



AN EXPERIMENTAL INVESTIGATION ON THE MECHANICAL PROPERTIES OF HYBRID FIBER STRENGTHENED ALLOYED CEMENT CONCRETE

Engineering

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ABSTRACT

Mechanical properties of quaternary blending cement concrete reinforced with hybrid fibers are evaluated in this experimental study. The steel fibers were added at volume fractions of 0.5%, 1%, and 1.5 % and polypropylene fibers were added at 0.25% and 0.5% by weight of cementations materials in the concrete mix individually and in hybrid form to determine the compressive strength, split tensile strength, flexural strength and impact resistance for all the mixes. The experimental results revealed that fiber addition improves the mechanical properties and also the ductility and energy absorption of the concrete. The results also demonstrate that the hybrid steel – polypropylene fiber reinforced concrete performs better in compressive strength, split tensile strength, flexural strength and impact resistance than mono steel and mono polypropylene fiber reinforced concrete.

KEYWORDS

steel fiber, mono steel, compressive strength, fiber reinforced concrete, flexural strength.

INTRODUCTION

In the present scenario fibre reinforced concrete has achieved many advantages over plain cement concrete. Concrete is a brittle material which is strong in compression and weak in tension. Concrete is most popular material used in construction. Cement used in concrete is produced at very large amount due to lower cost of production and large availability of raw materials. Cement causes environmental problems due to emission of CO₂, which causes greenhouse effect. So considering environmental problems usage of cement is to be reduced. Reduction of cement in concrete can be reduced by using admixtures as partial or complete replacement of cement. Hence the concept of blended cement has been used in the present investigation. As concrete is weak in tension, which can be improved by using of fibres. Hence fibres are used in PCC and blended cements to arrest the cracks and its propagation. Concrete which is used as major part of construction has following advantages and limitations.

Advantages

- Concrete is economical when the ingredients are readily available.
- Concrete's long life and relatively low maintenance requirements increase its economic benefits.
- It is not as likely to rot, corrode, or decay as other building materials.
- Concrete has ability to be moulded or cast into almost any desired shape.
- Building of the moulds and casting can occur on the work site which reduces cost.
- Concrete is a non-combustible material which makes it safe and able to withstand high temperatures.
- It is resistant to wind, water, rodents and insects. Hence concrete is often used for storm shelters.
- The durability of concrete is very high.

Limitations

- Concrete has a relatively low tensile strength (compared to other building materials), low ductility.
- Concrete is susceptible to cracking.
- Concrete may contains soluble salts.

FIBRE REINFORCED CONCRETE (FRC)

Fibre is a slender and elongated solid substance. Due to this property it offers resistance against tension and elongation. According to terminology adopted by the American Concrete Institute (ACI) Committee 544, in Fibre Reinforced Concrete, there are four categories namely,

SFRC – Steel Fibre Reinforced Concrete
GFRC – Glass Fibre Reinforced Concrete

SNFRC – Synthetic Fiber Reinforced Concrete

NFRC – Natural Fiber Reinforced Concrete

STEEL FIBRE REINFORCED CONCRETE

Concrete is most widely used construction material in the world. Because of its ability to get cast in any form and shape, it has almost replaced old construction materials such as brick and stone masonry.



Fig.1 Different Steel fibers available in market

Sources: [www.googleimages.com/steel fibres](http://www.googleimages.com/steel%20fibres)

POLYPROPYLENE FIBRE REINFORCED CONCRETE

Natta synthesized the first syndiotactic polypropylene. Polypropylene is a type of thermoplastic polymer resin. It is a part of both the average household and is in commercial and industrial applications. The chemical designation is C₃H₆. One of the benefits of using this type of plastic is that it can be useful in numerous applications. Fibrillated Polypropylene fibres of 15 mm, 20 mm and 24 mm cut length fibres having specific gravity 0.91 gm/cm³, collect from Bajaj Plast Fibre, Nagpur, Maharashtra, and India were used. Different cut lengths of polypropylene fibres with 0.5 % by weight of cement as shown below table.

Table 1 Different cut length of polypropylene fibres

Designation	Cut Length of Polypropylene Fibers (mm)	Polypropylene Fibers	Weight of Cement (%)
P1	15	0%	0.5%
P2	20	0%	0.5%
P3	24	0%	0.5%

HYBRID FIBRE REINFORCED CONCRETE

Hybrid fiber reinforced concrete is made from the combination of two or more fibers which is different in their properties, when these are added in concrete they remain bonded and exhibit their properties. In the present project hybrid fiber used is steel and polypropylene fiber of 0.5% separately. The physical properties of HFRC of steel and polypropylene fibers used in the project are as follows.

Table 3 Physical properties of steel and polypropylene fibers

Properties	Steel fibre	Polypropylene
Length(mm)	30	12
Diameter(mm)	0.5	0.034
Shape	Hooked end	Straight
Aspect Ratio	60	352.94
Density(kg/m3)	7850	910

LITERATURE REVIEW

M.G. Alberti, A. Enfedaque had found out that the mechanical properties of the concrete are increased by adding different proportions of polyolefin and hooked steel fibres. It is observed that the tensile strength is increased by 40% and modulus of elasticity is six times higher by addition of steel fibres [1]. **Rajarajeshwari B Vibhuti** has tested mechanical properties using two types of fibres i.e., steel and polypropylene of 1% and 0.036% separately and by using both as hybrid fibres. It is observed that there is 17% increase in compressive strength and considerable increase in other properties by HFRC [2]. **Alan Richardson, Marcus Heather** have investigated the toughness and flexural strength of concrete by using straight steel fibres and 3D steel fibres[3],etc.

SCOPE

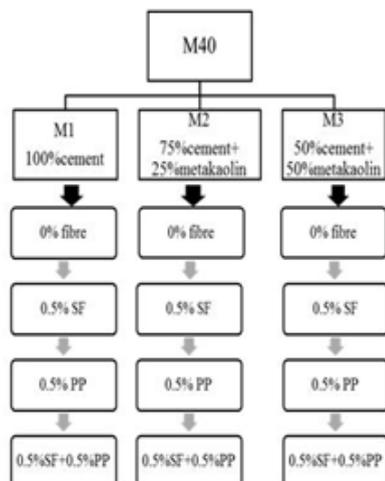
The main objective of the present investigation is to reduce the cement usage in the structures and to increase the mechanical property as well. This can be done by using cement admixtures. Hence an investigation has been made out by replacing cement with admixture met kaolin (MK). A replacement of cement is done partially by using MK with 25% and 50%. The scope of the project is whether the replacement of cement by MK will enhance the mechanical properties. Concrete which is having low tensile strength can be improved by using fibers into it.

In the present investigation the objective is

- To determine mechanical properties of hybrid fiber reinforced blended cement concrete.
- To compare mechanical properties of plane and blended cement concrete with and without hybrid fiber.

EXPERIMENTATION

In the present project different proportions used for the investigation are as follows



MIX DESIGN (M40)

Design Stipulation

Characteristic compressive strength required in the field at 28 days=40N/mm²
 Maximum size of aggregate=20mm
 Degree of supervision=good
 Minimum cement content=320kg/m³
 Type of cement=53 grade
 Maximum water cement ratio=0.45
 Workability (slump)=100mm
 Type of aggregate=crushed angular aggregate
 Maximum cement content=450kg/m³
 Chemical admixture=not used
 Type of exposure=mild
 Type of admixture= meta kaolin

Contents	Quantity
Cement	492.9(kg/m ³)
Fine aggregate	540.16(kg/m ³)
Coarse aggregate	1175.622(kg/m ³)
Water content	197.16(lit)
Mix Ratio	1:1.1:2.39

Test Data Material:

Specific gravity of cement=3.15
 Compressive strength of cement at 7 days=satisfies the requirements of IS269-1989
 Specific gravity of coarse aggregate=2.5
 Specific gravity of fine aggregate=2.6
 Water absorption:
 Coarse aggregate=0.5%
 Fine aggregate=1%
 Free (surface) moisture:
 Coarse aggregate=nil
 Fine aggregate=2%

Water	Cement	Fine aggregate	Coarse aggregate	Sum of ratio
0.4	1	1.1	2.39	4.88

Step 1:

As per Indian Standard Recommended method of concrete mix design (IS 10262:1982)
 Target mean strength of concrete
 $f_{ck}' = f_{ck} + k.s$
 $F_{ck} = 40 \text{ N/mm}^2$
 $f_{ck}' = 48.25 \text{ N/mm}^2$

Contents	Cube	Prism
Cement	0.492(kg)	2.416(kg)
Fine aggregate	0.539(kg)	2.697(kg)
Coarse aggregate	1.171(kg)	5.857(kg)
Water content (0.45%)	196(ml)	984(ml)
Steel fibre (0.5%)	39.25(gm)	196.25(gm)
Polypropylene fibre (0.5%)	4.5(gm)	22.75(gm)
0.5%Steel+ 0.5% polypropylene fibre	39.25(gm)+ 4.5(gm)	196.25(gm)+ 22.75(gm)

Step 2:

Selection of water cement ratio
 Adopt w/c ratio=0.4

Step 3:

Selection of water content:

Estimated water content for 100mm slump
 $W_{water} = 186 + (6/100) \times 186 = 197.16 \text{ litres}$

Step 4:

Calculation of cement content:
 Water cement ratio=0.4, water=197.16 litres
 Cement content=492.9kg/m³

Step 5:

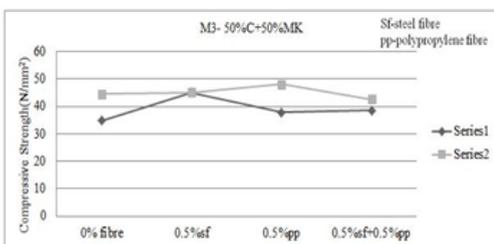
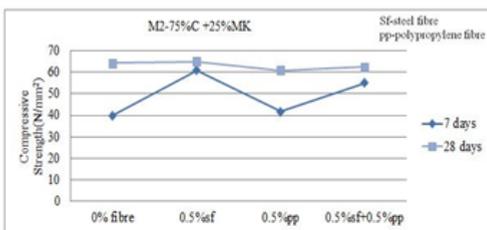
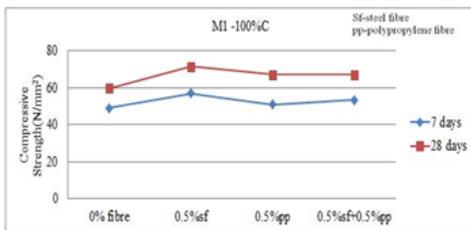
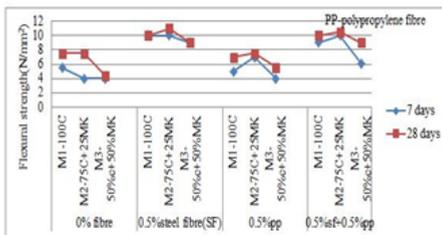
Calculation of fine aggregate and coarse aggregate:
 $F_a = (w + (c/se) + (1/p) * (fa/sfa)) \times 0.001$
 $ca = ((1-p)/p) * fa * (sca/sfa)$
 Fine aggregate=540.614kg/m³
 Coarse aggregate=1175.622 kg/m³

**Step 6:
RESULTS**

The flexural strength and compressive strength tests were performed and test results of 7 days and 28 days are as follows.

Cubes	% of fibres	Compressive strength(N/mm ²)	
		7 days	28 days
M1	0% fibre	48.9	59.5
	0.5%sf	57	71.5
	0.5%pp	50.9	67
	0.5%sf+0.5%pp	53.5	67
M2	0% fibre	39.8	64.5
	0.5%sf	61	65
	0.5%pp	41.6	61
	0.5%sf+0.5%pp	55	62.5
M3	0% fibre	34.8	44.5
	0.5%sf	45	45
	0.5%pp	37.8	48
	0.5%sf+0.5%pp	38.5	42.5

Prisms	% of fibre	Flexural strength(N/mm ²)	
		7 days	28 days
M1	0% fibre	5.5	7.5
	0.5%sf	10	10
	0.5%pp	5	7
	0.5%sf+0.5%pp	9	10
M2	0% fibre	4	7.5
	0.5%sf	10	11
	0.5%pp	7	7.5
	0.5%sf+0.5%pp	10	10.5
M3	0% fibre	4	4.5
	0.5%sf	9	9
	0.5%pp	4	5.6
	0.5%sf+0.5%pp	6.2	9



CONCLUSIONS

Experiments have been performed to investigate the mechanical properties of hybrid fibre reinforced blended cement concrete (HFRBCC). The tests performed are compressive strength, flexural strength. The test results obtained from HFRBCC are compared with plain cement concrete (PCC), FRCC HFRCC. The fibres used are SF and PPF with 0.5% of volume fraction. Cement admixture use are metakaolin (MK). Cubes and prisms are casted for conducting compressive and flexural strength tests respectively. Two specimens of each proportion are casted to get reliable average results.

The investigation reveals the following conclusions:

- From the results it can be concluded that the optimum flexural strength is obtained for M2 mix i.e., 75% cement and 25% metakaolin with 0.5% steel fibre and combination of 0.5% steel fibre and 0.5% polypropylene fibre.
- It can be concluded that the optimum compressive strength is obtained for M1 mix i.e., in 100% cement with 0.5% steel fibre and combination of 0.5% steel fibre and 0.5% polypropylene fibre.

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