EXPERIMENTAL INVESTIGATION ON STRENGTH AND BEHAVIOUR OF FIBRE REINFORCED PSC BEAMS WITH HIGH REACTIVE METAKAOLIN AND SILICA FUME

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ABSTRACT: Cement is been widely used in concrete, where the addition of mineral admixtures, like Metakaolin, Silica fume, GGBS, etc., replacing the cement has been widely accepting in the construction industry. Not only it increases the properties of the concrete but also plays a vital role in the environmental aspects. Even though concrete is most commonly used construction industry, it has certain disadvantages such as low tension and ductility characteristics. This low tensile strength and ductilty of concrete can be improved by the use of variety of fibres in the concrete.

Use of fibres in concrete helps in controlling plastic and drying shrinkage cracks effectively, also lessen the crack widths and enhances ductility characteristics. This experimental study involves finding out of optimum volume fraction of fibres for M-60 grade concrete. Casting and testing of post tensioned beams, incorporated with sisal, polypropylene and steel fibres, at optimum volume of fibres under two point loading experimental set up. Comparison of strength and behaviour of concrete in between these fibres are made. The use of mineral admixtures in the concrete, it lowers the permeability, and thus reduces the bleeding of water. Some of the fibre type builds higher resistance to abrasion, shatter and impact. Thus increases the strength of the composites. The tension weakness is typically overcome by intensifying their matrix with fibrous materials. The fibrous concrete possesses outstanding mechanical properties than the normal concrete.

INTRODUCTION

Cement, aggregates, and water make up the bulk of concrete. To create concrete with different qualities from regular concrete, additives are used. Prestressed concrete is one in which compressive stresses are added inside to improve its qualities. Post tensioning is a type of prestressing in which the tensioning is carried out after the concrete has been placed. They could be bound or unbound. The tendons are put in a metal or plastic duct during post tensioning, after which the concrete is poured. When the concrete is strong enough, wedges are used to secure one end of the tendons, and jacks are used to stress the other end. The conduit might or might not later be grouted. The duct is of the bonded kind if it is grouted. Comparing a post-tensioned member to a typical reinforced concrete member, there are various benefits. Greater stresses than those carried by the reinforcing bars are tolerated by the tensioned steel. They shrink less and are more resilient. Post-tensioned components are used in structures to ensure little deflection and breaking even when under full load. Concrete cracks can be efficiently controlled by adding fibers, which also helps to reduce fracture breadth. They even diminish the concrete's permeability, which lessens water bleeding. Some fiber types develop higher resistance to impact, shatter, and abrasion. Consequently, the composites' strength is increased. The usual method for overcoming the tension weakness is to add fibrous materials to their matrix to make it stronger. Compared to regular concrete, fibrous concrete has superior mechanical qualities. Fibers in concrete are distinct, evenly dispersed, and randomly orientated. The use of fibers in conjunction with high strength cementitious matrices to increase toughness and strength under tension is gaining popularity.

The main objective of this research work is to finding out the contribution of the fibres, Metakaolin and **Silica** Fume to concrete in terms of its strength and durability and also to assess the behaviour of post tensioned beam reinforced with prestressing steel and Sisal fibres, Polypropylene fibres, Crimped end steel fibres, in addition to the nominal steel reinforcement under the flexural loading.

RESEARCH SIGNIFICANCE

From past literature works it can be concluded that, in almost all the literature investigations are made to find out the suitable fibre concrete mixture, which resembles the ordinary Portland cement concrete or better performance than OPC concrete. Fibres helped in reducing strain by redistribution of stresses. With the addition of fibres, ultimate strain, ductility index, crack widths are reduced. It is observed that, steel fibres take more loads when compared to polypropylene fibres. Not much research work has been done on the post tensioned beams with fibres. Hence an attempt is to be done to review the properties of beams with fibres. Therefore the present work involves the use of fibres in post tensioned beams in studying the response of beams in ductility, tensile strength, ftexural strength, crack and distribution failure. The available literature on the properties of fibre reinforced post tensioned concrete beam was insufficient. So the present study is focused on the preparing optimal mix for casting of post tensioned fibre reinforced concrete beam specimens to find out their structural properties.

MATERIALS

The concrete basically consists of cement as a binder material, and also Metakaolin and Silica fume used as a partial replacement to the cement ,fine and coarse aggregate as filler material in the concrete and potable water. When these materials are mixed together and placed in the forms of shape and cured with water, it is going to become hard like stone. Steel reinforcement is introduced into this concrete, at the places required to withstand the stresses mainly due to tensile force then that is known as reinforced cement concrete. The same concrete when it is introduced with stressing prior to application of load then it is called as Pre stressed concrete.

Materials

Concrete can be defined as a stone like material that has a cementitious medium with in which aggregates are embedded. In hydraulic cement concrete, the binder is composed of a mixture of hydraulic cement and water (ACI Committee 116). Concrete has an oven-dry density greater than 2000 kg/m^3 but not exceeding 2600 kg/ ' (BS EN 206-1:2000).

1. Cement
2. Fine aggregates
3. Coarse aggregates
4. Admixture
5. Water
6. Reinforcing fibres
7. Barrels, Wedges. End anchorages and sheathing Pipe
8. High strength steel strands

Reinforcement

Reinforcement in the form of tendons is provided to withstand the tensile stresses which are developed inside concrete at prestressing. The other conventional reinforcement is also provided as longitudinal and transverse reinforcement, steel fibres and tendons helps in encountering micro cracks in concrete.

1) Untensioned steel: High yield strength deformed (HYSD) bars of grade Fe 500 of 8 mm and 10 mm as compression and tension steel respectively. 8mm bars was used as stirrups as shear reinforcement.

Fig 1: HYSD Bars

2) High tensile steel: 12.7 mm 7 ply tendons confirming to IS 4454-1981 part- 1 were supplied by Miki Steels, Hyderabad and were used in this research.

Prestressing Materials

Prestressing is done with the help of following materials like Sheathing pipe, Wedges, Barrels, and Anchorages etc. Post tensioning is done after placing of sheathing pipe in the concrete beam and later tendons are reinforced inside it and stressed using prestressing equipment by fixing wedges and barrels by the support of anchors to designed load.

FRESH AND HARDENED CONCRETE PROPERTIES

In the present experimental investigation, high strength concrete is used. The mineral admixture of Metakaolin (MK) and Condensed Silica fume (CSF) as partial replacement by weight of cement has been used. Sisal fibre, Polypropylene fibre, and Steel fibres having aspect ratio of 80 are also used. The proportion Sisal fibre, Polypropylene fibre and steel fibres are added at 0.3%,0.25% and 2% as total fibre percentage of the volume of concrete. Cubes, cylinders and beams were casted with M60 grade concrete design mix. The results are discussed under the following heads.

Workability

The Slump test results of mix design M60 are tabulated.

Table 1 Slump test results

Mix Description	Slump Values in mm				Slump Loss %		
	Conventional	5%	10%	15%			
CC	124	-	-	-			
CStFi	121	-	-	-	2.4		
CPPFi	122	-	-	-	1.6		
CSiFi	114	-	-	-	8.1		
CSF	-	119	117	114	4.0	5.6	8.1
CMK	-	115	112	110	7.3	9.7	11.3
CMKStFi	-	111	109	107	10.5	12.1	10.5
CSFStFi	-	116	114	110	6.5	8.1	11.3
CMKPPFi	-	112	110	108	9.7	11.3	12.9
CSFPPFi	-	114	111	107	8.1	10.5	10.5
CMKSiFi	-	113	110	105	8.9	11.3	15.3
CSFSiFi	-	112	108	105	9.7	12.9	15.3

Based on trial mixes, the tests showed decreased values of slump with the addition of CSF, MK, and water cement ratio of 0.34 and with an addition of maximum 0.8% Super plasticizer. The concrete mixes with admixtures of Silica fume and Metakaolin were found to have a slump value of 112 to 124 mm. Hence to increase the workability in the fibre reinforced concrete mix consisting of steel fibres, it requires a high dosages of super plasticizers. From the values of slump loss it can be seen that as the workability decreases and slump loss Increases.

Compressive strength

The compressive strength of fibre reinforced concrete cubes was determined for different percentages of sisal fibres, polypropylene fibres and steel fibres. The results are tabulated and comparison of strength between these fibres are made.

Table 2: Compressive Strengths for optimum percentage of fibres

Dosage of Fibre (%)	Compressive strength(MPa)		
	7 days	14 days	28 days
0	39.07	58.05	62.01
Sisal fibres (0.3%)	40.66	60.98	65.37
Polypropylene fibres (0.25%)	41.4	61.77	67.01
Steel fibres (2%)	42.65	63.79	70.65

Table 3: Compressive strength of M-60 grade concrete at 28" day

SLNo.	Mix Description	Compressive Strength of Cubes in N/mm^2			
		CC	5%	10%	15%
1.	CSF	-	72.55	73.56	72.86
2.	CMK	-	71.35	72.39	71.45
3.	CSFStFi	-	72.77	73.81	72.93
4.	CMKStFi	-	71.83	72.41	72.03
5.	CSFPPFi	-	72.65	73.70	72.74
6.	CMKPPFi	-	71.61	72.28	72.00
7.	CSFSiFi	-	72.33	73.41	72.69
8.	CMKSiFi	-	71.41	72.10	71.91

It has been observed that with the addition of Silica fume and Metakaolin, the compressive strength of concrete at the age of 28 days has increased with various proportions of the mix. The increase in strength is in the range of 2.57% - 7.78% for Silica fume concrete and 2.57% - 6.06% for Metakaolin concrete respectively. The same trend is observed with steel fibres in the concrete mix with various combination of blended percentage of SF and MK. It is clear from the above discussions that the additions of mineral admixtures, along with the fibres are giving higher compressive strength compared to the conventional concrete. However, silica fume concrete gives better result at all ages than metakaolin concrete.

Split tensile strength

The split tensile strength of fibre reinforced concrete cylinders was determined for optimum percentages of steel, polypropylene and sisal fibers.

The test results of tensile strength of design mix M6o grade concrete on standard 150 mm diameter and 300 mm length cylinder at 28 days age the comparison of tensile strength for different combinations of Silica fume concrete. comparison of Split tensile strength for different combinations of Metakaolin concrete .

Table 4: Split tensile strength of M60 grade of concrete at 28$^{t'}$ Day

SLNo.	Mix Description	Tensile Strength of Cubes in N/mm^2			
		CC	5%	10%	15%
1	CC	7.08	-	-	-
2	CStFi	7.51	-	-	-
3	CPPFi	7.39	-	-	-
4	CSiFi	7.24	-	-	-
5	CSF	-	7.75	7.96	7.80
6	CMK	-	7.67	7.86	7.71
7	CMKStFi	-	8.04	8.45	8.29
8	CSFStFi	-	7.89	7.97	7.94
9	CMKPPFi	-	7.86	7.98	7.91
10	CSFPPFi	-	7.54	7.81	7.66
11	CMKSiFi	-	7.50	7.89	7.61
12	CSFSiFi	-	7.39	7.66	7.51

It has been observed that with the addition of Silica fume and Metakaolin, the split tensile strength of concrete at the age of 28 days has increased with various proportions of the mix. It is found that fibre based concrete gives the highest split tensile strength amongst all the fibrous mixes. The strength increased is 3.1% and 5.1% for Metakaolin and Silica fume concrete respectively along with the Steel fibres.

Flexural strength

The test results of flexural strength of design mix on standard beams of size 150x150x700 mm at 28 days age obtained are tabulated in the Table for Silica fume and Metakaolin concrete.

Table 5: Flexural strength of M60 grade of concrete at 28thDay

SLNo.	Mix Description	flexural Strength of beams in N/mm^2			
		CC	5%	10%	15%
1	CC	7.18	-	-	-
2	CStFi	7.44	-	-	-
3	CPPFi	7.36	-	-	-
4	CSiFi	7.20	-	-	-
5	CSF	-	7.45	7.69	7.51
6	CMK	-	7.31	7.47	7.33
7	CSFStFi	-	7.54	7.67	7.61
8	CMKStFi	-	7.36	7.55	7.41
9	CSFPPFi	-	7.49	7.61	7.54
10	CMKPPFi	-	7.31	7.49	7.39
11	CSFSiFi	-	7.41	7.60	7.51
12	CMKSiFi	-	7.29	7.41	7.33

Flexural strengths are also higher for concretes with various combination, these values are further increased with addition of fibres and using nominal steel. It has been observed that with the addition of Silica fume and Metakaolin, the flexural strength of concrete at the age of 28 days has increased with various proportions of the mix. It is found that fibre based concrete gives the highest flexural strength amongst all the fibrous mixes. The strength increased is 5.1% and 6.08% for Metakaolin and Silica fume concrete with Steel fibres are compared with conventional concrete.

CONCLUSIONS

The purpose of introducing Silica fume, Metakaolin by partial replacing cement and fibres is to increase the strength, performance and tensile strength of the concrete respectively. Strength and durability properties of cement concrete was enhanced by introducing the fibres.

1. The optimum fibre volume fraction from the results of compressive strength for sisal fibre

is found to be 0.3%, polypropylene is 0.25% and steel fibber is 2%.

2. To increase the workability in the fibre reinforced concrete mix consisting of fibres cocktails, it requires high dosages of super plasticizers. From the values of slump loss it can be seen that as the workability decreases and slump loss **increases.**

3. The compressive strength of steel, polypropylene and sisal fibre in reinforced concrete after 28days of curing, has been increased by 12.98%, 8.06% and 5.42% than that of controlled concrete respectively.

4. The compressive strength of conventional concrete with steel fibre is compared to Silica fume and Metakaolin added with steel, polypropylene and sisal fibre after 28days of curing, has been increased by 5.3%,5.12%,4.66% and 3.34%,3.16%,2.91% than that of controlled concrete (With Steel fibre)respectively

5. The compressive strength of Silica fume concrete and metakaolin concrete after 28days of curing, has been increased by 18.62%, and 16.63% than that of controlled concrete(Without Fibre) respectively.

6. The split tensile strength of steel, polypropylene and sisal fibres in reinforced concrete has been increased by 6.08%, 4.36% and 2.2% than that of controlled concrete respectively.
7. The Split tensile strength of conventional concrete with steel fibre is compared to Silica fume and Metakaolin added with steel, polypropylene and sisal fibre after 28days of curing, has been increased by 5.99,%,3.99%,1.99% and 6.25%,5.05% 4.46%, than that of controlled concrete (With Steel fibre)respectively

8. The Split tensile strength of Silica fume concrete and metakaolin concrete after 28days of curing, has been increased by 12.42%, and 11.01% than that of controlled concrete(Without Fibre) respectively.

9. The Flexural strength of steel, polypropylene and sisal fibres in reinforced concrete has been increased by 3.6%, 2.5% and 1.6% than that of controlled concrete respectively.

10. The Flexural strength of conventional concrete with steel fibre is compared to Silica fume and Metakaolin added with steel, polypropylene and sisal fibre after 28days of curing, has been increased by 3.09,%,2.28%,2.15% and 1.46%,0.66% 0.40%, than that of controlled concrete (With Steel fibre)respectively

11. The flexural strength of Silica fume concrete and Metakaolin concrete after 28days of curing, has been increased by 6.10%, and 4.03% than that of controlled concrete(Without Fibre) respectively.

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