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The steel and polypropylene reinforced concrete beams: Shear behaviour study

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ABSTRACT

The research examines the outcomes of shear and flexure testing on reinforced concrete beams made from steel and polypropylene fibre. As well as assessing the impact of fibre in this structural integrity with shear strengthening ratios, certain elements in the characteristics of the cement that is both new and hardened are presented. 14 square beams being put into practice. Tests were made. There were beams produced from 7 distinct mixing dimensions, depending on the kind and the fibre content. For each composite mix there were two beams: one with and the other without stirrups. The primary changes caused by the introduction of fibres were enhanced shear strength, rigidity (especially after the first breaking stage) and ductility. The characteristics of hard concrete (tensile strength, compressive strength and elasticity modules), longitudinal reinforcement concrete, stresses in stirrups, were other factors utilized for the analysis of performance (at the compression and web zone).
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1. Introduction

Steel and polymeric fibres both of these materials have been used to strengthen concrete, improving its toughness of fracture resistance. In some structural applications, fibre-reinforced concrete can be utilized with less or even no traditional reinforcement. The fibres could be put to use improve the load-carrying capacity of concrete that has been exposed to shear. Several design techniques that account for the increase in shear strength caused by fibres have been presented. Each approach uses an index based on the material's hardness to account for the fibre contribution. Each formula, however, employs a different index derived from various test setups [5].

The goal of this paper is to report the findings of a study that was conducted to evaluate the structural behaviour of FRC beams under shear loading using different types of fibres (steel and polymeric). The study also attempts to assess the ability to forecast final shear capacity using code provisions or correlations with other test findings. Simultaneously, it is determined if the SFRC design techniques can be used to polypropylene fibre reinforced concrete (PFRC) [6,7].

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2. Literature review

Hybrid fibre reinforced concrete's (HyFRC) impact comprising varying mixes of polyolefin-basalt fibres with a 1% volume portion of total fibre is investigated in this article. Hybrid fibre reinforced concrete specimens were compared to plain concrete specimens in terms of performance. The study's findings tests reveal that composites made of hybrid fibres perform stronger. [1].

The investigates concrete has several advantages in terms of mechanical properties and building costs.. PFRC (polypropylene fibre-reinforced concrete) has given a technological foundation for addressing these flaws. Polypropylene is one of the cheapest and abundantly available polymers [2].

A comprehensive review on various aspects of Polypropylene fibre Reinforced Concrete concerning the behaviour, applications and performance of Polypropylene fibre Reinforced Concrete. Various issues related to the manufacture and strength of Polypropylene fibre Reinforced are also discussed [3].

The geometrical size and modulus of fibres are the primary determinants of the mechanical properties of fibre reinforced concrete. The employment of several types of fibre in a suitable mix has the ability to improve the overall mechanical properties of concrete and create performance synergy. Hybrid fibre reinforced concrete's synergistic mechanical characteristics (HyFRC) with various

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types and % of polypropylene fibre and steel fibres were investigated experimentally in order to determine which hybrid fibre reinforced concrete mixtures surpassed expectations in terms of mechanical characteristics. To evaluate mechanical concert of the HyFRC, four sets of test specimens were utilised, each having a macro and micro-fibre mix of steel and polypropylene fibre. [4].

3. Experimental program

In the present work, the experimental program consisted of testing two normal reinforced concrete and two fibre reinforced concrete beams of identical cross-section (100 mm ×150 mm). The span length of the beam was 2000 mm. The mix to resist the 25 MPa compressive strength of the cylinder. The shear span to effective depth ratio was the most important factor [8,9].

3.1. Properties of constituent materials

3.1.1. Cement

The capacity of cement to generate better microstructure in concrete is one of the most significant factors for cement selection. Normal Portland cement, also known as Type 1 by the ASTM, is the most widely used cement [10,11]. Fiber-reinforced concrete may be made with OPC. Table 1 shows the cement characteristics that were discovered.

3.1.2. Aggregates

The ASTM standard C-33 specifies the grading requirements for fine aggregates used in concrete. At least 80% of the particles should be less than 3 mm in size. Normal, lightweight, and heavyweight coarse aggregates are available [12]. In the field, fiber-reinforced concretes with lightweight or normal-weight aggregates have proven to be successful in a wide range of applications. Tables 2 show the characteristics of fine aggregate and Table 3 coarse aggregate, respectively.

3.1.3. Water

It takes part in the chemical processes that lead to the emergence of the hydration product, calcium silicate hydrate (C-S-H) gel, with cement [13].

3.1.4. Fiber

Polypropylene fibre and dramix 80/60 BN hook-ended steel fibres were the two types of fibres evaluated. In every situation, fibre the volume was set for 0.4%. Fig. 1 shows the photos of Glued DRAMIX Steel Fiber and Polypropylene Fiber [14].

Table 1
Properties of PPC.

Test	Result obtained	As per IS 4031-1998
Consistency	33	_
Initial setting time	90 min	Not less than 30 min.
Final setting time	5 h	Not more than 600 min.
Specific gravity	3.15	_

Table 2
Fine aggregate - properties.

Test	Result obtained	As per IS 383-1970
Fineness modulus	2.7	Medium sand
Specific gravity	2.6	2.55 minimum
Bulk density Kg/m^3	1607	_

Table 3
Coarse aggregate - properties.

Test	Result obtained	As per IS 383–1970
Fineness of modulus	5	5 to 7
Specific gravity	2.64	2.6 minimum
Bulk density Kg/m^3	1580	–

3.2. Mix design

In this experimental investigation, 0.4% of fibre In the M25 mix, a volume fraction is utilised.

3.2.1. Fiber reinforced concrete mixture

The fibres were removed from the wet mixture before it was utilised. Before adding the fibres, The concrete should have a larger slump (50 to 76 mm) perhaps required final slump. Add individual fibres to the mixer, ball-free, while the mixer is running at regular charging speed. To achieve a homogeneous concrete mix, reduce the mixer's power. to the specified speed of mixing and time spent mixing about 10 to 15 revolutions after all of the needed fibres have been added to the mixer [15,16].

3.2.2. Mixture proportion

This research makes use of fibre reinforced concrete with and without fibres in a mixed percentage of M25 Mpa is the design compressive strength. There was a 0.45 water-to-cement ratio. Initially, 0.4 percentage of fibre volume fraction was incorporated. Table 4 shows the proportions of the concrete mix utilized in the test.

Fig. 1. Photos of Glued DRAMIX Steel Fiber and Polypropylene Fiber.

Table 4
Design Mixture proportions.

Design Mix	Cement (Kg/m^3)	F.A (Kg/m^3)	Total C.A (Kg/m^3)	60% 0f 20 mm C.A (Kg/m^3)	40% of 12.5 mm C.A (Kg/m^3)	Water (Kg/m^3)
M25	414	552	1173	704	469	186

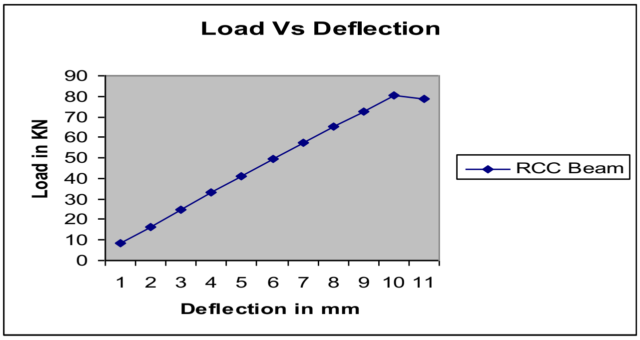

Fig. 2. Load Deflection diagram for the RCC beam.

4. Test results and discussions

The two-point load arrangement was used to test the structural-scale beams under shear loading, with a 2.67 shear span to depth ratio. The shorter anchoring longitudinal reinforcement length prevented the formation of the arch effect, which resulted in flexural reinforcement debonding and beam failure in the absence of shear reinforcement in the traditional sense [16].

Typical load–deflection responses are depicted in Fig. 2, demonstrating how fibre activity increases shear ductility. The maximum load in SFRC beams is roughly 40% greater than in RCC beams with minimal stirrups, resulting in an increase in deflection at maximum load. For all FRCs including RCC Beams with minimal stirrups, an improvement in ductility under shear loading may be noticed, as evidenced by a substantial rise in terms of deformability components at highest load [17].

Nonetheless, the capability of load-carrying for fibre-reinforced beams is never smaller than among stirrup-reinforced beams using the same quantity of steel. This is due to the dispersed nature of the fibre reinforcement, in which only certain fibres are orientated to prevent from cracking but both stirrups are in use inhibit opening crack.

4.1. Experimental results

The deflection of all RCC beams was measured using a dial gauge at three locations, the deflection grew as the load increased, with one at the mid-span and the other two at one-third point from the support.

4.1.1. Load and deflection for RCC beam

For RCC Beam-1, which has a shear span to an effective depth ratio of 2.67, a maximum of 9 mm deflection was obtained. The test result of RCC Beam-1 is presented in Table 5. The graph drawn for RCC Beam-1 is shown below.

Compared to all other beams the shear load-carrying capacity of the RCC beam with stirrups is maximum, up to the maximum load-carrying capacity the Load Vs Displacement relationship is linear. After that, the load and displacement are reducing gradually and then failure occurs in the beam. The area under the Load Vs Displacement curve is maximum, so the toughness and the shear carrying capacity is maximum for the RCC beam [18].

4.1.2. Load and deflection for RCC beam with minimum stirrups

For RCC Beam-2, which has a shear span to effective depth ratio of 2.67, a maximum of 6.71 mm deflection was recorded. The test result of RCC Beam-2 is presented in Table 6. The graph drawn for RCC Beam-1 is shown below in Fig. 3.

Compared to all other beams the shear the RCC beam's load-carrying capability with minimum stirrups is minimum, up to the maximum load-carrying capacity the Load Vs Displacement relationship is linear. After that, shear failure occurs in the beam.

4.1.3. Load and deflection for SFRC beam

For SFRC, a maximum deflection of 10.25 mm was recorded, this is for shear span to a depth of 2.67 effective depth. The test result of SFRC is presented in Table 7. The graph drawn for SFRC is shown below in Fig. 4.

Compared to PFRC & RCC Beam-2 the shear load-carrying capacity of the SFRC beam is maximum, up to the maximum load-

Table 5
Reinforced Concrete Beam Load and Displacement Values.

Sl. no.	Load in KN.	Measurement of displacement in millimetres (at point 1)	Measurement of displacement in millimetres (at centre)	Measurement of displacement in millimetres (at point 2)
01.	08.24	00.31	00.27	00.27
02.	16.67	00.65	00.64	00.60
03.	25.25	00.98	00.97	00.90
04.	33.78	01.46	01.40	01.31
05.	42.43	02.40	02.24	02.12
06.	50.34	03.24	03.0	02.86
07.	59.38	04.01	03.69	03.56
08.	66.55	05.10	04.72	04.55
09.	73.93	08.00	06.98	06.85
10	82.50	08.62	07.50	07.20
11	80.40	09.00	07.90	07.60

Table 6
Reinforced Concrete Beam Load and Displacement Values with Minimal Stirrups.

Sl. no.	Load in KN	Measurement of displacement in millimetres (at point 1)	Measurement of displacement in millimetres (at centre)	Measurement of displacement in millimetres (at point 2)
01.	08.45	0.43	0.43	0.35
02.	18.87	0.78	0.77	0.65
03.	26.87	1.26	1.20	1.06
04.	35.83	1.93	1.75	1.66
05.	43.78	3.05	2.70	2.60
06.	50.75	3.95	3.46	3.33
07.	58.58	4.75	4.25	4.10
08.	48.70	6.00	5.34	5.25
09.	48.57	6.71	5.90	6.08

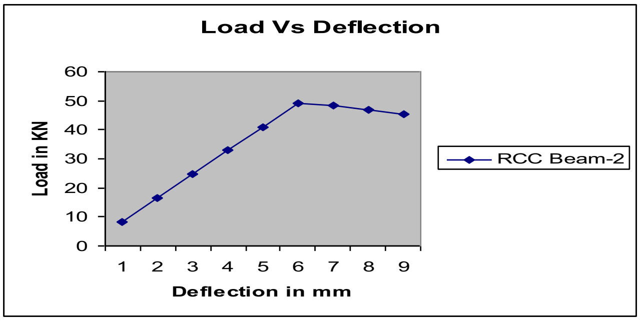

Fig. 3. RCC beam-2 load deflection diagram.

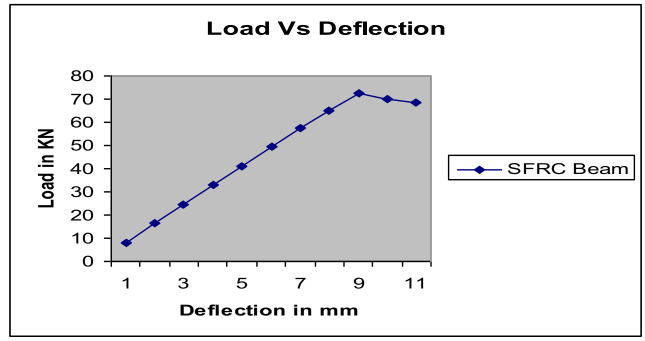

Fig. 4. SFRC beam load deflection diagram.

carrying capacity the Load Vs Displacement relationship is linear. After that, the load and displacement were reducing gradually and then failure occurs in the beam. The length and breadth of the crackers were decreased as a result of the use of steel fibres in concrete. The cracking pattern of the SFRC beam is shown in Fig. 4.

4.1.4. Load and deflection for PFRC beam

For PFRC, a maximum deflection of 9.80 mm was recorded for shear span to an effective ratio depth of 2.67.. The test result of PFRC is presented in Table 8. The graph drawn for SFRC is shown below in Fig. 5.

The shear load-carrying capability of the PFRC beam is the highest when compared to RCC Beam-2; up to the maximum load-carrying capacity, the Load Vs Displacement relationship is linear. After that, the load and displacement are reducing gradually and then failure occurs in the beam. The length and width of the fracture are decreased when polypropylene fibres are used in concrete. The cracking pattern of the PFRC beam is shown in Fig. 5.

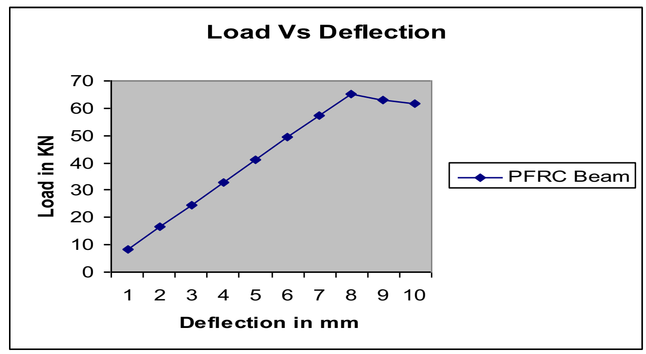

Fig. 5. PFRC Beam Load Deflection Diagram.

4.1.5. Test results of cubes, cylinders, prisms and beams

The inclusion of fibres in the concrete improves the concrete's compressive strength by a little amount. SFRC has a higher com-

Table 7
SFRC Beam Load and Displacement Values.

Sl. no.	Load in KN	Measurement of displacement in millimetres (at point 1)	Measurement of displacement in millimetres (at centre)	Measurement of displacement in millimetres (at point 2)
01.	07.98	00.45	00.47	00.46
02.	15.65	00.72	00.90	00.87
03.	26.77	01.81	01.22	01.54
04.	37.84	01.74	01.93	01.41
05.	44.80	02.72	02.76	02.65
06.	50.50	02.87	03.19	02.64
07.	57.40	03.81	04.34	03.61
08.	65.15	04.55	05.46	04.95
09.	72.73	05.55	06.73	05.51
10.	77.00	06.28	07.89	06.51
11.	69.39	09.00	11.25	08.78

Table 8
PFRC Beam Load and Displacement Values.

Sl. No.	Load KN	Measurement of displacement in millimetres (at point 1)	Measurement of displacement in millimetres (at centre)	Measurement of displacement in millimetres (at point 2)
01.	9.24	0.49	0.59	0.34
02.	17.45	0.79	0.87	0.78
03.	26.67	1.12	1.12	1.15
04.	34.94	1.97	2.32	1.67
05.	44.00	2.15	2.58	2.35
06.	48.30	2.69	2.99	3.64
07.	53.40	3.89	4.45	3.94
08.	67.15	4.58	4.98	4.24
09.	63.00	5.42	6.95	5.60
10.	61.50	8.60	9.87	8.80

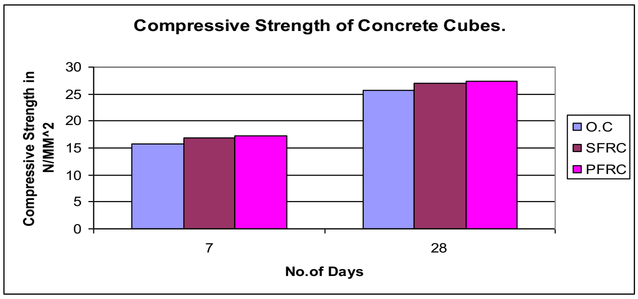

Fig. 6. Concrete Cube Compressive Strength.

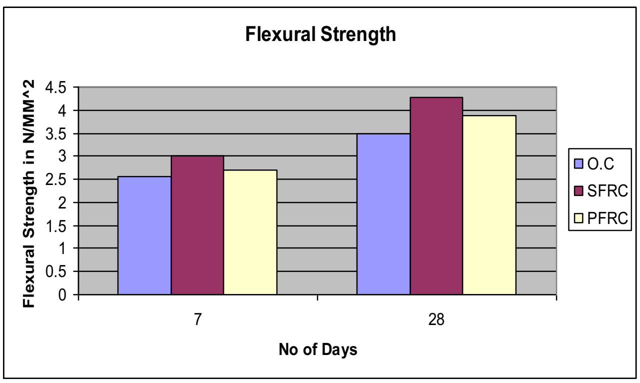

Fig. 7. Concrete's flexural strength.

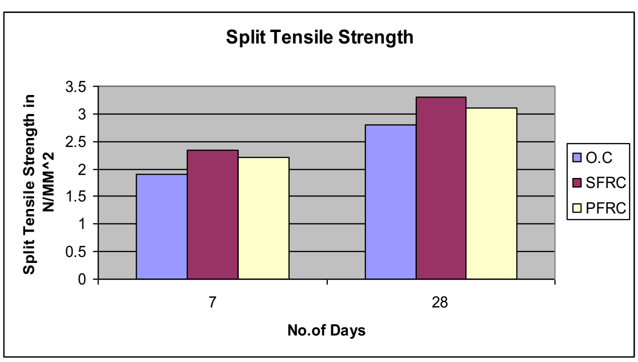

Fig. 8. Concrete Split Tensile Strength.

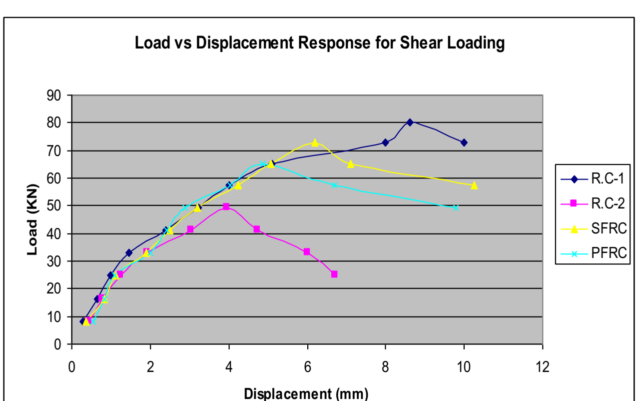

Fig. 9. Load-Displacement Response under Shear Loading.

pressive strength than PFRC. The compressive strength of concrete cubes is shown in Fig. 6.

In comparison to normal and PFRC, SFRC has the highest flexural and split tensile strength. Figs. 7 and 8 show that SFRC has the highest flexural and tensile strength.

From Fig. 9 we can note that the area under the curve is maximum for RCC Beam −1. Compared to RCC Beam with minimum stirrups, the area under the curve is maximum for both SFRC & PFRC beams. SFRC beam is having more shear carrying capacity than compared to PFRC beam.

5. Conclusion

Within the constraints of the experimental research, the following findings were reached.

- The addition of fibres into the mix has been found to enhance material toughness in tension as well as compression as reflected by ASTM and JSCE toughness indices.
- Increased concrete shear strength and better deformation enhance toughness, i.e. for FRC beams the deflections are considerably larger than for specimens of plain concrete.
- Due to the fibre part of concrete, the compression strength only rises slightly.
- In comparison to SFRC, the first crack develops earlier in PFRC.
- The maximum load in SFRC beams increased by around 20% of ordinary concrete.
- Due to incorporation, crack length and breadth are decreased

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] M. Dhanam, S. Dr, Eswari., Performance Evaluation of Hybrid Fibre Reinforced Concrete with Polyolefin and Basalt Fibres, Advances in Natural and Applied sciences 11 (9) (2017) 291–296.
[2] Brajkishor Prasad, Virendra Kumar, Properties of Polypropylene Fibre Reinforced Concrete and Structural Behaviour of Beam, International Journal of Innovative Research in Science, Engineering and Technology 6 (6) (2017) 10200–10210.
[3] T.Ch. Madhavi, L. Swamy Raju, Behavior of Polypropylene Fibre Reinforced Concrete, International Journal of Emerging Technology and Advanced Engineering 4 (4) (2014) 114–119.
[4] D. Parthiban D.S. Vijayan 22 2020 822 828.
[5] Shaik imam mohidin Ch Yuvaraju, Experimental investigation on Mechanical properties of Hybrid Fiber Reinforced Concrete, Journal of Emerging Technologies and Innovative Research. 5 (2) (2018) 1149–1157.
[6] A. Vijayakumar, D.L. Venkatesh Babu, E. Prabakaran, Experimental Study on Shear Behavior of Different Types of fibers in Reinforced Concrete Beams, International Research Journal of Engineering and Technology 2 (2) (2015) 269–272.
[7] K. Vidhya, S. Kandasamy, Study on properties of bricks manufactured using fly ash and pond ash, Pollution Research 32 (2) (2013) 405–409.
[8] N. Sudharsan, S. Saravanaganesh, Feasibility studies on waste glass powder, International Journal of Innovative Technology and Exploring Engineering. 8 (8) (2019) 1644–1647.
[9] N. Sudharsan, T. Palanisamy, A comprehensive study on potential use of waste materials in brick for sustainable development, Ecology, Environment and Conservation 24 (2018) S339–S343.
[10] D.S. Vijayan Dineshkumar S. Arvindan Thattil Shreelakshmi Janarthanan 22 2020 781 787.
[11] Pu. Wang, Zhen Huang, Performances of Hybrid fibre Reinforced Concrete with Steel Fibres and Polypropylene fibre", Construction and Building Materials 83 (2012) 150–158.
[12] N. Sudharsan, K. Sivalingam, Potential utilization of waste material for sustainable development in construction industry, International Journal of Recent Technology and Engineering. 8 (3) (2019) 3435–3438.

[13] K. Vidhya, S. Kandasamy, Experimental Investigations on the Properties of Coal-Ash Brick Units as Green Building Materials, International Journal of Coal Preparation and Utilization. 36 (6) (2016) 318–325.
[14] N. Sudharsan, B.C.J. Grant, Comparison of static response of laced reinforced concrete beams with conventional reinforced concrete beams by numerical investigations, International Journal of Civil Engineering and Technology. 9 (8) (2018) 700–704.
[15] Sanjay Gokul Venigalla, Swarna Swetha Kolaventi, Gummadi Amar, Experimental Investigation on the Behaviour of Hybrid Fiber Reinforced Concrete", International Journal of Engineering Development and Research. 4 (2) (2016) 792–796.
[16] N. Sudharsan, T. Palanisamy, S.C. Yaragal, Environmental sustainability of waste glass as a valuable construction material - A critical review, Ecology, Environment and Conservation 24 (2018) S331–S338.
[17] V. Lakshmi Shruthi M. Kalpana D.S. Vijayan 33 2020 48 51.
[18] K. Vidhya, S. Kandasamy, Study on the flexural strength of coal ash brick masonry wall elements, Journal of Structural Engineering (India) 41 (4) (2014) 410–419.