Correlation Involving Compressive Strength and Flexural Strength of Polyester Fiber-Reinforced Binary Blended Concrete

N. K. Amudhavalli, S. Sivasankar, M. Shunmugasundaram, and A. Praveen Kumar

Abstract Fibers were in increasing demand by the desirable quality of elongation and ductility, enhance the show of normal concrete. The recent venture was a relative study to resolve the correlation involving the strength parameters of fiber-reinforced binary blended concrete composites. Polyester fibers are exploited in trial exploration in various parts by addition to the weight of cement with an optimum dose of silica fume and rice husk ash as fractional substitution of ordinary portland cement. In this research, the flexural and compressive strength of polyester fiber-reinforced blended concrete were studied and begin that in present, there was major progress in the strength properties, by utilization of fiber with mineral admixtures in concrete. It was seen that the correlation between flexural and compressive strength played a crucial role and the empirical expression for calculating the strength features of polyester fiber-reinforced blended concrete was featured based on the regression analysis. The properties of concrete were found to be significantly developed by the addition of fiber reinforcement.

Keywords Polyester fiber-reinforced blended concrete · Silica fume · Rice husk ash · Compressive strength · Flexural strength · Regression equation

1 Introduction

The economic advantages and performance properties of concrete with fiber were far more considerable when compared to conventional concrete. The characteristics

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of fiber-reinforced concrete led to its large-scale recognition by the construction industry. The extent of the change depends on the quantity and quality of fibers used [1]. In present days, fibers such as polyester, polypropylene, and polyethylene were used in the market and became acceptable in the construction industry due to their exclusive properties. Exceptionally, a less number of literature were existing for understanding the behaviors of polyester fiber-reinforced blended concrete. Polyester strands were to some degree hydrophobic and the fibers have been utilized at a low amount to control plastic-shrinkage splitting in concrete [2]. In a hardened state, polyester fibers reduce micro-cracks and crack propagations [3]. An increase of about 15% in compressive strength and a significant improvement in flexural toughness were observed in the case of concrete containing polyester fiber (PE) [4].

The utilization of silica fume (SF) helps in accomplishing high starting age quality. The expansion in quality seen between 3 and 7 days, both in compressive and split tensile strength [5], was best to improve the property of the concrete composites due to the lessening of water ingestion in the composites [6, 7]. But there was no reasonable conclusion on SF substitution level, although some of the researchers had detailed different substitution levels [6, 8, 9]. Many researchers have undergone an investigation on the utilization of agricultural residue and extended in the construction industry. India produces a major quantum of rice husk ash (RHA) from the agricultural residue [10, 11]. In ultra-high performance, concrete with compressive strength of 120 MPa or more can be achieved by using an advantageous material RHA [10].

It was reviewed that in India, one-third of the accessible husk can be gathered and converted to ash about 20 million tonnes and can be used for substitution of cement. Along these lines, around one-million ton of RHA was conceivably accessible as mineral admixture as per the records [12, 13]. Cost reduction, performance, durability, and environmental factors are the essential attributes that can make RHA a substantial exchange for portland cement.

By and large, it was inferred that the incorporation of fiber improves compressive strength in the early days [14]. Fibers were known for the significant effect on the workability of the material. The rise in fiber capacity and aspect ratio impacts its workability in concrete [15, 16] The addition of superplasticizer increases the workability (120–150 mm slump). Tensile cracking in the combination of the material was reduced by adding fiber to concrete [17]. Enhancement of the concrete was attained depending upon the measurement rate and kind of fiber [18]. The essential target of this examination was to decide the advantages of utilizing PE in fiber-reinforced concrete. Simple regression analysis also additionally achieved to get expression and to build up the correlation between different strength given polyester fiber-reinforced blended concrete (PEFRBC) test outcomes.

2 Material Selection

2.1 Materials and Methods

Cement and supplementary materials such as SF and RHA were used in this investigation. 53 Grade cement affirming to IS: 12,269-1987(9), SF (Grade 920 D) affirming to ASTM-C (1240-2000) was utilized in the present study. 3.15, 2.2, and 2.67 were specific gravity of cement, SF, and RHA, respectively. The fineness of SF, RHA, and cement was found as 20000cm2/g, 2170 cm2/g, and 2950cm2/g independently. COLOPLAST-SP 430 affirming to IS: 9103-1999 and ASTM 494 was used as a superplasticizer. River sand and crushed aggregates of size 20 mm were utilized as fine aggregates and coarse aggregates affirming to IS: 383-1987.

2.2 Mix Proportions and Mix Details

The concrete mix proportions (m^3 of concrete) adopted in this investigation were given in Table 1. Mix design was followed as per IS 10,262-1982. Water binder ratio considered for this mixes was 0.5, 0.43, 0.38, and 0.35 for M20,M25,M30 and M35 grades of concrete. Fibers were reinforced in concrete during mixing in weight fractions of 0.2, 0.4, 0.6, 0.8 percentages and details were given in Table 2. Samples without fibers were cast as reference concrete. The quantities of cementitious

Table 1 Mix fraction for control concrete

Materials required per m^3 of concrete				
Concrete grade	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water (litre)
M20	383	578	1281.6	191.58
M25	445.53	537.64	1268.10	191.58
M30	487.83	431.65	1367.38	185.4
M35	515	463.5	1501.33	185.15

Table 2 Percentage of polyester fiber required for blended concrete

Polyester fiber (%)	Fibers required per m^3 of concrete (kg)			
	M20	M25	M30	M35
0.2	0.77	0.89	0.97	1.03
0.4	1.53	1.78	1.95	2.06
0.6	2.3	2.67	2.92	3.09
0.8	3.06	3.56	3.89	4.12

constituents in various mix combinations of blended concrete were shown in Table 3.

3 Experimental Program

Mixes with four different grades of concrete with different percentages of polyester fibers were cast. For all mixes, the time for mixing was kept consistent throughout the research. Compressive strength at 28 and 90 days was found with standard size cube specimens with the optimal proportion of SF and RHA. Prism and cubes were used to find the strength parameters such as flexural and compressive strength of PEFRBC as shown in Figs. 1 and 2. Curing was done for 28 days. The average strength of three specimens was taken for each strength value. A correlation involving the compressive and flexural strength of PEFRBC in the form of a simple regression equation had been proposed to examine the performance of PEFRBC. An experimental study in this research was mainly focused to develop a correlation between the compressive and flexural strength of SF- and RHA-based PEFRBC.

4 Results and Discussions

4.1 Compressive Strength Development of Silica Fume and RHA-Based Concrete

The strength at 28 and 90 days of various mixes was taken as the average test results of the three specimens each for obtaining the optimum percentage of SF and RHA in PEFRBC. Figure 3 shows the plot of compressive strength for various grades of concrete, against different percentages of SF content. It was practically observed that SF incorporation increases the strength in all grades of concrete. The voids filled by SF altogether improved the compressive strength; however, at more elevated levels, the improvement diminished. From the test outcomes, it was found that the compressive strength concrete with 7.5% replacement of cement by SF was higher than control concrete by 34.50, 20.47, 23.69, and 26.91% at 28 days and 33.31, 21.53, 22.63, and 26.92% at 90 days curing. Figure 4 shows the variation of compressive strength on the replacement of cement with RHA at 28 and 90 days. RHA diminished the porosity and subsequently increases the strength of the concrete composites at 28 and 90 days. From this examination result, it could be seen that the strength of 15% supplanting of concrete composite with RHA was elevated than the conventional concrete by 18.99%, 16.06%, 14.28%, 18.34%, and 18.98%, 18.12%, 13.30%, 18.34% at 28 days and 90 days, respectively. The results inferred, optimum percentage of SF and RHA in concrete was 7.5 and 15%.

Table 3 Cementitious material combinations for binary blended concrete

Mix	Cement content (kg/m^3)				Mineral admixture content (kg/m^3)							
					Silica fume (7.5%)				Rice husk ash (15%)			
	M 20	M 25	M 30	M 35	M 20	M 25	M30	M35	M20	M25	M30	M35
OPC	383	446	488	515	–	–	–	–	–	–	–	–
OPC + SF	354	412	451	476	29	33	37	39	–	–	–	–
OPC + RHA	326	379	415	438	–	–	–	–	57	67	73	77

Fig.1 Cube under compression test

Fig. 2 Prism under flexural test

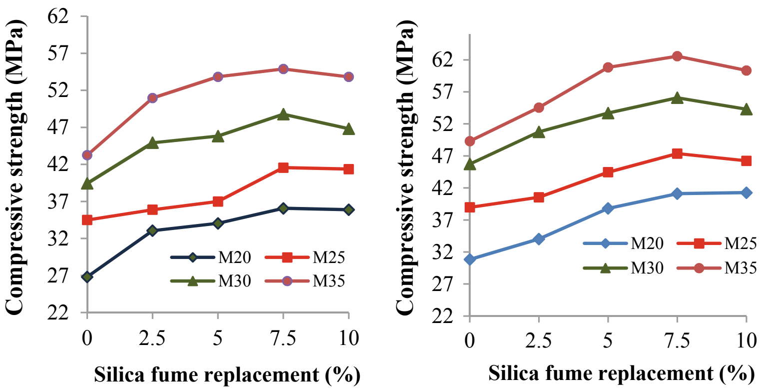

Fig. 3 Compressive strength development of silica-fume-based concrete at 28 and 90 days curing

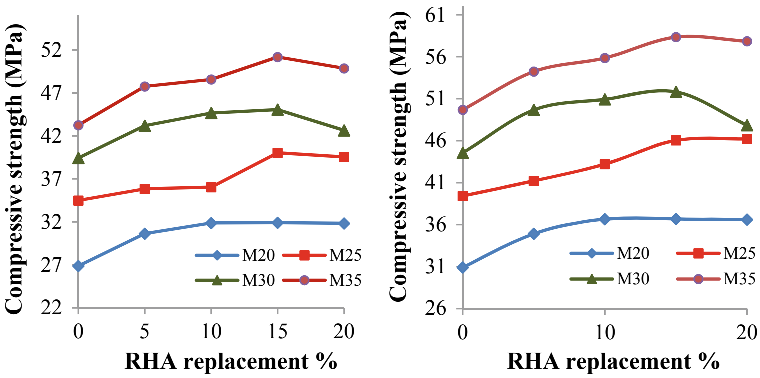

Fig. 4 Compressive strength development of RHA-based concrete at 28 and 90 days curing

4.2 Compressive Strength of Polyester Fiber-Reinforced Concrete

The strength of concrete composite blends made with admixtures SF and RHA with changing the level of polyester fiber was estimated at 28 days curing. The outcome for various grades of concrete in Figs. 5a, 6a, 7a and 8a was plotted. From the figure, it could be seen that development in strength proportionates an increase of fiber. However, the maximum strength at various percentages of fibers to 7.5% replacement of SF admixtures was more predominant. This trend was more obvious between 0.4 and 0.6% percentages for the addition of polyester fibers into the concrete. However, maximum compressive strength was found at 0.5% of polyester fiber in all mixes. This may be of pozzolanic effect and a toughened bond of the mortar and the aggregate. The compressive strength was 34.06 MPa and when fiber 0.5% was incorporated with SF-based concrete, there was a marginal increase in strength about 34.23 MPa in M20 grade of SF-based concrete composites at optimum % of SF (7.5%). For the same grade of concrete at optimum % of RHA (15%), the compressive strength was 31.9 MPa and with fiber (0.5%) incorporation with RHA-based concrete, the strength found was 33.56 MPa. The same increase was found in all grades of concrete. Fiber addition improves the strength; furthermore, it was observed that the strength marginally increased while fiber was added to the concrete, and this could be due to the bond between the mortar and the aggregate.

4.3 Flexural Strength of Polyester Fiber-Reinforced Concrete

The results for the strength of various grades of blended concrete composites (M20, M25, M30, and M35) were plotted against different percentages of fiber volumes. From Figs. 5b, 6b, 7b and 8b, it can be seen that when OPC was mixed with PE, a

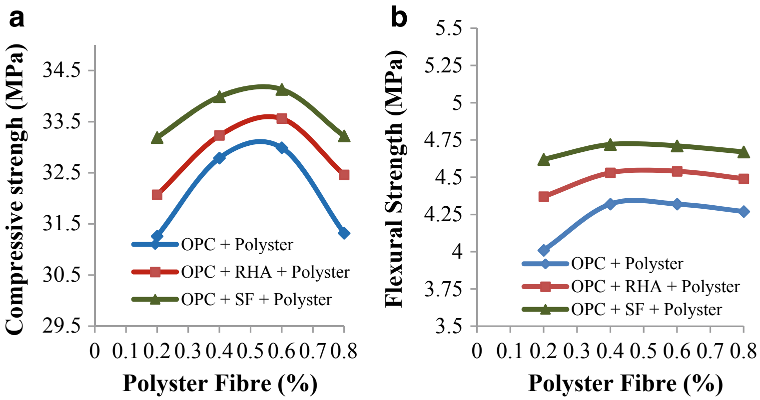

Fig. 5 **a** Compressive strength versus percentage, **b** flexural strength versus percentage of the polyester fiber of M20 grade of concrete polyester fiber of m20 grade of concrete

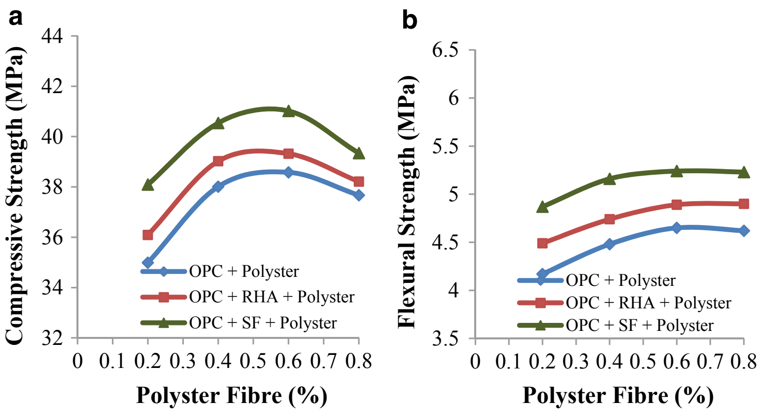

Fig. 6 **a** Compressive strength versus percentage, **b** flexural strength versus percentage of polyester fiber of M25 grade of concrete polyester fiber of m25 grade of concrete

noteworthy rise in strength was obtained. Flexural strength increased tremendously when fiber was combined with SF and it was computed as 70.04, 54.03, 91.14, and 68.60%. There was a decrease in strength in RHA-based PEFRBC. This may be of delayed pozzolanic effect forming pozzolanic C–S–H gel in RHA-based PFRBC.

For all grades of concrete, the optimum percentage of polyester fiber was 0.4–0.6%. Polyester fiber addition results in an increase of compressive strength related to plain concrete for grades M20, M25, M30, and M35. The highest compressive strength was examined in concrete containing 0.5% of polyester fiber to the weight of cement and at 7.5% of silica fume. The level of increment in compressive strength of binary blended mixes to that of binary blended concrete with PE, the strength improvement was negligible. The consequences of the present examination were to

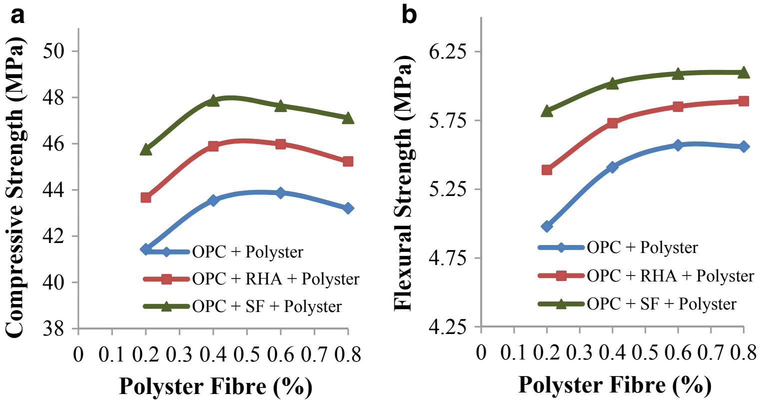

Fig. 7 **a** Compressive strength versus percentage, **b** flexural strength versus percentage of polyester fiber of M30 grade of concrete polyester fiber of m30 grade of concrete

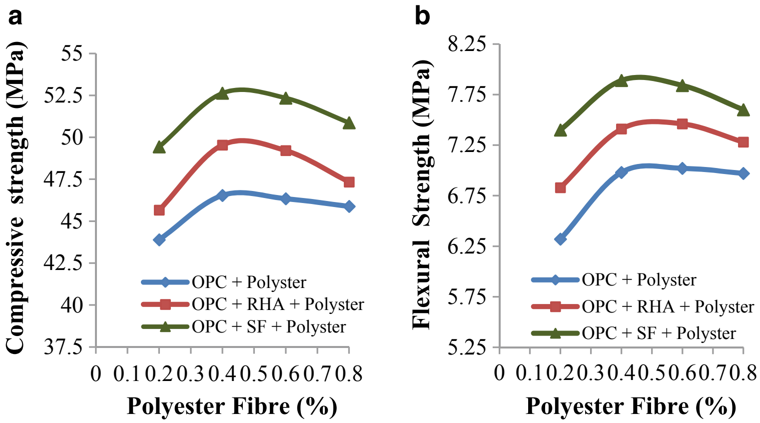

Fig. 8 a Compressive strength versus percentage, **b** flexural strength versus percentage of polyester fiber of M35 grade of concrete polyester fiber of m35 grade of concrete

specify that the incorporation of fiber in binary blended concrete was not constant but it was a component of C–S–H gel.

Once fibers were added toward the blended concrete and plain concrete, there were significant improvements in flexural toughness. The increase in flexural strength was as high as 70.40, 57.01, 62.33, and 70.11% in SF-blended concrete with polyester fiber to that of OPC. But in RHA-blended concrete with polyester fiber, flexural strength decreases. SF-blended concrete with fiber showed greater improvement in tensile strength when compared to RHA-blended concrete with fiber. These results might be due to the greater surface area of SF when compared to RHA and due to the incorporation of fibers which increased the flexibility of concrete composites. The role of fibers in the flexural strength of concrete was noteworthy as compared to the compression strength of concrete. Despite the fiber content that does not assume a significant role in the compressive strength of concrete could enormously raise the tensile strength of concrete composites.

Figure 9 shows the correlation graph of compressive vs flexural strength of polyester fiber-reinforced concrete with the value of $R^2 = 0.9214$. The correlation involving the investigational and calculated flexural strength results for all grades of polyester fiber-reinforced concrete was revealed in Fig. 10. It was seen that the regression line passes through the origin with an angle of 45° which indicates that

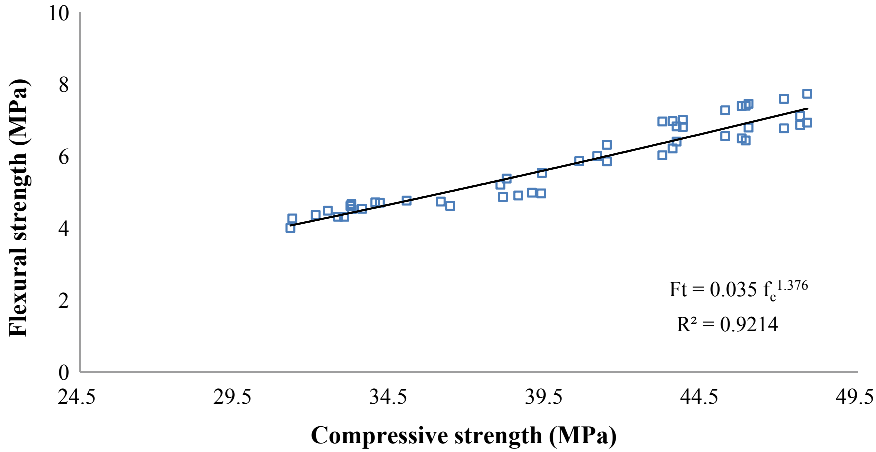

Fig. 9 Correlation graph of compressive versus flexural strength of polyester fiber-reinforced concrete

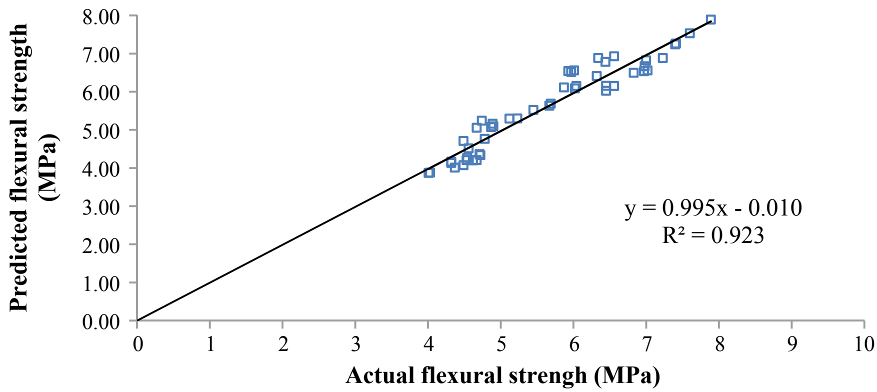

Fig. 10 Experimental and predicted flexural strength results for all grades of concrete of polyester fiber -reinforced concrete

the predicted value expressed in the Y-axis was equal to the actual value of flexural strength in the X-axis.

5 Conclusions

The important conclusions of the investigation with polyester fiber-reinforced SF- and RHA-based-blended concrete were summarized as below:

- The optimal gain of SF and RHA found was 7.5 and 15%. For different strength characteristics of fibers under the study, the optimum weight fraction of fiber ranged from 0.4 to 0.6%
- Compressive strength of concrete enhanced as the proportion of fiber raises. Adding polyester fiber along with SF results in enhance compression strength over polyester fiber with or without RHA.
- Owing to the addition of fibers in blended concrete and plain concrete, noteworthy improvements in flexural toughness were observed.
- The contribution of fibers toward the flexure strength of concrete was noteworthy as estimated to the compression strength of concrete. Though the fiber content does not play a major role in the compressive strength, it could greatly enhance the tensile strength of concrete composites.

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