An Experimental Study on Performance of Ternary Blended High Strength Fiber Reinforced Concrete

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Abstract - *Over the past several years, the ample research work is in progress throughout the globe in concrete technology in finding other materials which can partially or fully replace ordinary Portland cement (OPC) and which can also meet the requirements of strength, workability and durability aspects. Among the many alternative materials tried as fractional cement replacement materials, the strength, workability and durability performance of industrial by products like flyash, blast furnace slag, silica fume, metakaolin, rice husk ash, and industrial waste etc., now termed as complimentary cementitious materials (CCM) are quite promising. Consequently, these have led to the up growing of binary, ternary and tertiary blended concretes depending on the number of CCM and their combinations used as partial cement replacement materials.*

In the extant experimental investigation a mix design high strength concrete of M60 is tried using triple blending technique with ternary blend of ground granulated blast furnace slag (GGBS) and Metakaolin (MK) as partial replacement by weight of cement at various blended percentages ranging between 0% – 30% and with steel and glass fibers having aspect ratio of 80 and 150 are added at 0.5%, 1.0%, 1.5% and 2% as total fiber percentages. The results of fiber reinforced concrete specimens with various percentages of ternary blends are comparing with control specimen to study the performance of FRC properties with various percentages of the blends as partial replacement by of cement.

***Key Words*: Ternary blended concrete, matakaolin (MK), ground granulated blast furnace slag (GGBS), crimped steel fibers, glass fibers.**

1. INTRODUCTION

Over the past several decades, extensive research work is in progress throughout the globe in concrete technology in finding alternative materials which can partially or fully replace ordinary Portland cement (OPC) and which can also meet the requirements of strength and durability aspects.

Amongst the many alternative materials tried as partial cement replacement materials, the strength, workability and durability performance of industrial by products like flyash, blast furnace slag, silica fume, metakaolin, rice husk ash,etc., now termed as complimentary cementitious materials (CCM) are quite promising.

Subsequently, these have led to the development of binary, ternary and tertiary blended concretes depending on the number of CCM and their combinations used as partial cement replacement materials.

1.2 TRIPLE BLENDED CONCRETE(TBC)

Triple blended cement is characterised by part replacement of cement with mineral admixtures/additives such as pozzolanic admixtures (fly ash, silica fume, granulated slag etc.) or inert fillers. The corresponding concrete is termed as triple blended concrete. These admixtures are found to enhance the physical, chemical and mechanical properties of the concrete i.e. in terms of its strength parameters (compressive and flexural) as well as durability parameters.

1.3 Objective

The main objective of this experimental investigation is to study the performance evaluation of ternary blended hybrid fiber reinforced concrete. For the study, ternary blend (GGBS+MK) is chosen, in which 30% of cement is replaced by ternary blends in different proportions such as (30+0), (25+5),(20+10), (15+15), (10+20), (5+25) and (0+30). The strength characteristics such as compressive strength, tensile strength are studied. The work is carried out on fibre hybridization of (MK+GGBS) on M60 grade of concrete

1.4 Materials used

In this experimental study, Cement, sand, coarse aggregate, water, steel fibers and glass fibers, GGBS and metakaolin are used.

Cement: Ordinary Portland cement of 53 grade was used in this experiment conforming to I.S12269:1987
Coarse aggregates: Locally available, maximum size 20 mm, specific gravity 2.60
Sand: Locally available sand zone I with specific gravity 2.60, water absorption 1% conforming to I.S. – 383-1970.
Water: Potable water was used for the experiment. Chemical admixture: Super plasticizer
Metakaolin: It is supplied by Twenty Microns company Vadodhara. Metakaolin is obtained from the calcinations of kaolinitic clays at temperatures in the range of 700 - 8000 C. **GGBS:** Low calcium, ground granulated blast furnace slag from the ACC cement plant, Kudithini, Hospet.
Steel fibers: Crimped (L=35mm, thickness=1mm)
Glass fibers: 15mm lengths were used.

1.5 Mix Design of M60 Concrete

Target strength = 60 MPa
Max size of aggregate used = 20 mm
Specific gravity of cement = 3.12
Specific gravity of fine aggregate (F.A) = 2.59
Specific gravity of Coarse aggregate (C.A) = 2.77
Specific gravity of Metakaolin (MK) = 3.20
Specific gravity of GGBS = 2.77
Bulk Density of fine aggregate = 1627 kg/m3
Bulk Density of coarse aggregate = 1460 kg/m3
Bulk Density of GGBS = 480 kg/m3
Bulk Density of MK = 1055 kg/m3
Water-cement ratio = 0.29

Step-1 Calculation for weight of CA

From ACI 211.4R Table 6.3, Fractional volume of oven dry CA for 20 mm size aggregate is 0.712 m3
Weight of CA = 0.712*1460 = 1158.424 kg/m3

Step-2 Calculation for Quantity of Water

From ACI 211.4R Table 6.4
Assuming Slump as 50 to 75mm and for CA size 20mm,
The Mixing water = 132.66 kg/m3
Void content of FA for this mixing water = 35%
Void content of FA (V)
V = {1-(Dry unit wt / specific gravity of FA x 1000)} x 100 Eq (4.13)
= [1-(1627/2.59 x 1000)] x 100
= [1 – 0.628] x 100
= 37.18%
Adjustment in mixing water = (V-35) x 3.63
= (37.18 – 35) x 3.63
= 2.18 x 3.63
= 0.0792 kg/m3
Total water required = 132.66 + 0.099
= 132.76 kg/m3

Step-3 Calculation for weight of cement

From ACI 211.4R Table 6.5
Take W / C ratio = 0.29
Weight of cement = 132.765 / 0.29 = 457.81 kg/m3

Step-4 Calculation for weight of Fine Aggregate (FA)

a) Cement = 457.81 / 3.12 x 1000
= 0.1467
b) Water = 132.765 / 1 x 1000 = 0.1327
c) CA = 1158.424 / 2.77 x 1000
= 0.4182
d) Entrapped Air = 2 / 100 [For M60 concrete]
= 0.020
e) Total = 0.7286 m3
f) Volume of FA = 1- 0.7286 = 0.2714
g) Weight of FA= 0.2714 x 2.59 x 1000
= 702.926 kg/m3

Step-5 Calculation for quantity of Super plasticizer

Adjustments for water, for 1% = (0.01) x 457.81 x 1.22 [As per 10262-2009]
= 5.585 ml

Step-6 Correction for water

Weight of water (for 1%) = 132.765– 5.585 =127.18 kg/m3

Requirement of materials per Cubic meter

Cement = 457.81 kg/m3
Fine Aggregate = 702.926 kg/m3
Coarse Aggregate = 1158.424 kg/m3
Water = 127.18 kg/m3
Super plasticizers = 5.585 kg/m3
So the final ratio becomes Cement: FA: CA
1:1.535:2.53

I. Concrete Mix Combinations

There are 12 concrete mix combinations

S.no	Sample representation	Ceme nt %	Fiber %	Mk%	GGBS %
S1	M0G0F0	100	0	0	0
S2	M0G30F0	70	0	0	30
S3	M5G25F0	70	0	5	25
S4	M10G20F0	70	0	10	20
S5	M15G15F0	70	0	15	15
S6	M20G10F0	70	0	20	10
S7	M25G5F0	70	0	25	5
S8	M30G0F0	70	0	30	0
S9	M10G20F0.5	69.5	0.5	10	20
S10	M10G20F1	69	1	10	20
S11	M10G20F1.5	68.5	1.5	10	20
S12	M10G20F2	68	2	10	20

*MK=Metakaolin

*G=GGBS

*F=Fibers

*S=Samples

II. Experimental Results

a) Compressive strength results

i) Compressive strength between CC and TBC

S.no	Average 7-days Compressive strength (MPa)	Percentage increase or decrease	Average 28-days Compressive Strength (MPa)	Percentage increase or decrease
S1	44.37		64.82	
S2	56.86	+28.14	73.21	+12.95
S3	61.91	+39.52	75.30	+16.17
S4	64.24	+44.76	77.17	+19.05
S5	65.20	+46.94	79.64	+22.87
S6	63.13	+42.26	79.23	+22.24
S7	69.35	+56.28	81.79	+26.19
S8	65.68	+48.02	77.64	+19.78

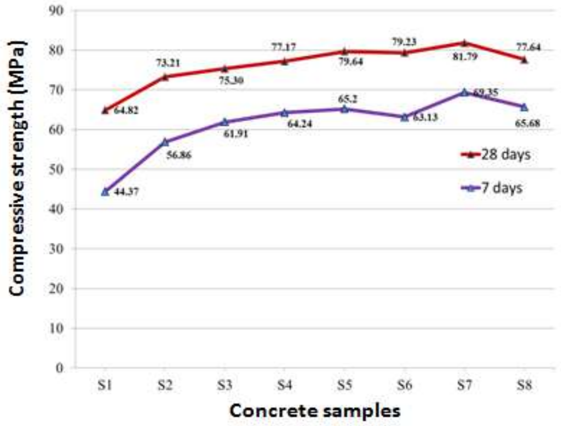

Fig 1: Compressive strength of concrete samples

Compressive strength of TBC is more when compared to CC.

III. Comparison of compressive strength between CC and Ternary blended fiber reinforced concrete (TBFRC)

Sample	Average 7-days Compressive strength (MPa)	Percentage increase or decrease	Average 28-days Compressive Strength (MPa)	Percentage increase or decrease
S1	44.37		64.82	
S9	64.41	+45.17	76.40	+17.87
S10	68.46	+54.28	78.81	+21.59
S11	71.79	+61.79	79.56	+22.73
S12	68.31	+53.95	79.57	+22.76

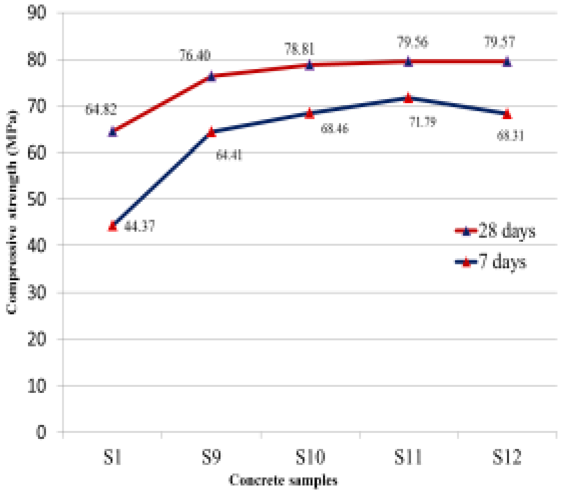

Fig 2: Comparison of compressive strength

The compressive strength of TBFRC is more when compared with CC.

iii) Comparison of compressive strength between TBC and TBFRC

Sample	Average 7-days Compressive strength (MPa)	Percentage increase or decrease	Average 28-days Compressive Strength (MPa)	Percentage increase or decrease
S4	64.24		77.17	
S9	64.41	+0.26	76.40	-0.99
S10	68.46	+6.56	78.81	+2.12
S11	71.79	+11.75	79.56	+3.09
S12	68.31	+6.33	79.57	+3.10

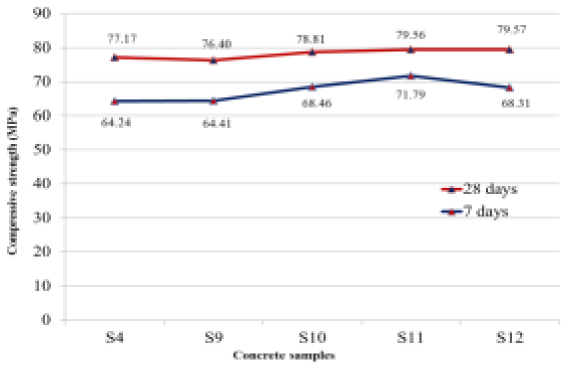

Fig 3: Comparison of compressive strength

b) Tensile strength

i) Comparison of Tensile strength between CC and TBC

Sample	Average 28 days Split Tensile Strength (MPa)	Percentage increase or decrease
S1	5.23	
S2	5.10	-2.05
S3	5.64	7.68
S4	5.94	13.54
S5	6.65	27.14
S6	6.26	19.68
S7	6.81	30.12
S8	6.51	24.46

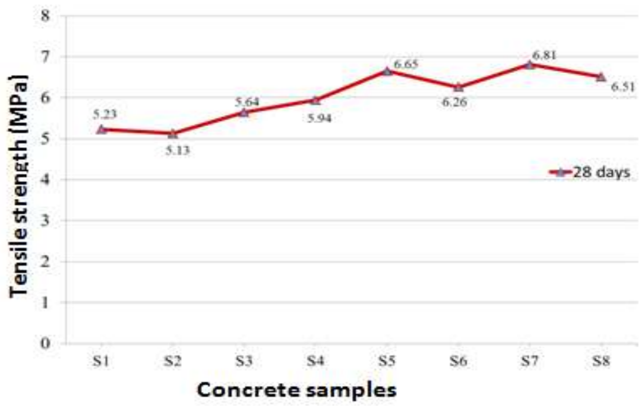

Fig 4: Comparison of tensile strength between CC and TBC

b) Comparison of tensile strength between CC and TBFRC

Sample	Average 28 days Split Tensile Strength (MPa)	Percentage increase or decrease
S1	5.23	
S9	6.87	+17.86
S10	7.11	+35.79
S11	8.20	+56.61
S12	8.24	+57.42

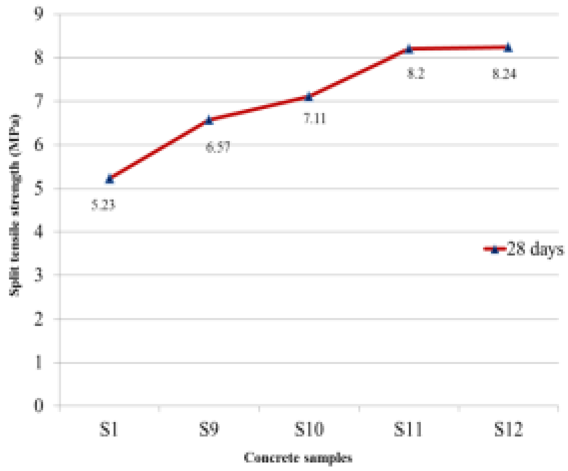

Fig 5: Comparison of tensile strength between CC and TBFRC

c) Comparison of tensile strength TBC and TBFRC

Sample	Average 28 days Split Tensile Strength (MPa)	Percentage increase or decrease
S4	5.94	
S9	6.87	+15.6
S10	7.11	+19.6
S11	8.20	+38.04
S12	8.24	+38.72

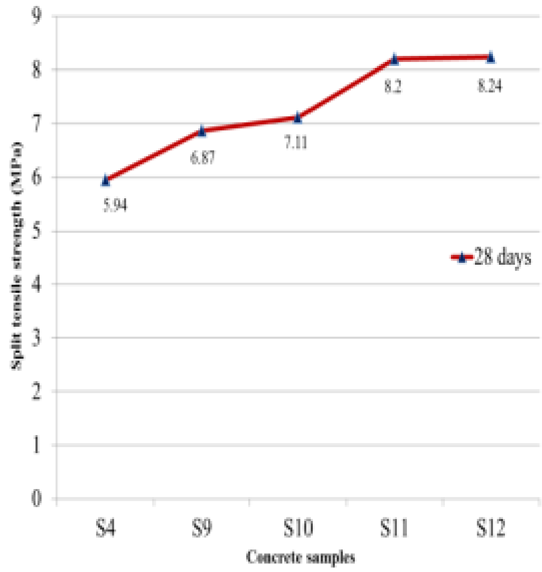

Fig 6: Comparison of tensile strength between TBC and TBFRC

c) Stress-Strain curve

i) Comparison of stress strain curve between CC and Sample 2

Mix	Stress (MPa)	Strain
Conventional concrete (cc)	0	0
	64.82	0.00167
S 2	0	0
	73.21	0.00189

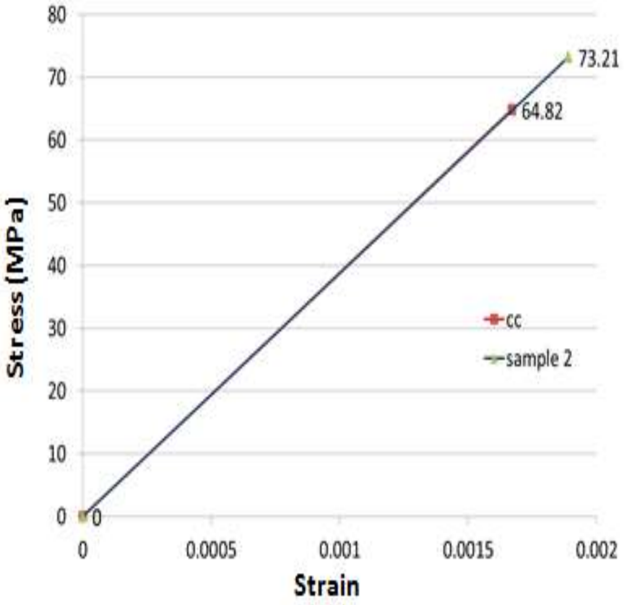

Fig 7: Comparison of stress-strain curve between CC and Sample 2

ii) Comparison of stress-strain curve between CC and sample 5

Mix	Stress (MPa)	Strain
Conventional concrete (cc)	0	0
	64.32	0.00167
S 5	0	0
	77.17	0.00199

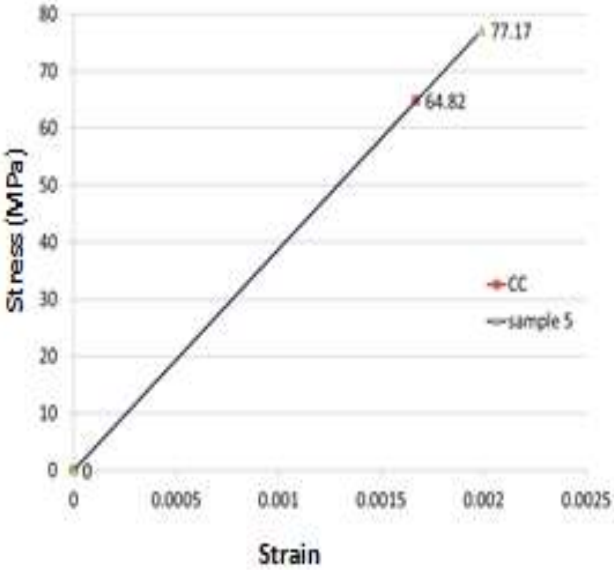

Fig 8: Comparison of stress-strain curve between CC and Sample 5

iii) Comparison of stress-strain between CC and Sample 12

Mix	Stress (MPa)	Strain
CC	0	0
	64.82	0.00167
S 12	0	0
	79.57	0.00205

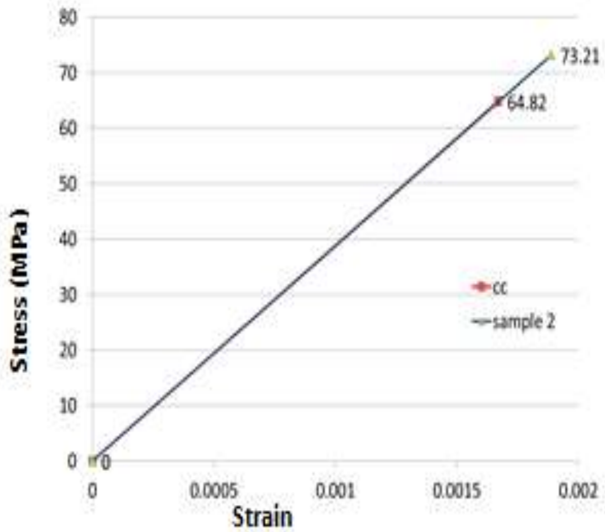

Fig 9: Comparison of stress-strain curve between CC and Sample 12

Conclusions

- Higher dosages of super plasticizer are required for high strength concrete mixes particularly when mineral admixtures and fibers were employed to maintain workability.

- For the combination of 10% MK with 20% GGBS the compressive strength has shown an increase from 19.06 to 22.76 % with various percentages of fiber.
- Among the different percentages of steel fibers i.e. 0.5%, 1.0%, 1.5%, 2.0% the optimum percentage which yielded higher compressive strength is 2.0%. hence percentage of steel fiber is confined to 2%.

- For this combination of 10% MK with 20% GGBS the tensile strength has shown an increase from 13.54 to 57.42 % with various percentages of fiber.

- Among the different percentages of steel fibers i.e. 0.5%, 1.0%, 1.5%, 2.0% the optimum percentage which yielded split tensile strength is 2%. hence percentage of steel fiber is confined to 2%.

- 20% GGBS generates marginal increase in strength. To compensate for the loss of strength when higher percentages of GGBS is used MK is added

- As the percentage of steel and glass fiber is increased there is marginal increase in compressive strength and higher increase in the tensile strength. For a mix with 2% fibers the tensile strength obtained was 8.24 MPa. The tensile strength of the reference mix without any mineral admixtures and without fiber was obtained as 5.23 MPa.

- M60 with GGBS replacing 30% of cement is considered optimum mix and adding certain fibers would help in improving durability properties.

- It is apparent that ternary cementitious blends of Portland cement, Metakaolin, and GGBS offer significant advantages over binary blends and even greater enhancements over plain Portland cement.

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