

# A Study on Fiber Reinforced High Performance Concrete

N. Sreeja<sup>1</sup>, Dr. B. Ramesh Babu<sup>2</sup>, G. Raghu Yadav<sup>3</sup>

M.Tech, Dept. of Civil Engineering, ALITS College, Affiliated to JNTUA, AP, India<sup>1</sup>

Principal, ALITS College, Affiliated to JNTUA, AP, India<sup>2</sup>

Dept. of Civil Engineering, ALITS College, Affiliated to JNTUA, AP, India<sup>3</sup>

**ABSTRACT:** Concrete is mostly used in large quantity for civil engineering industries. Concrete is a mixture of cement, fine aggregate, coarse aggregate & water. The production of cement releases a huge volume of carbon-dioxide in the atmosphere, which creates various environmental hazards so it is necessary to go for alternative binder material in the concrete.

This projects deals with experimental investigations of high performance property of the concrete and the strength of the concrete when the cement is partially replaced with fly ash and silica fume and also adding of fiber reinforced plastics.

Experimental investigation were carried out by preliminary test on all the ingredients of the concrete such as specific gravity test, fineness test & crushing strength etc., and where determined according to the IS codes.

Fly ash is a fine, glass powder recovered from the gases of burning coal during production of electricity. Concrete containing fly ash becomes stronger, more durable, and more resistant to chemical attack. Silica fume is a waste by-product of the production of silicon and silicon alloys. By the addition of silica fume in concrete, it is easier to make HPC for strengths between 63-98 N/mm<sup>2</sup>.

The mix was designed by Indian method, since this method gives approximate results. The mix design is done for M 20. Then the concrete cubes and cylinder are casted. The cubes and cylinder are subjected to compression test and the tension test as per codal provision. Silica fume and fly ash was replaced by 15 % and 30% of weight of concrete while fibre reinforced plastics was used at 0.5%, 1.0% and 1.5% of weight of concrete.

## I. INTRODUCTION

The use of HPC is on increasing trend in the construction industry and is being seen as an optimized solution considering the economics, strength and durability required for special structures. The important governing factors for HPC's are strength, long term durability, serviceability as determined by crack and deflection control, as well as response to long term environmental effects. The ingredients of HPC's are almost same as those of conventional cement concrete (CCC). The high performance concrete usually contains both pozzalonic and chemical admixtures. Hence, the rate of hydration of cement and the rate of strength development in HPC is quite different from that of conventional cement concrete. The scope of using HPC in our constructional activities lies large, viz., Precast prestressed Bridges, Multi-storied buildings, and structures on coastal areas.

Silica fume is a waste by-product of the production of silicon and silicon alloys. Silica fume is available in different forms, of which the most commonly used is in a densified form. By the addition of silica fume in concrete, it is easier to make HPC for strengths between 63-98 N/mm<sup>2</sup>.

Fly ash is a finely divided residue that results from the combustion of ground or powdered coal. Of the hundreds of millions of metric tons of fly ash which are produced annually on a worldwide basis, only a small portion i.e., 20% - 40% of the fly ash is reused for productive purpose, such as additive or stabilizer in cement. The remaining amounts of fly ash produced are disposed in controlled landfills.

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Thus, silica fume and fly ash is used as an alternative binder material in the production of concrete which is seen as an optimized solution considering economics, strength and durability.

In this project the mix design is done for M20. Then the concrete cubes and cylinder are casted. The cubes and cylinder are subjected to compression test and the tensile test as per codal provision

## II. RELATED WORK

Research efforts in the last 30 years into understanding the mechanism of cement hydration and the benefits of using alternative materials to replace have been responsible for a great improvement in concrete strength and durability. These improvements are of significant importance to the corps of engineers because of the large volume of cement the corps uses every year, and because of the high demands we place on performance and durability of the structures we build. In the middle years of this past century, “high performance” of concrete was measured in terms of high strength, and high strength meant using high cement content mixtures with low water-cement ratios. Compressive strength of 45 to 50 N/mm<sup>2</sup> where considered high strength then, and durable concrete had approximately a 50 years life span. Today, with the many improvements that have been made, high performance can mean many things, and we are routinely capable of producing strength in the range of 100 N/mm<sup>2</sup> and often ask for design lives of 90 years or more.

In fact, today Portland cement based concretes incorporating Pozzolans such as silica fume and fly ash in combination with super plasticizers are known as High Performance Concretes (HPC). In High Performance Concretes, silica fume is used for its chemical and physical benefits. The chemical reaction known, as the “Pozzolanic” reaction, takes place when the Portland cement is hydrated (mixed with water), producing many compounds, including calcium silicate hydrate (CSH) and calcium hydroxide Ca(OH)<sub>2</sub>. The calcium silicate hydrate (CSH) sometimes called the gel is the source of strength in concrete. When silica fume is added to fresh concrete, it chemically reacts with the calcium hydroxide Ca(OH)<sub>2</sub> to produce additional calcium silicate hydrate (CSH). The benefits of this reaction can be seen in the crucial interfacial zone increasing the bond strength between concrete paste and aggregates, yielding greatly increased compressive strengths and a concrete that is more resistant to attack from aggressive chemicals than the weaker calcium hydroxide found in ordinary Portland cement concretes.

Long-term performance of structures has become vital to the economies of all nations. Concrete has been the major instrument for providing stable and reliable infrastructure since the days of the Greek and roman civilization. At the turn of the 20th century, concrete compressive strength was in the range of 13.8 N/mm<sup>2</sup>, by the 1960s it was in the range of 27.6 - 41.4 N/mm<sup>2</sup>.

As a result, new materials and composites have been developed and improved cements evolved. Today concrete structures with a compressive strength exceeding 138 N/mm<sup>2</sup> are being built world over. In research laboratories, concrete strengths of even as high as 800 N/mm<sup>2</sup> are being produced. One major remarkable quality in the making of High performance concrete (HPC) is the virtual elimination of voids in the concrete matrix, which are mainly the cause of most of the ills that generate deterioration.

ACI defines HPC as “Concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing and curing practices”. Such concretes can be either normal strength or high strength. Normal strength concrete by ACI definition is a concrete that has a cylinder compressive strengths not exceeding 42 N/mm<sup>2</sup>. All other concretes are considered High Strength Concretes (HSC). HPC’s with 140 N/mm<sup>2</sup> are currently being used in High rise structures in USA and Europe. Important governing factors for HPCs are strength, long term durability, serviceability as determined by crack and deflection control, as well as response to long term environmental effects.

High performance concretes (HPC) are concretes with properties or attributes which satisfy the performance criteria. Generally, concretes with higher strengths and attributes superior to Conventional concretes are desirable in the Construction Industry. HPC is defined in terms of Strength and Durability. Therefore HPC can be considered as a logical development of cement concretes in which the ingredients are proportioned and selected to contribute efficiently to the various properties of cement concrete in fresh as well as in hardened states.

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## III. HIGH PERFORMANCE CONCRETE

High performance concrete means which performs better than conventional concrete. High performance concrete as described as “concrete which meets special performance and uniformity requirements that cannot always be achieved by using only the conventional materials and normal mixing, placing and curing practices”.

This definition allows us to consider any concrete that serves a specific purpose very well and that is not achievable with the conventional materials and mixing practices as a high performance concrete. Under this definition very high strength and very low strength, highly flowable concrete are both considered as high performance concrete.

### Salient Features of HPC

Compressive strength  $> 80 \text{ N/mm}^2$ , even up to  $800 \text{ N/mm}^2$

- Water-binder ratio = 0.25- 0.35, therefore very little free water
- Reduced flocculation of cement grains
- Wide range of grain sizes
- Densified cement paste
- No bleeding homogeneous mix
- Less capillary porosity
- Discontinuous pores
- Stronger transition zone at the interface between cement paste and aggregate
- Low free lime content
- Endogenous shrinkage
- Powerful confinement of aggregates
- Little micro-cracking until about 65-70% of fck
- Smooth fracture surface

### SUPPLEMENTRY CEMENTING MATERIAL

Fly ash, ground granulated blast-furnace slag, silica fume, and natural pozzolans, such as calcined shale, calcined clay or metakaolin, are materials that, when used in conjunction with Portland or blended cement, contribute to the properties of the hardened concrete through hydraulic or pozzolanic activity or both. These materials are also generally categorized as supplementary cementing materials (SCM's) or mineral admixtures.

The most commonly used supplementing cementitious materials/mineral admixtures for achieving HPC are:

1. Silica Fume
2. Fly Ash

#### 1. Silica Fume:

Silica fume is a waste by-product of the production of silicon and silicon alloys.

Silica fume is available in different forms, of which the most commonly used now is in a densified form. In developed countries it is already available readily blended with cement. It is possible to make high strength concrete without silica fume, at compressive strength of upto  $98 \text{ N/mm}^2$ . Beyond that strength level however, silica fume becomes essential. With silica fume it is easier to make HPC for strengths between  $63\text{-}98 \text{ N/mm}^2$ .

#### 2. Fly Ash:

Fly Ash of course, been used extensively in concrete for many years. Fly ash is unfortunately, much more variable than silica fumes in both their physical and chemical characteristics. Most fly ashes will result in strengths of not more than  $70 \text{ N/mm}^2$ . Therefore for higher strengths, silica fume must be used in conjunction with fly ash. For high strength concrete, fly ash is used at dosage rates of about 15 % of cement content.

### FIBRE REINFORCED CONCRETE

In fibre reinforced concrete, fibres can be effective in arresting cracks at both micro and macro levels. For an optimum response different types of fibres may be suitably combined to produce fibre reinforced concrete. This includes combining fibres with different shapes, dimensions, tensile strength and young's modulus to concrete matrices.

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## IV. METHODOLOGY

### RESULTS OF THE PRELIMINARY INVESTIGATION

#### 1 CEMENT

##### a) Specific gravity

Table 1 Specific gravity of cement by density bottle

S.No	W1(g)	W2(g)	W3(g)	W4(g)	G
1	377	913	1364	998	3.15
2	377	925	1370	998	3.2
3	377	902	1355	998	3.12

Thus the specific gravity of cement was found to be 3.15

##### b) Fineness

Table 2 Fineness of cement

S.No	Size of sieve in $\mu$	Wt of cement taken in g	Wt of the residue in g	Wt of cement passing through the sieve in g	Fineness of cement in %
1	90 $\mu$	100	3	97	
2	90 $\mu$	100	2	98	97.33%
3	90 $\mu$	100	3	97	

The fineness of cement is found to be 97.33 %

##### c) Consistency

Table 3 Normal consistency of cement

S.No	Wt of cement in gms	% of water added	Amount of water added in ml	Depth of penetration from the bottom of mould in mm
1	300	25	75	2
2	300	26	78	4
3	300	27	81	6

Time at which 5-7 mm penetration occurs is the consistency of the cement.

Thus the consistency of cement was found to be 27%.

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### d) Initial setting time

Table 4 Initial setting time of cement- test result

S . No	Wt of cement in g	Qty of water added for initial setting time in ml	Time at which water is first added	Time at which readings are taken	Impenetr ate depth from the bottom of mould in mm
1	300	70	2.10 PM	2.20	2.0
2	250	70		2.25	2.5
3	250	70		2.30	3.0
4	250	70		2.32	4.0
5	250	70		2.34	4.0
6	250	70		2.36	5.0
7	250	70		2.40	6.0

Time at which 5-7 mm penetration occurs is the initial setting time and is noted as 30 minutes.

### FINE AGGREGATE

#### a) Specific gravity

Table 5 Specific gravity of fine aggregate by density bottle

S.No	W1(g)	W2(g)	W3(g)	W4(g)	G
1	380	1204	1635	1130	2.58
2	380	1212	1645	1130	2.62
3	380	1260	1675	1130	2.63

Thus the specific gravity of cement was found to be 2.61

#### b) Sieve analysis

Table 6 Sieve analysis results of sand

S.No	IS sieve size	Wt of sand retained in gm	Cumulative wt retained in gm	Cumulative % wt retained	Cumulative % wt passing
1	4.75mm	0	0	0	100
2	2.36mm	44	44	8.8	91.2
3	1.18mm	110	154	30.8	69.2
4	600 $\mu$	168	322	64.4	35.6
5	300 $\mu$	131	453	90.6	9.4
6	150 $\mu$	42	495	99	1
7	75 $\mu$	5	500	-	-

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Sieve analysis result of sand 293.6  
Fineness modulus =  $293.6/10$   
Fineness Modulus = 2.94

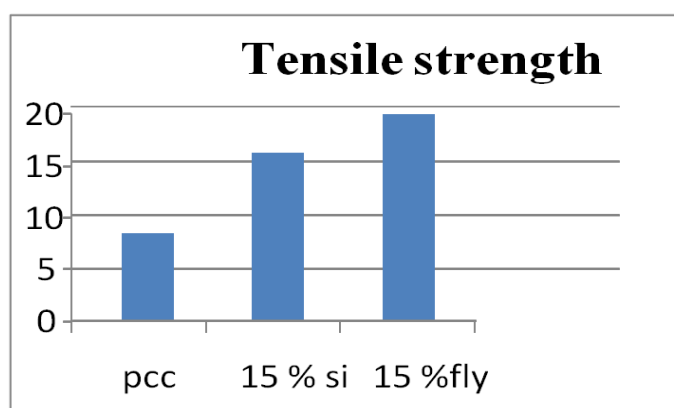
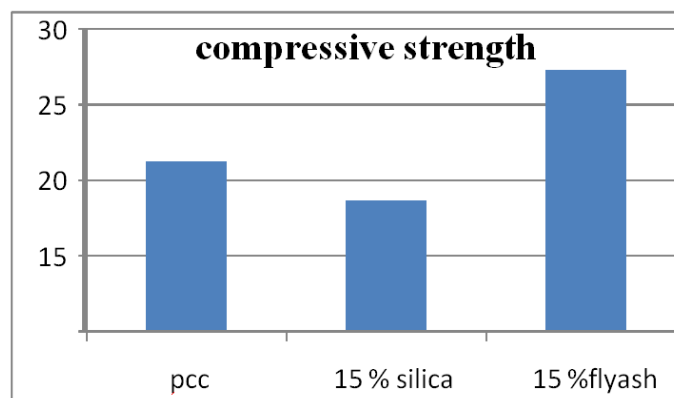
## FLYASH

### a) Specific gravity

**Table 7 Specific gravity of cement by density bottle**

S.No	W1(g)	W2(g)	W3(g)	W4(g)	G
1	379	735	1177	980	2.24
2	379	652	1122	980	2.08
3	379	679	1133	980	2.04

Thus the specific gravity of cement was found to be 2.12



## V. CONCLUSION

From the experimental investigation the following conclusions are drawn:

- 1) Concrete with 15% fly ash and 0.5% fibre reinforced plastics gives the ultimate compressive strength.
- 2) When concrete with 30% fly ash is added the compressive strength is less than the plain cement concrete.
- 3) Concrete with silica fume (15%, 30%) does not achieve the required strength.
- 4) Concrete with 15% fly ash and 1.5% fibre reinforced plastics gives the ultimate tensile strength.
- 5) Replacement of 15% fly ash with cement concrete gives more strength and lesser cost.



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