COMPARATIVE EXPERIMENTAL INVESTIGATION ON FOAM CONCRETE WITH POLYPROPYLENE FIBER AND CARBON FIBER

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This paper demonstrates the comparative study of properties of foam concrete with polypropylene fiber and carbon fiber. The experimental investigations were done between foam concrete with 10% and 20% foam volume. As well as cuttle bone powder was partially replaced with cement as bio-filler in the aspect of cost cutting in foam concrete production and reducing environmental hazard. Both polypropylene and carbon fibers were added in the foam concrete in the percentage of 0.5%, 1%, 1.5%, 2%, 2.5%, 3% by mix volume fraction. The physical, mechanical, thermal and durability properties of foam concrete were investigated. The result showed inclusion of fibers in foam concrete increases the compressive strength with minimal reduction in densities. The hydrophobic properties of foam concrete were improved with polypropylene fiber addition, which decreases the adsorption and sorptivity characteristics. Irrespective of the type of fiber added the thermal conductivity of foam concrete also decreases when compared to conventional foam concrete. Polypropylene fiber in foam concrete showed the highest reduction in thermal conductivity. With the gainful impact saw on the density and strength performance and from the cost investigation, 2% Polypropylene fiber with 25% cuttlebone powder as cement replacement in foam concrete is recommended for the production of low cost and sustainable foamed concrete.

Keywords: *Foam concrete, polypropylene fiber, carbon fiber, cuttle bone powder, compression strength, density, thermal conductivity, sorptivity*

1. Introduction

Building's energy efficiency and CO_2 emission reduction are two key roles to measure the sustainability criteria for any buildings and materials. In recent days the materials used in building construction highly concerned to reduce environmental hazards. The waste generated from carbon fiber manufacture has limited number of reuse applications. Alternatives for disposal of carbon fibers as landfills incineration and recycling will consume huge cost. Carbon fibers are projected to reach a demand of $200x10^6$ kg in the year 2023 [1]. The concept of enhancing fibers in concrete was established in 1900. Natural fiber, steel fiber, glass fiber, carbon fiber and synthetic fibers like polypropylene, polyethylene, polyvinyl alcohol and polyacrylonitrile fiber were established in concrete to study its mechanical properties[2]. The mechanical properties of the concrete differ with fiber addition, volume, aspect ratio, orientation and fiber property. Dispersion of fiber in concrete creates a homogeneous mix[3][4].Foam concrete is one of the lightweight materials that has high application in trench reinstatement, bridge abutment, void filling, roof insulation, flooring, road sub base and non-load bearing walls. It reduces the dead load, foundation cost and materials usage. Foam concrete, the concept of introducing air voids into the mortar [5]. The air voids created in the form of foam should be stable enough from mixing till hardening of concrete. Protein based foaming agent produce most durable and micro foams compared to synthetic type foaming agents, the average density of foam should be between 60 to 80 kg/m^3[6][7]. No coarse aggregates were used in foam concrete preparation; it reduces the density of the concrete. By varying the foam dosage the density in the range of 600kg/m^3 to 1800kg/m^3 can be achieved [8]. However, foam concrete possesses poor durability properties and achieving uniform mix and uniform grade of concrete is difficult. While few studies have done on the properties of ultra-light weight foam concrete which shows good thermal insulation property than the ordinary foam concrete [9]. At the same time foam concrete possess low strength compared to silicate concrete of same density. Achieving higher compressive strength at lower density was the problems faced by researchers till now. Due to its high porosity foam concrete showed low-density, high-water absorption characteristics and high drying shrinkage. Pre-foaming method will have control over density and uniform dispersion of voids in foam concrete compared to mixed foaming method[10]. However, the foam breakage occurs before initial setting of concrete. Enhancing calcium rich components in foam concrete act as setting accelerator and helps to achieve the apparent density of foam concrete. CaO based expansive agents in concrete gives early age strength to the concrete [11][12]. Some researchers used calcium rich seashell powder as cement replacement and yielded positive results [13].The use of cuttle bone powder up to 25% by weight of binder decreases the

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mechanical properties like compressive strength, split tensile strength, flexural strength but durability properties like thermal conductivity, water absorption, and porosity was improved [14]. The hydrophobic nature of concrete was improved due to cuttle bone powder addition [15]. The micro aggregate filling effect and higher surface area of cuttle bone powder supports the hydration process in mortar matrix. Besides the water solid ratio is also significantly reduces with cuttle bone powder substitution in foam concrete.

Polypropylene fiber, the most commonly used fiber has significant improvement in mechanical properties of foam concrete. Polypropylene fibers could change the behaviour of foam concrete from brittle nature to elasto-plastic[6]. The author reported addition of Polypropylene fibers in concrete enhances the crack limitation, tensile strength, impact strength, flexural resistance, toughness, spalling resistance, freezing and thawing effect, abrasion resistance, eco-friendly nature and cost reduction characteristics[16][17].

High tensile strength property of carbon fibers was used in the study of reinforced concrete. Compared to all other fibers, carbon fiber addition creates good bond in the transition zone. Twisted, hooked, rough or wavy fiber exhibits good interfacial adhesion[18]. carbon fibers into the concrete mixture may improve characteristics like mechanical strength, flexural strength, deformation resistance, and crack control. Dispersed and discontinuous carbon fiber waste was not introduced into the concrete mixture yet [19][20]. Even though very less researchers have studied the property of lightweight concrete influenced by carbon fiber addition. In majority of Light weight concrete durability is affected due to its plastic shrinkage. This may be due to water evaporation in fresh state. This is one of the important problems in all types of concrete. This phenomena also leads to crack in the concrete allowing aggressive agents into the concrete [21][22]. With this background, this paper presents the experimental comparative study conducted on foam concrete with two different types of fibers (Polyropylene fiber and Carbon fiber) at different foam volumes. Density, Compression strength, water absorption, Ultrasonic Pulse velocity test, Sorptivity, Porosity, Thermal conductivity, Shrinkage were the test performed in the study. Also, the study compares the economic viability of producing foam concrete with polypropylene fiber and carbon fiber by conducting cost comparison study with foam concrete commonly used for construction purposes.

2.Materials and Methods

Ordinary Portland cement (C), cuttle bone powder (CBP), manufactured fine aggregate (F), foaming agent (FA), normal tap water, polypropylene fiber (PF) and carbon fibers (CF)

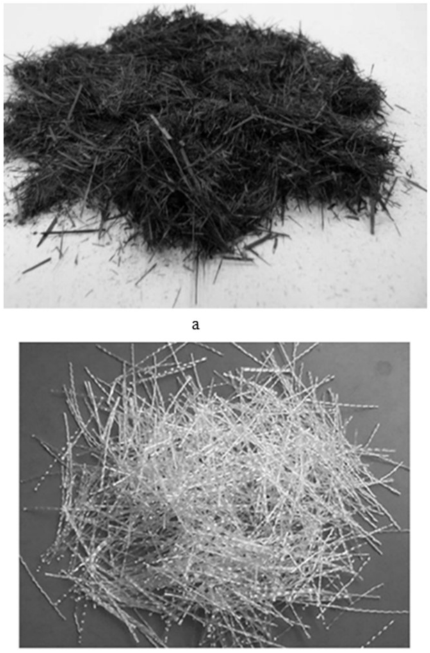

Fig. 1 - (a) Discontinuous Carbon Fiber (b) Polypropylene Fiber

Table 1

Composition of Cement and CBP

Oxide constituents (%)	Cement	CBP
CaO	63.5	95.3
SiO_2	21.6	3.8
Al_2O_3	5.4	-
SO_3	4.61	0.84
Fe_2O_3	3.33	-
MgO	1.35	-
K_2O	0.79	-
TiO_2	0.4	-
P_2O_5	0.18	-
Na_2O	0.07	-
Loss on ignition (%)	1.1	47.1

were used in this study. Fig. 1 shows the carbon fiber and polypropylene fiber used in this study. 17μm diameter and 10mm length carbon fiber were chosen for study. A protein based foaming agent Rheocell 30 was used in foam generation process. The technical characteristics of foaming agent used are shown in Table 2. It was diluted in the ratio of 1:30 (FA: water) to achieve stable foam with adequate foam density (60kg/m^3 to 80 kg/m^3). The aspect ratio of the CF was maintained as 588.23. The aspect ratio of the CF were based on the literature [23]. Polypropylene fibers having high tensile strength of 750 MPa and toughness 8.0 GPa is employed in the study. The length and diameter of PF fibers are 15mm and 100μm respectively. The

Table 2
Technical characteristics of foaming agent - Rheocell 30

Cement (kg/m^3)	356
water (kg/m^3)	160
w/c	0.45
Target Density (kg/m^3)	561
Initial density (kg/m^3)	1890
Density after foaming (kg/m^3)	590
Foam time (sec)	26

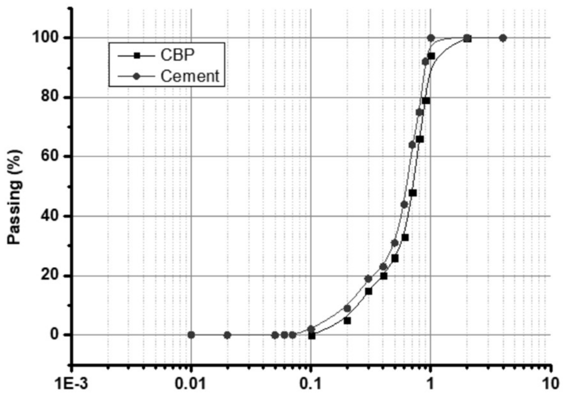

Fig. 2- Particle Size Distribution of CBP and Cement

Table 3
Physical properties of cement

Initial setting time (minute)	45 minutes
Final setting time (minute)	620 minutes
Fineness (m^2/kg)	300 m^2/kg
Compressive Strength (MPa)	
7days	20 MPa
28 days	45 MPa
Specific gravity (g/cm^3)	3.05
Loss on ignition (%)	3.07

aspect ratio of PFs was 150. The dimensions and strength of the PF were chosen based on literature study [24]. The selected length of fibers enhances the crack bridging and mechanical properties of the FC mix. Surface treated CF waste have surface protective coat, which acts as a water repellent and allow the foam to be stable during mixing and placing the mix. PFs naturally possess a smooth surface hence it was used without any surface coats in the mix. CBP are found in the east coast regions of fishing areas especially in Tuticorin, and Nagapattinam. The chemical composition of non-bio-degradable CBP and cement are shown in Table 1. Cuttle Bones were washed and dried in sunlight for 24hrs grounded in a grinding machine to match the fineness of cement. Fig. 2 shows the particle size distribution of the cement and CBP. The physical properties of the cement used were listed in Table 3.

3. Mix Proportion of Concretes

The comparative study was performed on FC by incorporating PF and CF. The PF and CF were separately added in to FC by its volume at 0%, 0.5%, 1%, 1.5%, 2%, 2.5% and 3%. The experiments were performed in FC with foam volumes of 10% and 20%. The FC were prepared with constant w/b ratio of 0.45. The w/b ratio was adopted based on trial error method by performing slump test to attain a slump flow not less than 200mm. The mix proportion details are tabulated in Table 4. Preparation of FC mixture includes three steps Initially, base-mix (C + CBP + F + Water) was prepared separately. secondly, foam was prepared by agitating FA with air at minimum of $5kgf/cm^2$ pressure. Finally, the proposed foam volume and fiber were mixed with the base mix immediately. The mixing process was continued until the foam and fiber mixes uniformly in the concrete.

For every mix ratio 15 cubes (100mm x100mmx100mm), 3 Cylinder (100mm x200mm) and 3 Prisms (40mmx40xmmx160mm) were casted in steel moulds at room temperature of 24±2ºC and at relative humidity of 97±2%. The surfaces of the cubes, cylinders and prisms were levelled manually. After de-moulding 24h the cubes are membrane cured till its testing age. Average of 3 test values were reported.

Tests

Fresh state test like flow spread measurements test were performed as per ASTM C143 (2015). The wet and dry density of the mix were recorded as per ASTM C188(2017). The compressive strength and split tensile strength test were performed on cubes and cylinders respectively as per the procedure stated in BS EN 12390-3 (2019). The water absorption, Sorptivity and porosity were the test carried out to find the water permeability characteristics of FC. Water Absorption was conducted by following ASTM C642-13

% of water absorbed = $\{(Ws - Wd)/Wd\} * 100$

W_s – Saturated weight of sample after immersion, W_d – Dry weight of sample before immersion in water for 24 hrs. Cubes were subjected to sorptivity test on 28 days cured cube specimens as per ASTM C1585-13

$$S = I - A/\sqrt{t}$$

S – sorptivity in mm/√min, A - surface area of immersed specimen (mm^2), I – Cumulative volume of water absorbed at the time (mm^3 /min), t - time recorded in min.

Non-destructive test was performed on concrete to ensure its strength quality. Ultrasonic

Table 4

Mix Proportions Details

Foam Volume	Specimen ID	Cement	Sand kg	w/b ratio	CBP (cement Replacement)	Polyproplene Fiber (%)	Carbon fiber
FV 10%	Conventional	420	1680	0.4	25%	0.0	0.0
	FC-PF 1	420	1671.6	0.4	25%	0.5	-
		420	1663.2	0.4	25%	1.0	-
		420	1654.8	0.4	25%	1.5	-
		420	1646.4	0.4	25%	2.0	-
		420	1638	0.4	25%	2.5	-
		420	1629.6	0.4	25%	3.0	-
	FC-CF 1	420	1671.6	0.4	25%	-	0.5
		420	1663.2	0.4	25%	-	1.0
		420	1654.8	0.4	25%	-	1.5
		420	1646.4	0.4	25%	-	2.0
		420	1638	0.4	25%	-	2.5
		420	1629.6	0.4	25%	-	3.0
FV 20%	Conventional	420	1680	0.4	25%	0.0	0.0
	FC-PF 2	420	1671.6	0.4	25%	0.5	-
		420	1663.2	0.4	25%	1.0	-
		420	1654.8	0.4	25%	1.5	-
		420	1646.4	0.4	25%	2.0	-
		420	1638	0.4	25%	2.5	-
		420	1629.6	0.4	25%	3.0	-
	FC-CF 2	420	1671.6	0.4	25%	-	0.5
		420	1663.2	0.4	25%	-	1.0
		420	1654.8	0.4	25%	-	1.5
		420	1646.4	0.4	25%	-	2.0
		420	1638	0.4	25%	-	2.5
		420	1629.6	0.4	25%	-	3.0

pulse velocity test, thermal conductivity test was performed on 100mm cube samples as per ASTM C597-07 and IS 9489:1980. Thermal conductivity was calculated from the equation

$$k = \frac{W}{A}[\,1\,X\,\frac{d}{\Delta T}\,]$$

A-Surface area of cube in contact with hot or cold plates, d- depth of the specimen, W – electric power in Watt, ΔT – difference in temperature between hot and cold plates.

4.Results and Discussions

4.1. Workability

The workability of FC with different proportions of PF and CF by varying the foam volume was conducted and the test results are presented in Fig.3. The result showed spread diameter increases with the addition of fiber. Increase in PF shows a maximum spread for both 10% and 20% FV. In addition to, irrespective of fiber type and increase in foam volume increases spread diameter and reduces the time of spread. Good correlation was maintained between spread diameter and flow time (R^2=0.98 to 0.99). In CF addition comparatively less spread diameter and increased flow time was observed than the PF addition. It is evident from the figure that the flow pattern follows similar path irrespective of foam volumes. Slight increase in spread diameter was absorbed for FV 20% in both CF and PF mix. PF addition creates a smooth texture on the fresh state FC. Higher workability was absorbed with PF increment compared to CF increment. It helps the foam to be more stable and the target density of the mix was achieved. Higher foam breakage was noted and the mix was comparatively less workable for the same w/c ratio. FC with higher PF addition shows good surface finish in the hardened concrete. This is due to PF have higher water repellent property, also uniform dispersion of air bubbles reduces the density of the matrix compared to CF[25].

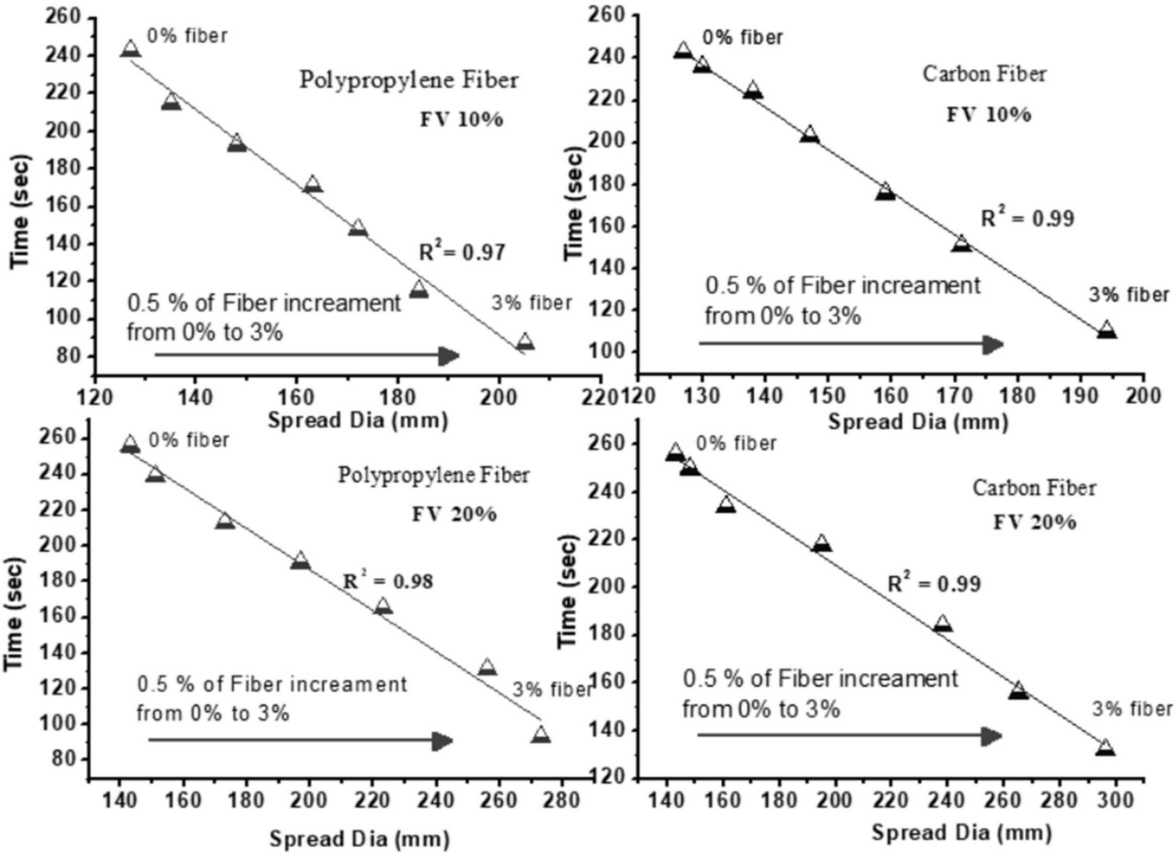

Fig. 3 - Relationship between Spread Diameter and Flow time of Fresh State FC at various Percentage of Fiber and at different FV

4.2. Density (Wet and Dry)

Density of FC is a function of FV and fiber volume which evident from the graph shown in Fig.4 The density of the mixes prepared in this study ranges between 1000kg/m^3 to 1500 kg/m^3, it denotes these concrete mixes suit for lightweight construction. Dry Density of FC with PF ranges between 1129kg/m^3 to 1453kg/m^3 in 10% FV and 1036kg/m^3 to 1350kg/m^3 in 20%FV. Whereas the density of FC with CF ranges between 1349kg/m^3 to 1429kg/m^3 in 10% FV and 1149kg/m^3 to 1357kg/m^3 in 20% FV. This shows irrespective of FV the lowest density is achieved with PF addition. This is due to the specific gravity of CF fibers. Difference in wet density to dry density shows water exhausted during drying. which was high in CF-FC mix. The w/c ratio for all mixes were kept uniform. CF cubes has less water repellent property hence the water lost after oven drying was low. Increase in fiber percentage decreases the wet and dry density. The curve plotted shows a curvilinear profile. Higher percentage of CF in the mix absorbs more water and less difference was noted between dry and wet densities. Uniform CF dispersion happen when the slump flow is high, however lesser slump flow results in poor distribution of CF [26]. From the graph shown in Fig. 4, Increase in PF fiber showed higher density reduction which directly results in higher spread flow. On the other hand, CF addition showed lesser density reduction.

4.3 Compressive Strength

Relationship between dry density and compressive strength at different FV is shown in Fig.5. CF addition improves the compressive strength and dry density. Compressive strength was a relative function of density, hence addition of PF in FC showed reduced density and correspondingly lesser compressive strength. The strength declination was in the acceptable range of foam concrete construction. The PF in FC increases the workability of the mix , later age strength and reduces the density of the matrix[27]. In 10% FV maximum strength was 13.8 MPa with 0.5% fiber volume and minimum strength was noted to be 13 MPa for 3% fiber volume, this showed even for greater density reduction the compressive strength reduction was negligible. For the same 10% FV the maximum compressive strength was 17MPa with 3% CF and 14.5 MPa for 0.5% CF, it showed addition of CF improved the compressive strength and decreases the density of the mix. Light weight

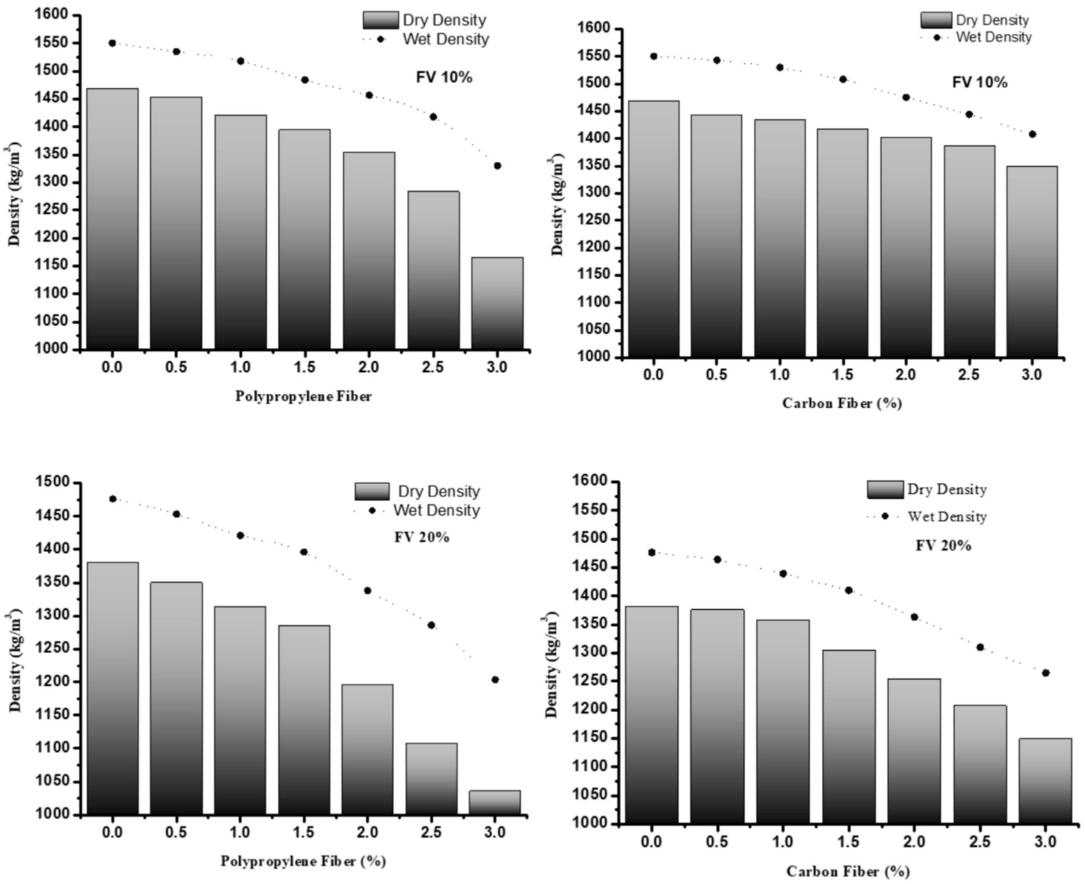

Fig. 4. Density (wet and Dry) vs Fiber (%) at different FV

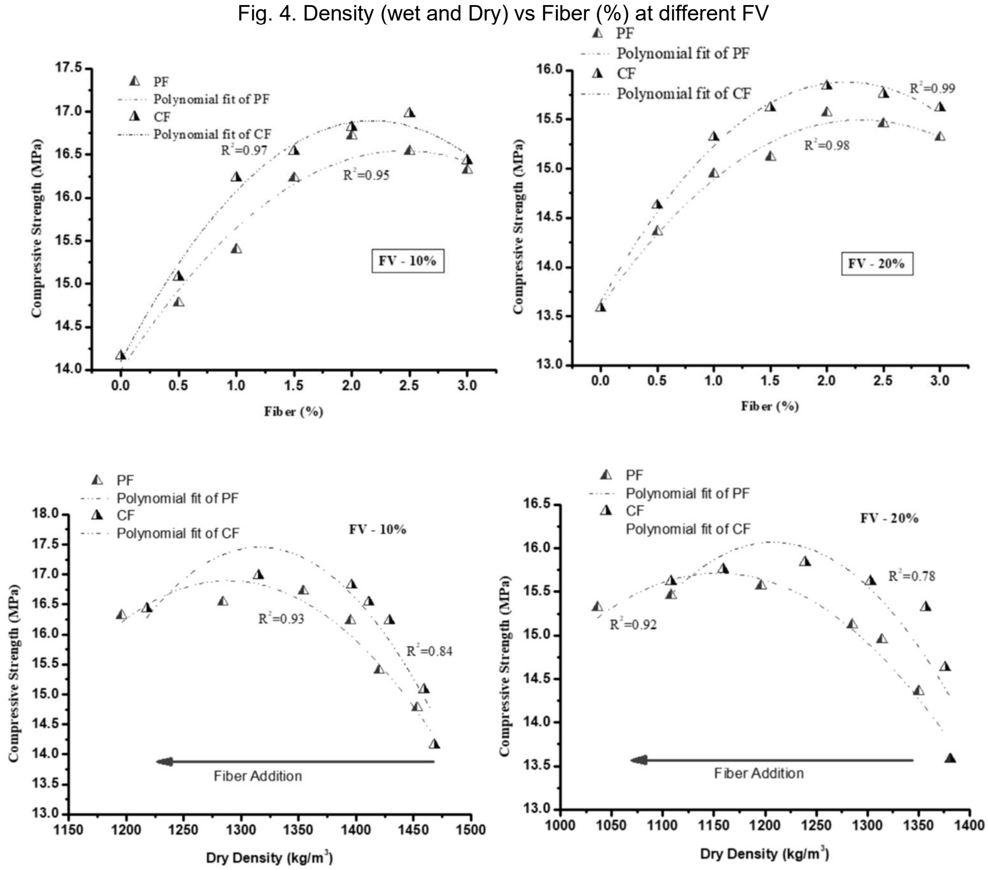

Fig. 5. Relationship between Dry Density and Compressive Strength at various FV

concrete density ranges between 600-1500kg/m^3[28]. In this study the maximum density reached was 1480kg/m^3 which satisfies light weight concrete criteria. Curvilinear rise in compressive strength is noted with respect to density. FC with 10% and 20% FV showed similar graph pattern in PF and CF addition.

4.4. Ultrasound Pulse Velocity

The quality of FC was tested by conducting Ultrasonic Pulse Velocity Test (UPV) and the test results were interpreted in the Fig.6. As the FV increases the velocity decreases. Mix with PF addition showed a concave upward profile of increase in velocity in both the FV. In 10% FV the Velocity of PF addition ranged between 1994m/s to 2588 m/s and for 20% FV, PF addition ranged between 1873m/s to 2412m/s which demonstrates velocity is proportional to the dry density of the specimen. Decrement in velocity was noted in CF addition but the not similar pattern of fall. The exponential relationship between the FC compressive strength and UPV as obtained through regression analysis and the R^2 value as presented in Fig 7.

4.5. Water Absorption

The variation of water absorption with respect to fiber content were shown in Fig 8. Also, the relationship between compressive strength, water absorption and density were shown in the Fig. 9. As the FV increases the water absorption increases. Reduction in water absorption is seen in CF addition compared to PF addition. This is due to PF are good in water repulsion characteristics. Plain FC mix without any fiber addition showed 4.5% and 9.6% water absorption for 10% FV and 20% FV, which is less than value for normal brick water absorption. Hence FC can be used in water logging areas with suitable water repellent surface plastering, water repellent agents have high impact on foam stability [29]. Higher water absorption, higher density and higher compressive strength in CF added FC matrix proves lesser void, higher foam breakage and low permeability was influenced by CF addition. PF addition showed lower water absorption, lower density and lesser compressive strength which denotes the foam is highly stable to create maximum number of voids there by reducing its density and compressive strength. Nambiar and Ramamurthy showed water absorption of FC directly relates with density of the cube [30].

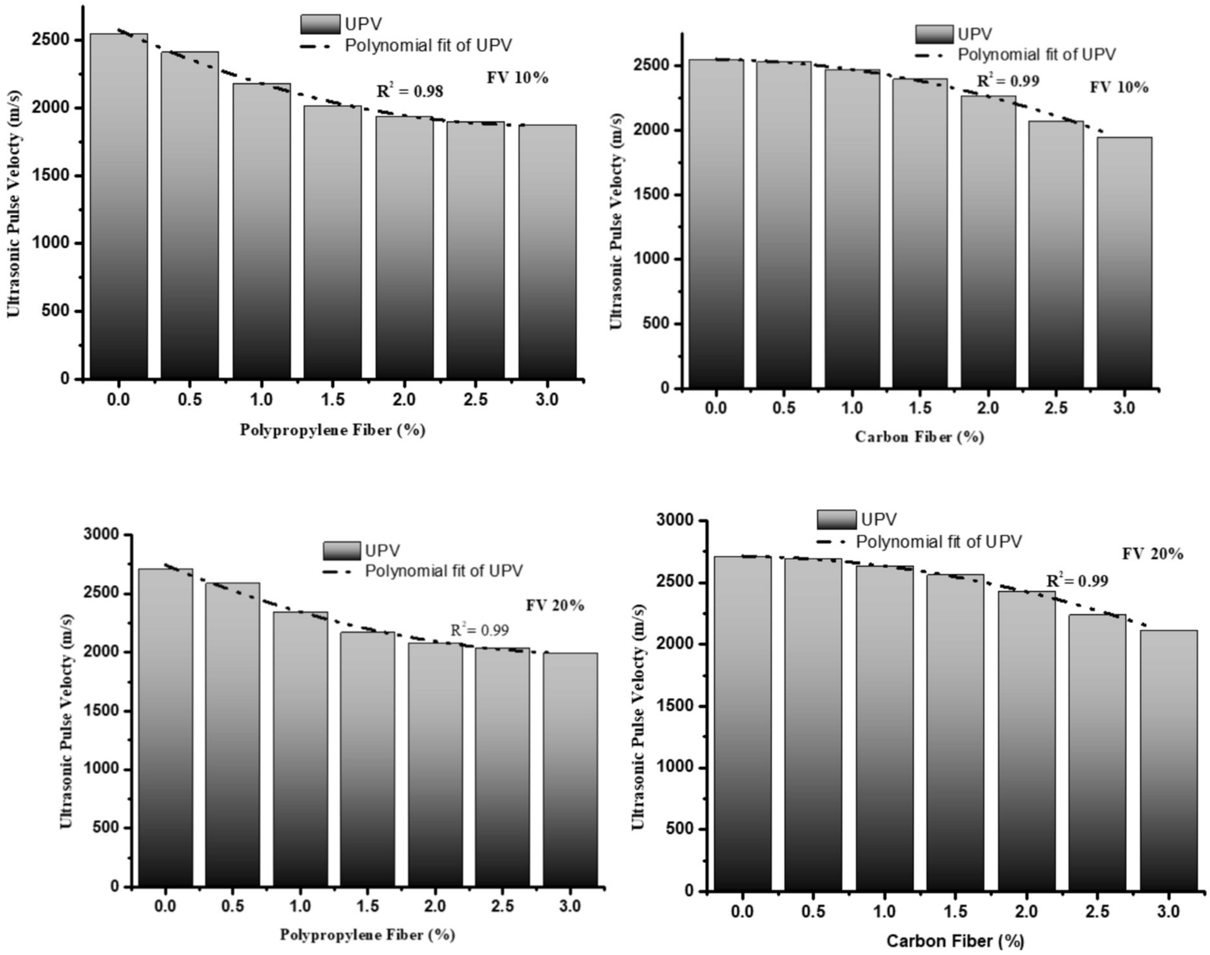

Fig. 6. Ultrasonic Pulse Velocity of FC at various Fiber proportions

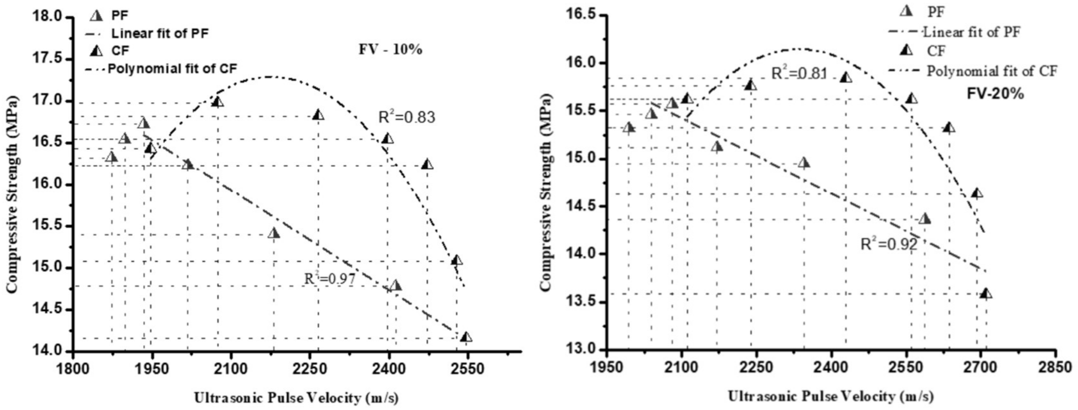

Fig. 7- Relationship between Compressive strength and Ultrasonic Pulse velocity at different FV

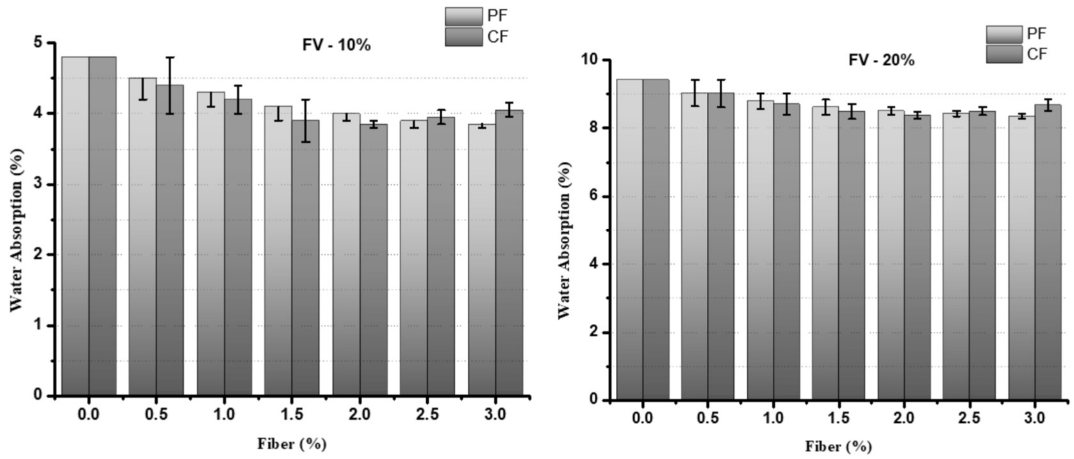

Fig. 8 - Percentage of Water Absorption vs Percentage of Fiber at various FV

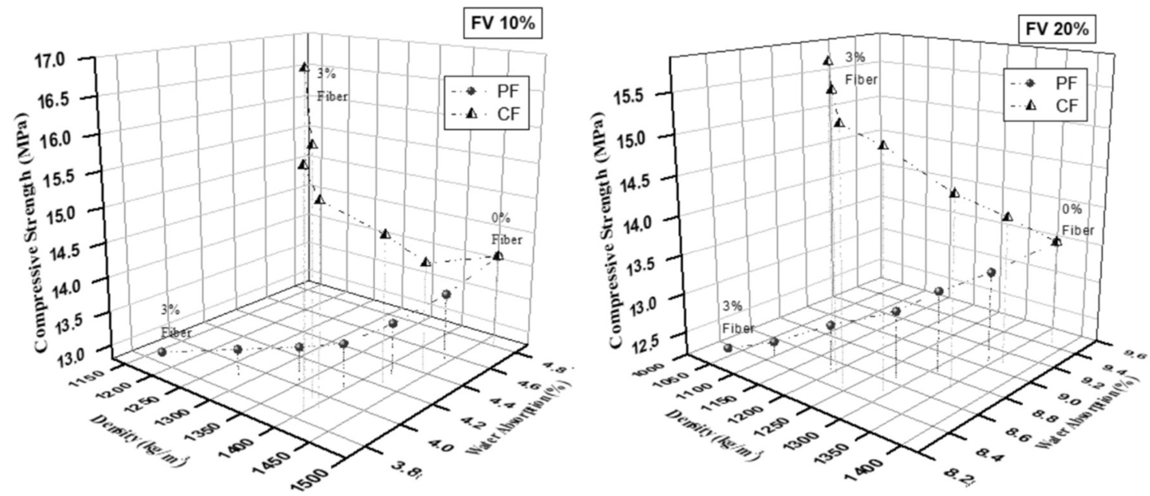

Fig. 9 - Relationship between Compressive Strength, Density and Water absorption

4.6 Porosity

The foam sustains till the hardening time of concrete was defined as pore in FC. The quantity of water entering the pore was accounted in porosity calculation. The result is shown in Fig.10. The value of porosity increases with fiber addition. For 10% FV PF addition maximum porosity was noted as 11% and in CF addition the maximum porosity is 10.75%. Similarly for 20% FV CF addition showed lesser porosity than PF fiber. It is evident from the water absorption test and porosity test result than along with artificial voids (Foam voids) there are some natural voids created during the mixing of concrete which increases the porosity and reduces the density of the concrete. These natural created voids are more in case of PF addition and slightly lesser for CF addition. Julia and Rafal studied the porosity of FC with fiber addition and stated fiber addition increases the porosity [16]. Merging of foam was the major cause for increase in porosity, shape

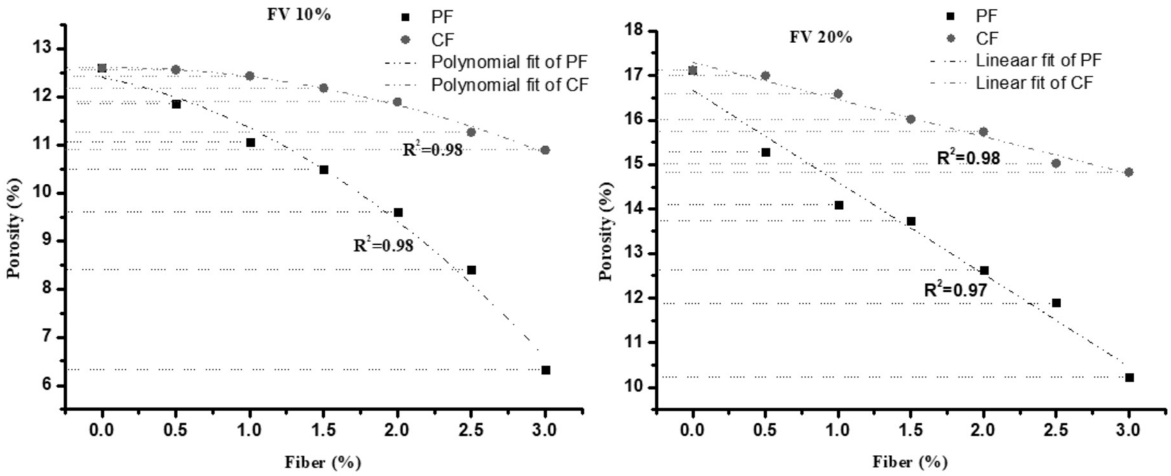

Fig. 10 - Relationship between Porosity and Percentage of Fiber in FC at different FV

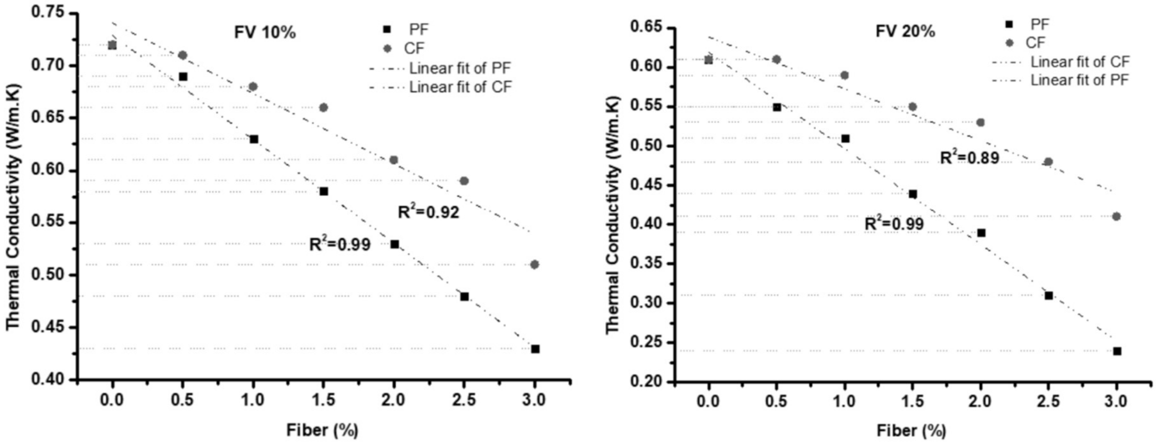

Fig. 11 - Relationship between Thermal Conductivity and Percentage of Fiber in FC at different FV

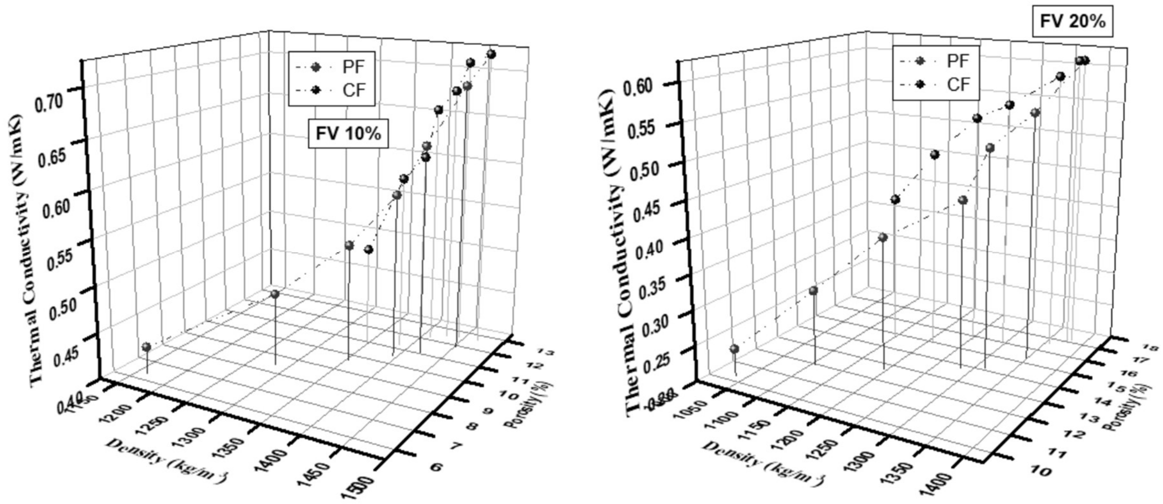

Fig. 12 - Relationship between Thermal Conductivity, Density and Porosity of FC

factor for the pore was uniformly maintained with flyash addition [31].

4.7. Thermal Conductivity

Thermal conductivity of the FC was tested by heat flow meter and the test results were shown in Fig.11The heat flow meter setup was made following IS 9489-1980 [32].The thermal conductivity was related to density. As the foam volume increases the thermal conductivity decreases. Thermal conductivity values for PF addition ranged between 0.43 W/mK to 0.68 W/mK and 0.23 W/mK to 0.55 W/mK for 10% FV and 20% FV respectively. Similarly for CF addition 0.51 W/mK to 0.72 W/mK and 0.41 W/mK to 0.62 W/mK for 10% FV and 20% FV. Test results of PF addition

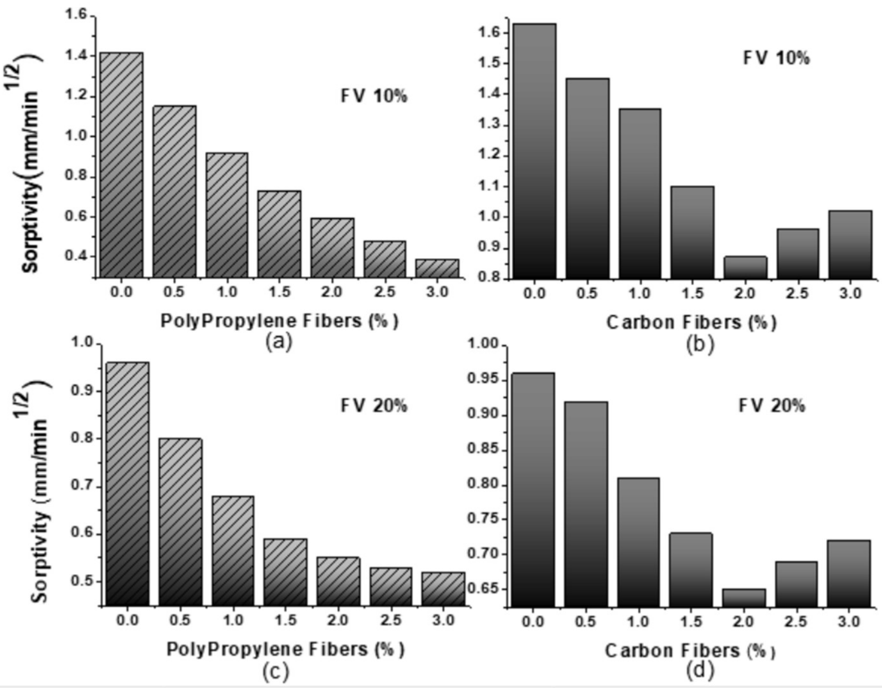

Fig. 13 - Relationship between Sorptivity and Percentage of Fiber in FC at different FV

showed lower thermal conductivity than CF addition. Which denotes lesser density because of higher porosity achieved in PF mix the thermal conductivity of FC was less. The increased moisture content of the concrete improve the thermal conductivity [33]. CF addition improves the water holding characteristic of the cube. This showed improved thermal conductivity of the specimen. Well defined uniform pores affect the thermal conductivity [34]. As mentioned in porosity study, well defined uniform pores are achieved in PF addition. The relationship between density porosity and thermal conductivity of FC is shown in Fig. 12.

4.8 Sorptivity

The sorptivity of FC was measured by capillary water absorption techniques was shown in Fig. 13. It is essential to perform sorptiity test in FC, as FC wall panels are highly used in room partitions and bathroom partitions as well. Water in the environment can severely affect the FC structures. Sorptivity coefficient denotes the durability parameter of FC. Capillary water absorption was reduced due to fiber addition. As the foam volume increases the sorptivity of FC decreases, this is due to increase in void size. Resulted in reduction the capillary action between the pores. Nambiar and Ramamoorthy also stated in their studies about increased FV and corresponding reduction in sorptivity, FC with water repellent admixtures shows less sorptivity than ordinary FC [30][29]. It is well defined from Fig. 13 FC with PF fiber showed curvilinear drop in sorptivity values. CF addition showed initial drop upto 2% fiber volume and slight increase in capillarity rise was noted due to water absorption characteristics of CF [1].

4.9 Drying Shrinkage

The drying shrinkage was carried out following the ASTM C596-01. Once demoulded the sample were cured for 24hrs followed by soaking it in water for 48hrs. The samples were left in room temperature 23±3ºC at relative humidity 50%. The length changes were noted at 1, 3, 7, 14, 28 and 60 days of drying. Drying shrinkage rate was absorbed to be higher during 3, 7, and 14th days. The increase in FV has no adverse effect on drying shrinkage. Drying shrinkage increases with decrease in FV this is due to lower paste content in the mix and thus the lower content of pores affected by shrinkage [35]. In the present study the FV was not much varied hence there is no tremendous changes in shrinkage is noted. The difference in shrinkage value due to PF addition and CF addition was absorbed. The Fig. 14 shows drying shrinkage value with respect to fiber (%) and the corresponding day for the four different mixes. More than 2% CF addition showed slightly lesser shrinkage values compared to PF mix and the conventional mix. PF Addition from 0.5% up to 2% showed lesser shrinkage values. Fiber addition in FC reduces the drying shrinkage irrespective of its type.

5. Cost to benefit analysis

Cost to benefit analysis was conducted to estimate the practical cost of PF addition and CF in conventional FC used in industry. Both CF and PF are taken form reusable waste materials, hence only the treatment cost (grinding and cleaning) of the material is considered. The Table 5 represents the cost of producing 1m^3 of conventional FC and FC with fibers and CBP additions. The usage of environmental hazard materials like CBP, PF and

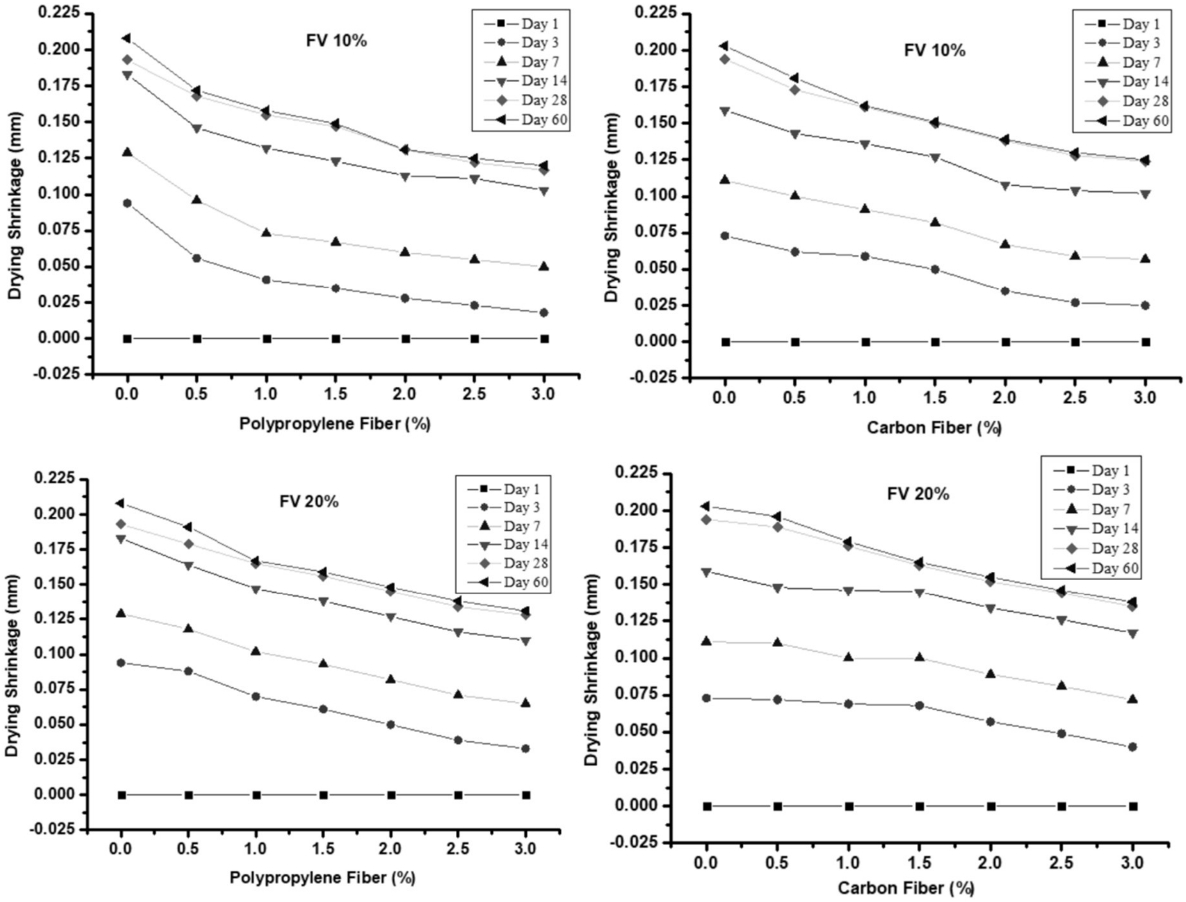

Fig. 14 - Drying Shrinkage of FC at various fiber percentages and at different FV

Table 5

Quantity of Materials required and Cost of producing FC (FV 20%)

Mix	Materials Used	Price/Unit (INR)	Quantity Required (per m^3)	Cost (Rs.)
Conventional FC	Cement	485 Rs. (50kg bag)	420kg	4,074
	Pulverized Sand	55 Rs. / Cubic ft	36 cubic ft	1,980
	Water	30 Rs. / Kilo litre	168 litres	5,040
	Foaming Agent (Rheocell 30)	2500 Rs / 20 litre	60 litres	7,500
			Total Cost	18,594
FC with CBP and PF	Cement	485 Rs. (50kg bag)	315 kg	3,055
	25% CBP	2 Rs / kg	105 kg	210
	Pulverized Sand	55 Rs. / Cubic ft	36 cubic ft	1,980
	Water	30 Rs. / Kilo litre	168 litres	5,040
	Foaming Agent (Rheocell 30)	2500 Rs / 20 litre	60 litres	7,500
	Polypropylene fibers (3% Addition)	300 Rs / kg	0.3 kg	90
			Total Cost	17,875
FC with CBP and CF	Cement	485 Rs. (50kg bag)	315 kg	3,055
	25% CBP	2 Rs / kg	105 kg	210
	Pulverized Sand	55 Rs. / Cubic ft	36 cubic ft	1,980
	Water	30 Rs. / Kilo litre	168 litres	5,040
	Foaming Agent (Rheocell 30)	2500 Rs / 20 litre	60 litres	7,500
	Carbon fibers (3% Addition)	200 Rs / kg	0.2 kg	40
			Total Cost	17,825

CF in FC minimize the cost of conventional FC and reduces the cement requirement to create an eco-friendly environment.

6. Conclusion

- Increase in FV increases the diameter of flow spread and reduces the flow time in

FC. 29.8% increase in spread diameter was noted in FC with PF when the foam volume increases from 10% to 20%. Similarly, 53.8% increase in spread diameter was noted in FC with CF when the foam volume increases from 10% to 20%. Maximum spread diameter was noted in FC with PF than FC with CF irrespective of percentage of fiber. This shows PF in FC makes the concrete more workable than FC with CF. Also, smooth surface finish of FC can be achieved by adding PF.

- Other than flow spread, all the test results of 10% FV and 20% FV follows similar test result pattern. PF in FC showed the lowest values of dry density, wet density, UPV, Porosity, Thermal conductivity, Sorptivity and Shrinkage. This was due to uniform dispersion of air voids in FC, implies denotes FC with PF addition improve the performance characteristics of FC.
- CF fiber showed maximum compressive strength at 2.5% fiber addition in 10% FV, which is 1.5% more than the maximum compressive strength of FC with PF (2% PF fiber addition) in 10% FV. Similarly higher strength with correspondingly higher densities was noted in 20% FV at 2% CF addition and also in 2% PF addition. However, for the same strength CF addition showed lowest density. Hence CF addition in FC showed highest strength at lowest density.
- Thermal conductivity and porosity values decrease with the increase in fiber addition. Both the fiber showed desirable thermal conductivity values. Comparatively FC with PF has the lowest thermal conductivity. The results thus show that not only the foam volume affects the FC properties but also the type and proportion of fiber also affect the properties of FC.
- The reduction in UPV values were noted with increase in fiber addition (both PF and CF) makes the FC to be unstable and most doubtful. Hence can be proposed for non-load bearing walls and partition walls.
- A detailed investigation on contribution of PF and CF in pore size, pore shape, pore distribution characteristics of FC will be explored in our next research.

It is concluded that PF and CF fiber in FC improves the performance and strength characteristics when compared to conventional FC. The engineering properties at both fresh and hardened state of FC with PF was better when compared to FC with CF. Inclusion of waste fiber in concrete creates an environmentally protected and sustainable development in construction practice. Hence 2% PF by the weight of FC, addition can be proposed for practical applications under economical and eco-friendly infrastructure.

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