive strength is around 30%.

$f_{cka\ (7day)}$=0.724 ($f_{ck\ (28day)}$)$^{0.729}$ ……………………3.1

Where,
$f_{cka(7day)}$ = Analytical 7 day compressive strength in MPa
$f_{ck(28day)}$= 28 day compressive strength in MPa

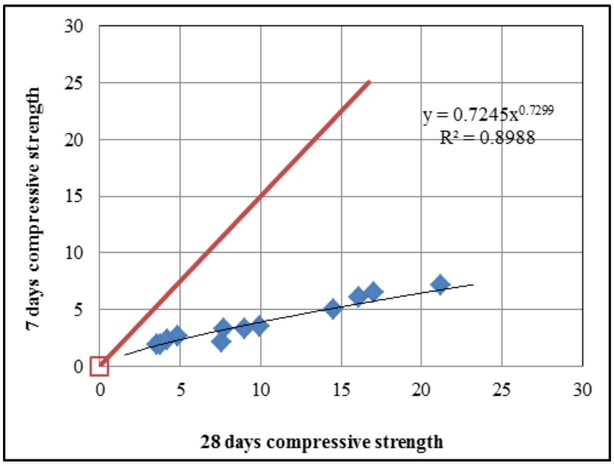

Fig.6 Relation between 7 days and 28 days compressive strength

D. Comparison of porosity and compressive strength

Figure 7 shows the relation between compressive strength and porosity of glass fibre concrete. From Fig. 7 it is observed that, compressive strength of foam concrete is inversely proportional to porosity. The experimental data points have been considered for regression analysis and a relation between compressive strength and porosity is proposed in equation 3.2. Regression coefficient for proposed equation is about 0.96.

$f_{ck\ (28day)}$ = -0.002× P^2– 0.263 × P +17.65…………3.2
Where,
$f_{ck(28day)}$ = 28 days compressive strength in MPa
P = Porosity in %

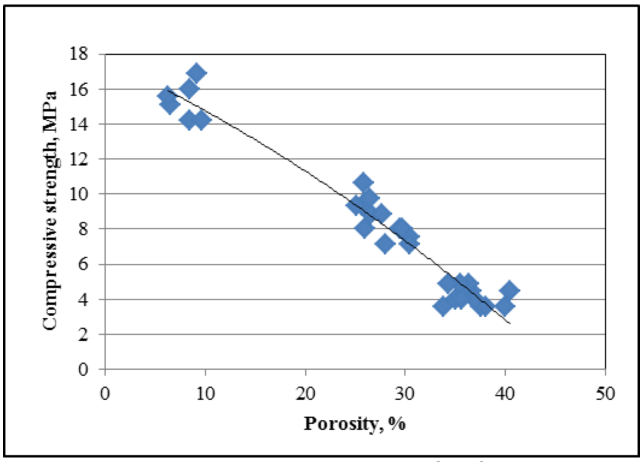

Fig. 7 Variation in compressive strength with porosity

E. Flexural strength

The variation in flexural strength with fiber content for various densities of foam concrete is shown in Fig. 8. From Fig. 8 it is observed that, flexural strength increase with increase in fibre content. For higher density of concrete flexural strength is more. Figure 8 shows variation in flexural strength with density for different percentage of glass fibre. Fibres are more influence on the flexural strength of foamed concrete than compressive strength. For all density of glass fibre foam concrete the flexural strength increases by about 33% as compared with non fibred foam concrete.

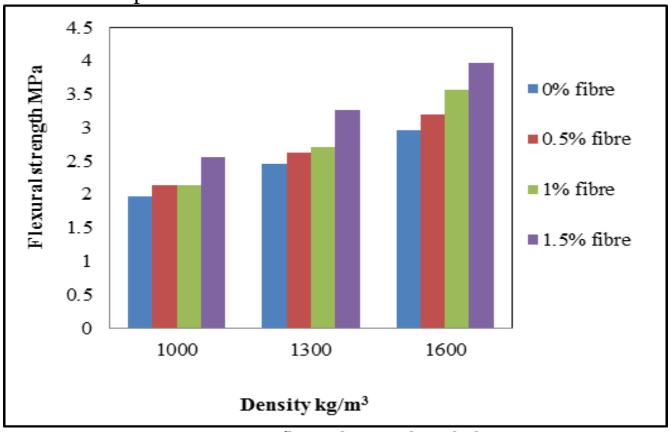

Fig. 8 Variation flexural strength with density

F. Comparison of compressive and flexural strength

In the present study, experimental results of flexural strength and compressive strength are compared with the established formula included in IS 456:2000. Table 7 shows relation between experimental compressive and flexural strength. From the Table 7 it is found that the experimental flexural strength is much higher than the analytical flexural strength of foam concrete and glass fibre foam concrete. The error is more for glass fibre foam concrete as compared with non glass fibre foam concrete. To establish a relation between flexural strength and compressive strength regression analysis is carried out as shown in Fig. 9 and proposed analytical equation. The equation 3.3 gives the flexural strength from the compressive strength of foam concrete.

$f_{fs(28day)}$ =1.355×($f_{ck(28day)}$)$^{0.328}$…………………3.3

Where,
f_{fs}(28day) = 28 days flexural strength in MPa
f_{ck}(28day) = 28 days compressive strength in MPa

TABLE 7: RELATION BETWEEN EXPERIMENTAL COMPRESSIVE AND FLEXURAL STRENGTH

Actual 28 day compressive strength (MPa)	Actual flexural strength (MPa)	Analytical flexural strength (MPa) $0.7\times\sqrt{f_{ck\ (28days)}}$	Error in percentage (%)
3.55	1.96	1.31	33.1
3.77	2.13	1.35	36.6
4.22	2.13	1.43	32.8
4.88	2.56	1.54	39.8
7.56	2.46	1.92	21.9
7.70	2.63	1.94	26.2
9.03	2.70	2.10	60.0
9.92	3.26	2.20	32.5
14.52	2.96	2.66	10.1
16.14	3.20	2.81	12.1
17.03	3.56	2.88	19.1
21.18	3.96	3.22	18.6

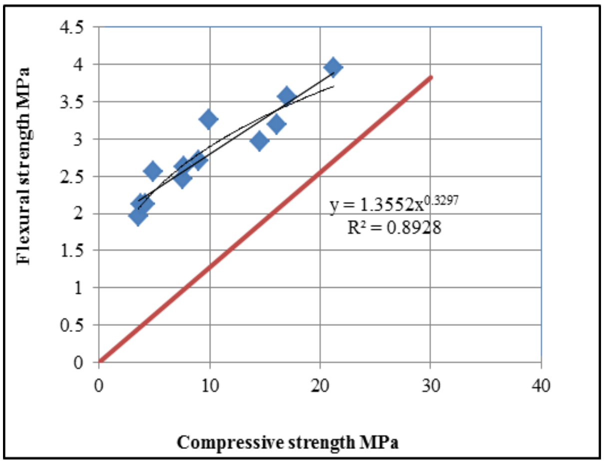

Fig. 9 Relation between experimental compressive and flexural strength

G. *Response Surface Plots*

Figure 10 and 11 presents the response surface plots for compressive strength and flexural strength of glass fibre foam concrete with fibre content and density respectively. From Fig. 11 it is clearly observed that the increase in compressive strength after 1300 kg/m^3 density of concrete is sharp. From Figure 11 it is clearly pointed that the increase in flexural strength after 1.0% of fibre content is sharp at 1000 kg/m^3 of foam concrete. Increase in flexural strength with density of glass fibre concrete is linear.

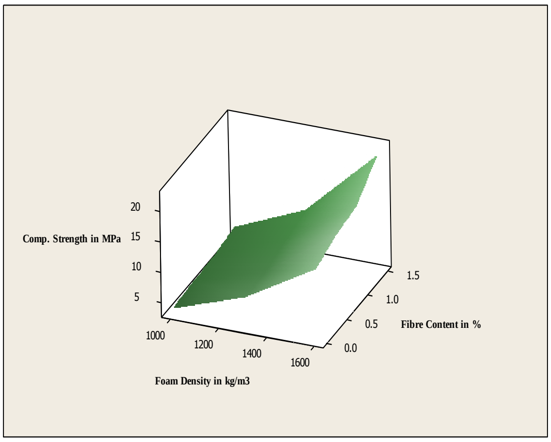

Fig. 10 Response surface plot of compressive strength, fibre content and density

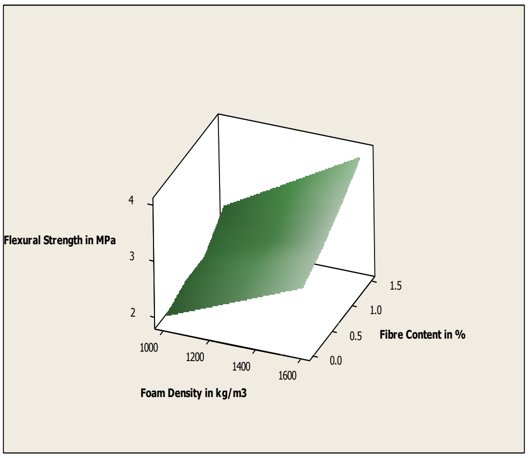

Fig. 11 Response surface plot of flexural strength, fibre content and density

H. *Analysis of Variance (ANOVA)*

From the experimental results analysis of variance is carried out to see the significant effect of fibre content and density on compressive and flexural strength of foam concrete. Table 8 shows the results of ANOVA for compressive strength of foam concrete. Table 9 presents the results of ANOVA for flexural strength of foam concrete. The results of ANOVA illustrate that, in compressive strength density of concrete (92.45%) contributes more than fibre content (5.25%). In case of flexural strength of foam concrete fibre content (25.28%) contributing more as compared with the case of compressive strength of concrete.

TABLE 8: RESULTS OF ANOVA FOR COMPRESSIVE STRENGTH

Control factor	Degree of freedom	Sum of square	Variance	F	Contribution percentage
Fibre content	3	20.195	6.732	4.58	5.25
Density	2	355.734	177.867	120.96	**92.45**
Error	6	8.823	1.470		
Total	11	384.752			

TABLE 9: RESULTS OF ANOVA FOR FLEXURAL STRENGTH

Control factor	Degree of freedom	Sum of square	Variance	F	Contribution percentage
Fibre content	3	1.04549	0.34850	25.17	25.28
Density	2	3.00665	1.50333	108.57	72.70
Error	6	0.08308	0.01385		
Total	11	4.13523			

IV. CONCLUSIONS

Following conclusions are drawn from the study,

- The variation in fibre content does not much affect on porosity and water absorption of foam concrete.
- Increase in compressive strength with respect to density is more as compared to the increase in fibre content.
- Compressive strength of foam concrete increases by 10%, 20% and 40% with 1000 kg/m^3, 1300 kg/m^{3}and 1600 kg/m^3 density respectively.
- Flexural strength of foam concrete increases by 10%, 20% and 30% with 0.5%, 1.0% and 1.5% fibre content respectively.
- The relation between 7days and 28 days compressive strength, and porosity and compressive strength of glass fibre reinforced foam concrete is proposed.
- Proposed the relation between compressive and flexural strength is useful for the flexural strength prediction of glass fibre reinforced foam concrete

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