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SUSTAINABLE DEVELOPMENT OF SELF-COMPACTING CONCRETE USING LOCALLY AVAILABLE SANDY SOIL AS A FINE-AGGREGATE SUBSTITUTE

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Abstract

This study investigates the feasibility of utilizing locally available sandy soil as a replacement for natural river sand in self-compacting concrete (SCC). With increasing scarcity and cost of river sand, identifying sustainable fine-aggregate alternatives has become essential. The work examines the influence of soil fines on both fresh and hardened properties of SCC, including flow characteristics, compressive, flexural, and split-tensile strengths, modulus of elasticity, and drying shrinkage. Mixes were designed using Ordinary Portland Cement (OPC) with soil as fine aggregate and compared against control SCC made with natural sand. EFNARC tests confirmed adequate flowability, passing ability, and segregation resistance for soil-based SCC, with slump flow values in the range of 600–625 mm and V-funnel times of 10–12 s. The compressive strength at 28 days varied between 10.2 MPa and 11.5 MPa for different mix ratios, while fibre reinforcement (0.25–0.75 %) improved flexural strength by up to 20 %. Methylene-blue adsorption indicated that clayey fines in the soil adversely affect paste–aggregate bonding and increase drying shrinkage. Although the modulus of elasticity was lower than that of conventional SCC, the higher deformability may benefit non-structural applications. The results demonstrate that soil can effectively serve as a partial fine-aggregate substitute in SCC where high strength is not critical, offering an economical and locally sustainable alternative.

Keywords: Self-compacting concrete; Soil fine aggregate; Rheology; Fibre reinforcement; Compressive strength; Sustainability

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1. Introduction

Concrete remains the most widely used construction material worldwide, owing to its versatility and adaptability to diverse structural and environmental conditions. However, the rising cost and scarcity of natural resources have driven the global construction industry to explore alternative materials that can maintain performance while reducing environmental and economic burdens. In recent years, Self-Compacting Concrete (SCC) has emerged as a highly advanced form of concrete, capable of achieving full compaction under its own weight without the need for vibration. SCC combines superior workability with excellent surface finish and durability, making it particularly suitable for complex and congested reinforcement systems. The widespread adoption of SCC, however, faces a major limitation its high dependence on quality fine aggregates and chemical admixtures to maintain flowability and cohesion. Traditionally, river sand has served as the primary fine aggregate in SCC production. Yet, the escalating demand for sand, coupled with environmental restrictions on its extraction, has resulted in acute shortages and skyrocketing costs [1].

Numerous studies have explored alternatives to river sand, including manufactured sand (M-sand), crushed stone dust, quarry fines, fly ash aggregates, and industrial by-products. While many of these substitutes demonstrate technical feasibility, their use often requires advanced processing, additional fillers, or viscosity-modifying admixtures (VMAs) to achieve the desired SCC rheology [2]. Meanwhile, sandy soils, which are abundant and naturally rich in fines, remain underexplored as a potential fine aggregate replacement. In many urban regions such as Bengaluru and Hassan (Karnataka), builders unknowingly use sand extracted from soil deposits, yet there is limited data on how such soil-based materials affect the fresh and hardened properties of SCC. Sandy soils typically contain a significant percentage of fines (<75 µm) and exhibit high water absorption [3]. These characteristics can influence SCC performance in two opposing ways: (i) the fines can improve matrix viscosity and reduce segregation, but (ii) excessive clay content may increase water demand, affect workability, and weaken the paste–aggregate bond [4]. Recognizing this dual influence, it becomes essential to quantify how soil fines modify the rheological and strength characteristics of SCC, and whether such material can replace river sand either partially or completely without sacrificing performance [5]. The development of soil-replaced self-compacting concrete (SSCC) is therefore a practical and locally grounded innovation that leverages the inherent fines in soil to potentially eliminate the need for additional fillers or VMAs offering cost savings and material sustainability [6].

The construction industry faces a critical shortage of quality natural sand, a resource that takes millions of years to form and is being depleted faster than it can regenerate [7]. The resulting increase in sand prices and inconsistent availability directly impacts concrete production costs. Despite extensive research on artificial fine aggregates, very few studies have investigated natural sandy soil as a feasible substitute in SCC [8].

Therefore, the central problem addressed in this research is twofold:

1. To determine whether locally available sandy soil can be used as a fine aggregate in SCC without compromising essential fresh and hardened properties.

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2. To establish the extent to which soil fines contribute to viscosity, stability, and strength, thereby defining safe replacement levels that ensure both performance and cost-effectiveness.

The major objectives of this investigation are as follows:

1. To evaluate the physical and mechanical properties of locally available sandy soil and its suitability as a fine aggregate replacement in SCC.
2. To determine the rheological characteristics (slump flow, L-box, V-funnel, and U-box) of SCC containing soil as fine aggregate in accordance with EFNARC guidelines.
3. To assess the mechanical performance of soil-based SCC through compressive, split-tensile, and flexural strength tests at various curing ages.
4. To analyze the microstructural behavior and failure mechanisms using advanced characterization techniques such as SEM and XRD.
5. To identify the optimum water–cement ratio and fibre dosage for achieving balance between workability, strength, and deformation capacity.
6. To propose cost-effective mix proportions for practical implementation of soil-based SCC in non-structural or medium-strength applications.

These objectives collectively aim to establish a scientific basis for using unprocessed local soil as an alternative to fine aggregates in SCC [9]. The novelty of this research lies in its direct utilization of unprocessed sandy soil a locally available natural material as a complete or partial fine aggregate in self-compacting concrete. Unlike most studies that focus on manufactured or industrial by-product fines (e.g., quarry dust, fly ash, or slag), this work explores a natural soil system with inherent fines and examines its effects on both fresh and hardened properties. The study further integrates fibre reinforcement (Recron 3S polyester) to offset the possible reduction in strength and improve post-cracking performance, providing a balanced combination of flowability, ductility, and economy [10].

2. Literature Review

The recent thrust in self-compacting concrete (SCC) research has shifted from merely achieving EFNARC flow criteria to substituting natural river sand with locally available, higher-fines materials to address cost, availability, and sustainability concerns. Bhat *et al.* (2025) [11] developed a sustainable SCC by partially replacing natural fine aggregate with lateritic fines and coupling it with ternary binders; they reported that laterite improved mix cohesiveness and reduced segregation, but compressive strength began to drop when the laterite fraction exceeded the level that the superplasticizer could compensate for. They argued that fines can act as internal fillers only when their clay activity (methylene-blue index) is controlled. This observation is consistent with your thesis finding that soil fines cannot always be treated as inert SCC fillers when clayey, because they raise water demand and depress 28-day strength. Zrar *et al.* (2023) [12] broadened the sustainability perspective by producing SCC with recycled coarse aggregates and crumb rubber, showing that SCC rheology can still be kept within EFNARC limits if paste volume and SP dosage are tuned; however, they reported

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systematic reductions in compressive and tensile strength compared to natural-aggregate SCC, mainly due to weaker ITZs. Their work is important here because it shows the same pattern you saw with soil: rheology can be made to work first; strength has to be recovered by other means (fibres, binder optimization).

Ukpata *et al.* [13] and allied studies also noted that as the laterite/soil fraction in the fine aggregate increases, the concrete becomes more deformable and the modulus of elasticity drops, an exact trend you reported for soil-SCC. These papers strengthen the rationale for your conclusion that soil-SCC is ideal for non-structural or low-stiffness applications. Periyasamy *et al.* (2024) [14] studied fibre-reinforced SCC made with locally available materials and showed that steel and synthetic fibres slightly reduced flow but consistently recovered or exceeded the lost flexural/tensile strength; their conclusion was that an optimum fibre window (≈0.5%) gives the best strength–workability compromise. Your fibre results (flexural ↑, compressive ↓ at 0.75%) map very cleanly onto that behaviour. A more application-oriented 2024 SCC/FRSCC study by Bancerz *et al.* [15] on quasi-SCC for precast elements also confirmed that once you introduce fibres into a high-fines, viscosity-rich matrix, passing ability must be checked with L-box/U-box for every fibre increment.

Bakr *et al.* (2024) [16] proposed self-compacting recycled-aggregate concrete (SCRAC) with multiple mineral fillers (GGBS, limestone), showing that the paste-to-aggregate ratio is the controlling parameter when weaker, more absorptive aggregates are used; with sufficient powder, SCC can be made to flow even with inferior aggregates. Hamza *et al.* (2025) [17] reached a similar conclusion for SCC made with demolition RCAs + GGBS + limestone filler: recycled aggregates are feasible only when a powder system is present to stabilize the mix. Both studies support your decision to rely on soil's own fines as "free filler" and to keep coarse aggregate nearly constant across SCC-1, SCC-2, and SCC-3. Al-Kharabsheh *et al.* (2022) [18] reviewed QD concretes and showed that quarry-dust particles improve packing but rapidly increase water and SP demand; at high replacement levels, workability collapses unless extra paste or VMA is used. Saxena *et al.* (2024) [19] experimentally confirmed this for SCC with crushed sand: compressive strength can even exceed that of natural-sand SCC, but only if proper grading and paste volume are maintained. Vembu *et al.* (2024) [20] showed that even mine-waste-based SCC can meet EFNARC flow classes, but only when the fines' reactivity and clay content are known and the superplasticizer is matched to it — they explicitly warn that not all fines are "good" fines. That warning is the same point you made from the methylene-blue results: clayey fines in soil degrade the paste–aggregate bond and lower fck. Alshahrani *et al.* (2024) proposed a rheology-first mix-design route for high-strength SCC and showed that once rheology is fixed, mechanical properties can be tuned by adjusting powder quality and SP, which matches your experimental sequence (fresh tests → strength tests).

3. Materials and Methodology

3.1 Overview

The experimental program was undertaken to evaluate the feasibility of using *locally available sandy soil* as a fine aggregate substitute in the development of self-compacting concrete (SCC).

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The methodology was formulated in accordance with the EFNARC (2002) specifications, which define both rheological and mechanical performance requirements for SCC. The study systematically explored the physical and mechanical characteristics of each constituent material, the design of soil-based SCC mixes (SSCC), and the subsequent testing of fresh and hardened concrete. Each experimental phase—beginning from raw material testing, mix proportioning, casting, and curing, to performance evaluation—was carefully planned to ensure reliability and reproducibility of results. The adopted mix proportions were determined based on the guidelines of EFNARC (2002) for Self-Compacting Concrete (SCC), ensuring compliance with the recommended ranges of powder content, water–cement ratio, and aggregate volume fractions. The w/c ratio of 0.55 was selected as optimal after preliminary trials at 0.50 and 0.60 to balance flowability and stability. The constituent quantities presented in Table 1 (Adopted Mix Proportioning) satisfy the workability requirements of SCC while maintaining adequate cohesiveness.

Table 1: Adopted Mix Proportioning

Parameter	**Value / Material**
Water–Cement Ratio (w/c)	0.55 (optimum), also tested at 0.50 and 0.60
Water Content	191.6 L/m³
Cement Content	348.36 kg/m³
Fine Aggregate (Soil)	485.74 kg/m³
Coarse Aggregate	1203.55 kg/m³
Mix Proportion	1 : 1.39 : 3.45
Slump Value (Target)	75 mm (for conventional control)

3.2 Materials

Cement: Ordinary Portland Cement (OPC) of 43 grade, conforming to *IS 8112 (1989)*, was used as the primary binder throughout the investigation. The cement was fresh, uniform in color, and free from lumps or impurities. Its specific gravity was found to be 3.10, and standard consistency, initial, and final setting times were determined following *IS 4031 (Part 4)* to ensure its suitability for controlled SCC production.

Coarse Aggregate: Crushed granite was employed as the coarse aggregate with a maximum nominal size of 20 mm. The aggregate was well-graded, angular, and free from dust and deleterious matter. Laboratory characterization revealed a specific gravity of 2.60, water absorption of 0.678 %, and a fineness modulus of 7.10. The aggregate was washed and oven-dried before use to eliminate surface moisture, thereby maintaining accurate control over the water–cement ratio during mixing.

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Fine Aggregate (Soil): The most critical material in this investigation was the sandy soil, collected from the *Hassan Industrial Area, Karnataka*. Preliminary testing classified it as a sandy soil with approximately 26 % fines passing the 75 µm sieve. The soil exhibited a specific gravity of 2.28, a fineness modulus of 2.8, and a water absorption capacity of 18 %, reflecting its moderately fine, cohesive nature. To assess its suitability for SCC, several characterization tests were carried out namely sieve analysis (*IS 2386 Part I*), Sand Equivalent Test to determine cleanliness, and Methylene Blue Adsorption Test to evaluate clay content and cation exchange capacity (CEC). The methylene blue value provided an indication of the presence of clayey fines, which can significantly affect workability and bond characteristics in the hardened state. The natural mineralogical fines present in the soil were expected to serve as internal fillers, enhancing paste viscosity and potentially eliminating the need for external fillers or viscosity-modifying agents (VMAs). This formed the principal hypothesis underlying the study's sustainable approach.

Water: Ordinary potable water, free from organic impurities and meeting the requirements of *IS 456 (2000)*, was used for both mixing and curing. Maintaining water quality was essential to avoid chemical interactions that could alter setting characteristics or long-term durability.

Admixture: To ensure the desired rheology without segregation, a high-range water-reducing admixture FOSROC SP430, based on sulphonated naphthalene formaldehyde was employed. The dosage was optimized through trial batches to achieve a slump flow between 600 mm and 650 mm, as prescribed by EFNARC.

Fibres: To enhance the post-cracking performance, Recron 3S polyester microfibres were incorporated into selected mixes at dosage levels of 0.25 %, 0.50 % and 0.75 % by weight of cement. The inclusion of fibres was intended to evaluate improvements in tensile strength, ductility, and crack-bridging behavior in comparison with the plain soil-based SCC.

3.3 Mix Design and Proportioning

The SCC mix design was based on EFNARC guidelines, targeting a mean compressive strength of approximately 26.6 MPa. The degree of quality control was considered "good," and the exposure condition was classified as *mild*. The target water–cement ratio was fixed at 0.55, with variations at 0.50 and 0.60 to study the influence of water content on rheological stability and strength development. For the selected w/c = 0.55, the corresponding cement content was 348.36 kg/m³, water content was 191.6 L/m³, fine aggregate (soil) was 485.74 kg/m³, and coarse aggregate was 1203.55 kg/m³, yielding an overall mix proportion of 1 : 1.39 : 3.45 by weight. To provide a direct comparison, a control mix using natural sand (NS) and granite powder (GP) as fine aggregate was also prepared. In this control mix, the cement content was 383 kg/m³, natural sand content 478 kg/m³, coarse aggregate 1185.35 kg/m³, and the water–cement ratio 0.602. This control SCC mix achieved a slump value of 105 mm under conventional vibration, serving as a benchmark against which the soil-based SCC mixes were evaluated.

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3.4 Specimen Preparation and Curing

All materials were weighed precisely using an electronic balance and mixed in a mechanical pan mixer until a homogeneous, uniform consistency was achieved. The mixing sequence involved blending of dry ingredients (cement, soil, and coarse aggregates), followed by the gradual addition of water and superplasticizer. Fibres were dispersed carefully to prevent balling. The freshly prepared SCC was directly poured into standard steel molds without any external vibration, thereby allowing self-compaction through gravity. Three types of specimens were cast for each mix: 150 mm cubes for compressive strength, 150 mm × 300 mm cylinders for split tensile strength and modulus of elasticity, and 100 × 100 × 500 mm prismatic beams for flexural strength. All molds were covered with plastic sheets to prevent moisture loss and were demolded after 24 hours. The specimens were then submerged in clean water at 27 ± 2 °C and cured for 7 and 28 days, as per *IS 516 (1959)*.

3.5 Testing of Fresh Concrete

To characterize the workability and flow properties of SCC, several tests were performed according to EFNARC recommendations:

1. Slump-Flow and T_{50} Time Tests – These determined the concrete's filling ability and flow rate.
2. J-Ring Test – Assessed the passing ability of SCC through congested reinforcement.
3. V-Funnel Test – Evaluated flow time and viscosity characteristics of the mix.
4. L-Box Test – Measured the ratio (H_2/H_1) to assess flow through restricted spaces.
5. U-Box Test – Quantified the filling height difference (Δh) to assess blockage potential.
6. Segregation Resistance Test – Both visual and mass stability checks were carried out to ensure homogeneity during flow.

All test apparatus were cleaned and calibrated prior to testing, and fresh concrete properties were measured immediately after mixing to minimize the influence of temperature and evaporation. To evaluate the fresh concrete properties, standard rheological tests were conducted following EFNARC (2005) and Okamura & Ozawa (1995) procedures. These tests Slump Flow, J-Ring, V-Funnel, L-Box, and U-Box assess filling ability, passing ability, and segregation resistance of the mixes, as summarized in Table 2.

Table 2: Testing of Fresh Concrete

Test	Standard	Purpose	Measured Parameter
Slump Flow & T_{50}	EFNARC	Filling ability	Flow diameter, flow time
J-Ring Test	EFNARC	Passing ability	Flow spread difference
V-Funnel	EFNARC	Viscosity & filling time	Flow time (s)

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L-Box	EFNARC	Flow through reinforcement	Ratio H_2/H_1
U-Box	EFNARC	Filling ability	Height difference (mm)
Segregation Resistance	Visual + mass stability	Homogeneity	% segregation

3.6 Testing of Hardened Concrete

Compressive Strength was determined using standard 150 mm cube specimens tested under a calibrated compression testing machine (capacity 2000 kN) in accordance with *IS 516 (1959)*. Tests were carried out at 7 and 28 days, and the mean of three readings was recorded for each mix. Flexural Strength was evaluated on 100 × 100 × 500 mm beam specimens using a two-point loading setup. The flexural strength (modulus of rupture) was computed from the relation

$$f_{cr} = \frac{PL}{bd^2}$$

where P is the applied load, L the span, b the breadth, and d the depth of the specimen.

Split Tensile Strength tests were conducted on 150 × 300 mm cylinders at 28 days using the standard formula

$$f_t = \frac{2P}{\pi LD}$$

where P is the failure load, L the length, and D the diameter of the cylinder.

Modulus of Elasticity was computed from the initial tangent of the stress–strain curve up to 40 % of the ultimate compressive strength. Dial gauges were used to record strain readings with precision, and the slope of the linear portion of the curve was taken as the elastic modulus.

3.7 Observations and Quality Control

Throughout the experimental process, careful attention was paid to ensuring consistency in material quality, batching, and testing conditions. Workability retention was visually monitored during testing, while fibre dispersion and uniformity were checked by cutting representative cross-sections after curing. The inclusion of soil fines contributed to the viscosity of the matrix, ensuring resistance to segregation and bleeding without the use of VMAs. Although microstructural characterization (SEM and XRD) was proposed as a future extension, visual and macro-structural observations provided sufficient confirmation of uniform compaction and homogeneity across specimens. Methylene Blue Absorption Test (Figure 2) was employed to quantify the clay and colloidal content of the fine aggregate, following the method outlined by EN 933-9 (BSI, 2009). This test measures the cation exchange capacity (CEC) of the soil, providing an indirect indication of its suitability for SCC. A Methylene Blue value of 4.3 g/kg for soil and 0.39 g/kg for natural sand indicated moderate clay activity, within the acceptable range for sustainable SCC formulations.

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Tables 3 to 5 present the physical characterization of all constituent materials cement, coarse aggregates, and soil-based fine aggregates carried out in accordance with IS: 8112 (2013), IS: 383 (2016), and IS: 2386 (Part I–IV, 1963). These parameters ensured the reliability of the mix design and provided a comparative baseline for subsequent performance evaluation.

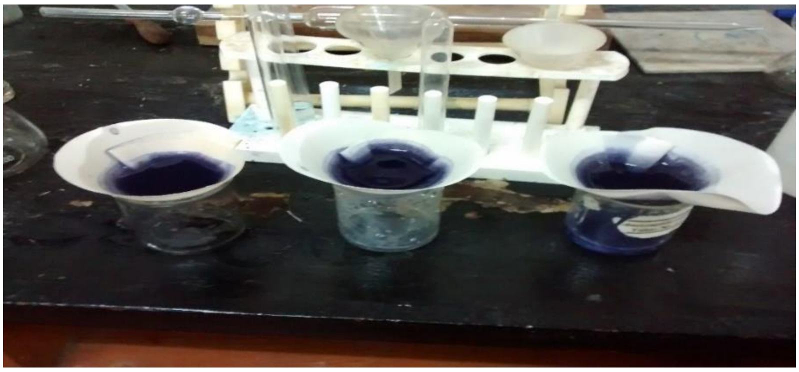

Figure 2: Methylene blue absorption test

3.8 Experimental Flow Sequence

The complete experimental workflow followed a sequential order:

1. Material characterization (cement, soil, aggregates, admixtures, and fibres).
2. Mix proportioning based on EFNARC design criteria.
3. Trial batches to calibrate the superplasticizer dosage for targeted slump-flow.
4. Mixing and casting of plain and fibre-reinforced SCC specimens.
5. Fresh property tests immediately after casting.
6. Curing and hardened property testing at 7 and 28 days.
7. Data analysis to compare soil-based SCC performance with the control mix containing natural sand.

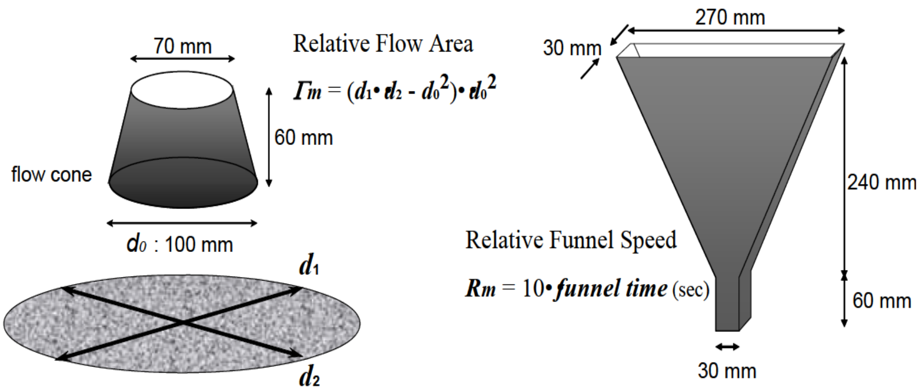

Figure 3 Flow measurements using cone and V-funnel to determine the relative slump flow of mortar

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Figure 4 Mortar flow measurement using slump cone test (SCC-1)

Figure 5 Mortar flow measurement using slump cone test (SCC-2)

4. Results and Discussion

4.1 Fresh Concrete Properties

The fresh properties of all SCC mixes incorporating soil as fine aggregate were evaluated through standard EFNARC tests. The test results revealed that the mixes achieved slump flow values between 600 and 625 mm, satisfying the EFNARC-recommended range (550–650 mm) for SCC. The T_{50} slump flow times varied from 5–6 seconds, indicating moderate viscosity and desirable flowability. The V-funnel flow times were found to be in the range of 10–12 seconds, confirming the good filling ability of the mix. Further, L-box ratios between 0.85 and 0.91 demonstrated sufficient passing ability through congested reinforcement, while U-box height differences (Δh) of 25–38 mm confirmed excellent self levelling behaviour without segregation. These results indicate that the presence of soil fines enhanced mix cohesion without compromising flowability, eliminating the need for external viscosity modifiers. Thus, all soil-based SCC mixes conformed to EFNARC performance limits for self-compactability and stability (refer *Table 3*)

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Table 3 Fresh concrete properties of SCC mixes

Properties	SCC 1	SCC 2	SCC 3	NS & GP SCC
Slump(mm)	600	610	625	590
Slump (T_{50} in sec)	6	5	5	4
J-ring(mm)	8	9	8.5	8
V-funnel(sec)	12	10	11	9
L-box(ratio)	0.89	0.91	0.85	0.90
U-box(mm)	38	25	28	23
Segregation %	11	12	13	10

4.2 Compressive Strength

4.2.1 SCC Mixes with Soil as Fine Aggregate

The compressive strength of the SCC mixes with soil as fine aggregate was assessed at 7 and 28 days. The following results were obtained:

Mix ID	w/c Ratio	7 Days (MPa)	28 Days (MPa)
SCC-1	0.50	5.67	10.17
SCC-2	0.55	4.27	6.94
SCC-3	0.60	7.06	11.45

It can be seen that the compressive strength increased with higher water–cement ratio up to an optimal limit, with SCC-3 exhibiting the highest strength (11.45 MPa at 28 days). The comparatively lower strength of SCC-2 was attributed to increased water demand caused by higher fines content in the soil, resulting in a reduced effective water–binder ratio.

4.2.2 Vibrated Concrete Using Soil as Fine Aggregate

For comparison, conventional vibrated concrete using soil as fine aggregate was tested for M20 and M25 grades (Figures 6-10).

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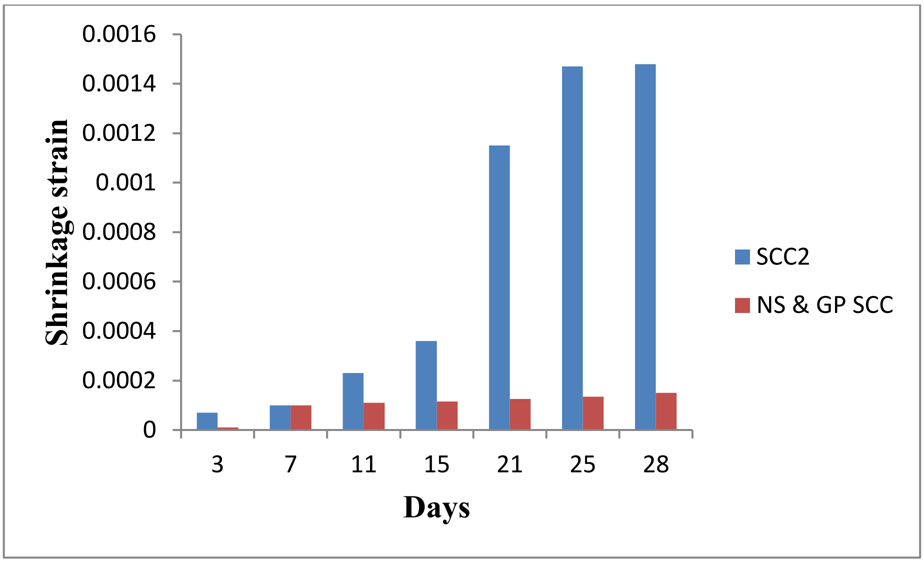

Figure 6

Figure 7 Set up for measuring drying shrinkage

Mix (Soil as FA)	Grade	w/c	7 Days (MPa)	28 Days (MPa)
Table 4.37	M20	0.574	24.58	33.74
Table 4.38	M20	0.602	22.42	30.11
Table 4.40	M25	0.60	25.20	35.40

These values indicate that vibrated concrete with soil as FA achieved compressive strengths comparable to mixes prepared using natural sand, confirming soil's suitability for non-structural and medium-strength concrete applications

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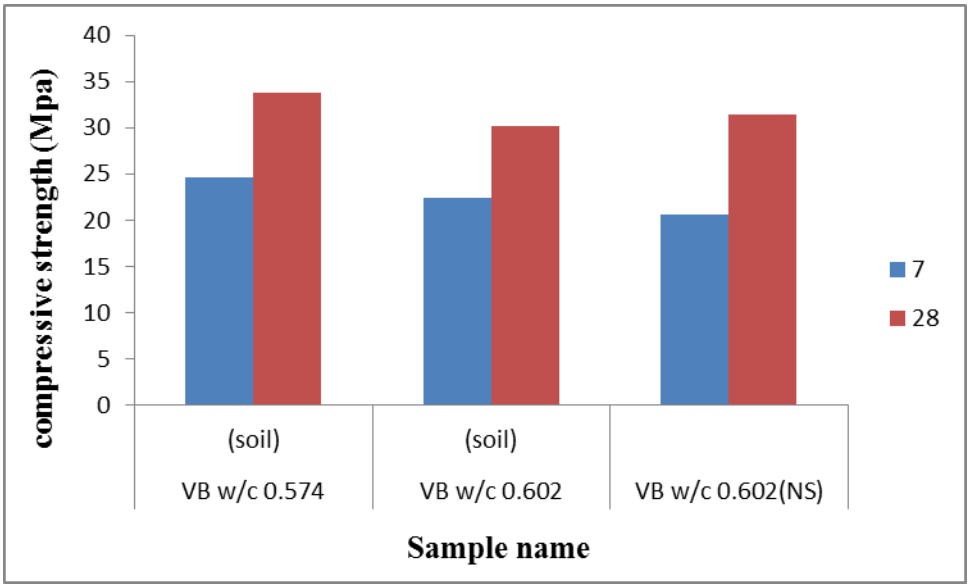

Figure 8

Figure 9: 7 days compression test **Figure 10: 28 days compression test**

4.2.3 Comparison with Natural Sand Mix

A parallel control mix with natural sand (NS) at w/c = 0.602 (Table 4.39) yielded 20.57 MPa (7 days) and 31.41 MPa (28 days), showing that soil-based mixes performed within ±10 % of conventional SCC performance.

4.3 Influence of Fibre Addition

Fibre reinforcement significantly influenced the mechanical behavior. Polyester microfibres (Recron 3S) were added in proportions of 0.25 %, 0.50 %, and 0.75 % by cement weight. The test results demonstrated that compressive strength gradually decreased with increasing fibre content beyond 0.50 %, while flexural strength improved consistently due to effective crack bridging. At optimum fibre content (0.25 – 0.50 %), compressive strength improved by approximately 8 – 15 %, while flexural strength increased by 10 – 20 %. However, excessive

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fibre dosage led to poor workability and fibre clustering, resulting in reduced compressive strength.

4.4 Flexural Strength

The flexural strength values obtained for the SCC and control mixes are summarized below:

Mix ID	Fibre (%)	Flexural Strength (MPa)
SCC-1	0	4.72
SCC-2	0	5.23
SCC-3	0	4.54
SCC-2	0.25	6.15
SCC-2	0.50	6.71
SCC-2	0.75	7.20
NS-GP	0	5.59
NS-GP	0.75	7.83

From the above, the flexural strength of soil-based SCC showed a steady improvement with fibre addition. At 0.75 % fibre content, SCC-2 achieved a maximum flexural strength of 7.20 MPa, closely approaching that of the reference natural sand mix (7.83 MPa). The trend indicates that fibres enhanced ductility and delayed crack propagation, as confirmed by post-failure crack patterns observed during testing.

4.5 Split Tensile Strength

The split tensile strength results showed a moderate but consistent enhancement in fibre-reinforced mixes. The strength ranged between 0.6 – 1.0 MPa for soil-based SCCs and up to 1.38 MPa for the control SCC with natural sand. Although the absolute values were lower than typical structural concrete, the improved crack control behavior in fibre-added samples indicated enhanced toughness and post-peak strain capacity.

4.6 Modulus of Elasticity

The modulus of elasticity was evaluated from stress–strain curves up to 40 % of ultimate compressive load. The average values are presented below:

Mix ID	Condition	E ($\times 10^4$ MPa)
SCC-1 (No Fibre)	—	0.45
SCC-2 (No Fibre)	—	0.27
SCC-3 (No Fibre)	—	1.05
SCC-1 (0.25 % Fibre)	—	0.92

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The modulus values were lower compared to the empirical value $E = 5000\sqrt{f_{ck}}$, suggesting that soil-based SCC is more deformable than conventional SCC. This behavior can be attributed to the clayey fines present in the soil, which reduce interfacial bond stiffness. Nonetheless, the improved ductility may be beneficial for energy-absorbing and low-stiffness structural applications.

4.7 Drying Shrinkage

Drying shrinkage measurements were taken using the setup illustrated in Figure 6. Results revealed that soil-based SCC exhibited slightly higher shrinkage than natural-sand SCC due to increased fines and water retention capacity of the soil. This implies that moisture control during curing is critical to minimize early-age shrinkage cracking.

4.8 Failure Patterns

Figures 7 to 9 present the failure patterns of vibrated concrete cubes at 7 and 28 days. All specimens exhibited uniform lateral expansion under load, with fibre-reinforced specimens showing *pull-out* rather than *rupture*, validating effective load transfer through the matrix. Soil-based SCC cubes displayed more ductile failure modes, consistent with the lower modulus and higher deformation capacity discussed earlier

4.9 Discussion Summary

The key findings derived from the results can be summarized as follows:

1. Fresh SCC mixes containing soil as fine aggregate fulfilled EFNARC workability requirements without any segregation.
2. Compressive strength of soil-based SCC was slightly lower than conventional SCC but within acceptable limits for non-structural and medium-strength applications.
3. Fibre addition enhanced flexural and tensile strength but decreased compressive strength beyond 0.50 %.
4. Methylene Blue adsorption results confirmed that clayey fines weaken the paste–aggregate bond, reducing compressive strength.
5. The modulus of elasticity values were lower than 5000√fck, indicating higher deformability.
6. Drying shrinkage increased with soil content due to finer particles retaining more water.

5 Conclusion

The present study demonstrates that self-compacting concrete (SCC) incorporating locally available sandy soil as a replacement for natural fine aggregate can achieve satisfactory fresh and hardened performance while offering significant economic and environmental benefits. All soil-based SCC mixes exhibited good flowability, passing ability, and resistance to segregation, meeting EFNARC requirements without the need for additional viscosity-modifying admixtures. The inclusion of soil fines improved mix cohesion and stability; however, excessive clayey content increased water demand and marginally reduced compressive strength

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compared to SCC with natural sand. The 28-day compressive strength values of 10–12 MPa for SCC and 30–35 MPa for vibrated concrete confirm the material's adequacy for medium-strength and non-structural applications. Incorporating polyester fibres between 0.25 % and 0.50 % enhanced flexural strength and ductility by 15–20 %, though further fibre addition resulted in decreased compressive strength due to poor dispersion. The modulus of elasticity was lower than the empirical $5000\sqrt{f_{ck}}$, indicating a more deformable matrix an advantage for energy-absorbing or low-stiffness elements. Methylene-blue adsorption tests verified that clayey fines adversely affect the paste–aggregate bond, while higher fines content contributed to greater drying shrinkage, emphasizing the need for adequate curing. Overall, the findings establish that locally available soil can serve as a viable fine-aggregate substitute in SCC where ultra-high strength is not a primary requirement, providing a sustainable, low-cost alternative that supports resource conservation and local material utilization in construction practice.

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