

Experimental Investigation on Strength Characteristics of Fly Ash Based High Performance Concrete with Steel Fiber and Polypropylene Fiber

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ABSTRACT: Cement is the most popular material used in construction, recent trend is in concrete cement is replaced by admixtures such as GGBS, fly ash, slag, silica fume and metakaolin to improve the characteristics of high performance of concrete in order to reduce the creep and shrinkage and to improve tensile strength, fibers are added. The scope of present investigation deals with the strength properties of high performance concrete, on the effect of partial replacement of cement by fly ash with different percentages viz 0%, 10% and 20% was used in the concrete mix containing composite fibers (steel and polypropylene) of different percentages viz 0%, 0.50%, 0.75% and 1% steel fibers and 0.25% polypropylene fiber constant for all fly ash concrete mixes on the properties of high performance concrete. An aggregate binder ratio of 2.5 and different water binder ratio viz 0.30, 0.35 and 0.40 with super plasticizer of 0.6% by weight of binder was used in this investigation. Each series consists prisms, cylinders and cubes as per IS standard. The tests are conducted to find out the flexural strength, split tensile strength and compressive strength at the age of 7 days and 28 days.

KEYWORDS: Fly ash, steel fiber, polypropylene fiber, super plasticizer, strength properties.

I. INTRODUCTION

Cement is a very commonly used construction materials, it has ability to get cast in any form and shape in general and rigid pavement in particular. Also replaces old construction materials such as stone and brick masonry. A good concrete much possess high strength and low permeability. The strength of concrete can be changed by making appropriate changes in its ingredients like aggregate, water and cementitious material, also adding some special ingredients. However concrete has some deficiencies as

- Low impact strength
- Low post cracking capacity
- Low tensile strength
- Incapable of accommodating large deformations
- Brittleness and low ductility
- Limited fatigue life

Certain mineral admixture are also added to concrete to improve their strength properties of concrete materials such as fly ash, which are usually very fine, may be finer than cement, when added to concrete in right proportion can improve the strength of concrete extremely and high strength and high performance concrete is received in this manner. In order to improve the mechanical properties of concrete it is good to mix cement with fiber which have good tensile strength. Addition of polypropylene fibers decreases the unit weight of concrete and increases its strength. Incorporation of composite materials (steel and polypropylene fibers) in concrete significantly improve its plastic settlement, strains and stress concentrations imposed by external restraints, bleeding, thermal and shrinkage.

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II. LITERATURE REVIEW

1. Naaman A.E, Al-khairi F.M, and Hammoud H. Showed that use of steel fibres in lower strength concretes increases their compressive strength significantly compared to plain unreinforced matrices and is directly related to volume fraction of steel fibre used. This increase is more for hooked fibres in comparison with strength polypropylene fiber, steel fiber or glass fiber.
2. Siva kumar.A and Manu Santhanam. Studied on high strength concrete reinforced with hybrid fibres (combination of hooked steel and a non metallic fibre) up to a volume fraction of 0.5% and found the flexural toughness of steel polypropylene hybrid fibre concrete was better to steel fibre concrete.
3. Jain Tong Ding and Zongjin Li. Studied about the effect of metakaolin and silica fume on properties of concrete. Seven concretes were cast at a water/binder ratio of 0.35 with 0, 5, 10 and 15% cement replaced by metakaolin or silica fume. The incorporation of both metakaolin and silica fume in concrete can reduce the free drying shrinkage and restrained shrinkage cracking width.
4. X. Qian and Z. Li. Reported the results of a study of stress – strain relationship in compression, tension and flexural strength measurements for concrete incorporating 0%, 5%, 10% and 15% metakaolin. The test results show that the tensile strength and peak strain increase with increasing metakaolin content where as the tensile elastic modulus shows only small changes. The lowering/downward-moving/originating area over peak stress is improved when 5% and 10% of cement is replaced by metakaolin. Also, the modulus of rupture and compressive strength increase with increasing metakaolin content. The compressive elasticity modulus of concrete shows a small increase with increasing metakaolin replacement,
5. Cengiz Duran Atis and Okan Karahan. Study the influence of using fly ash, polypropylene fibers, and steel fibers in concrete showed that strong relation existed between abrasion and flexural tensile strength, than between abrasion and compressive strength of the concrete containing either fly ash or fibers or both.
6. Ramadevi K, venkatesh babu D.L. Concluded the workability of hybrid fiber reinforced concrete mix was increased by addition of a super plasticizer. The test results of the research shows that use of hybrid fiber reinforced concrete improves flexural performance of the beams during loading.
7. Scott R and Singh S.P. The high performance concrete is concrete which secures/makes sure of long-time ability of last in structures exposed to aggressive surrounding conditions. Ability to last of concrete is its ability to resist weathering action, chemical attack, scrape/injury and all other worsening/rusting, crumbling, etc. processes. Weathering includes related to surrounding conditions effects such as exposure to cycles of wetting and drying, heating and cooling, as also freezing and thawing. Chemical worsening/rusting, crumbling, etc. process includes acid attack, big and wide chemical attack due to moisture and chloride ingress.
8. K.Murahari, Rama mohan Rao P. Studied the effect of polypropylene fiber in fly ash concrete. Fiber volume fraction of 0.15%, 0.2%, 0.25% and 0.3% was used in fly ash concrete with class C fly ash of specific gravity 1.96, obtained from NLC. Fly ash content was varied as 30%, 40% and 50%. 12mm (40%) and 20mm (60%) coarse aggregate with specific gravity of 2.7 were used. The cube specimens were tested for 28days and 56days strength. The compressive strength gained maximum strength at early age as observed for all fly ash and polypropylene fiber concrete. It is also observed that the compressive strength increased gradually from 0.15% to 0.3% fiber content.

III. MATERIALS

- a) Cement (OPC): Ultra tech cement 43 grade was used. Specific Gravity of Cement was 3.08.
- b) Coarse aggregate: - crushed granite metal with 60% passing 20 mm and retained on 12.5mm sieve and 40% passing 12.5mm and retained on 4.75mm sieve were used. The weight of coarse aggregate was 60% of the total aggregate and specific gravity of coarse aggregate was 2.70.
- c) Fine aggregate: - River sand from local sources was used as fine aggregate. Specific Gravity was 2.50.
- d) Water: Water used for both mixing and curing should be free from harmful amounts of harmful materials. In the present work drinkable tap water was mixed directly with concrete.
- e) Fly ash: Fly ash obtained from thermal power plant at KUDITHINI BELLARY THERMAL POWER STATION was used in the investigation. The specific gravity is 1.9.

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- f) Super plasticizer: To improve the workability of the mixes, a high range water reducing agent Fosroc conplast SP430 (SNF- Sulphonated Naphthalene Formaldehyde) is used.
- g) Steel fibers: Crimped steel fibres of 30mm length with a dia of 0.6mm and an aspect ratio of 50, density is 7840 Kg/m³ and specific gravity is 7.9 were used throughout the experimental program.
- h) Polypropylene fibers: RECRON 3S TYPE-CT 2012 polypropylene fibres of density 946 Kg/m³ are used in experimental program.



Figure: - 1 Specimens casted



Figure: - 2 Specimens kept in curing tank

IV. MIX DESIGN

Sample calculation of the quantities required for the mix with aggregate-binder ratio 2.5 and for water binder ratios of 0.30, 0.35 and 0.40 and for 0%, 10% and 20% fly ash are tabulated below. Table:-1

Materials	0% fly ash			10% fly ash			20% fly ash		
	0.30% W/B Ratio	0.35% W/B Ratio	0.40% W/B Ratio	0.30% W/B Ratio	0.35% W/B Ratio	0.40% W/B Ratio	0.30% W/B Ratio	0.35% W/B Ratio	0.40% W/B Ratio
Cement (kg)	35.60	34.51	33.48	31.64	30.68	29.78	27.77	26.94	26.16
Fly ash(kg)	-	-	-	03.52	03.41	03.31	06.94	06.74	06.54
Water (ml)	10.68	12.08	13.39	10.55	11.93	13.23	10.42	11.79	13.08
Coarse aggregates (kg)	53.40	51.77	50.23	52.73	51.13	49.63	52.08	50.52	49.05
Fine aggregates (kg)	35.60	34.51	33.48	35.15	34.09	33.09	34.72	33.68	32.70
Super plasticizer (ml)	213.60	207.06	200.88	210.96	204.54	198.54	208.26	202.08	196.20
Mix proportion	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5	1:1:1.5

V. METHODOLOGY

In this study the mixtures of fly ash in ratio of 0%, 10% and 20% was used in the concrete mix containing steel fiber of different dosage i.e. 0%, 0.5%, 0.75% and 1% and 0.25% polypropylene fiber constant was used for fly ash concrete mixes. An aggregate binder ratio of 2.5 and different water binder ratio viz 0.30, 0.35 and 0.40 with super plasticizer of 0.6% was used in this investigation. Each series consists prisms, cylinders and cubes as per IS standard. The tests are conducted to find out the flexural strength, split tensile strength and compressive strength at the age of 7 days and 28

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days. The above said mixtures with fly ash containing composite fibers in different dosage with different water binder ratio were composed in this study. At the age 7 days and 28 days of each mixture were tested and analysed in order to find out the best efficient mixture in following of strength characteristics of concrete mix.

Compressive Strength Test: Concrete cubes conforming to IS: 516-1964 of size 150x150x150 mm was cast for determination of compressive strength. After 24 hours the moulds were de moulded and subjected to water curing. Before testing, the cubes were air dried for 2 hours, crushing loads were noted and average compressive strength of 3 specimens is determined at 28 days.

Table:-2, Test results for 28 days compressive strength

S No	% of steel Fibre	% of ppf	Total % of composite fibres	Cube Compressive strength (MPa)								
				0% fly ash w/c Ratio			10% fly ash w/c Ratio			20% fly ash w/c Ratio		
				0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40
1	0	0	0	50.28	49.22	47.48	52.11	51.55	49.88	48.11	47.55	45.77
2	0.50	0.25	0.75	55.00	53.12	50.15	57.33	55.11	53.33	52.77	50.85	48.11
3	0.75	0.25	1.00	58.90	57.45	55.48	60.66	58.66	57.53	54.88	53.55	52.44
4	1.00	0.25	1.25	63.66	61.33	60.11	63.88	62.67	60.62	60.22	57.77	55.11

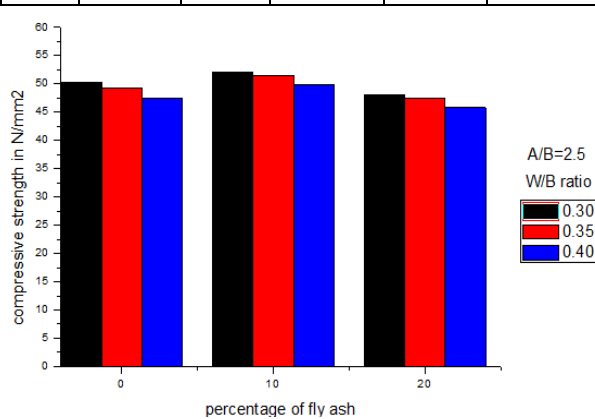


Figure: - 3 (a)

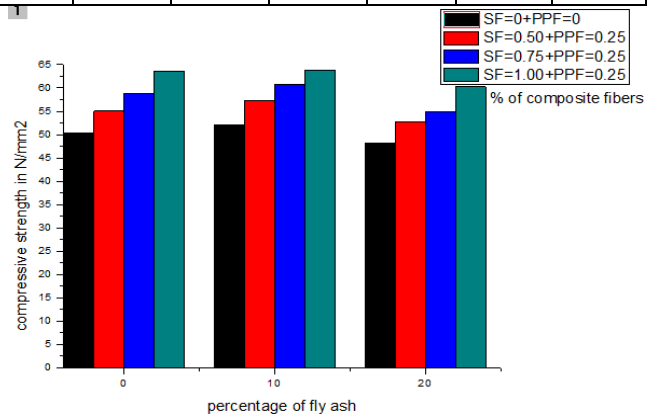


Figure: - 3 (b)

Figure: - 3 (a) Variation of 28 days compressive strength with percentage of fly ash for different W/B ratio & Figure: - 3 (b) Variation of 28 days compressive strength on different percentage of fly ash for different percentage of composite fibers.

➤ It is observed that at 10% replacement of cement by fly ash compressive strength increases over 0% fly ash. Further increase in fly ash by 20% the compressive strength decrease over 0% fly ash. Hence the maximum replacement of cement by admixture fly ash is 10%. As W/B ratio increases the compressive strength decreases. It is observed that the 28 days compressive strength increases with increase in composite fibers.

Split tensile strength test: Tensile strength is one of the basic and important properties of concrete. Size of test sample of 15cm diameter, 30cm height and 0.3cm thick cylindrical mould is used. The cylinder is placed left and right between

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the two plates of the compressive testing machine and the load is applied. The load at which the sample in the end fails is noted and split tensile strength is calculated. The split tensile is calculated by using the formula.

Table:-3 Test results for 28 days split tensile strength

S.No	% of steel Fibre	% of ppf	Total % of composite fibres	Split Tensile strength (MPa)								
				0% fly ash w/c Ratio			10% fly ash w/c Ratio			20% fly ash w/c Ratio		
				0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40
1	0	0	0	4.92	4.83	4.64	5.08	4.92	4.72	4.82	4.72	4.51
2	0.50	0.25	0.75	5.21	4.98	4.91	5.31	5.18	5.04	5.07	4.86	4.77
3	0.75	0.25	1.00	5.34	5.26	5.12	5.42	5.37	5.21	5.22	5.11	4.92
4	1.00	0.25	1.25	5.56	5.44	5.33	5.62	5.51	5.39	5.35	5.26	5.18

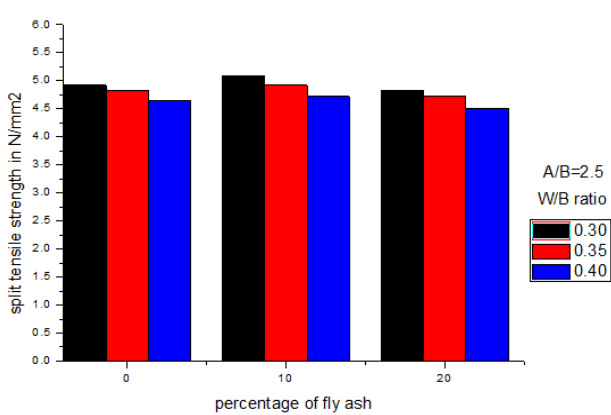


Figure: - 4 (a)

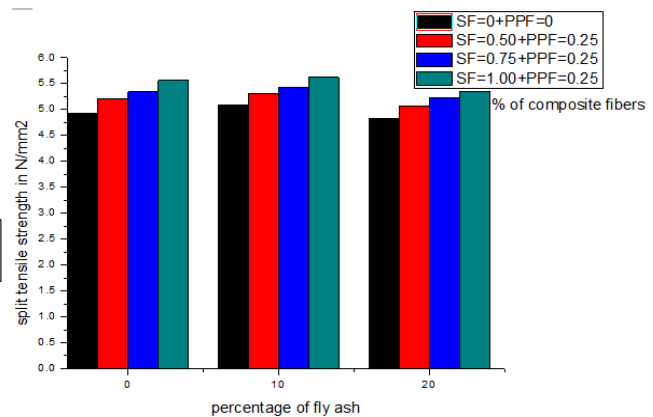


Figure: - 4 (b)

Figure: - 4 (a) Variation of 28 days split tensile strength with percentage of fly ash for different W/B ratio & Figure: - 4 (b) Variation of 28 days split tensile strength on different percentage of fly ash for different percentage of composite fibers.

- It is observed that at 10% replacement of cement by fly ash split tensile strength increases over 0% fly ash. Further increase in fly ash by 20% the split tensile strength decrease over 0% fly ash. Hence the maximum replacement of cement by admixture fly ash is 10%. As W/B ratio increases the split tensile strength decreases. It is observed that the 28 days split tensile strength increases with increase in composite fibers.

Flexural strength test: The prism is generally tested to identify the flexural behaviour of the hardened concrete. The test is carried in a universal testing machine of 60T load ability. Standard prism of size 10cm x 10cm x 50cm were tested under one point loading to study the flexural strength of concrete. The maximum tensile stress read at the failure of prism is called modulus of rupture and is calculated. The flexural strength is calculated by using formula.

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Table:-4 Test results for 28 days flexural strength

S.No	% of steel Fibre	% of ppf	Total % of composite fibres	flexural strength (MPa)								
				0% fly ash w/c Ratio			10% fly ash w/c Ratio			20% fly ash w/c Ratio		
				0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40
1	0	0	0	5.75	5.43	5.27	5.83	5.56	5.39	5.67	5.31	5.08
2	0.50	0.25	0.75	5.92	5.77	5.48	6.09	5.92	5.62	5.76	5.71	5.37
3	0.75	0.25	1.00	6.18	5.96	5.82	6.28	6.17	5.97	5.83	5.78	5.73
4	1.00	0.25	1.25	6.31	6.24	6.11	6.42	6.31	6.21	6.02	5.92	5.85

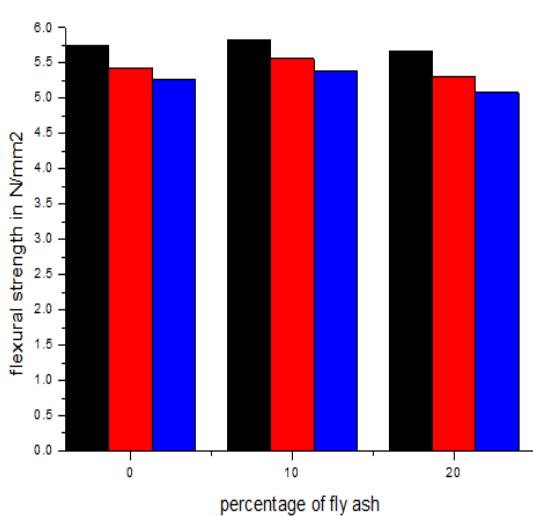


Figure: - 5 (a)

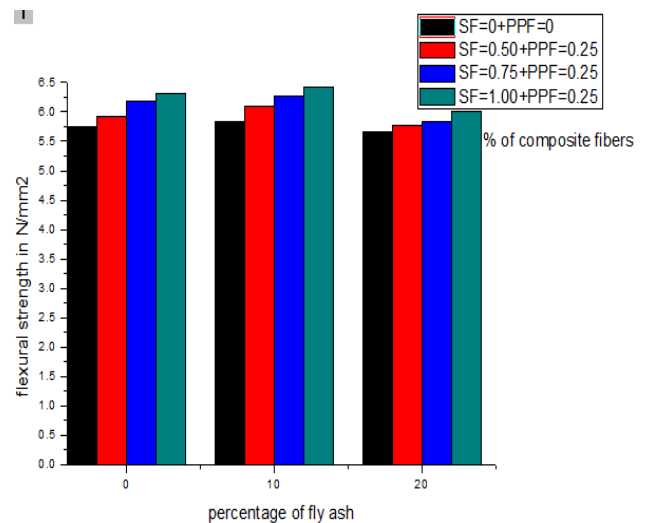


Figure: - 5 (b)

Figure: - 5 (a) Variation of 28 days flexural strength with percentage of fly ash for different W/B ratio & Figure: - 5(b) Variation of 28 days flexural strength on different percentage of fly ash for different percentage of composite fibers.

- It is observed that at 10% replacement of cement by fly ash flexural strength increases over 0% fly ash. Further increase in fly ash by 20% the flexural strength decrease over 0% fly ash. Hence the maximum replacement of cement by admixture fly ash is 10%. As W/B ratio increases the flexural strength decreases. It is observed that the 28 days flexural strength increases with increase in composite fibers.

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V. CONCLUSION

1. 10% fly ash can be taken as Optimum dosage, which can be used as a partial replacement to cement for giving maximum possible compressive strength at any age for composite fibers (steel and polypropylene) reinforced high performance concrete.
2. Addition of composite fibers (steel and polypropylene) improves the tension stiffening effect considerably and this increase the bond stress of reinforced bars in composite fiber reinforced concrete than in plane concrete.
3. 1.25% composite fiber volume can be taken as the optimum dosage which can be used for giving maximum possible compressive strength at any age for steel fiber reinforced high performance concrete.
4. Composite fibers increase the compressive strength of concrete and also resist the sudden collapse of the hardened concrete.
5. From experimental results it has been observed that at 28days of 1.25% composite fiber (steel and polypropylene) volume with 10% fly ash concrete the increase in compressive strength is 26.61%, split tensile strength is 13.00% and flexural strength is 9.73% over plane concrete without fiber.
6. From experimental results it has been observed that at 28days of 1.25% composite fiber (steel and polypropylene) volume with 20% fly ash concrete the decrease in compressive strength is 4.31%, split tensile strength is 2.03% and flexural strength is 1.39% over plane concrete without fiber.
7. From experimental results, the optimum percentage recommended as 1.25% composite fiber volume with 10% fly ash for achieving maximum benefits in compressive strength, flexural strength and split tensile strength.
8. Polypropylene fibers reduce the settlement, plastic, water permeability and shrinkage.

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BIOGRAPHY



Adanagouda received his BE in Civil Engineering, M.Tech in Structural Engineering and is currently pursuing his Ph.D (VTU, Belagavi) in Hybrid fiber reinforced concrete with mineral admixtures. He is an Assistant Professor in Department of Civil Engineering at RYMEC Ballari, Karnataka, India. He has around 06 years of academic teaching, consultancy and research works. His research interests include HPC, hybrid fiber, concrete admixtures and durability of concrete.

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