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Procedure for mix designing used for steel fibre reinforced self-compacting concrete

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Abstract

This work focuses on a methodical design process for developing self-compacting concrete (SFRSCC) using steel fibre reinforcements. The objective is to create a self-consolidating concrete that has the double advantage of self-consolidating characteristics and composite toughness. Experimental modelling involved building the mortar phase with manufactured sand (M-sand) as fine aggregate utilising a systematic mix design process based on the particle packing idea. Optimisation of aggregates was determined using the packing density idea and slump cone research. By conducting a paste consistency test, cement and ground granulated blast furnace slag (GGBFS) powder combinations were chosen. Finally, the amount of superplasticizer was determined based on Marsh cone experiments and the percentage by volume of steel fibres determined by slump flow research. The addition of steel fibre dosage impacts the workability of both standard and high strength concrete, and the fresh properties emphasised the necessity to maintain a large paste volume for increased workability. On the basis of the recommended mix design technique using M-sand, self-compacting concrete with a maximum strength of 70MPa was manufactured. On the other hand, experimental studies on the fresh and hardened properties of recommended self-compacting steel fibre concrete mixes were presented. In addition, test findings demonstrated the viability of employing M-sand as a replacement for river sand in its entirety.

Keywords: Self Compacting Concrete; Steel Fibres; Compressive strength; Mix Designing

1. Introduction

SCC (Self Compacting Concrete) is a contemporary concrete that does not need vibration for compaction or placing. Even when reinforcement is dense, it may flow under its own weight, fully filling formwork and achieving full compaction [1], [2]. SCC can also aid in speedier building, easier placement, a better surface polish, and uniform consolidation, among other things. Because compaction is removed during placement, the concrete construction industry is predicted to become more automated, reducing construction time[3],[4]. Furthermore, SCC promotes the health of construction workers by avoiding the use of vibrators. SCC can be produced by lowering the water-to-powder ratio, using a high amount of powder, reducing aggregate size, and using superplasticizers, among other things.

To avoid segregation, SCC is a mixture that is almost fluid but stable at the same time. These two requirements are obviously diametrically opposed[5], [6]. Employing an effective new generation superplasticizer satisfies the first condition, while high finer content (cement and filler) and viscosity-modifying chemicals satisfy the second (VMA). The following are some of the benefits of SCC: (a) Complete compaction in congested reinforcing areas with limited access. (b) Improved concrete durability due to improved compaction and reinforcement cover. (c) The surface smoothness of produced concrete has been improved. (d) Elimination of health and safety hazards related with the continuous use of vibratory equipment (such as white finger) (e) Lower noise levels during installation (f) A reduction in the time and labour force involved with concrete placement resulted in a shorter construction period and increased productivity. (g) Cost savings for vibrating concrete in terms of machinery, energy, and personnel. (h) Exceptionally well-suited to

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slender and complex moulds. Using M-Sand, an attempt will be made to study the genesis of SCC containing mineral admixture in this study[7]. Steel fibres' impact on SCC's fresh and hardened characteristics will be investigated. Under evenly distributed load, the flexural behaviour of SCC slabs with and without fibres and with varying boundary conditions was investigated and compared to identical CVC slabs[8].

1.1. Research significance

The development of high-quality SCC necessitates a methodical mix design technique. In the past, a great deal of study has been conducted on SCC, but few studies have been conducted on the use of steel fibres in self-compacting concrete. In addition, limited research using steel fibre reinforced self-compacting concrete employing M-sand and GGBS (SCM) to improve the paste characteristics of SCC. Due to environmental effects and river sand shortages, the use of M-sand must be promoted. In the current study, a mix design approach based on a packing concept containing steel fibres and employing M-sand fine aggregate is provided. We analysed the fresh and hardened characteristics of the produced mixtures. The relevance of the research lies in assessing the applicability of M-sand and evaluating its fresh and hardened qualities so that the proposed approaches may be used to beneficiate the material for field applications.This study presents simpler concrete mix design approaches for the production of self-consolidating concrete with the addition of steel fibres and M-sand.

1.2. Design principles for scc

Three phases comprised SFRSCC's M-sand-based research plan. In the first step, a novel mix design approach based on the notion of packing density was established. Using studies on slump cones and the Puntke test, the greatest packing density was achieved using aggregate and powder phase. By adjusting the w/p ratios, three unique mixes (M1, M2, and M3) were formed, and the freshness properties of the developed mixtures were examined.

In the second phase, the volume fraction (Vf) of steel fibres was optimised for M1, M2, and M3 by adding various volume fractions and analysing the flow characteristics using slump cone tests. With the optimum V_f of steel fibres, fresh characteristics for each mixture were characterised.

The third phase involves the examination of the hardened characteristics of formed SCC with and without fibres. Compressive strength, tensile strength, and modulus of elasticity, as well as their impacts at various ages of concrete, are investigated (3, 7 and 28 days).

1.3. Proposed mix design methodology

For the production of self-compacting, fiber-reinforced concrete with excellent flowability, segregation resistance, and bleeding, it is vital to choose the correct concrete materials and to optimise their proportions. In the present study, numerous substances were optimised using the particle packing principle. The suggested approach for mix design aims to achieve maximum packing density for aggregates and powder phase, resulting in enhanced fresh and hardened qualities. For assessing the packing density of aggregates, a modified adaptation of the test protocol outlined in ASTM C29 was employed. The packing density of aggregates was determined using a slump cone and the Puntke test on powder. Marsh cone research determined the optimal dose of SP. Slag Activity Index was used to confirm the cement and slag's reactivity (SAI). Flow studies were used to optimise the addition of steel fibres to maximise the mechanical qualities. The following stages provide a summary of the procedure for the suggested mix design technique.

1.3.1. Fixing the Optimized Proportion of Coarse Aggregate

For the purpose of calculating the optimal number of coarse aggregate combinations (12.5mm and 20mm), the packing density of various combinations of 12.5mm and 20mm aggregates was measured. The volumetric proportion of 12.5mm and 20mm aggregates was altered from 0% to 100% with a 10% increment.

$$Packing\ Density = \frac{\{\left(\frac{M1}{S1}\right)+\left(\frac{M2}{S2}\right)\}}{Vc} \ldots\ldots\ldots\ldots(1)$$

Where M1 and M2 represent the mass of each aggregate type, S1 and S2 represent the specific gravity of corresponding aggregate types, and Vc represents the volume of the container. The combination that resulted in the highest packing density was deemed the optimal combination and utilised to determine the amount in step 2.

1.3.2. Optimization of Combination of Coarse Aggregates, M-Sand and Determination of the Void Content

In order to optimise the aggregate mixture (12.5 mm, 20 mm, and M-sand), the M-sand concentration was increased from 40 to 60 percent (a 10 percent increase) by volume. The selection of Fine aggregate (M-sand) was based on EFNARC recommendations.

$$Packing\ Density = \frac{\{\left(\frac{M1}{S1}\right)+\left(\frac{M2}{S2}\right)+\left(\frac{M3}{S3}\right)\}}{Vc} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where M1, M2, & M3 = Mass of each aggregate type; S1, S2, & S3 = Specific gravity of the corresponding aggregate type; Vc = Volume of the container.

$$Void\ Content = 1 - Packing\ Density \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

1.3.3. Paste Volume Calculation Based on Required Slump Flow

The theoretical volume of paste necessary to fill the spaces is based on the void content determined in step 2. employed an empirical relationship to predict the amount of paste based on void content and needed slump flow.

$$Volume\ of\ paste = Void\ volume + (required\ slump\ flow - 321) / 4.068 \ldots\ldots\ldots (4)$$

This relationship will just offer an idea of paste volume for the desired slump flow, hence decreasing the number of experiments.

1.3.4. Determining the Total Volume

Total concrete volume = 1000l

Typically, 2% air is assumed for SCC (20l)

$$\text{Net concrete volume} = 1000-20 = 980 \ldots\ldots\ldots (5)$$

980 = paste volume plus aggregate volume

Volume of aggregate = 980 - the volume of paste

1.3.5. Establishing the w/p Ratio and Determining Powder Volume

The w/p ratio by volume can be fixed according to the required compressive strength. The paste's volume may be stated as:

$$\text{Volume of paste} = \text{quantity of powder} + \text{volume of water} \ldots\ldots\ldots (6)$$

(Volume of powder = volume of cement volume of extra cementitious ingredients)

From the chosen w/p ratio, the volume of powder was calculated.

1.3.6. Determining the Optimal Powder Content Combination

The Puntke test was performed to improve the powder (Cement: GGBS) combination using the notion of packing density.The Puntke test protocol is a well known procedure of mix design. The packing density of cement:GGBS was measured for several combinations ranging from 0% to 100% (with a 10% increase) by volume.

$$Packing\ Density = 1 - \left(\frac{Vw}{Vp-Vw}\right) \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Vw = Volume of water (cm^3), Vp = Volume of Particle (cm3)

The powder mix that had the highest packing density was chosen. Conducting a slag activity index validated the reactivity of slag and cement for the final mixture.

1.3.7. Superplasticizer Dosage Calculation

For the chosen powder combinations and w/p ratio, the optimal superplasticizer dose was determined by conducting Marsh cone investigations.

1.3.8. Evaluation of New Properties

Using the determined proportions, trial mixing must be undertaken. The classification of SCC in its early stages is based on EFNARC criteria.

1.3.9. Modifying the Proportions of the Mixture

On the basis of the test results obtained in step (8), the EFNARC standards for the proposed concrete are reviewed, and if required, the concrete is adjusted until satisfactory results are achieved.

1.3.10. Optimisation of Steel Fibre Content

Slump flow experiments were conducted with the purpose of optimising steel fibres. Various volume fractions of steel fibres can be employed for the mixture formed in step (9). Considered to be the optimal volume fraction of steel fibres is the flow that produces a minimum 600mm spread diameter and uniform dispersion of concrete fibres along the flow.

2. Material and methods

2.1. Lab testing methodology

In the present investigation, six different concrete mixtures were evaluated, three of which contained fibres and three of which did not. Based on concrete volume, the various volume fractions (V_f) utilised are 0.5 and 0.75 percent. The concrete mix design is shown in Table 1, and the fresh characteristics, including slump flow and J-ring, were evaluated based on EFNARC criteria.

The hardened characteristics of 150×150×150 mm cubes (compressive strength), 150 mm diameter with 300 mm length cylinders (elastic modulus), and 100 mm diameter with 200 mm length cylinders (elastic modulus) were investigated using reference specimens (tensile strength). After filling the mould, the surface of the casting was smoothed and completed using a trowel. The moulds were left alone for 24 hours. After twenty-four hours, the moulds are reformed, and the specimens are placed in water to cure in a controlled environment. According to IS 516, all of the hardened qualities of concrete sample were evaluated at 3, 7, and 28 days.

Table 1 Proportion of SCC Mix

Mix	**Vf**	**Vol of Cement**	**Vol of GGBS**	**Vol of Water**	**Vol of Paste**	**w/p**	**Vol of CA (12.5mm)**	**Vol of CA (20mm)**	**Vol of M Sand**
M1+0.0%	0.00	135	95	155	385	0.72	125	185	300
M1+0.50%	0.00	135	95	155	385	0.72	125	185	300
M2+0.0%	0.00	125	85	185	385	0.92	125	185	300
M2+0.75%	0.00	125	85	185	385	0.92	125	185	300
M3+0.0%	0.00	110	75	200	385	1.12	125	185	300
M3+0.75%	0.00	110	75	200	385	1.12	125	185	300

Table 2 Material Properties

Sl. No	Material	Properties
1	Cement	OPC 53 Fineness- 320m^2/kg Specific Gravity- 3.18
2	GGBS	Fineness- 450m^2/kg Specific Gravity- 2.85
3	Coarse Aggregate	Size- 12.5mm and 20mm Specific Gravity- 2.82 and 2.76 respectively
4	M-Sand	Well Graded Sand falling under Zone-II category Specific Gravity- 2.85 Bulk Density- 15.95 kN/m3
5	Super Plasticizer	40% solid content polycarboxylic ether-based high-range water reducer Specific Gravity- 1.09-1.11
6	Steel Fibres	Aspect ratio of the fibers is 65 Tensile strength is 1100 MPa.
7	Water	Potable water free from chlorides and sulphates

Table 3 Tests Performed

Sl. No	Parameter	Test Performed
1	Packing Density of Aggregates	Slump Cone Apparatus
2	Optimization of Powder Combination	Puntke Test
3	Slag Activity Index	Compressive Strength Comparison of Mortar Containing the Mineral Component to Plain Cement Mortar.
4	Optimization of Steel Fibre	Slump Flow Study

3. Results and discussion

3.1. Packing Density of Coarse Aggregates

Table 4 Combinations used for Packing Density

Mix	%Vol of 12.5mm	%Vol of 20mm	Weight (kg)	M1 (kg) 12.5mm	M2 (kg) 20mm	M1/S1	M2/S2	Packing Density (%)
A1	0	100	7.56	0.00	7.56	0.00	2.73	50
A2	9.9	90.1	7.64	0.76	6.89	0.28	2.49	59
A3	19.9	80.1	7.85	1.57	6.28	0.57	2.27	52
A4	29.9	70.1	7.91	2.38	5.56	0.86	2.01	53
A5	39.9	60.1	7.95	3.18	4.79	1.15	1.73	53
A6	49.9	50.1	8.11	4.05	4.06	1.46	1.47	54

A7	59.9	40.1	7.97	4.79	3.18	1.72	1.16	53
A8	69.9	30.1	7.93	5.54	2.39	1.97	0.87	51
A9	79.9	20.1	7.79	6.23	1.57	2.23	0.56	52
A10	89.9	10.1	7.77	6.99	0.77	2.48	0.29	51
A11	99.9	0.10	7.48	7.47	0.01	2.68	0.02	49.45

By adjusting the mixture of coarse aggregates from 0% to 100% by volume with a 10% increment, the best packing density of coarse aggregate combinations (12.5 and 20 mm) was identified. Using Eq. (1), the packing densities of each combination were calculated, and the results are shown in Table 4. Referring to Fig. 1, it can be seen that the packing densities of 12.5 mm and 20 mm aggregates exhibit a distinctive pattern, with maximum density at the optimal position. As the amount of smaller size aggregate (12.5 mm) rises, the packing density up to a mixture of 50:50 (53%) becomes more effective. Following this combination, a decrease in packing density was noted.

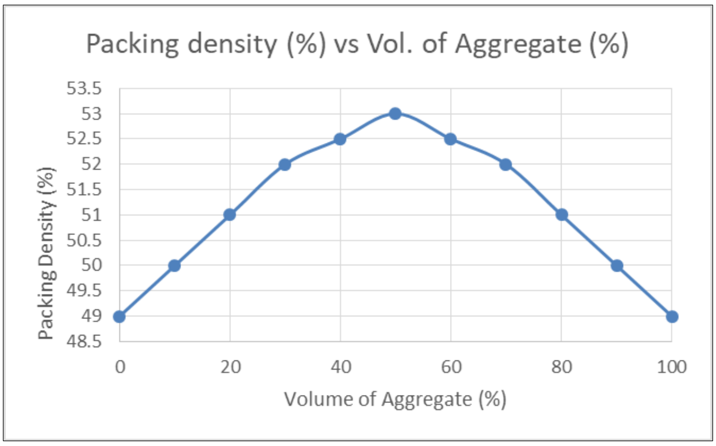

Figure 1 Coarse aggregate content vs. packing density

3.2. Packing Density of M-Sand & Coarse Aggregate

Table 5 Combination of M-Sand & Aggregate used for Packing Density

Mix	%Vol of CA	%Vol of 12.5mm	%Vol of 20mm	%Vol of M sand	Weight (kg)	M1(kg) 12.5mm	M2(kg) 20mm	M3(kg) M-sand	Packing density (%)
X1	60	31	31	40	9.68	2.91	2.91	3.87	66
X2		35	25		9.66	3.48	2.33	3.87	66
X3		25	37		9.81	2.36	3.55	3.93	65
Y1	50	27	26	50	9.82	246	2.44	4.92	65
Y2		32	21		9.81	2.97	1.98	4.91	64
Y3		21	32		10.02	2.02	3.01	5.02	67
Z1	40	21	22	60	9.45	1.88	1.88	5.64	65
Z2		25	18		9.44	2.28	1.52	5.68	65
Z3		14	25		9.42	1.51	2.27	5.64	66

In order to determine the void content, the packing density of a mixed aggregate combination (12.5, 20mm, and M-sand) must be determined. Void content represents the quantity of paste necessary to fill voids. The aggregate mix with the highest packing density will influence the concrete's behavior. To examine the effect of packing densities, a broad variety of M-sand and coarse aggregate combinations were explored. Typically for SCC, the ratio of fine to coarse aggregate is 1, and based on this, the amount of M-sand to CA was altered using 40:60, 50:50, and 60:40. Even though the highest packing density for 12.5mm and 20mm coarse aggregate combinations was 50:50 by volume, for a better understanding of packing densities, 50:50, 60:40, and 40:60 by volume were evaluated. The results obtained by using Equation (2) are shown in Table 5.

The obtained findings reveal relatively slight changes in packing densities for various M-sand mixtures. For aggregates combined with 40–50% M-sand, the highest packing densities are reached with 20mm aggregates. The combination of coarse aggregate and 60% M-sand exhibits the lowest packing density (64%), as seen in the table. The claimed maximum packing density is for a mixture of 20:30:50 (12.5mm, 20mm, M-sand), with an M-sand/coarse aggregate ratio of 1. Additionally, it is important to mention that the maximum packing density of aggregate (12.5mm & 20mm) with M-sand is 40:60. Referring to Table 4, the maximum packing density for the 50:50 combination was 53%, whereas the maximum packing density for the 40:60 combination was 52, which is an acceptable range.

3.3. Optimization of Powder & Super-plasticizer dosage

The optimal ratio of Cement to GGBS was determined using the Puntke test. According to research, the optimal ratio of cement to GGBS (packing density of 50.5%) is 60:40 by volume. Studies on the Slag activity index validated the reactivity index of Cement:Slag (60:40) and revealed that the reactivity index decreases when replacement levels above 40%. To determine the optimal dosage of superplasticizer for different w/p ratios, Marsh cone tests were undertaken. The optimal dosage of superplasticizer is the dosage over which the flow time does not diminish noticeably. M1 (2%), M2 (1%) & M3 (0.5%) are the optimal proportions of different mixes based on the total weight of cement and GGBS.

3.4. Properties of Fresh Concrete

Self compactability cannot be evaluated using a single test technique; often, many methods are required. The present inquiry assessed the self-compactability of the suggested mixture using Slump flow studies for flowability and segregation resistance and J ring tests for passing ability. It is generally known that fibre influences the fresh state features of SCC. To limit the impact of fibres on fresh qualities, fibre optimization procedures and placement must be used with care.

The fresh qualities of SCC with and without fibres are detailed in Table 6. In the absence of impediments, the slump flow test measures horizontal free flow (deformation). A greater slump flow suggests that the concrete may fill the mould under its own weight. Despite altering w/p ratios and SP dosages, all mixtures without fibres had a spread diameter more than 700 mm and within the range of 610-660 mm when fibres are added. This might be owing to the high volume of paste used and the consistent volumetric ratio of paste to aggregates throughout the mix.

Table 6 Fresh Concrete Properties

Mix ID	Slump flow (mm)	Flow time T500(sec)	J ring flow (mm)
M1+0.0%	711	4.9	645
M1+0.50%	612	5.2	604
M2+0.0%	724	3.3	676
M2+0.750%	641	4.1	624
M3+0.0%	742	2.1	691
M3+0.750%	661	3.2	622

This clearly demonstrated the impact paste volume has on spread diameter. Even though the diameter of the flow has decreased due to the inclusion of fibres, these values are within the EFNARC-specified range. The decrease in flow diameter of mixes containing steel fibres can be explained as follows: the fibres are needle-like particles that increase the resistance to flow and contribute to an internal structure in the fresh state, as well as the fibre's elongated shape, which is greater than that of aggregate and creates a greater surface area per unit volume.

During the testing period, it was discovered that mixture M3 exhibited a minuscule amount of segregation. T500 is the time necessary to reach a 500mm slump flow. It has to do with viscosity. The more the necessary time, the greater the viscosity, and vice versa. All obtained values are within the standards-prescribed range. Compared to the other mixtures, mixture M1 is the most viscous, which may be attributable to its lower w/p ratio. To evaluate passing ability, a J ring with slump flow was undertaken. All of the mixtures with and without fibres demonstrate an adequate capacity to pass. Due to the fact that the mixes utilised a larger paste content, the aggregates had sufficient area to disseminate, hence preventing congestion at the reinforcements.

3.5. Properties of Hardened Concrete

It is essential to comprehend the mechanical performance of a material under various loading situations, especially when a new element is added. Also, a greater knowledge of the impact of strength parameters at different ages would bolster trust, particularly for the safety of the remoulding process. This study was primarily concerned with compression, tensile strength, and elastic modulus within the context of hardened characteristics. All experiments were conducted with three replicates, and the mean values are used to describe test results. At three, seven, and twenty-eight days, the evolution of toughened characteristics was examined.

Compressive strength is the greatest stress that a material can withstand under crush loading. The compressive strength of a specimen is calculated by dividing its maximum load by its initial cross-sectional area. In the present experiment, concrete cubes of size were subjected to uniaxial compression tests. 150×150×150mm utilizing a compression testing equipment with a maximum capacity of 2,000kN. The findings obtained at various ages are shown in Table 7.

Table 7 Average Value of Compressive Strength

Mix ID	**Compressive strength (MPa)**		
	3 days	**7 days**	**28 days**
M1+0.0%	42.40	60.40	67.90
M1+0.50%	48.40	66.50	70.70
M2+0.0%	40.30	49.90	55.20
M2+0.750%	43.50	54.60	58.80
M3+0.0%	30.58	43.80	45.80
M3+0.750%	32.55	45.10	46.30

A fundamental characteristic of concrete is its tensile strength. Concrete is intrinsically incapable of withstanding tensile pressures. Fiber addition will increase the tensile strength of concrete, with the degree of improvement dependent on a number of characteristics. 100mm diameter by 200 mm length cylindrical specimens were subjected to a split tensile test to determine tensile strength. Horizontally placing a cylindrical specimen between the loading surface of compression testing equipment and applying a load until the specimen fails along its vertical diameter was used to perform the test. When the load is applied, the horizontal stress on the vertical diameter of the cylinder is 2P/ld. The data collected are shown in Table 8.

Table 8 Average Value of Split Tensile Strength

Mix ID	**Split tensile strength (MPa)**		
	3 days	**7 days**	**28 days**
M1+0.0%	2.85	3.45	4.45
M1+0.50%	4.94	5.08	6.04
M2+0.0%	2.76	3.12	4.19
M2+0.750%	5.08	5.35	6.51
M3+0.0%	2.68	3.01	3.94
M3+0.750%	3.13	4.15	4.94

The results of the split tensile strength test (Figure 3) demonstrated that the addition of steel fibres significantly increased the tensile strength. Compared to simple SCC, the rate of growth in tensile strength is more noticeable at younger ages for the same mixture. A 30% average increase is reported for M1+0.5% steel fibres, 40% for M2+0.75% steel fibres, and 20% for M3+0.75% steel fibres. The increase in tensile strength is mostly attributable to the steel fiber's resistance to the spread of microcracks in the matrix.

This is performed by improving the matrix's resistance to overall cracking and by bridge over the tiny fractures created by the applied stress, so preventing the small fracture from enlarging. During testing, it was discovered that the crack-bridging actions of steel fibres prevented the cylindrical specimens from cracking entirely at failure stress.

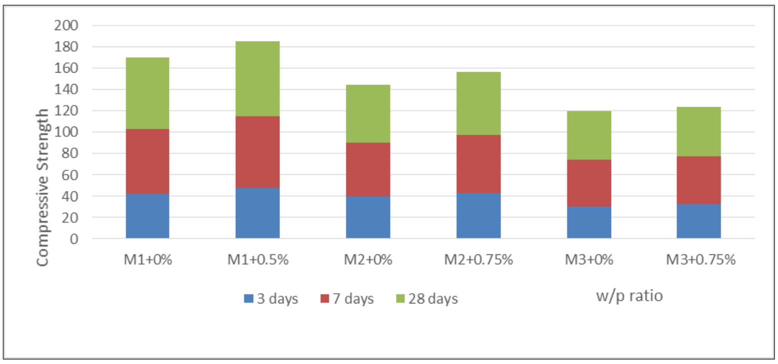

Figure 2 Variation of Compressive Strength with Age

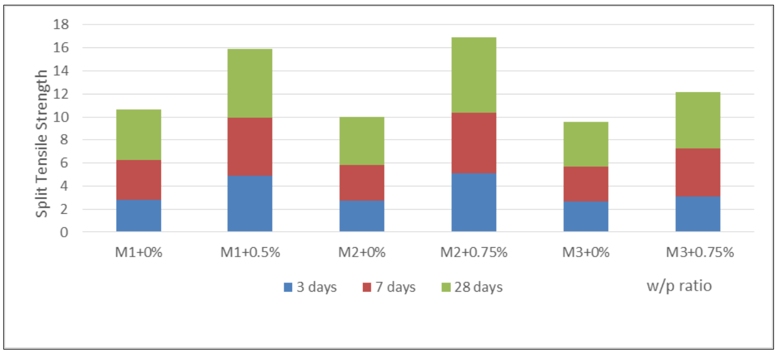

Figure 3 Variation of Split Tensile Strength with Age

Concrete's elastic modulus was tested to determine the material's resistance to distortion. From the slope of the line drawn from the origin, 0.45 times the compressive stress of concrete was determined to be the compressive stress. The test was carried out using a compression testing equipment with a maximum capacity of 2,000 kN. Attaching a compressometer with a dial gauge to the cylinder enabled the measurement of cylinder deformation. The secant modulus is derived from the stress-strain curve, and the average values are shown in Table 9. The examined concrete mixes have elastic moduli ranging from 29 to 38 GPa. The results reveal that the average elastic modulus of fiber-reinforced concrete is 10% more than that of plain SCC.

Figure 4 illustrates the elastic modulus found at various ages in reference to IS 456-2000 $Ec = 5000 \times \sqrt{fck}$ and NF EN 1992-1(1) $Ecm = 22 \times \left(\frac{fcm}{10}\right)^{0.3}$. After doing the comparison, it is determined that, for a given compressive strength, the experimental findings are less than those derived from codal specifications. Typically, SCC utilises a greater paste volume and a smaller maximum aggregate size to achieve the requisite flowability. The modulus of elasticity of concrete is governed by the aggregate's modulus of elasticity and the quantity of aggregate by volume in concrete. The range in findings for 28-day modulus of elasticity according to IS 456-2000 and Eurocode 2 is 10 to 18%, 7.0 to 22.0% without steel fibres, and 7 to 9% and 2% for concrete with steel fibres. When the strength of concrete decreases, greater variety is evident. According to IS 456-2000, real values may differ by 20% from the expression values. The acquired experimental results can thus be regarded as having a high likelihood of occurring.

Table 9 Average Value of Young's Modulus

Mix ID	Young's Modulus (G-Pa)		
	3 days	7 days	28 days
M1+0.0%	29	34	35
M1+0.50%	32	35	38
M2+0.0%	27	31	34
M2+0.750%	30	35	36
M3+0.0%	23	28	29
M3+0.750%	24	30	33

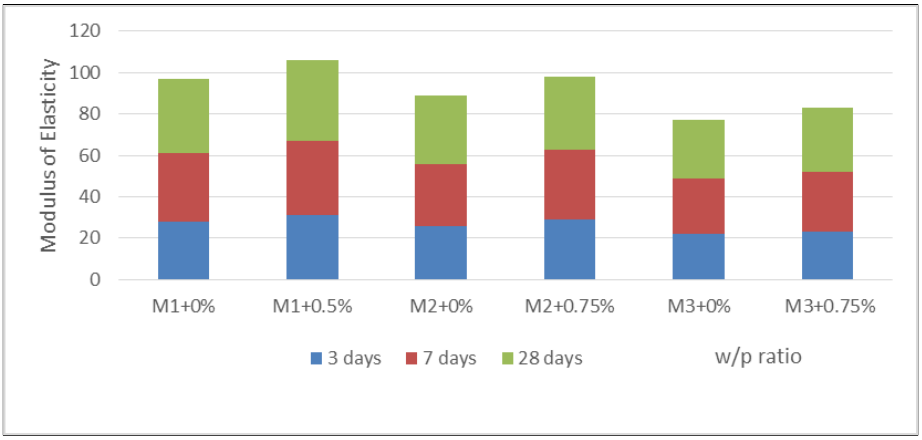

Figure 4 Variation of Modulus of Elasticity with Age

4. Conclusion

This research describes a method for building an SFRSCC based on the density of packing by substituting 100 percent river sand with M-sand. The suggested approach for mix design based on density of packing is simple and efficient. On the basis of the packing density concept, optimal combinations for 12.5mm: 20mm: M-sand were determined to be 20:30:50 (maximum packing density of 68%) and 60:40 (packing density of 50.5%) for Cement: GGBS. Slump cone studies were used to optimise fibre doses, and marsh cone studies were used to optimise superplasticizer dosages. There was a total of six mixtures created, three of which contained fibres and the other three of which did not. The production of concrete mixes containing fibre volume fractions of 0.50 and 0.750 percent by volume of concrete. The inclusion of steel fibre decreased the fluidity and permeability of the material, while still meeting the prescribed limits for SCC.

At various ages, the hardened characteristics (compression, tension, and elastic modulus) of concrete were analysed (3, 7 and 28 days). All the qualities were first strengthened with ageing and the inclusion of steel fibres. The compressive strength found in the present study ranges between 46 and 70 MPa. In addition to its environmental benefits, M-sand is a superior filler ingredient for concrete compared to river sand. The M-sand employed in this investigation meets the grading requirements of IS 383 and is devoid of silt and clay. The present study focuses on durability and practicability factors. The confidence acquired from the current study's experimental investigations may be utilised to investigate more concrete parameters, such as hardness, effect at different curing circumstances, performance at increased temperatures, etc., In conclusion, the established mix design approach allowed for the production of standard and high strength concrete with the inclusion of M-sand and the advantages of steel fibre reinforcing on the compressive strength.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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