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Research Article

Influence of Marble Powder and Polypropylene Fibers on the Strength and Durability Properties of Self-Compacting Concrete (SCC)

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The purpose of this study was to investigate the effect of polypropylene fiber reinforced self-compacting concrete (SCC) at both the fresh and hardened stages, as well as their durability behavior. Properties of marble powder-based fiber reinforced SCC at fresh state were studied by means of slump flow diameter and flow time, V-funnel, and L-box test. The concrete properties at the hardened state were examined regarding compressive strength, split tensile strength, and flexural strength. Cement was replaced with marble powder with a substituting ratio of 4%, 8%, 12%, and 16% while polypropylene fibers were added as 0.1%, 0.2%, 0.3%, and 0.4%. The durability properties were analysed in the form of water permeability and chloride migration. In accordance with the outcomes of the tests, the workability of SCC deteriorated with an increase in fiber content, although it performed effectively at higher marble dosages. There was little impact of fibers on compressive strength and water permeability property of SCC. However, by adding the fibers in SCC improved both the split tensile strength and flexural strength by 16.92% and 11.36%, respectively. The addition of marble powder showed a synergetic effect with polypropylene fibers, which showed its applicability in SCC. The chloride resistance was improved at lower content of polypropylene fiber addition. For optimizing polypropylene fibers (pp) and marble powder substitution, the polynomial work expectation justifies the response surface technique (RSM). When a p value of 0.05 is used to analyse the variation in the (Linear-ANOVA), the model is considered statistically significant. Performance of concrete was greatly enhanced by substituting 12% marble powder with cement and adding 3% polypropylene fiber.

1. Introduction

Self-compacting concrete (SCC) is a type of concrete that is distinct from other types of concrete for self-compacting under its own weight. This means that there is no need for any mechanical compaction. Since its beginning, it has been considered an important advancement in the construction industry. Because of its technical advantages, SCC has become increasingly popular in the construction industry. The concept of SCC was introduced in 1986 [1]. Since its inception, SCC has revolutionized the construction industry opening an entire new field of research and knowledge. SCC has number of benefits, which include enhanced construction quality, improved productivity and more importantly much better functioning environment on-site. It has been warmly welcomed in the construction industry with the thinking that it can be the one to substitute the conventional concrete in the near future. Concrete is a highly fragile material under tensile and flexural loading circumstances. It has significantly high compressive strength, but has very low tensile strength [2]. Consequently, if concrete is subjected to tensile forces, it needs to have a stronger tensile strength.

Over the years, various types of fibers have been incorporated to increase the tensile strength of concrete. During the early twentieth century, asbestos fibers were used to boost the tensile strength of concrete, which proved to be effective [3]. Polypropylene (PP), glass, natural [4], and steel fibers have been used in concrete in the 60s [5]. Numerous studies claim that fibers in concrete have minimal or little impact on compressive strength [6–8]. It has been proved from significant research that the fibers added in concrete not only improve the tensile strength but also boost the flexural strength of concrete [9–13]. The durability of concrete improves significantly when fibers are incorporated with other supplementary cementitious materials [14–19]. The effectiveness of the SCC can be increased additionally by inclusion of fibers such as glass fibers, steel fibers, and PP fibers in terms of tensile strength, toughness, and challenging the crack propagation [20–22]. Many researchers have presented their research on use of fibers in SCC mixes [23, 24]. Putting fibers into concrete decreases the workability of concrete. However, a variety of factors contribute to this decline in workability, such as the type of fiber, maximum dimension of aggregates, geometry of fiber, aspect ratio, and volume. Yap et al. [25] reported that by adding nylon and polypropylene fiber in oil palm shell concrete caused significant improvement in flexural and split tensile strength of concrete. It is necessary for concrete to perform well within their specified durability requirements. Most often, durability of concrete is being overlooked. Many researchers have investigated various characteristics of SCC globally. The durability performance of SCC with fibers, specifically PP fibers in combination with marble powder, has not yet been investigated, despite the fact that the material is widely used. Therefore, the goal of this experiment was to look at the mechanical and durability properties of SCC with PP fibers as reinforcement and marble powder as a fractional replacement for cement.

2. Research Significance

This study demonstrates that the industrial wastage i.e. marble powder is incorporated in self-compacting concrete to improve mechanical and durability of concrete in a sustainable approach. This research work indicates that marble powder, which is an industrial wastage, could be used as a partial replacement of cement. The test results showed that adding marble powder and polypropylene fibers showed a synergetic effect. This study could pave the way to minimize the global Co_2 emissions by utilizing sustainable construction materials especially in developing countries and meets the United Nation's Sustainable Development Goals (SGDs) 9 and 12 targeting goals 9.1, 9.5, 12.2, 12.5, and 12, respectively [26]. The Response surface approach (RSM) for optimization provides the forecast indication of concrete properties.

3. Experimental Program

3.1. Materials. The cement integrated to produce SCC was Ordinary Portland cement (OPC) confirming to the ASTM Type 1 (ASTM C150). Marble powder was used as a mineral additive. The chemical composition of cement and marble powder is presented in Table 1. The fine aggregates with specific gravity of 2.48 were used. The maximum size and saturated surface dry specific gravity of coarse aggregates used was 12 mm and 2.69, respectively. The fiber used was polypropylene (PP) fiber. The tested properties of polypropylene fiber are listed in Table 2. Figure 1 shows the marble powder and polypropylene fibers that were used. A poly-carboxylic ether-based high-ranged water reducer (HRWR) having a specific gravity of 1.06 supplied by a local manufacturer was used to produce the SCC.

3.2. Mix Proportions. This research investigation was conducted in two phases. In phase-1, the optimum quantity of marble powder was used as a partial substitute of cement to produce self-compacting concrete using EFNARC 2005 guidelines [27]. The control mix of SCC was produced for a 500 kg/m^3 cement binder. The water to binder proportion was kept as 0.45. In certain combinations, cement was gradually replaced by 4%, 8%, 12%, and 16% of marble powder. Cement was replaced gradually to find a best dosage keeping the strength of concrete intact. In the phase-2, the optimum mix selected from phase-1 was used as control mix and in the other mixes varying amount of PP fibers have been used. Mix proportions for all SCC combinations are displayed in Table 3.

3.3. Specimen Preparation. All batches were mixed for 5 minutes. On the completion of mixing time, the fresh properties tests, namely, slump flow test, V-funnel, and L-box test were executed as per EFNARC [27]. The steel molds were cleaned and oiled properly. The molds were then placed on the floor and packed with concrete using the necessary compaction techniques. The top surface of each of the sample was leveled. The samples in their mold were kept in the laboratory for a contained temperature. The molds were detached after 24 hours and the samples were placed for moist curing as per ASTM C192.

3.4. Testing Methods. Fresh properties of SCC were determined in accordance with the SCC committee of EFNARC's [27] recommendations. The fresh properties were measured in relation of slump flow time (T500) and diameter, viscosity, and passing-ability. Compressive strength, split tensile strength, flexural strength, water permeability, and chloride migration were all used to determine the hardened properties of concrete. The compressive strength test was completed according to BS standards [28] while split tensile strength and flexural strength test were accomplished in accordance with the ASTM procedures. The compressive strength was tested on 150 mm cubes as per British Standard. The split tensile strength was tested on cylinders (150 mm diameter and 150 mm height) as per ASTM Standards C496 [29]. Three prisms of size (100 mm × 100 mm x 500 mm) were cast for each of the mixes to determine flexural strength. In line

Table 1: Chemical properties of cement powder and powdered marble.

Chemical (%)	Cement	Marble powder
SiO_2	21.14	4.98
CaO	63.21	36.60
MgO	0.81	1.73
$A_{12}O_3$	5.42	0.74
Fe_2O_3	3.08	0.07
SO_3	2.41	—
K_2O	0.54	0.01
Na_2O	0.18	0.22
Loss of ignition (LOI)	1.26	42.19
Fineness (cm^2/g)	3112	3680
Specific gravity	3.12	2.74

Table 2: Properties of added polypropylene fibers.

Properties	Value
Fiber type	Polypropylene fibers
Fiber length	12 mm
Specific surface area	200 m^2/kg
Fiber diameter	20 micron
Tensile strength	400 MPa
Elongation at break	15%
Softening point	160 0C
Density	900 kg/m^3
Appearance	White color fibers
Alkali resistance	100%

with ASTM C1609, a three-point bending test was performed [30]. The plan for testing the flexural strength is shown in Figure 2.

The mixtures' water permeability was measured in accordance with IS: 3065–1965 [31]. Four Cell Automatic Concrete Water Permeability apparatus was used. Specimens were cured for 28 days before the water permeability testing. Earlier this test, samples were oven-dried at 105°C and emulsion paint was used to coat sides of specimens so that water can permeate through top and bottom surfaces only. Samples were placed in the cell and then 0.5 MPa water pressure was applied. This water pressure was suggested and used by Li and Chung-Kong [32]. Water pressure was applied until steady state of flow was obtained. By measuring the quantity of water passed through each sample, the coefficient of permeability was calculated using Darcy's law. The following formula was used:

$$\mathrm{K} = \frac{\mathrm{Q}\,.\,h}{\mathrm{A}\,.\,t\,.\,\mathrm{P}}. \tag{1}$$

K= water permeability coefficient (cm/sec), Q = infiltrated water (cm^3), A = specimen surface area (cm^2), H = specimen height (cm), T = time to permeate (sec), and P= hydrostatic pressure (cm).

The chloride migration test was carried out on the basis of the NT-BUILD 492 design specification [33]. From 150 mm cubes, 100 mm dia samples were first drilled and then these were sliced in the size of thickness of (50 mm) and diameter of (100 mm) as per the requirements of NT build 201 and 202. For vacuum treatment, the surface-dried specimens were placed in a vacuum container. The specimens were immersed in $Ca(OH)_2$ solution for three hours after the vacuum was maintained. The vacuum was further maintained for an hour. The catholyte solution was 10 percent NaCl by mass in tap water, and anolyte solution was NaOH in distilled water. The samples remained in the solution for 18 hours. The temperature of the solution and specimens were maintained at 20–25°C. The chloride migration set-up along with cross-sectional view of catholyte and anolyte is shown in Figure 3.

An exterior electrical voltage of 30 V was exercised axially through the specimen to force the chloride ions to transfer into the specimen. Specimens were allowed to dry for 24 hours before being cut into two halves and sprinkled with silver nitrate solution. This was followed by a measurement of the chloride's depth of penetration. Following this, the nonsteady state chloride migration coefficient was calculated:

$$\mathrm{Dnssm} = \frac{[0.0239(273+T)L]}{(U-2)t} \left[(x_d - 0.0238)\sqrt{\frac{(273+T)L\,x_d}{(U-2)}} \right], \tag{2}$$

where Dnssm: nonsteady state migration, ($\times 10^{-12}$ m^2/s), X_d: average penetration depths, mm; T: average of final and initial temperatures in acolyte solution, °C, L: thickness of the specimen, mm; t: test time duration in hour, and U: voltage

3.5. Response Surface Method (RSM). When developing mathematical models, the response surface method (RSM) is a quantitative method for showing one or more responses within a set of input variables [34–36]. Relative importance and impact of each input and response are calculated using the RSM's polynomial relationship. A mixed design can be predicted and optimized using this example. In building a statistical model, the gathering of experimental data is the first step, followed by choosing an appropriate model to fit the data. The demonstration at that point is if the appraisal is adequate. Design-Expert v11 is a type of quantifiable software that contains test designs, numerical equations, factual research, and response optimization [37]. This approach of analysis of variance (Linear-ANOVA) is used to design the interaction between input variables and their impact on the output. This study investigates the responses of compressive strength (y1), split tensile strength (y2), flexure strength (y3), and workability of specimens using the slump test (y4), polypropylene/B (x1) and marble powder/B (x2), which refer to the proportion of polypropylene and marble powder, respectively, are the factors that govern these reactions and individually account for the whole cement's vent gas substance.

4. Results and Discussion

4.1. Fresh Concrete Properties. Table 4 summarizes the parameters of the fresh concrete mix. The results of slump flow

(a) (b)

Figure 1: (a) Marble powder; (b) polypropylene fibers.

Table 3: Concrete mix proportioning.

Mix ID	Cement	Fine aggregate	Coarse aggregate	Water	Marble powder	HRWR	PP fibers volume fraction (%)
	Mix proportions in kg/m^3						
CM-0	500	760	745	225	0	7.80	0
CM-1	480	760	745	225	20	7.80	0
CM-2	460	760	745	225	40	7.80	0
CM-3	440	760	745	225	60	7.80	0
CM-4	420	760	745	225	80	7.80	0
M-1	440	760	745	225	60	7.80	0
M-2	440	760	745	225	60	7.80	0.10
M-3	440	760	745	225	60	7.80	0.20
M-4	440	760	745	225	60	7.80	0.30
M-5	440	760	745	225	60	7.80	0.40

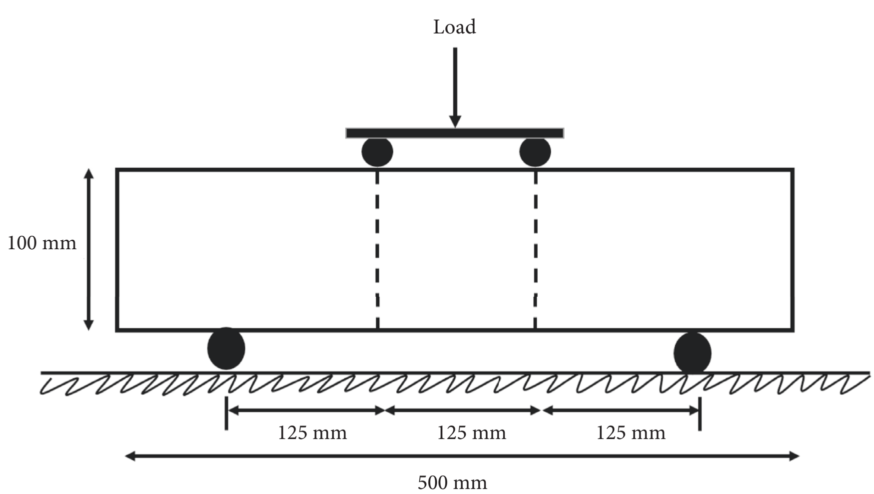

Figure 2: The arrangement for testing flexural strength.

tests and T500 slump time tests are graphically presented in Figures 4 and 5, respectively. All the mixtures except M-5 has shown good flow ability, with slump value ranging from 670 mm to 745 mm. The upper and lower limit as per EFNARC is from 650 mm to 800 mm. With the fractional replacement of cement with marble powder in SCC, the flow ability has improved. This may be due to lower density of marble powder, which increases paste volume, and reduces the friction between aggregates, and also results in improvement of flow ability and cohesiveness. Moreover, it is reported in the literature that with addition of mineral admixtures, workability is improved due to the fineness of

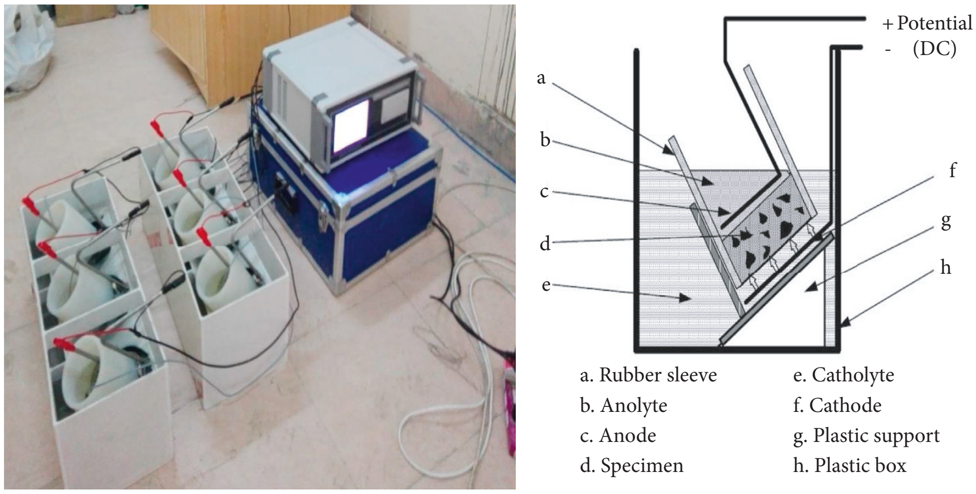

Figure 3: Chloride migration test apparatus and cross-sectional view of catholyte and anolyte.

Table 4: Fresh properties of SCC.

Mix	Slump flow diameter (mm)	Flow time T500 (s)	V-funnel (s)	Passing-ability (H_2/H_1)
CM-0	710	3.10	11.00	0.90
CM-1	713	3.07	10.60	0.91
CM-2	730	2.85	10.10	0.95
CM-3	735	2.65	10.20	0.96
CM-4	745	2.40	9.80	0.98
M-1	735	2.65	10.20	0.96
M-2	725	2.95	10.46	0.94
M-3	705	3.15	11.04	0.84
M-4	670	4.90	11.40	0.81
M-5	498	6.30	14.60	0.52

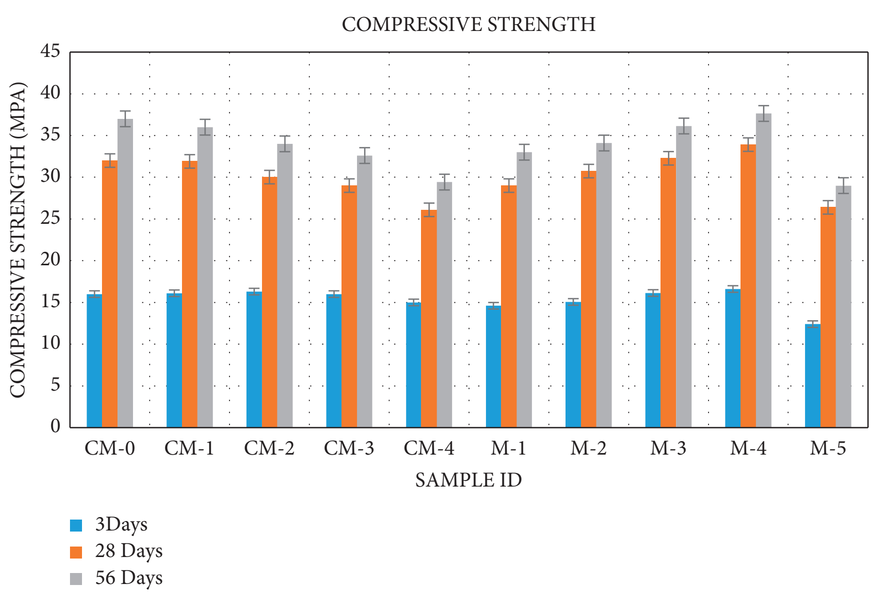

Figure 4: 3D surface diagram for split tensile strength.

mineral admixtures [38]. The addition of polypropylene fibers greatly decreased the slump flow of SCC. As fiber percentage increased, the slump flow of SCC decreased, particularly above 0.30% PP fiber content. For SCC mix, with PP fiber content of 0.40%, a drop in slump flow below 650 mm (lower permissible limit as per EFNARC) was observed [27]. The addition of PP fibers makes the mix more viscous thus slowing down the flow of concrete resulting in a

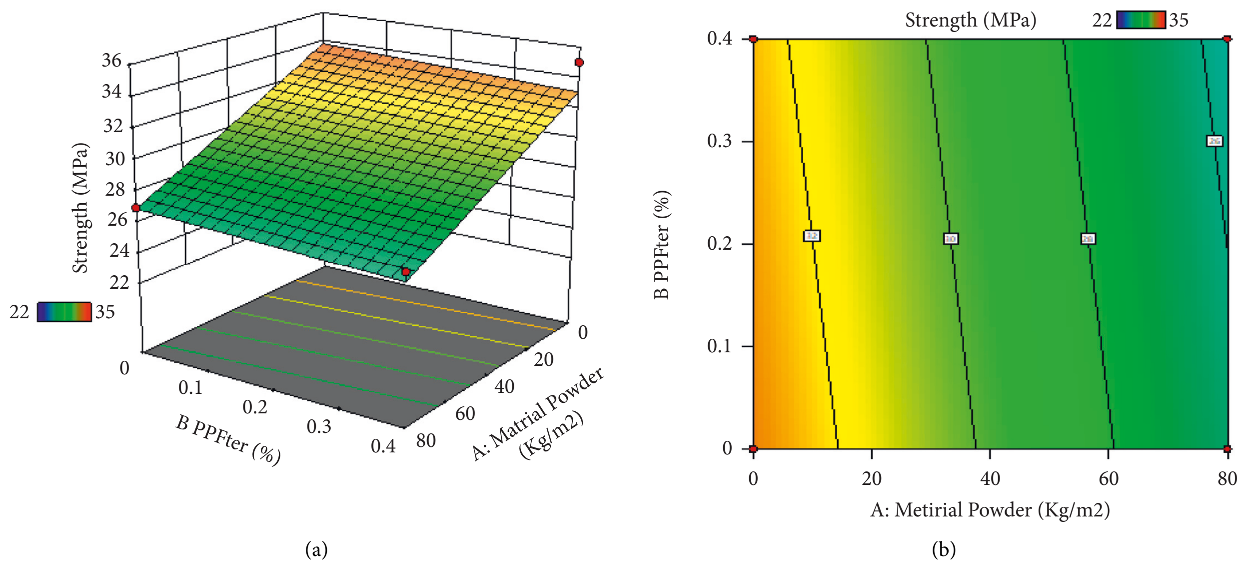

Figure 5: 2D contour plot for split tensile strength.

decrease in the workability of concrete. This might be due to the amalgamation of high volumes of PP fibers, which hinders the flow of SCC. Yap et al. [25] noted that with addition of multifilament PP fibers of 12 mm length, the workability of concrete had reduced significantly. Similar results have been reported by other studies as well [39-40].

Table 4 presents the test results for L-Box and V-funnel test, respectively. It has been observed from the results that with surge in replacement level of marble powder, L-Box values (H2/H1) were increased which show that the passing capability of SCC was improved. The addition of PP fibers has decreased the passing-ability remarkably. This decrease in the passing capability of SCC could be due to the presence of high volume of PP fibers, which constrained the concrete in passing through the spacing between re-bars of the apparatus. It can be perceived from Figure 6 that the V-funnel time was decreased with increasing replacement level of marble powder, however, the V-funnel time was increased significantly with increasing PP fiber content. The increase in V-funnel time is due to the partially blocking effect of polypropylene fibers. Previous research has found similar outcomes [23, 24].

4.2. Mechanical Properties

4.2.1. Compressive Strength. The compressive strength of SCC mixes was evaluated at 3, 28, and 56 days of age. As illustrated by the graph in Figure 7, the compressive strength of all mixes increased with time. It was also observed that the compressive strength decreased as the marble powder content increased. The compressive strength of 4% marble powder has similar strength as that of control design at 28 days. Concrete of 29 MPa can be successfully prepared at 12% of marble powder. The early age strength was improved by addition of marble powder. As a result of this reaction, rate of hydration is increased, thus compressive strength is improved at an early age. Another aspect of gain in strength is the packing and filler effect of marble powder. Marble powder shows its reactive properties if it is finer while a finer cement provides higher early heat of hydration that ultimately provides a path to the reactivity with marble powder [34]. It has been noticed that with addition of PP fibers, compressive strength has been increased except at high volume of fiber i.e. 0.40%. This decrease of compressive strength at 0.40% might be due to improper compaction, as this mix has not fulfilled the requirements of SCC. The increase of compressive strength with surge in PP fiber content might be due to limiting the crack propagation by the fibers. The bridging result of fibers enhances the compressive strength [41, 42]. For self-compacting concrete along with marble powder, the ideal compressive strength was 34.53 MPa at 3% polypropylene fibers and 12% marble powder, respectively. The contours' skewed appearance showed that there is a weak interface between the factors (percentages of polypropylene fibers and marble powder). According to the 3D response surface scheme depicted in Figure 8, the SCC compressive strength decreases drastically as the concentrations of polypropylene fibers and marble powder increase [43, 44].

4.2.2. Split Tensile Strength. The split tensile strength was measured during three different periods: three days, twenty-eight days, and fifty-six days. The results are depicted graphically in Figure 9. It can be comprehended from Figure 9 that tensile strength has been decreased with increase in content of marble powder. It is witnessed that the tendency of tensile strength reduction for marble content is in same way as for that of compressive strength. It is perceived from the results that adding PP fibers to SCC mixes improved the tensile strength and the addition of PP fiber is beneficial for increasing split tensile strength of the concrete. The mix containing 0.3% of PP fiber has enhanced the split

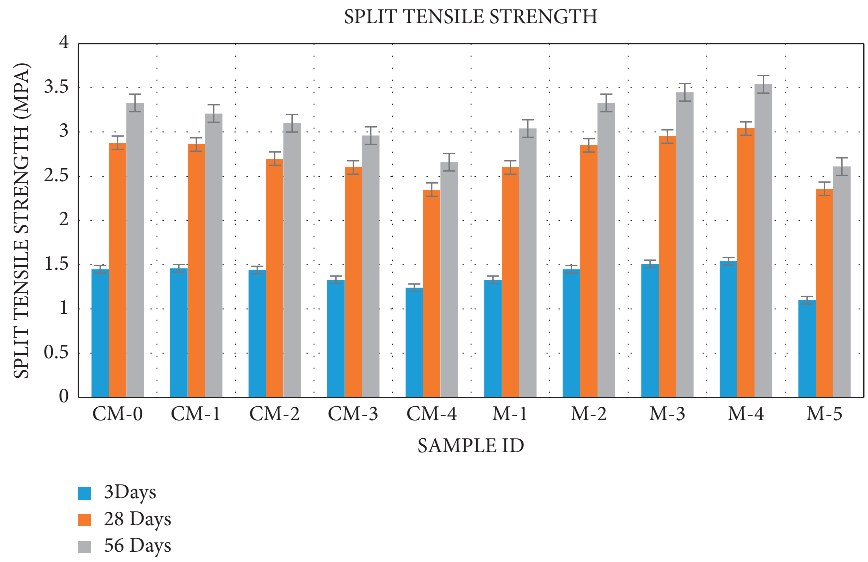

Figure 6: 3D surface diagram for flexural strength.

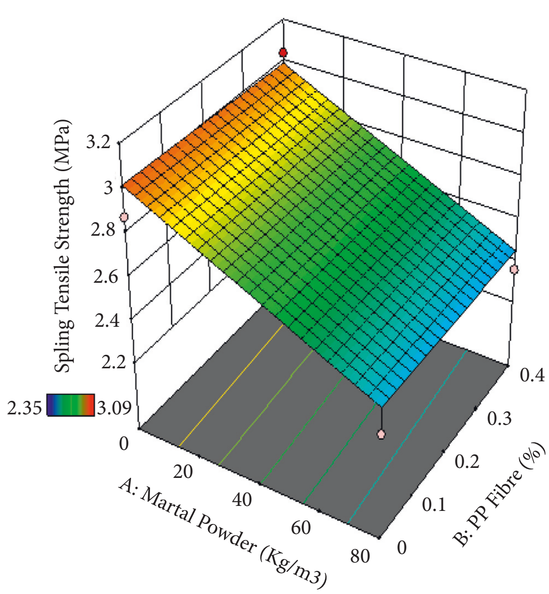

Figure 7: Compressive strength development.

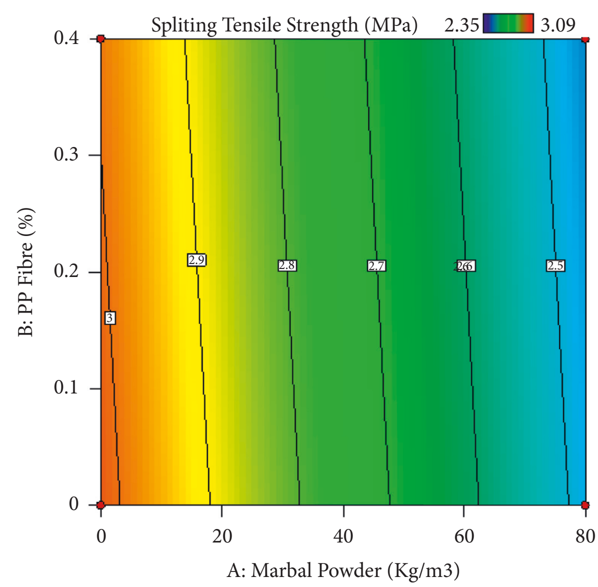

Figure 8: (a) 3D surface diagram for compressive strength; (b) 2D contour plot for compressive strength.

tensile strength by 16.92% of the control mix. Addition of fibers in concrete improve the strength by bridging effect and carrying the part of the applied load [29]. As it is evident from the research community that PP fiber reinforced concrete is helpful to provide extended flexural and tensile strength by minimizing the crack widths and avoids the sudden failure of concrete structures, Figures 4 and 5 show a 2D contour plot and a 3D response surface plot that were used to figure out the maximum split tensile strength, which is measured in MPa. The model constructed from the parameters is good and appropriate, as demonstrated by the observation. The model's split tensile strength and the semielliptical lines in the contour illustration presented in Figure 5 demonstrate a fair relationship between the polypropylene and marble powder. The split tensile strength dropped as the amount of marble powder and polypropylene content increased, as shown in the 3D surface diagram.

4.2.3. Flexural Strength. Figure 10 shows the results of a flexural strength test conducted over the course of 3, 28, and 56 days. It is found from the study that the flexural strength improved (up to 11.36%) with the surge in polypropylene fiber dosage up to 0.30%, beyond which decrease in flexural strength was observed. The lower volume of PP fibers could have caused obstacles in propagating the cracks, whereas high volumes of PP fibers might have deteriorated the bond strength between concrete ingredients by causing

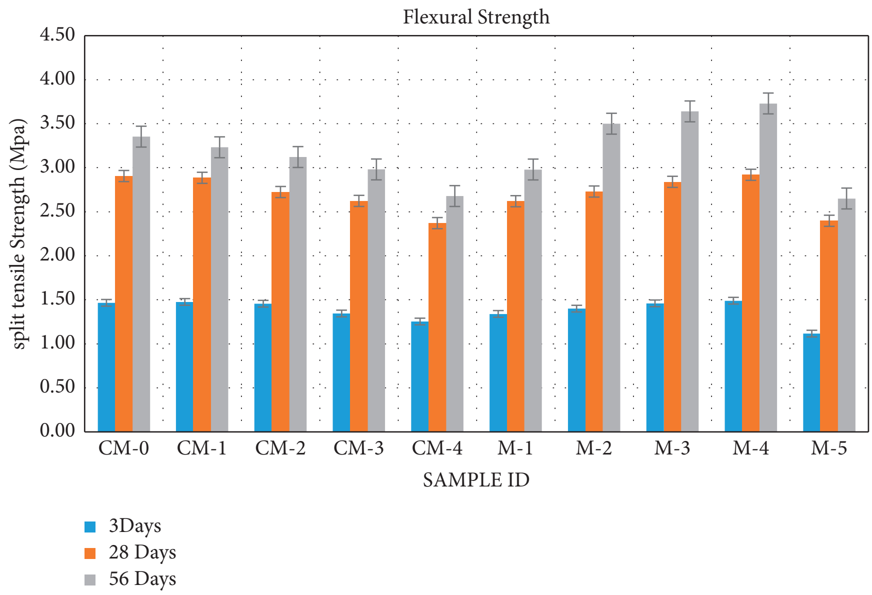

FIGURE 9: Split tensile strength development.

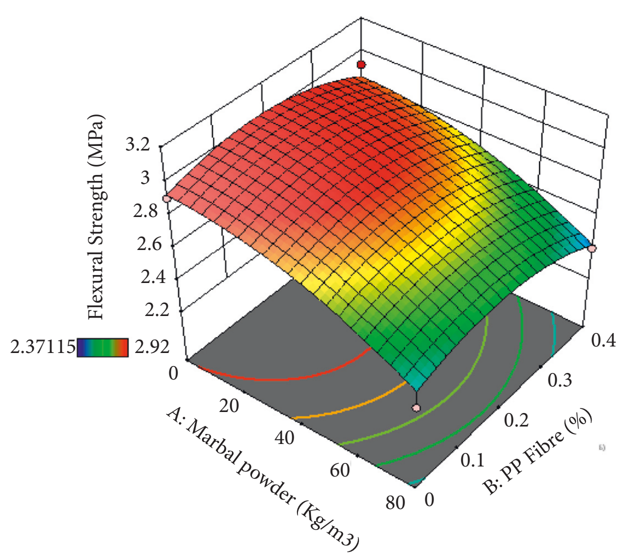

FIGURE 10: Flexural strength development.

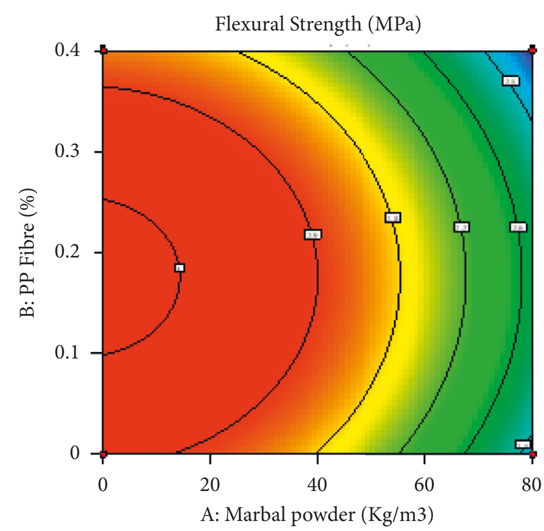

FIGURE 11: 2D contour plot for flexural strength.

agglomeration of fibers [12, 45]. The flexural behavior of all concrete mixtures is shown in Figure 10 under various formulations. RSM-generated 2D and 3D contours and response surfaces for flexural strength are depicted in Figures 6 and 11. At polypropylene and marble powder content, the maximum flexural tensile strength of MPa was attained. The slope of the SCC variable in this model, however, is rather sharp, representing that even minor change in the amounts of polypropylene and marble will cause a large change in flexural tensile strength. When the amount of marble powder is fixed, adding more polypropylene to the design mix lowers the flexural tensile strength. The straight-line contour scheme, which shows how each fraction of the red, yellow, and green regions is evenly spread over the plot, supports this reasoning.

4.3. Durability Properties

4.3.1. Water Permeability. Water permeability tests were carried out after the curing time of 28 days. Test results are shown in Figure 12. It is witnessed that the coefficient of water permeability decreased slightly with the addition of marble content. At 12% marble powder, the water permeability coefficient was declined by 0.84%. The logic for this improvement in durability of SCC was the filler effect of the added marble powder. Marble powder fills the gaps and microstructural pores and thus makes the concrete a less porous structure. The inclusion of PP fibers reduces the water permeability of SCC in a beneficial manner. It can be understood from Figure 12 that the water permeability is reduced by increasing the PP fiber content. The fibers control the microcracks and help to maintain the structural integrity, which reduces the water permeability by providing

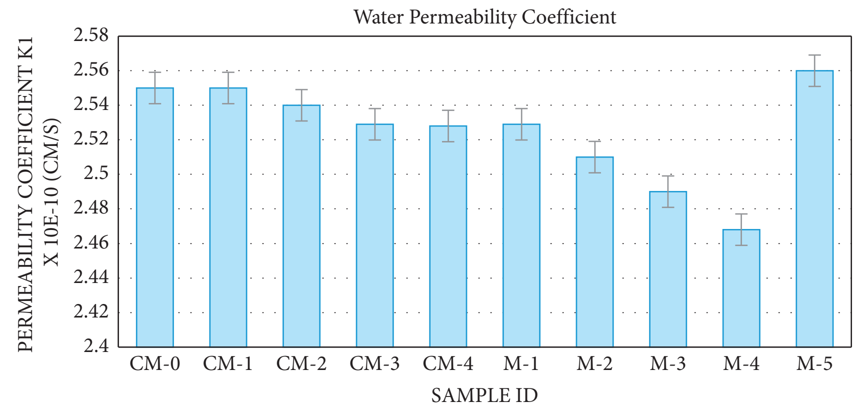

Figure 12: Water permeability of concrete.

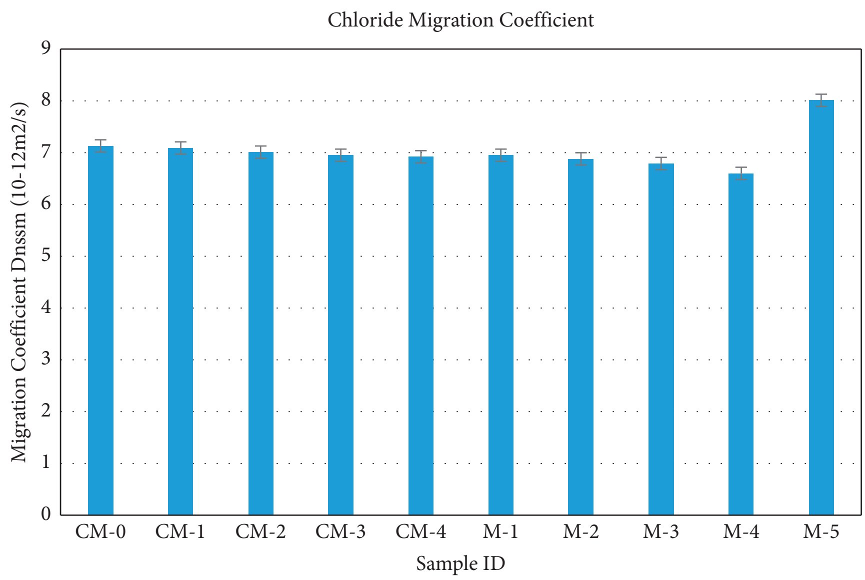

Figure 13: The values of chloride migration coefficient.

a resistance to the flow of water. The uniform distribution of fibers reduces the possibility of microcracks in concrete matrix that can be a channel for water to seep through [46]. The microfibers along with marble powder (MP) show a synergetic effect by reducing overall water permeability. These results agreed well with the previous studies [47].

4.3.2. Chloride Migration. Chloride permeability is considered to be one of the most perennial cause of concrete structures durability, it is a major concern for engineers and researchers on the sustainability of marine structures [13, 48]. Microstructural properties such as the pores, microcracks, and inter facial bonds between concrete ingredients are the causing factors of permeability. The values of chloride migration coefficient in Figure 13 showed that chloride penetration has decreased slightly with the increase in marble powder content. This increase of chloride resistance was because of the filler effect of marble powder. It may be contributed as the marble powder will improve the pore structure of interfacial transition zones. Besides, the PP fibers also demonstrate an important role in minimizing the chloride permeability [48, 49]. However, the research community agrees that larger fiber volumes may result in routes that are more permeable. A perfect blend of fiber dosage and other supplementary filler materials are necessary to design a durable concrete. In this research program, the influence of marble powder is remarkable. It is observed from the Figure 13 that adding PP fibers has improved the chloride resistance of concrete. With addition of 0.3% of marble powder, the chloride migration coefficient was decreased by 5%.

5. Anova Analysis

The effect of three independent variables, a combination of polypropylene (B) and marble powder, on SCC strength is investigated (*A*). Study of variance was used to establish the model's importance (ANOVA). The compressive strength (MPa) of the model has an "F" value of 8.2. Similarly, flexural strength (MPa) and split tensile strength (MPa) is 7.5 and 10.5, respectively, as indicated in Table 5. A high F-number denotes the model's relevance and appropriateness. These figures show that all models are significant. The model's F-number has a 0.01 percent risk of being affected by noise. Models with *P* values less than 0.05 are considered essential.

Table 5: ANOVA analysis of the response models.

Model	Source	Sum of squares	df	Mean square	F-value	P value	Significance of the model
Compressive strength	Model	164.38	3	54.79	8.20	0.0038	Significant
	A-marble powder	161.34	1	161.34	24.14	0.0005	
	B-PP fiber	1.82	1	1.82	0.2719	0.6124	
	C-cement	1.23	1	1.23	0.1833	0.6768	
	Residual	73.53	11	6.68			
	Cor total	237.91	14				
Split tensile strength	Model	1.00	3	0.3345	10.50	0.0011	Significant
	A-marble powder	0.9958	1	0.9958	31.25	0.0001	
	B-PP fiber	0.0027	1	0.0027	0.0846	0.7762	
	C-cement	0.0051	1	0.0051	0.1586	0.6974	
	Residual	0.3823	12	0.0319			
	Lack of fit	0.3823	11	0.0348			
	Pure error	0.0000	1	0.0000			
	Cor total	1.39	15				
Flexural strength	Model	0.8897	9	0.0989	7.50	0.0117	Significant
	A-marble powder	0.6440	1	0.6440	48.89	0.0004	
	B-PP fiber	0.0179	1	0.0179	1.36	0.2880	
	C-cement	0.0005	1	0.0005	0.0394	0.8492	
	Residual	0.0790	6	0.0132			
	Lack of fit	0.0789	5	0.0158	159.28	0.0601	Not significant
	Pure error	0.0001	1	0.0001			

Table 6: Models' validation.

Model terms	Compressive strength	Split tensile strength	Flexural strength	Source	Sequential p value
Std. dev	2.83	0.1207	0.6101	Linear	
Mean	20.59	2.33	9.81	Linear	
C.V %	13.74	5.18	6.22	Linear	
R^2	0.9135	0.9208	0.9039	Linear	<0.0001
Adj. R^2	0.9081	0.8982	0.8759	Linear	<0.0001
Pred. R^2	0.8801	0.8279	0.8385	Linear	<0.0001

Table 7: Optimization of the mix.

No. of runs	PP fiber (%)	Marble powder (%)	Compressive strength (MPa)	Flexural strength (MPa)	Split tensile strength (MPa)
1	3	12	34.6	2.85	2.98
2	3	12	34.5	2.86	2.96
3	3	12	34.3	2.82	2.98
4	4	16	26.0	2.41	2.63

Table 5 illustrates the outcomes. The coefficient of determination, often recognized as R-squared (R2) of the model ought to be around 0.88 to demonstrate its reliability. Adjusted R2 and projected R2 have a variance of less than 0.2. This suggests that the modified R2 and the projected R2 are reasonably consistent. The signal-to-noise ratio measurement is also a minimum need for optimal (Adeq) accuracy. All models can direct the design space, as shown in Table 6. As a result, the predicted number will be more accurate than expected if all points are parallel to the normal line. Normal residual plots 3d surface diagram and 2D contour plot are used to verify the model's validity and ability to select extraction parameters depending on response outcomes.

5.1. Optimization and Experimental Validation. The interaction of two factors, polypropylene and marble powder, on mechanical strength, was modeled using response surface methodology (RSM). As soon as all of the data from the initial mixture has been successfully collected, 14 new RSM mixture designs are generated and re-entered into the RSM to evaluate their efficacy, generating the final model, which is illustrated in Table 7. The comparison results demonstrate that the experiment and RSM findings differ slightly, but this is still acceptable. The desire is 0.592, indicating that with polypropylene and marble powder, achieving 34.6 MPa compressive strength, 2.85 MPa flexural strength, and 2.98 MPa split tensile strength.

6. Conclusions

Results of this experimental study demonstrated that self-compacting fiber reinforced concrete with acceptable workability and high mechanical properties can be produced using marble powder and low volume of polypropylene (PP) fibers:

(i) Addition of low PP fibers content (i.e., up to 0.30% of concrete volume) to SCC has insignificant effect on its compressive strength.

(ii) Addition of PP fibers (0.30%) of concrete by volume increases the split tensile strength remarkably compared to control mix

(iii) Flexural strength also improved significantly by adding PP fibers up to 0.30% of SSC concrete volume.

(iv) Polypropylene fibers offered opposition to water permeability and chloride penetration at low volumes of PP fibers.

(v) The results are also the reflection of concrete performance related to compressive strength. The chloride penetration decreased by 5% on addition of 0.30% PP fibers.

(vi) Two-way ANOVA with a significance level less than 0.001 was employed by researchers to determine the statistical significance of their model predictions. The overall error and the residual error due to the poor fit are both insignificant. The predictive model's R2 values indicate that the variable-response relationship is accurately represented and that it can be improved. The RSM model used to calculate SCC concrete's compressive, split tensile, and flexural strengths were correct which can be used to generate predictions.

(vii) The results of the prediction model are in agreement with the experimental data, which indicates a little difference [7, 10, 11, 15–18, 21, 35].

Data Availability

The data will be provided upon request to the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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