An Experimental Study on Fibre Reinforced Foam Concrete Using Hybrid Fiber

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Abstract: Foam concrete is one of the light weight concrete which contains cement, filler, water and foaming agent. Nowadays, this foam concrete has very useful characteristics for building construction. It requires no compaction and can easily fill the irregular cavities. In construction industry, various types of industrial waste materials was used to improve the strength and durability properties of the concrete. The endeavours to improve the strength properties such as cement, silica fume, fly ash, foaming Agent,Poly Vinyl Alcohol (PVA) fiber and carbon fiber were used. The combination of two fibers were added in the foam concrete with the different proportion of 0.3%, 0.4% and 0.5%.This paper describes the strength properties such as compressive strength, split tensile strength, water absorption characteristics and prediction of compressive strength of the fibre reinforced foam concrete using python. The targeted design density of foam concrete is 1650 kg/m^3. All the specimens were tested and determined the strength at the age of 7 days, 14 days and 28 days.

Keywords*: Cement, Flyash, PVA Fibre, Foaming Agent,mechanical strength, and python.*

1. Introduction

Concrete is one of the widely used materials in building structures, owing to its better composite properties with steel[1]. The ingredients of the concrete is fully or partially replaced by a various types of substitutes to change its mechanical and durability properties[2]. Foamed concrete is a type of light weight concrete that implies the density ranges from 300kg/m^3 to 1850kg/m^3 with arbitrarily enclosed air voids in the slurry, which is responsible for its self weight reduction[3,4]. The other names for foamed concrete such

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as low density concrete, lightweight concrete, cellular lightweight concrete et., In recent years he materials used in the foam concrete creates cost effectiveness and sustainable alternative to the traditional concrete. Foam concrete comprises cement, fine aggregate and foaming agent, which imparts the light weight behaviour to the concrete[5-7]. The use of supplementary materials such as glass powder, rice husk ash, silica fume, bagasse ash, granite powder, marble powder, egg shell powder, seashell powder, paper ash etc act as a solution to the environmental issues. In this research cement, silica fume, flyash, sodium lauryl sulphate, PVA fiber and coir Fibre combination had significantly showed different mechanical property as compared to conventional concrete. Utilization of flyash and silica fume in this concrete is an effective management of waste and it is a safe and consistency in environmental disposal[8-10].

Although several studies were made by researchers in the structural element, the low density foamed concrete found an application in the production of multi-functional building components as the non-structural elements of the foamed concrete[11,12]. This paper aims to present the mechanical behaviour of fibre reinforced foamed concrete with a density of 1600kg/m^3 to be used in the casting processes. Many studies revealed the preparation of foamed concrete[13]. All the major studies revealed that the performance of the foam concrete is significantly affect the pore structure. Always there is a close relationship exists between the pore structure of the foamed concrete and properties of the foamed concrete such as mechanical strength and durability strength.

The concrete comes under the category of brittle material, the use of discontinuous fibre will influence the strength characteristics [14]. By the addition of hybrid fibers, the main factor controlling the fibre reinforced foamed concrete is mechanical properties of mix, bond strength between the matrix and fibre and volume fraction of fiber, orientation and its distribution[15,16]. For light weight concrete the purpose of adding fibre is to reduce the crack of the foam concrete at early ages. And also it possess high modulus of elasticity and good tensile resistance[17,18]. The fibre reinforcement can change the brittleness property in the foamed concrete. The production of the foam concrete uses glass fiber, natural fiber, synthetic fiber and carbon fiber however steel fiber is not suitable for foamed concrete since it may settle at the bottom of the mix and there is a possibility of breaking foams in the mix.

2. Materials and Mix proportions

Ordinary Portland cement of grade 53 was used in this work.The silica fume is used as a partial replacement for cement upto 30%. The flyash used was supplied from thermal power plant, Tuticorin. Class F flyash was used. Whereas the physical and chemical properties of cement, silica fume and flyash is presented in table 1 and table 2 respectively. The foaming agent of Sodium Lauryl sulphate is used to get the foam concrete by entraining a controlled amount of air bubbles. This liquid is bought from nearby supplier. Poly vinyl alcohol fibre with 25 mm length with density of 1.5 g/cm^3 and carbon fibres with 10mm length, 7 micron diameter and density of 1.8g/cm^3 were used with the foamed concrete.

Table 1. Physical Properties

Properties	Results		
	Cement	Silica Fume	Fly ash
Specific Gravity	3.0	2.3	2.9

Fineness (%)	5.3	5.17	9.1
Density (kg/m^3)	1440	580	430
Soundness	8	6	7
Compressive strength MPa (3 Days)	32	41	43

Table 2. Chemical Properties

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	SO_3
Cement	18.6	3.8	4.03	66.3	2.1	0.5	0.2	0.3	2.7
Silica Fume	93	0.8	1.9	0.9	0.8	0.3	0.3	0.2	0.3
Flyash	39	26.3	0.7	3.5	2.2	1.1	0.2	0.9	0.6

3. Test Methods

The compression Test, split tensile strength and water absorption for all fibre reinforced foam concrete mixes were tested as per IS Code. The average of three specimens were used for all the mentioned tests. The material characterization and compressive strength prediction by using python was carried out.

3.1 Mix proportions

Table 3. shows the mix proportion of fibre reinforced foamed concrete. The cement to filler ratio is 1:1 was followed. The water cement ratio is 0.45 and foaming agent to water ratio is 1:30. From the previous work it was concluded that the greater than 0.25% only gives significant higher compressive strength. Therefore the combination of PVA fibre and carbon fibre with the maximum volume proportions of 0.3%, 0.4% and 0.5% was used.

Table 3. Mix Proportion

Specimen	Cement	Silica Fume	Flyash	PVA Fiber	Carbon Fibre
FC1	100	0	100	0	0
FC2	80	20	100	0	0
FC3	80	20	100	0.3	0
FC4	80	20	100	0.4	0
FC5	80	20	100	0.5	0
FC6	80	20	100	0	0.3
FC7	80	20	100	0	0.4
FC8	80	20	100	0	0.5
FC9	80	20	100	0.2	0.3
FC10	80	20	100	0.3	0.2
FC11	80	20	100	0.2	0.2
FC12	80	20	100	1.5	1.5

4. Results and Discussion

4.1 Compression Strength

Table 4, shows compressive strength testing values of fibre reinforced foamed concrete at the age of 7 Days, 14 Days and 28 Days. The size of the cube specimen is

150x150x150mm was used. In this result, FC8 shows the optimum mix which contains 80% of cement and 20% of silica fume, 100% of fly ash as a fine aggregate, 0.2% of PVA Fiber and 0.3% of carbon fiber.

Figure 1: Testing of Cube Specimen

Table 4. Test results on Compressive strength Test

Specimen	Compressive Strength (MPa)		
	7 Days	14 Days	28 Days
FC1	5.8	7.1	8.3
FC2	6.1	8.2	9.1
FC3	11.3	12.7	13.2
FC4	10.6	12.1	12.5
FC5	8.2	10.6	11
FC6	5.2	6.1	7.3
FC7	10.2	11.5	12.2
FC8	6.8	7.5	8.4
FC9	9.1	12.1	14.6
FC10	9.5	12.7	13.3
FC11	6.5	8.8	10.6
FC12	4.3	5.8	7.5

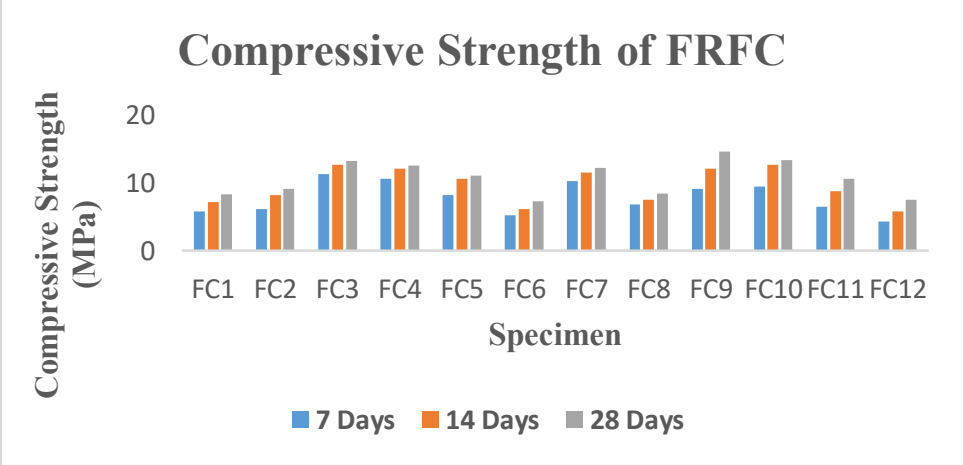

Figure 2. Test results on Compressive strength

The variation of compression strength with addition of fibres is shows in Fig 2.This results shows that, the addition of fibresgives anincrement in compressive strength was observed. Because of addition of PVA fiber,gives 44% of increment in compressive strength as compared to nominal mix. Due to addition of carbon fiber, percentage increase of 34% in compressive strength was observed as compared to nominal mix. The combination of both PVA fiber and carbon fibre the compressive strength is optimum of 0.5% which contains 0.2% of PVA fiber and 0.3% of carbon fibre. The presence of hybrid fibres gives the compressive strength of 14.6 MPa which is 60% of increment as compared to the nominal mix. The higher percentage of PVA fibre increases the possibility of pores connections in the matrix which leads to lower strength.

4.2 Split Tensile Strength

The Table 2 shows the split tensile results of fibre reinforced foamed concrete. The size of the cylinder specimen is 300mm height and150mm diameter was used. In this result, FC8 shows the optimum tensile strength which contains 80% of cement and 20% of silica fume, 100% of fly ash as a fine aggregate, 0.2% of PVA Fiber and 0.3% of carbon fiber. The split tensile strength was tested at the age of 28 Days.

Figure 3: Testing of Cylinder Specimen

Table 5. Test results on Split Tensile Strength

Specimen	Split Tensile Strength (MPa)
FC1	1.0
FC2	1.2
FC3	1.63
FC4	1.8
FC5	1.59
FC6	1.3
FC7	1.7
FC8	1.3
FC9	2.3
FC10	2.1
FC11	1.9
FC12	1.5

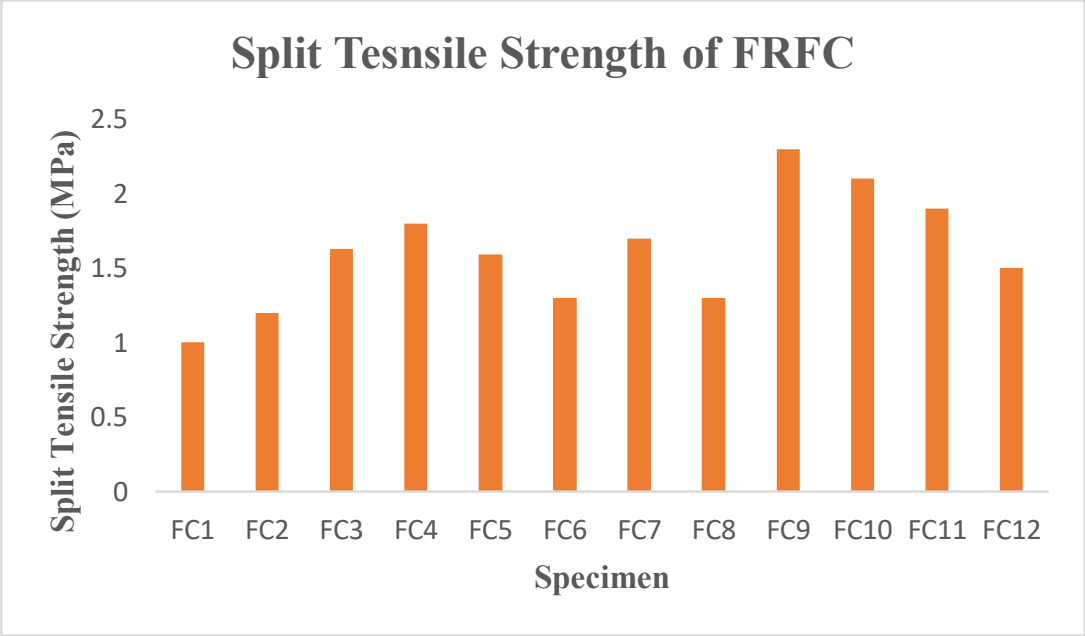

Figure 3. Test results on Split Tensile strength

Figure 3, shows the variation of split tensile strength of the PVA fiber and Coir fibre incorporated in the foam concrete. By the addition of PVA fiber, it shows higher tensile strength of increases 33% as compared with the nominal mix. By the addition of Carbon fibre the tensile strength is increases 41.6% of tensile strength than the conventional mix. The PVA fibre compared with the coir fibre in the foam concrete exhibits lower tensile strength because of its lower tensile strength of fibres. It is inferred that the combinations of 0.2% of polypropylene and 0.3% of carbon fibre shows 27% and35% of increment of monotype PVA fiber and Carbon fibre.

4.3 Water absorption Test

Table 6, shows the results of Water absorption test in fibre reinforced foamed concrete. The water absorption characteristics was observed at the age of 28days.

Figure. 4 Water Absorption Test

Table 6.Test results on Water Absorption

Specimen	Water Absorption (%)
FC1	15
FC2	14
FC3	17
FC4	21
FC5	26
FC6	19
FC7	25
FC8	27
FC9	16
FC10	15
FC11	15
FC12	14

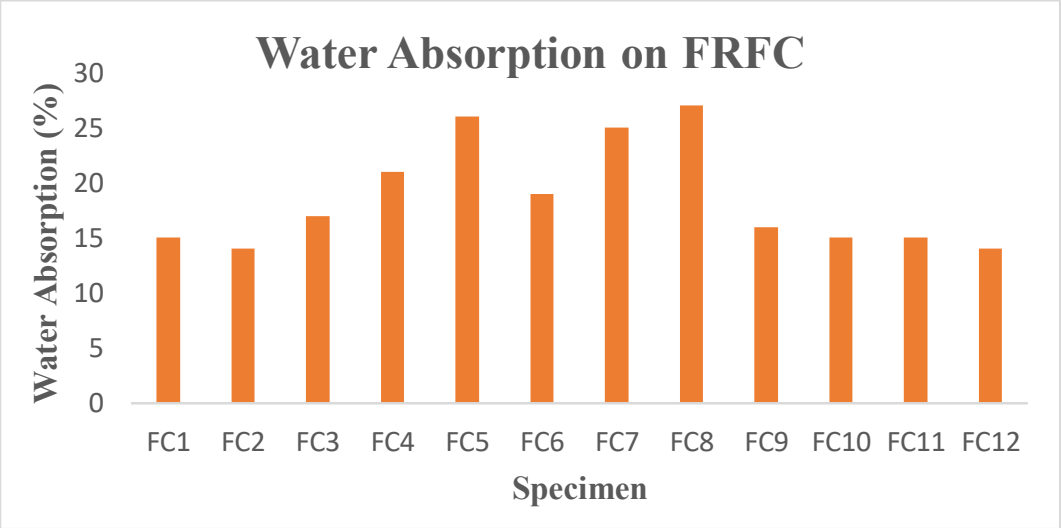

Figure 5. Test results on Water Absorption

The impregnation of water in the foam concrete is difficult because of the uncertain microstructure formation in the hardened stage. The incorporation of silica fume reduces the water absorption in the FRFC. From the fig 5, the result shows that the addition of fibre content increases the water absorbing capacity. The increase of water content in the specimen is due to the usage of fly ash material in the foam concrete. The water absorption of PVA fiber is 85.7% greater than nominal mix. The water absorption of carbon fibre is 92% greater than nominal mix. In all hybrid combinations, the water absorption is reduced than the monotype mix of PVA fiber and carbon fiber has lesser water absorption.

5. Heat Map

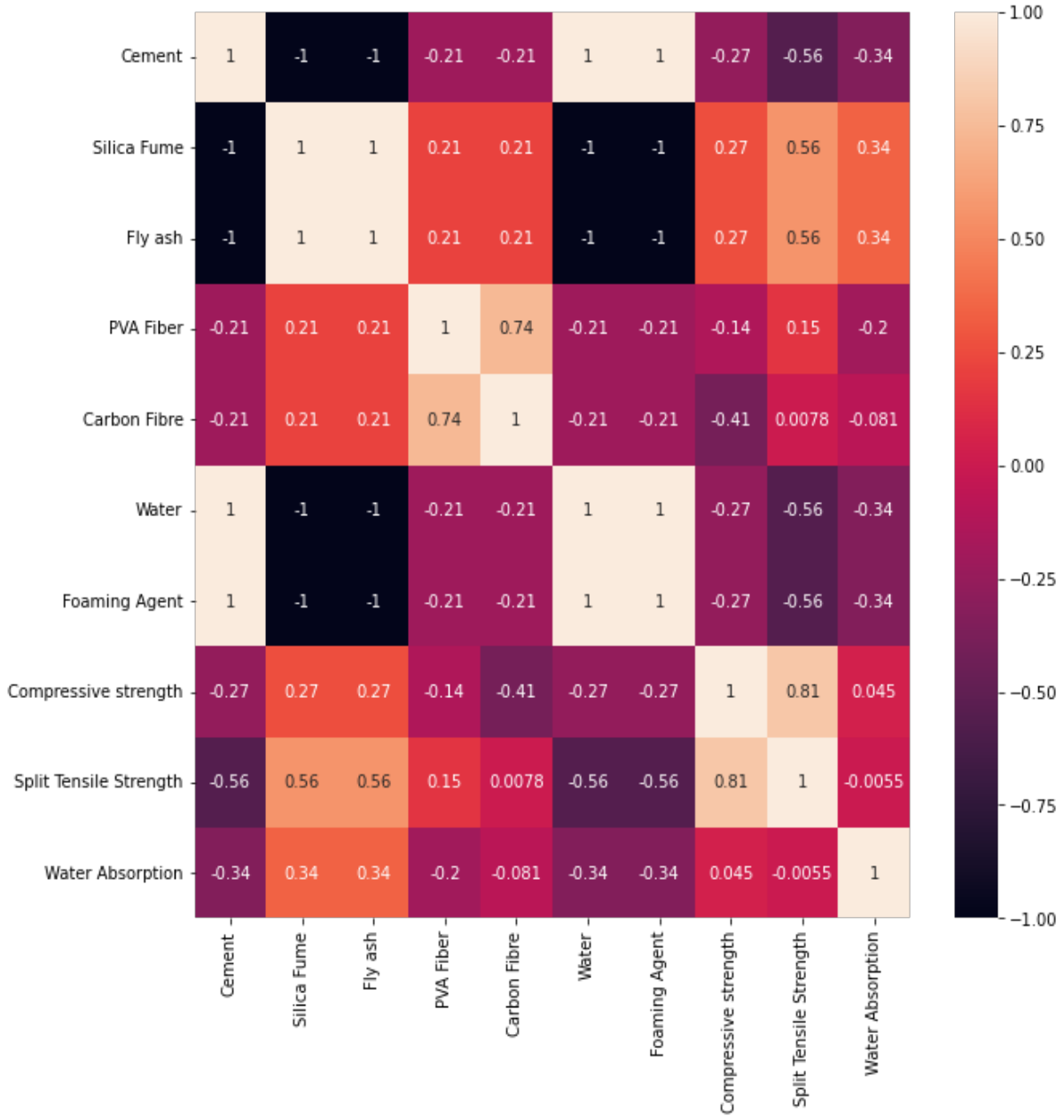

Figure 6. Heat map of FRFC

The correlation plot shows the correlation coefficient between all the used variables in the fibre reinforced foam concrete. This plot contains the correlation matrix-like table. Fig 6 shows that the material variation and we can easily visualize the correlation between variables the material properties such as cement, silicafume, flyash, polyvinyl alcohol fibre, carbon fibre, water, foaming agent and mechanical properties such as compressive strength, split tensile strength and water absorption test by plotting plot. In this seaborn library was used to plot the correlation plot between variables and each and every variable is showing a relationship with another variable. From the observations of the heat then we find that cement has a strong correlation with water and foaming agent and the fibres has a strong correlation with the fibre content.

6. Conclusion

From the results of the mechanical property tests the discussions are given as below,
The compressive strength results indicates that the fibre content beyond the limit shows no improvement in its strength.
In hybrid combinations the mix with 0.3% of PVA fiber and 0.2% of carbon fibre is performed better as compared to all other mixes.
The addition of PVA fiber shows the better results of mechanical properties such as compressive strength, split tensile strength and water absorption characteristics as compared with carbon fibre.
The characteristics of the water absorption is increases with the addition of fibres for both PVA fiber and Carbon fibre.
It is inferred that the combinations of 0.2% of polypropylene and 0.3% of carbon fibre shows better results.

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