STM JOURNALS

Recent Trends in Civil Engineering & Technology
ISSN: 2249-8753(online), ISSN: 2321-6476(print)
Volume 6, Issue 2
www.stmjournals.com

Experimental Investigation on Mechanical Properties of Hybrid Fibres in M25 Grade Concrete with Partial Replacement of Cement Using GGBS

S. Revathi**, *R.S. Gandhimathi
Department of Civil Engineering, Sona College of Technology, Salem, Tamil Nadu, India

Abstract
An investigation is made on the mechanical properties of Hybrid Fibre Reinforced Concrete (HFRC) using steel (ST) fibres and Recycled polyethylene terephthalate (RPET) fibres in M25 grade concrete. Steel fibres and Recycled PET fibres were added individually as mono fibres and then they were added together as hybrid fibres into the concrete mix for a fibre volume fraction of 1%. Mechanical properties such as compressive strength, split tensile strength, flexural strength and impact strength of the specimens were found out for various mix proportions of Hybrid Fibre Reinforced Concrete as RPET0.75-ST0.25, RPET0.5-ST0.5 and RPET0.5-ST0.75 and the results are compared with the control mix. After arriving at the optimum percentage of hybrid fibres, cement is partially replaced by Ground granulated blast furnace slag (GGBS) in percentage of 10, 20, 30, 40, 50 and the optimum percentage is determined. This study aims at the dual optimization of volume fraction of hybrid fibres and GGBS in M25 grade concrete. The structural behaviour of Hybrid Fibre Reinforced Concrete with optimized percentage of GGBS is studied by comparing with conventional reinforced concrete beam.

Keywords: *Recycled polyethylene terephthalate (RPET), Fibre, Steel fibre, Compressive strength, Split tensile strength, Flexural Strength, Impact strength, GGBS*

****Author for Correspondence*** E-mail: sambarevathi@gmail.com

INTRODUCTION

Concrete is the most popular material used in the construction industry [1]. Plain cement concrete has some drawbacks such as limited ductility, low tensile strength, high brittleness, poor toughness and little resistance to cracking [2]. The addition of fibres into the concrete mix improves the postcracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and also to provide crack resistance and crack control [3].

In the recent days, a lot of nonbiodegradable plastic wastes (PET bottles) are used as beverage containers, and after their usage, they are dumped into the environment causing pollution problems [4]. To address this issue, a method in which short fibres made from recycled PET are used within structural concrete is presented in this project [5]. The base polyethylene Terephthalate is highly resistant to the majority of aggressive agents and will never oxidize when exposed to the conditions, which cause steel to rust [6]. In the present days the demand for cement is increasing day by day and its production creates a lot of environmental pollution also there are lots of industrial waste coming which could be used as a replacement for cement [7]. This paper is used to investigate the addition of hybrid fibres into the concrete mix with 1% fibre volume fraction and also find the optimum percentage of Ground granulated blast furnace slag (GGBS) that is used as a replacement for cement and study the structural behaviour [3].

EXPERIMENTAL PROGRAM

Materials

The materials used for this experimental work are listed below:

Cement

Ordinary Portland Cement of grade 53 is used in this experimental work with specific gravity 3.15 and consistency 31%.

Fine Aggregate

Clean and dry locally available river sand conforming to zone II as per IS: 383:1970 with specific gravity 2.67 was used.

Coarse Aggregate

Broken granite stone satisfying gradation in Table 2 of IS: 383-1970 with specific gravity 2.72 is used as coarse aggregate.

Water

Ordinary potable water of good quality was used in this experimental study.

Super Plasticizer

Glenium (B233) at a dosage of 1% by weight of cement was used as Super plasticizer.

Steel Fibres

Crimped steel fibres of length 30 mm and diameter 0.5 mm with aspect ratio 60 is used (Figure 1).

Recycled PET Fibre

Recycled Polyethylene Terephthalate fibre of length 38 mm and diameter 0.02 mm with aspect ratio 1900 was used in this study (Figure 1).

GGBS

Ground granulated blast furnace slag (GGBS); a by-product from blast furnaces is used as a replacement for cement.

Mix Design

The mix design for M25 grade concrete is done as per IS: 10262-2009. The quantities of various materials for concrete mix are shown in Table 1.

Table 1: *Quantities of Materials.*

Material	Quantity(kg/m^3)	Mix Ratio
Cement	402.75	1
Fine aggregate	677.44	1.68
Coarse aggregate	1130.5	2.81
Water	181.24	0.45
Super plasticizer	4.0275	0.01

Tests Conducted

Compressive Strength

Compressive strength is one of the most important properties of concrete. Cubes of size 150×150×150 mm were cast, allowed for 28 days of curing and tested in compression testing machine (CTM) as per IS: 516-1959.

Split Tensile Strength

It is the well-known indirect test conducted to determine the tensile strength of concrete. Cylinders of length 300 mm and diameter 150 mm were cast, cured for 28 days and tested. The tests were conducted as per IS: 5816-1999.

Fig. 1: *Steel Fibre and Recycled PET Fibre.*

Flexural Strength

Concrete prisms of size 100×100×500 mm were cast. It is cured for 28 days and tested under two point loading as per IS: 516-1959.

Impact Strength

Impact strength of concrete is used to find the impact resistance and percentage of energy absorption under impact loading. The test is conducted by drop hammer test as per ACI 544.

RESULTS AND DISCUSSION

In this present study the results on mechanical properties of M25 grade concrete under different combinations of fibres is done and the results were compared with the control mix as shown in Table 2.

Optimization of Hybrid Fibres

Table 2: *Comparison on Mechanical Properties of Concrete Specimens.*

Mix Details	Compressive Strength (N/mm^2)	Split Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)	Impact strength	
				Impact resistance (%)	Energy Absorption (Joules)
Control mix	32.8	2.85	4.46	2.85	1942.38
RPET fibre 1%	34.5	3.08	4.80	3.08	2494.19
Steel fibre 1%	36.4	3.38	5.87	3.38	3023.9
RPET 0.75 +ST0.25	36.9	3.98	6.10	3.98	3112.22
RPET 0.25+ ST0.75	**44.3**	**4.55**	**7.25**	**4.85**	**4922.17**
RPET 0.5 + ST 0.5	40.2	4.20	6.95	4.20	3597.82

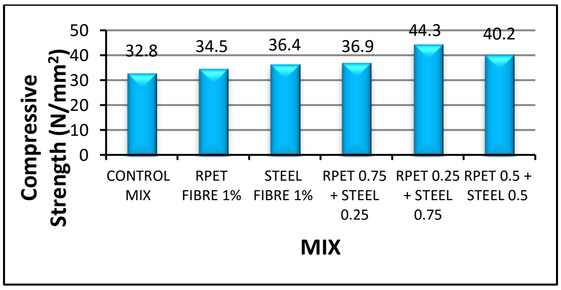

Fig. 2: *Compressive Strength at 28 days.*

Compressive Strength

From Figure 2, it is clear that the compressive strength of the mono fibres is 5.2% (RPET 1%) and 11% (steel 1%) greater than the control mix. It is observed that the compressive strength of all hybrid fibre reinforced concrete mixes is greater that the control mix and the mono fibre mixes and the hybrid mix RPET 0.25 + ST 0.75 attains a maximum strength which is 35% higher than the control mix.

Split Tensile Strength

From Table 2 it is clear that the maximum split tensile strength is obtained for the mix RPET 0.25 + ST 0.75, which is 70.2% greater than the control mix. This is mainly because of steel fibre that has higher modulus of elasticity and when first crack occurred, the RPET fibre restricts growth of crack. Hybrid fibres thus improve the split tensile strength noticeably.

Flexural Strength

The flexural strength of mono fibres, i.e., STEEL fibre 1% and RPET fibre 1% has flexural strength 31.6 and 7.6% higher than the control mix. Therefore, steel fibers are effective to arrest the macro cracks while RPET fibers are effective to arrest the micro cracks. Hybridization keeps improving the flexural strength as compared to the mono fibres.

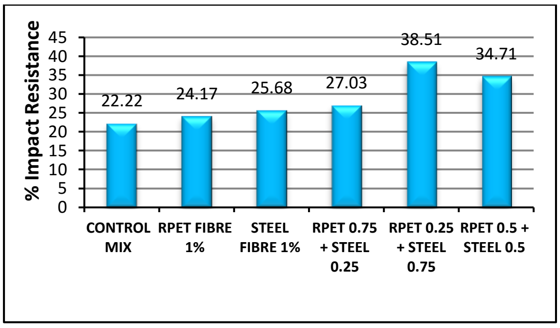

Fig. 3: *Percentage Impact Resistance.*

Impact Strength

From the Figure 3, it is evident that the percentage impact resistance is much higher for the hybrid mix, i.e., RPET 0.25 + ST 0.75 when compared to the control mix and mix with mono fibres.

Impact strength of fibre reinforced concrete is an important parameter to be studied because the addition of fibre to the concrete finds major application in the pavements.

Optimization of GGBS in Hybrid Fibre Reinforced Concrete

The optimum combination of hybrid fibres in M25 grade concrete is determined. In the next stage, in the optimum percentage of hybrid fibres, cement is replaced partially by GGBS and the mechanical properties are evaluated as shown in Table 3.

Table 3: *Comparison on Mechanical Properties of Concrete Specimens.*

Mix Details	Compressive Strength (N/mm^2)	Split Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)
MIX A – 10% GGBS	44.8	4.55	7.25
MIX A – 20% GGBS	45.32	4.60	7.67
MIX A – 30% GGBS	46.8	4.71	7.9
MIX A – 40% GGBS	48.38	4.85	8.45
MIX A – 50% GGBS	46.2	4.62	7.55

**MIX A - Optimum Percentage of Hybrid Fibres, i.e., (RPET 0.25 + ST 0.75) in M25 Grade Concrete*

Compressive Strength

From the Figure 4 it is clear that the maximum value for compressive strength is attained for Mix A with 40% GGBS. Beyond 40% of replacement of cement by GGBS, compressive strength is gradually reduced. The compressive strength is 10% higher than the hybrid mix without GGBS.

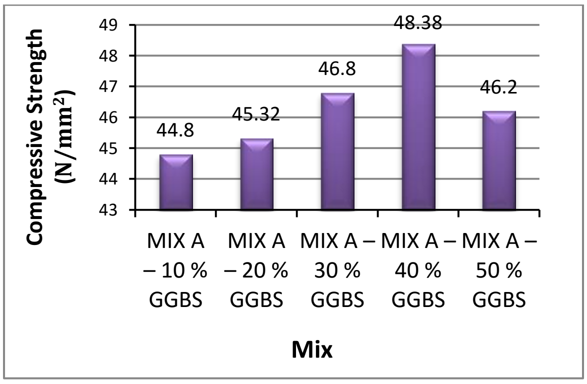

Fig. 4: *Compressive Strength.*

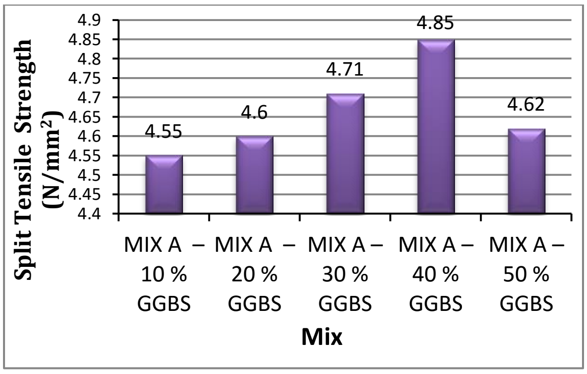

Fig. 5: *Split Tensile Strength.*

Split Tensile Strength

Figure 5 gives the results of split tensile strength. The maximum value is arrived for the replacement of cement by GGBS for a percentage of 40. The split tensile strength is 7% greater than the mix without GGBS.

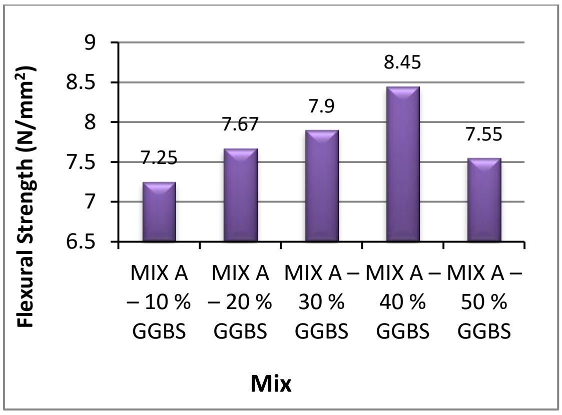

Fig. 6: *Flexural Strength.*

Flexural Strength

From the Figure 6, it can be made clear that the flexural strength is maximum for the hybrid mix with 40% replacement of cement by GGBS. The flexural strength is increased by 17% when compared with the mix without GGBS.

STRUCTURAL BEHAVIOUR

The structural behaviour of hybrid fibre reinforced concrete with partial replacement of cement by GGBS is studied using beam element.

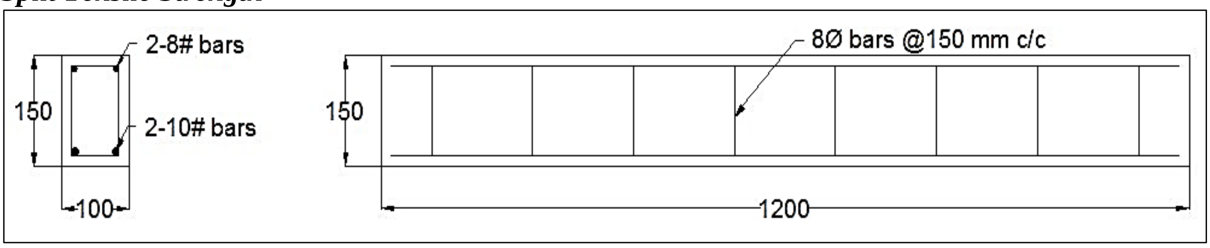

Fig. 7: *Reinforcement Details of Beam.*

Reinforcement Details of Beams
Beams of length 1200 mm with breadth 100 mm and depth 150 mm were cast. The longitudinal and cross section details are shown in Figure 7.

Test Procedure
Two numbers of reinforced concrete beams were cast and were subjected to two points loading in Universal Testing Machine (UTM) of 100 kN to evaluate the structural behaviour (Figure 8). The beam is described as follows:
Beam 1 Conventional R.C.C. beam.
Beam 2 Beam with optimized combination of hybrid fibres and GGBS.

Fig. 8: *Testing of Beam in UTM.*

RESULTS AND DISCUSSIONS
Load versus Deflection
The beam is fitted with deflectometers and the deflections are recorded at every 2 KN load interval. The beam was found to fail under flexure. The load-deflection curve is shown in Figure 9.

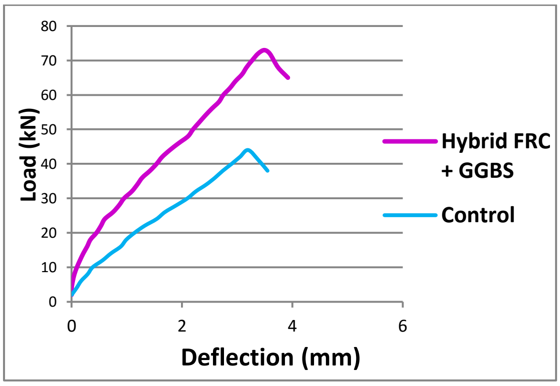

Fig. 9: *Load versus Deflection.*

The structural behaviour of the beam element is evaluated and results are given in Table 4.

Table 4: *Test Results of Beam.*

Parameters	Beam 1	Beam 2
Cracking Load(kN)	7.7	16
Ultimate Load(kN)	44	73
Ductility Factor	7.18	9.8
Energy Absorption capacity (kNmm)	81.95	166.305
Stiffness(kN/mm)	15.082	19.979

Ductility Factor
Ductility is defined as the ability of a member to undergo inelastic deformations beyond the yield deformation without significant loss in the load carrying capacity. It is found from the load-deflection curve. The ratio of ultimate deflection to the deflection at first yield is known as ductility factor. The results of ductility factor are given in Figure 10.

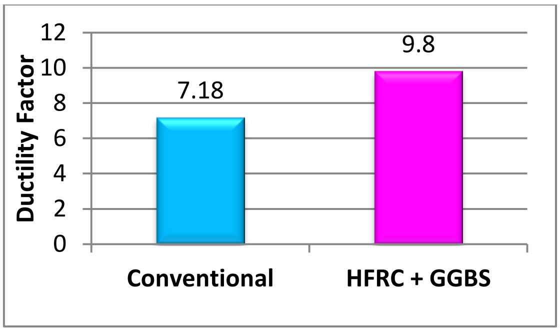

Fig. 10: *Ductility Factor.*

From the Figure 10, it is clear that the ductility factor of beam with hybrid fibres and GGBS is 31% much higher than the conventional RC beam.

Energy Absorption Capacity
Energy absorption capacity is determined from the load-deflection curve. Figure 11 shows the energy absorption capacity of M_{25} grade RC beam.

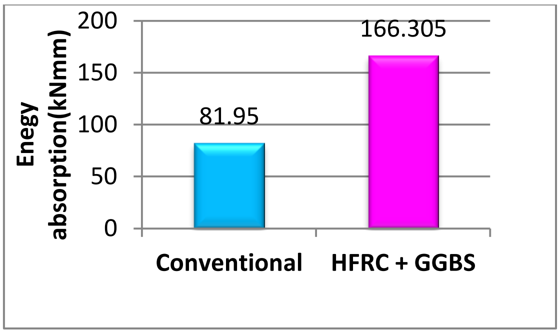

Fig. 11: *Energy Absorption Capacity.*

From the above Figure 11, it is clear that the energy absorption capacity is increased significantly in the beam with hybrid fibres and GGBS when compared with conventional RC beam.

Stiffness

Stiffness is the rigidity of an object, the extent to which it resists deformation in response to an applied force.

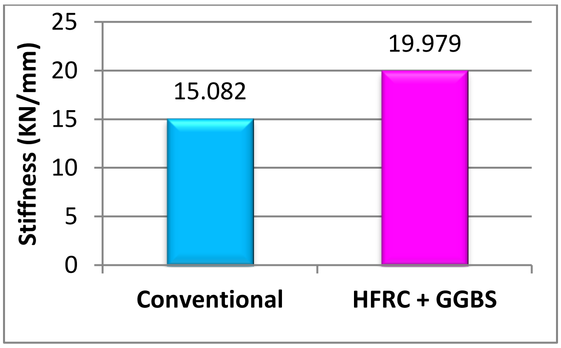

Fig. 12: *Stiffness.*

From the Figure 12 it is clear that stiffness of the beam with hybrid fibres and GGBS is 32.5% much higher than the conventional RC beam.

CONCLUSION

From the experimental study, the following conclusions are drawn:

- It is evident from the present investigation that the hybridization of fibres is proved to be much superior when compared to mono fibres.
- The maximum compressive, split tensile, flexural and impact strength is attained for the hybrid fibre reinforced concrete mix (RPET 0.25 + ST 0.75) which is much greater than the mono fibre reinforced concrete, i.e., (RPET FRC and STEEL FRC) and conventional concrete. This is because of the high elastic modulus of steel fibre and the low elastic modulus of recycled PET fibre that work in perfect combination.
- The maximum compressive, split tensile and flexural is attained for 40% replacement of cement by GGBS into the optimized hybrid fibre reinforced concrete mix.
- The structural behaviour of hybrid fibre reinforced concrete beam with GGBS is greatly improved when compared to the conventional RC beam.

REFERENCES

1. Darole, *et al*. Effect of Hybrid Fibre on Mechanical Properties of Concrete. *Int J Eng Res Technol*. 2013; 3(4): 1408–1411p.
2. Selina Ruby, *et al.* Influence of Hybrid Fiber on Reinforced Concrete, *Int J Adv Struct Geotech Eng.* 2014; 03(01): 40–43p.
3. Neeraja D. Experimental Investigation on Strength Characteristics of Steel Fibre Reinforced Concrete, *Int J Sci Eng Res*. 2013; 4(2): 1–6p.
4. Murali G, *et al*. Influence of Steel Fibre on Concrete, *Int J Eng Res Appl*. 2012; 2(3): 075–078p.
5. Ankush Khadwal, *et al.* Strength Evaluation of Steel-nylon Hybrid Fibre Reinforced Concrete, *Int J Eng Res Appl*. 2014; 4(7): 32–36p.
6. Gurpuneet Singh, *et al.* Improving Structural Performance Using Fibers in Concrete, *Int Res J Eng Technol. (IRJET)*. 2015; 02(04): 6–11p.
7. Hasan MJ, *et al*. An Experimental Investigation on Mechanical Behaviour of Macro Synthetic Fibre Reinforced Concrete, *Int J Civ Environ Eng*. 2011; 11: 18–23p.

Cite this Article

Revathi S, Gandhimathi RS. Experimental Investigation on Mechanical Properties of Hybrid Fibres in M25 Grade Concrete with Partial Replacement of Cement Using GGBS. *Recent Trends in Civil Engineering & Technology*. 2016; 6(2): 51–56p.