An Experimental Study on Mechanical Properties of Concrete with Steel and Glass Fibre, Silica & Fly Ash

Allipilli Lakshman Rao[1], Karnena Venugopal[2]

[1]*Research Scholar,*
[2]*HOD, Civil Engineering,*
Kakinada Institute of technological Sciences (JP)

---***---

Abstract - The indiscriminate infrastructural growth is leading to rapid environmental degradation. Steel, cement, synthetic polymers and metal alloys used for construction activities are energy intensive as well as cause environmental pollution during their entire life cycle.

Due to ever increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world. Scarcity of land-filling space and because of its ever increasing cost, recycling and utilization of industrial by- products and waste materials has become an attractive proposition to disposal. There are several types of industrial by-products and waste materials. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns.

A review of literature regarding the requirements of ingredient-materials for producing high strength concrete along with the results of an experimental study on achieving HSC has been reported in this paper. Use of quality materials, smaller water-cement ratio, larger ratio of coarse aggregate (CA) to fine aggregate (FA), smaller size of coarse aggregate, and suitable admixtures with their optimum dosages are found. In the experimental study, the targeted strengths of concretes were from 30 MPa to 50 MPa. A larger ratio of CA to FA (1.81 except one mix of 1.60) was considered in the study.

Additional to this fibre inclusion, about 1% & 2% silica fume, glass fibre and steel fibre 5% & 10% of mineral admixture such as Fly ash is used. Slump test was carried out for each mix in the fresh state. 28-day compressive strength and tensile strength were performed in the hardened state. Various numerical analyses were carried out to quantify the determined mechanical properties and to describe the effects of fibre inclusion on these mechanical properties

***Key Words*:** Glass fibre, Steel fibre, silica fume, Fly ash, Mechanical Properties.

1.INTRODUCTION

The benefit of increased compressive strength is to lower volumes and produce smaller designs in terms of design prospective, thus allowing its immediate application into design. The concept of helical reinforcement. of beams came after the demand of industry due to the improvement of stiffness factor; this improvement was associated with increasing of brittleness phenomenon in the compression zone, having said that, it is significant to minimize this problem.

For the last few years there is a remarkable increase in the compressive strength of structural concrete. In Australia concrete has been used up to 100 MPa in some cases while in some countries they used concrete with compressive strength up to 130 MPa.

Due to industrial demand the development of high strength concrete have improved rapidly because the industrial demand of new features in concrete members with serious advantages such as increased capacity and stiffness.

The brittle nature of high strength concrete is a major obstacle in its widespread use, as any benefits in terms of reduced member size are negated by the need for increased factor of safety to prevent brittle failure

In the present approach the strengthening and toughening mechanisms for cement based composites are viewed on two different scales. To strengthen the matrix, the specific fiber spacing must be decreased in order to reduce the allowable flaw size. This may be achieved through the use of short discrete fibers. These fibers can provide bridging of micro cracks before they reach the critical flaw size. To provide the toughening component, fibers of high ultimate strain capacity are required so that they can bridge the macro cracks in the matrix

2. LITERATURE REVIEW

In their work "Development of Hybrid Polypropylene-Steel Fiber Reinforced Concrete" Qian and Stroeven measured the compressive strength, split tensile strength, and modulus of rupture of different mixes incorporating various volume fractions of steel and polypropylene fibers.A common concrete matrix was used in all mixes, with a water cement ratio of 0.40 and cement content of 400 kg/m3. Properties of the fibers are shown in Table

.

Fiber Type	Designation	l(mm)	d (mm)
Monofilament PP	PP	12	0.018
Hooked Steel	SF1	40	0.300
Hooked Steel	SF2	30	0.300
High-Strength Steel	SF3	6	0.1

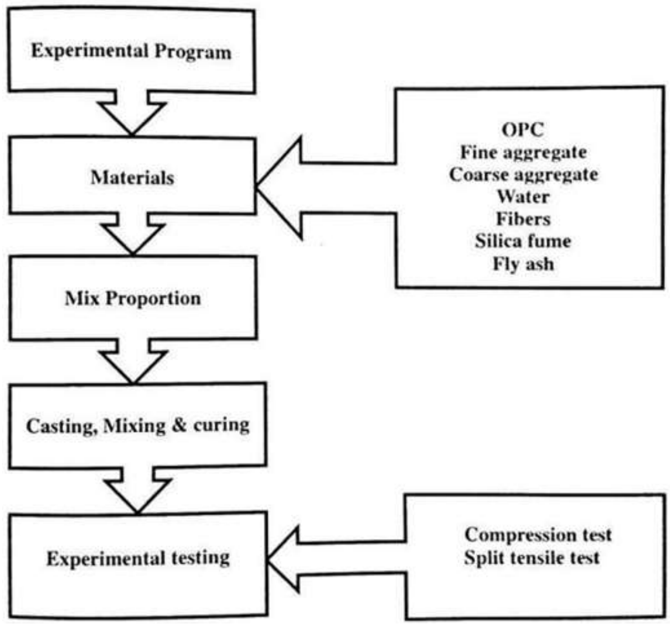
Volume fractions of fibers and obtained test results are presented in Tables below

Fiber Content (%)					
Mix No:	PP	SF I	SF2	SF3	Total
1	0.15	0.00	0.00	0.00	0.15
2	0.15	0.20	0.20	0.20	0.75
3	0.15	0.40	0.40	0.40	1.35
4	0.30	0.00	0.20	0.40	0.90
5	0.30	0.20	0.40	0.00	0.90
6	0.30	0.40	0.00	0.20	0.90
7	0.00	0.00	0.40	0.20	0.60
8	0.00	0.20	0.00	0.40	0.60
9	0.00	0.40	0.20	0.00	0.60

Types and properties of fiber

Fiber Type	Length (mm)	Diameter (mm)	Density (g/cm³)	Elongatio At Break %	Young's Modulus (GPa)
Carbon	5	7	1.60	240	1.4
Steel	30	500	7.80	200	3.2
Polypropylene (PP)	15	100	0.90	8	8.1

3. EXPERIMENTAION &METHODOLOGY



Experimental Program

In this study, the aim is to determine the experimental studies on HIGH STRENGTH CONCRETE and then to characterize its properties, especially the mechanical properties in the hardened state. Two different types of fibers were used in combination. For this purpose eight mixes, one plain control mix and seven fiber reinforced mixes were prepared. In four of the fiber-reinforced mixes, Fly ash and silica fume as admixture were used.

The volume percentage of fibers was kept constant at 1.0% and 2.0% this value was chosen after a careful examination of available literature considering the capability of compaction equipment in the laboratory. Steel fibers constituted most of the total fiber content in a hybrid mix whereas the remaining part was composed of glass fibers in hybrid fiber reinforced mixes.

Slump test was performed for each mix in the fresh state. Compressive strength, Split tensile strength is carried out for each mix in the hardened state.

Materials

Ordinary Portland cement.

Fine aggregates. & Coarse aggregates.

Water.

Fibers.

Silica fume as admixture.

Fly ash as admixture

4. MIX DESIGN

Mix design earn be defined as the process of selecting suitable ingredients of concrete and determining the relative proportions with the objective of producing concrete of certain minimum strength and durability as economically as possible. There are many methods available for mix design. Here Indian Standard method, based on IS 10262- 1902 is adopted.

Mix design for control cubes, for optimization of steel slag using zone I sand and for optimization using zone II and zone III combinations are carried out in this section.

Stipulations for proportioning

a) Grade designation : M 30
b) Type of cement : OPC 53 grade
c) Maximum nominal size of aggregate : 20 mm
d) Maximum water-cement ratio : 0.45
e) Exposure condition : mild
f) Type of aggregate : crushed angular aggregate
g) Chemical admixture type : Nil

Test data for materials

a) Cement used : OPC 53 grade
b) Specific gravity of cement : 2.13
c) Chemical admixture : Nil
d) Specific gravity of
   1. Coarse aggregate : 2.8
   2. Normal sand : 2.6
e) Water absorption
   1. Coarse aggregate : 0.5%
   2. Normal sand : 1.0%
f) Free (surface) moisture : 1.0%
   1. Coarse aggregate : Nil
   2. Normal sand : Nil
g) Sieve analysis
   1. Normal sand : Conforming to grading zone I of table 4 of IS 383:1970
   2. Combinations D, E : Conforming to grading zone II of table 4 of IS 383:1970
   3. Combinations A, B, C, D, E : Conforming to grading zone III of table 4 of IS 383:1970

Table: A.4. Mix design calculation

Cement Kg/m^3	Fine Aggregates Kg/m^3	Coarse Aggregate kg/m^3	W/C ratio
466.2	398.373	1292.99	186.48
1	0.85	2.77	0.40

5. RESULTS & DISCUSSION

In this Chapter, the laboratory results are executed and discussed. The details are as follows in tables and figures.

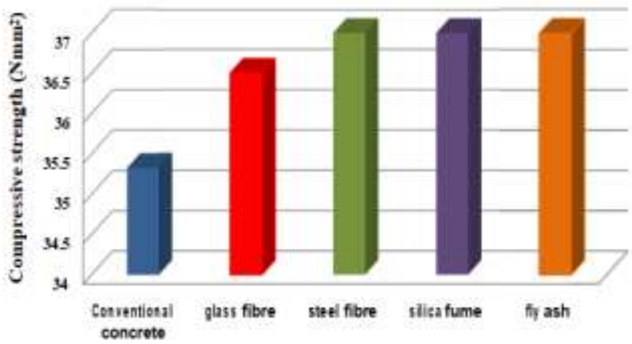
Compressive and Split tensile strength results for M30

S. NO	MIX DESIGNATION M30 (I: 1.16 :2.84)	TYPE OF MIX	COMPRESSIVE STRENGTH (N/mm^2)	SPLIT TENSILE STRENGTH (N/mm^2)
1.	M30 W/c=0.45	Ordinary	35.33	2.65
2.	M30 W/c=0.45	1% Glass fiber	36.5	2.75
		2% Glass fiber	37	2.8
3.	M30 W/c=0.45	1% Steel fiber	37	2.7
		2% Steel fiber	37.5	2.75
4.	M30 W/c=0.45	1% Silica fume	37	2.7
		2% Silica fume	38	2.79
5.	M30 W/c=0.45	5% Fly ash	37	2.7
		10% Fly ash	38	2.71

Table 5.1: Compressive strength results for 1% glass fibers, steel fibers, silica fume and 5% fly ash

% of fibers and admixtures	Compressive Strength(N/mm^2)
Conventional	35.33
1% Glass fiber	36.5
1% steel fiber	37
1% Silica fume	37
5% Fly ash	37

Graph 5.1 Various compressive strengths of concrete with 1% of fibers, silica fume and 5% fly ash



- According to bar chart, the conventional mix reaches to 3.1N/mm2. Also 1% steel fibers and silica fume in composition made about 3.2N/rnm2 and 3.15 N/mm2 respectively. However, 5% fly ash made about 3.2N/mm2

Table 5.2: Compressive strength results for 2% glass fibers, steel fibers, silica fume and 10% fly ash

% of fibers and admixtures	Compressive Strength(N/mm^2)
Conventional	35.33
2% Glass fiber	37
2% steel fiber	37.5
2% Silica fume	38
10% Fly ash	38

Graph 5.2 Various compressive strengths of concrete with 2% of fibers, silica fume and 10% fly ash

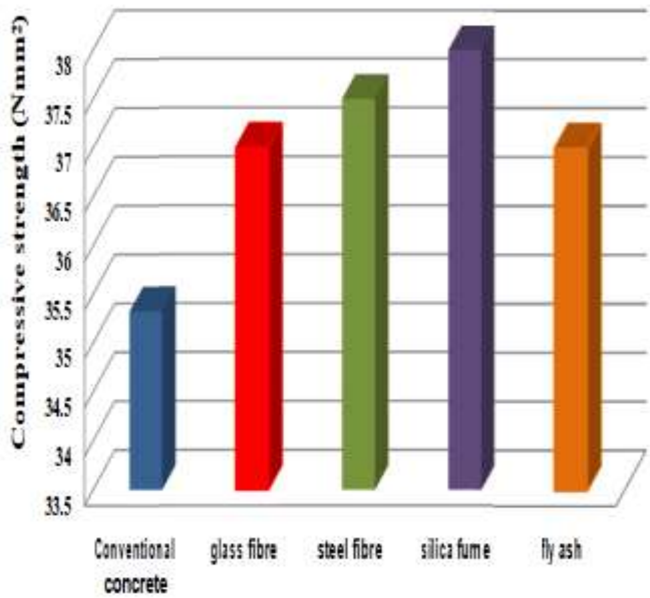


Table 5.3: Split Tensile strength results for 1% glass fibers, steel fibers, silica fume and 5% fly ash

% of fibers and admixtures	Split Tensile Strength(N/mm^2)
Conventional	2.65
1% Glass fiber	2.75
1% steel fiber	2.7
1% Silica fume	2.7
5% Fly ash	2.7

Graph 5.3 Various tensile strengths of concrete with 2% of fibers, silica fume and 10% fly ash

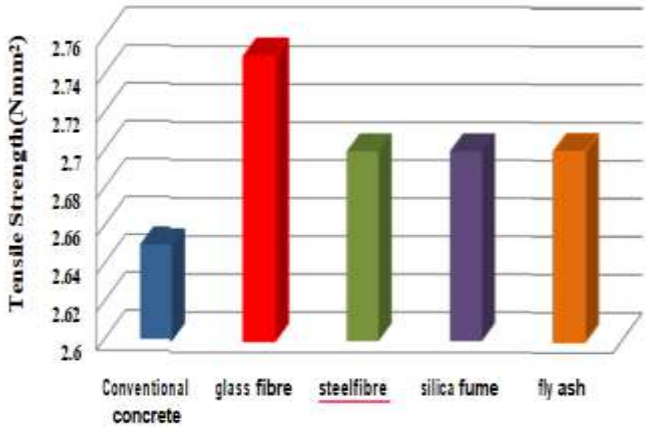
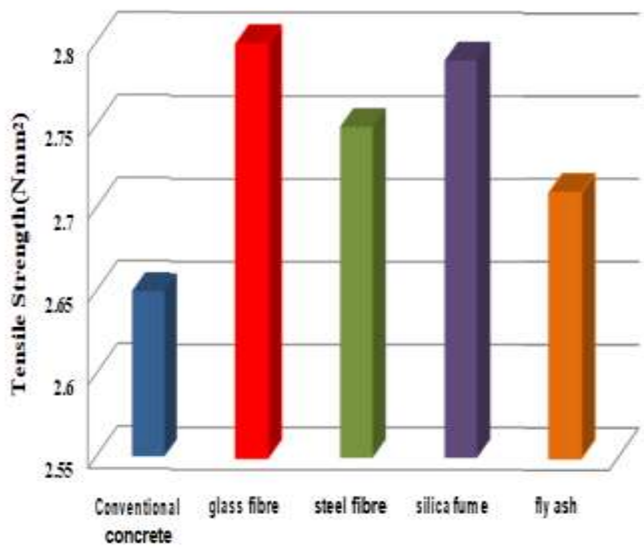


Table 5.4: Split Tensile strength results for 2% glass fibers, steel fibers, silica fume and 10% fly ash

% of fibers and admixtures	Split Tensile Strength(N/mm^2)
Conventional	35.33
2% Glass fiber	37
2% steel fiber	37.5
2% Silica fume	38
10% Fly ash	38

Graph 5.2 Various tensile strengths of concrete with 2% of fibers, silica fume and 10% fly ash



6. CONCLUSION

On observing the experimental investigations conducted on the carted cubes and cylinders, the usage of fibers and admixtures with conventional concrete have given predominant outputs in physical and mechanical properties of concrete. Since the steel fibers and glass fibers are of high elastic modulii. The following conclusions were drawn as follows,

Concrete with 1% & 2% glass fiber, steel fiber, silica fume and 5% & 10 % fly ash when compared with the conventional concrete of grade M30 showed a maximum increase in Compressive Strength to 5.78%

Concrete with 1% & 2% glass fiber, steel fiber, silica fume and 5% & 10 % fly ash when compared with the conventional concrete of grade M30 showed a maximum increase in Split Tensile Strength to 4.5%.

Concrete with 1% & 2% glass fiber, steel fiber, silica fume and 5% & 10 % fly ash when compared with the conventional concrete of grade M35 showed a maximum increase in compressive strength to 3.85

Concrete with 1% & 2% glass fiber, steel fiber, silica fume and 5% & 10 % fly ash when compared with the conventional concrete of grade M35 showed a maximum increase in Split Tensile Strength to 5.59%.

Concrete with 1% & 2% glass fiber, steel fiber, silica fume and 5% & 10 % fly ash when compared with the conventional concrete of grade M40 showed a maximum increase in compressive strength to 5.05%.

Concrete with 1% & 2% glass fiber, steel fiber, silica fume and 5% & 10 % fly ash when compared with the conventional concrete of grade M40 showed a maximum increase in Split Tensile Strength to 4.27%.

.

7. REFERENCES

1. “Mechanical properties of Hybrid Fiber Reinforced Concrete at Low Fiber Volume Fraction", Yao, Li, and Wu.
2. "Bond Mechanisms In Fiber Reinforced Cement-Based Composites" Final Report, Department of Civil Engineering, University of Michigan, Ann Arbor, MI, Naaman, A. E., Namur.
3. Chemical admixtures of concrete- Rixom MR, E & FN spon. Ltd. london-1978.
4. Proceedings of rilem symposium on fiber reinforced concrete volume II- ASTM special technical publication no.I69-A 1966.
5. Design and control of concrete mixture -Steven H. kosmatka and William C.- PCA 1988.
6. Concrete technology- Theory and Practice by M.S. Shetty, S. Chand publications.
7. CM-425, Fiber reinforced concrete journal by University of Washington.
8. P.K. Mehta and P.J.M. Monteiro, Concrete: Microstructure, Properties, and Materials.
9. Celik T, Marar K (1996). Effects of crushed stone dust on some properties of concrete, Cement Concrete Res., 26(7):1121-1130.
10. De Larrard F, Belloc A (1997). The influence of aggregate on the compressive strength of normal and high-strength concrete. ACI Mater J., 94(5):417–426.
11. Galetakis M, Raka S (2004). Utilization of limestone dust for artificial stone production: an experimental approach. Miner. Eng., 17:355–357.
12. Gambhir ML (1995). Concrete Technology-Second Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.
13. Goble CF, Cohen MD (1999). Influence of aggregate surface area on mechanical properties of mortar. ACI Mater. J., 96(6):657–662. IS: 516-1959. Indian Standard Methods of Test for Strength of concrete. Bureau of Indian Standards, New Delhi.
14. Nevillie AM (2002). Properties of Concrete –Fourth and Final Edition, Pearson Education Limited, Essex.
15. IS 456 : 2000 , Plain and Reinforced Concrete code of practiceIn 1988