Asian Journal of Advanced Research and Reports

Volume 18, Issue 7, Page 303-317, 2024; Article no.AJARR.119020
ISSN: 2582-3248

Enchancing the Mechanical Properties of Self–compacting Concrete: Means to Achieve a Better Economy in Concrete Construction

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajarr/2024/v18i7703

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/119020

Original Research Article

Received: 25/04/2024
Accepted: 27/06/2024
Published: 02/07/2024

ABSTRACT

Traditional concrete mixtures that include aggregates from naturally occurring sources offer advantages in terms of strength, workability, and water absorption, as well as a wide range of application possibilities. There is a need to further investigate the enhanced mechanical characteristics of Self-compacting concrete as compared to ordinary conventional concrete.

An experiment on the mechanical properties, comprising compressive strength, split tensile strength, flexural strength, and also density of self-compacting concrete SCC and the corresponding properties of normal conventional concrete (NCC) is outlined in this paper.

Based on the various test results, it is concluded that self-compacting concrete provides better characteristics in terms of durability, strength, and economy in concrete production, although their

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Cite as: *Junior, John K. Quarm, and Charles K. Kankam. 2024. "Enchancing the Mechanical Properties of Self–compacting Concrete: Means to Achieve a Better Economy in Concrete Construction". Asian Journal of Advanced Research and Reports 18 (7):303-17. https://doi.org/10.9734/ajarr/2024/v18i7703.*

use should be dependent on the percentage volume of superplasticizer admixture added to achieve higher strength properties in the utilization to substitute conventional concrete (control). In terms of the compressive, flexural, and tensile strength of concrete produced in comparison with both the control and self-compacting concrete, the results still point out clearly that the self-compacting concrete mixes offer the highest compressive, tensile, and flexural strength. The study included 12 cubes, 12 cylinders, and 12 rectangular prisms for the self-compacting concrete, whilst the same numbers were made for the normal conventional concrete. Three (3) specimens each for both mixes were tested on 7,21,28 and 56 days with equivalent cement to aggregate volumes being 1:2:4 (1:6) for the normal conventional concrete and 1: 3.75:2.25(1:6) for the self-compacting concrete. The compressive strength of the self-compacting concrete as compared to the normal concrete (control) offered a percentage increase of 90.44% on the 7th day, a further increase to 98.82% on the 21st day, and reduced to 43.86% on the 28th day and 33.07% on the 56th day. This marginal increase shows that self-compacting concrete offers better compressive strength than conventional concrete even under the same curing parameters and aggregate ratios. For the split tensile strength, the self-compacting concrete showed a percentage increase of 71.96% on the 7th day, 80.56% on the 21st day, the highest being 98.99% on the 28 days and reduced to 49.55% on the 56th day as compared to the normal concrete (control). This shows that the self-compacting concrete has a better tensile capacity than the conventional concrete(control). This means the self-compacting concrete is the least brittle and has a higher tensile strength than the normal concrete (control). The flexural strength recorded a declining differential percentage increase of 93.24% on the 7th day, 56.59% on the 21st day, 46.53% on the 28th day, and 28.01% on the 56th day. This shows that the self-compacting concrete has a higher ability of composites to resist bending deflection when the force is applied. Hence this was an indirect measure to compare the tensile strength of both the self-compacting concrete and normal concrete(control) and was determined by a third point loading or centre point loading test of the specimen in which the self-compacting concrete specimen proved a higher flexural strength.

Since the self-compacting concrete does not need any vibration during casting, comparing the densities of both self-compacting concrete and the normal concrete (control), the self-compacting concrete shows a higher percentage increase in densities of all specimens. The self-compacting concrete exhibited a higher percentage increase in densities of all the concrete specimens which indicates good durability and less porosity of the concrete.

Keywords: Strength characteristics; self-compacting concrete; normal conventional concrete; cubes; cylinders; prisms.

1. INTRODUCTION

Aggregates are encased in a cement matrix, which fills the voids and holds the aggregates together, to form concrete. The usage of concrete, a remarkably durable building material, stretches back to times before the Roman Empire. It was extensively utilized for construction in the Middle East, Greece, and Egypt prior to the Romans using it extensively for building roads [1]. “From the middle of the eighteenth century to the present, concrete has been the most widely used construction material. The components of concrete vary in each of these uses. Although concrete's tensile strength is only around 10% of its compressive strength, it has extremely strong fire resistance and compressive strength, which has prompted a lot of current research to improve concrete's overall strengths” [2,1].

Modern buildings in industrialized and developing countries are mostly made of concrete since, over time, there hasn't been a superior material. According to Joseph and Raymond's [3] research, concrete gains strength at an earlier age than at a later age. On average, it gains 26% of its 28-day strength in just one day and 85% in 21 days.

The use of self-compacting concrete (SCC) has transformed the placing of concrete since it compacts itself under its own weight without the need for outside vibration. According to Khayat et al. [4], the mix is solid, boasting a high deformability, significant isolation obstruction, low yield pressure, and moderate uniformity. This material flows under its own weight and needs external vibration to undergo compaction. In the development industry, the creation of self-compacting concrete (SCC) is an appealing achievement to overcome cast set-up concreterelated problems. Self-compacting concrete can be pumped farther because of its great fluidity and resistance to segregation, and it is unaffected by worker competence, the design and quantity of reinforcing bars, or the layout of a structure [5].

Self-compacting concrete is the only option when using compacting vibrators to consolidate concrete is not feasible. Japanese researchers initially produced SCC in the late 1980s. It is a very workable concrete that can pass through narrow spaces without bleeding or segregating under its own weight [6].

Superplasticizers are typically required for SCC in order to achieve high mobility. Segregation can be removed by adding a significant amount of powdered material or a viscosity-modifying additive. Fly ash, silica fume, limestone powder, glass filler, and quartzite filler are among the powdered materials that can be added [7].

Since material properties and mix proportions have a significant impact on self-compatibility, a process for the mix design of SCC must be developed. From the perspective of standardizing concrete, research has been done to provide a logical mix-design process and self-compatibility testing procedures. Vageesh et al. [8] state that SCC is cast in a way that eliminates the need for further inner or outer vibration for compaction. After installation, it has a very smooth surface and glides like "honey." In terms of composition, self-compacting concrete is made up of cement, aggregates, and water, much as traditionally vibrated concrete, with varying amounts of chemical and/or mineral admixtures added [9].

In a 2014 paper, Koehler and Fowler, [10] presented a mixed proportioning approach for SCC in which the dose of superplasticizer and the water/powder ratio were adjusted to achieve self-compatibility while the coarse and fine aggregate contents remained constant.

In self-compacting concrete, the fine and coarse aggregate contents are typically set at 40% and 50% of the mortar volume, respectively. The water to powder ratio is typically assumed to be 0.9–1.0 by volume, contingent upon the powder's characteristics and the dosage of superplasticizer [11].

Many trials are conducted in order to find the necessary water to powder ratio. According to Lofty et al. [12], in concrete application, the fresh condition of SCC exhibits great fluidity, self-compacting ability, and segregation resistance, all of which contribute to a decreased risk of concrete honeycombing.

With the aforementioned beneficial qualities of SCC generated, the reliability and longevity of reinforced concrete buildings may be significantly enhanced. The components that are used to make Self-Compacting Concrete (SCC) must, in general, meet BS-EN 206 specifications.

SCC is primarily characterized by three unique fresh concrete qualities that are vital to its functionality in both the pliable and hardened states. Additionally connected, these qualities need to be preserved for the necessary amount of time following mixing according to Aslani et al. [13].

To achieve these properties, material selection, proportioning, and quality control including production control are critical. The three essential fresh properties required by SCC are:

I. **Filling Ability:** Under the weight of its weight, the concrete must be able to flow through the formwork and fill every space without leaving any gaps. Because of its extreme fluidity, it may fill vertical components from the bottom and travel great distances in both the horizontal and vertical directions.
II. **Passing Ability:** Under the weight of the specified aggregate size, the concrete must be able to pass freely through the narrow crevices between reinforcements and other embedded items without stumbling or segregating.
III. **Segregation Resistance:** In order to stay homogenous during transit, placement, and after placement, the concrete must be able to meet the standards for both filling ability and passing ability.

Concrete is somewhat weak in shearing strength and notably poor in tensile or pulling strength, but it has a significant compressive or crushing strength [14]. According to Sabet et al. [15], the compressive strength (CS) of concrete indicates the degree of uniaxial compressive stress, or the qualities of the concrete upon hardening. Self-compacting concrete (SCC) is a popular concrete because it requires no vibration during placement, even in complex formwork, and it has a high degree of reinforcing [16].

2. MATERIALS AND METHODS

2.1 Materials

The concrete mix comprised ordinary Portland cement which satisfied the requirement of BS EN 197-1:2019; river sand as fine aggregate; crushed granite as coarse aggregate (12 mm); and potable water. In addition, a superplasticizer was added to the concrete to produce self-compacting concrete. Fig. 1 shows the coarse aggregates used in the study.

2.1.1 Superplasticizer

Superplasticizers are an essential component of modern concrete since they improve workability at low water-to-cement levels, allowing to production of long-lasting and environmentally friendly concrete. Superplasticizers are high-range water reducers that comply with ASTM C 1017 and are used in concrete to provide high-slump streaming concrete with a low-to-normal slump and water-cement ratio. Flowing concrete is a very fluid and workable concrete that requires minimal to no vibration to compress and is generally free of bleeding and segregation. The type of superplasticizer used for this research was MC-Power flow 6425.

2.2 Sieve Analysis

Tests of particle size distribution of the aggregates and silt content in fine aggregates were conducted per BS EN 933-1:2002.

2.3 Design of Test Specimens

Tables 1 and 2 present the details of test specimens for different mixes as outlined in the following:

Type A – cement, sand, gravel.
Type B – cement, sand, gravel and superplasticizer.

Fig. 1. Coarse aggregates (gravel)

Table 1. Details of compressive strength test specimens

Type of test specimen	**Curing days**					**Mix ratios**
		7	**21**	**28**	**56**	
A (control)	Cement, river sand, gravel	3	3	3	3	1:2:4, w/c 0.55
B	Cement, river sand, gravel, superplasticizer.	3	3	3	3	1:3.5:2.5 concrete mix, w/c ratio 0.28, superplasticizer of 1.4**%**
Total Number of cubes		24				

Table 2. Details of Split tensile strength test specimens

Type of test specimen	**Curing days**					**Mix ratios**
		7	**21**	**28**	**56**	
A (control)	Cement, river sand, gravel	3	3	3	3	1:2:4, w/c 0.55
B	Cement, river sand, gravel, superplasticizer.	3	3	3	3	1:3.5:2.5 concrete mix, w/c ratio 0.28, superplasticizer of 1.4%
Total number of cubes		24				

Table 3. Details of Flexural strength test specimens

Type of test specimen	Curing days					Mix ratios
		7	21	28	56	
A (control) B	Cement, river sand, gravel	3	3	3	3	1:2:4, w/c 0.55 1:3.5:2.5
	Cement, river sand, gravel, superplasticizer.	3	3	3	3	concrete mix, w/c ratio 0.28, superplasticizer of
Total Number of cubes		24				1.4%

2.4 Preparation of Concrete Test Specimens

2.4.1 Mix design

Concrete mix proportions of 1:2:4 (cement; fine aggregates; coarse aggregate) by weight with a water/cement ratio of 0.55 were used to prepare the control concrete and a mix proportion of 1:3.5:2.5 (cement; fine aggregates; coarse aggregate) by weight with water /cement ratio of 0.28, and 1.4**%** of cement weight for the Superplasticizer to prepare the Self-Compacting concrete. The concrete mix design was per IS: 10262 [17]. The cement content of 380 kg / m³ was used to meet a minimum requirement of 300 kg / m³ to avoid the balling effect. 12.5 mm is the average size of the coarse aggregate. A sieve analysis and silt test conforming to BS 1377-1:[18] were carried out for both the fine and coarse aggregate. A silt test was conducted on the fine aggregates per BS 1377-2:[19].

2.4.2 Mixing, casting and curing

In a concrete mixer, the concrete was mixed mechanically. The concrete mixer was filled with equal parts of fine and coarse aggregates after the cement and fine aggregates were batched in. The component materials were combined for approximately two minutes without water, and then water was gradually added to the dry mixture in the mixer. Mixing was standardized and had a consistent hue in a plastic mix. For thorough mixing, the time for blending was 1.5 to 2 minutes per rotation. The concrete mixer's output was 15 to 20 mixtures per hour. A slump test was conducted to determine the workability of the concrete. A total of 24 concrete cubes measuring 150mm x 150mm x 150mm, 24 cylinders measuring 150mm x 300mm, and 24 prisms measuring 150mm x 150mm x 500mm were cast to study the compressive strength, split tensile strength, and flexural strength of the concrete mixes. Concrete for each test specimen was cast in four layers and each layer was compacted by tampering 25 strokes using a rod. Fig. 2 shows the concrete cubes, cylinders, and prisms.

Curing of the test cubes, cylinders, and prisms was done by covering specimens with a sack and kept at an ambient average laboratory temperature of 28ºC and 100 percent relative humidity to avoid micro–cracking of the test specimens**.**

Fig. 2. Concrete test specimens

(a) Concrete test cubes, cylinders and Prisms

2.5 Testing of Specimens

2.5.1 Compressive strength

The test specimens were first weighed to determine the density of each concrete mix. The test was conducted in 150mm x 150mm x 150mm concrete cubes in a compression testing machine after a curing period of 7 days, 21 days, 28 days, and 56 days for 7th, 21st,28th, and 56th-day strength, respectively. The cubes were loaded monotonically until failure at a rate of 140kg/cm^2 per minute per British Standards BS EN 12390-3:[20]. Fig. 3a shows a concrete cube specimen under test.

The compressive strength of concrete was calculated using the formula in equation 1;

$$f_{cu} = P/A \qquad \text{(Eq 1)}$$

where:
f_{cui} = Compressive strength of concrete (N/mm^2)
P = maximum compressive load (N)
A = Cross-sectional area of cube (mm^2)

2.5.2 Split tensile strength

The split tensile test was carried out on 150mm x 300mm concrete cylinders and provided an indirect way of determining the tensile strength of the concrete. The test was carried out on the cylindrical samples after 7 days, 21 days, 28 days, and 56 days for 7th, 21st,28th, and 56th-day strength, respectively. The specimen was placed length-wise in a compression test machine as shown in Fig. 3b, and loading was applied along its length until failure per BS EN 12390-3:[20]. The tensile strength of the concrete was computed using the formula:

$$f_t = 2P / \pi DL \qquad \text{(Eq 2)}$$

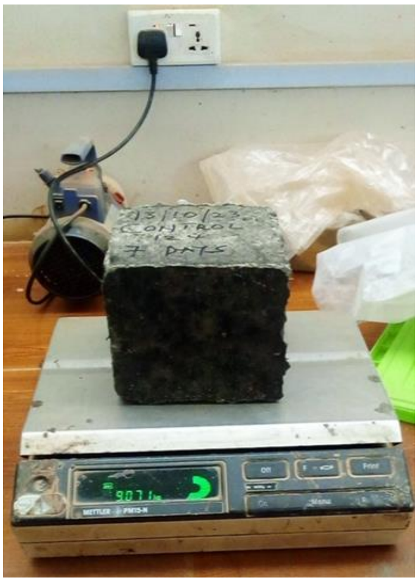
where:
f_t = tensile strength of concrete (N/mm^2)
P = maximum applied load (N)
D = diameter of cylinder (mm)
L = Length of cylinder (mm)

2.5.3 Flexural strength

The flexural strength or modulus of rapture test was carried out on 150mm x 150mm x 500mm concrete prisms and provided an indirect way of determining the tensile strength of the concrete. The test was carried out on plain concrete prism after 7 days, 21 days, 28 days, and 56 days of curing for 7th, 21st,28th, and 56th day strength, respectively. The specimen was placed length-wise in a beam test machine as shown in Fig. 3c, and loading was applied at the center of the prism across its length until failure with supports at ends leaving a clearance of 100mm at both ends. This test was per BS EN 12390-3:[20]. The tensile strength of the concrete was computed using the formula:

$$f_t = 1.5\,[P\text{max}\,L/BD^2] \qquad \text{(Eq 3)}$$

where:
f_t = tensile strength of concrete (N/mm^2)
P = maximum applied load (N)
D = depth of prism (mm)
B = breadth of prism (mm)
L = span of beam (mm)



(a) Concrete cube under test

(b) Split concrete cylinder under test

(c) Concrete Prisms under test

Fig. 3. Concrete specimens in test machine

3. RESULTS AND DISCUSSION

3.1 Sieve Analysis

Fig. 4 shows the particle size distribution for the coarse aggregate and fine aggregate. The results show that the coarse granitic aggregate lies within 6.3mm and 37.5mm. On the other hand, the fine aggregate component falls within 0.15mm and 10mm.

The effective size (D_{10}) of fine aggregate was 0.46mm. while the effective size was 14.5mm for the coarse crushed granitic aggregate. The coefficient of uniformity ($C_u = D_{60}/D_{10}$) was 1.66 for the crushed coarse aggregate and 1.96 for fine aggregates. These values of C_u less than 5 indicated the aggregate was poorly graded soil materials.

The coefficient of curvature ($C_c = D_{30}^2 / D_{10}\ D_{60}$) for the different aggregates was as follows:

Crushed coarse aggregate = 1.27; Fine aggregates = 1.0. With a C_c of between 1.0 and 3.0, the grain sizes would be expected to be so arranged that dense packaging was possible [21], (BS 812: 1973 1990), [22]. With a C_c value of 1.27, the crushed coarse aggregate would result in denser and stronger concrete compared with all the other aggregates whose C_c value was 1.0 and coincident with the lower limit.

3.2 Silt Content

The test results of silt content in the fine aggregates are presented in Tables 4 and 5, respectively. The average silt content recorded was 3.33 percent in the fine aggregates respectively These values were less than the permissible maximum silt content limit of 8 percent of sand for concrete production [23].

3.3 Workability

Workability may be defined as the ease with which concrete may be placed, compacted and finished. The slump test and compaction factor test were utilised to assess the workability of the fresh concrete. Slump test was conducted according to BS 1881-102 and compaction factor test was conducted according to BS 1881-103.

3.3.1 Slump test for normal conventional concrete

Slump test was performed according to BS 1881-102. The reduction in slump in time was measured. The mould's internal surfaces were cleaned and oil was applied. The mould was then placed on a flat, non-porous horizontal base plate and filled in four roughly equal layers with the prepared concrete mix, uniformly tamping each layer over the cross-section of the mould with 25 strokes of the rounded end of a tamping rod. Tamping of a subsequent layer of the concrete was carefully done to just penetrate the underlying layer. After filling mould with the final layer, the excess concrete was removed with a trowel and the top levelled. The leaking mortar or water between the mould and the base plate was cleaned and the mould was immediately and steadily raised from the concrete in a vertical direction. The difference between the height of the mould and the height of the test specimen of the slump was measured. The above procedure was carried out in a vibration-free or shock-free environment and within 2 minutes after sampling.

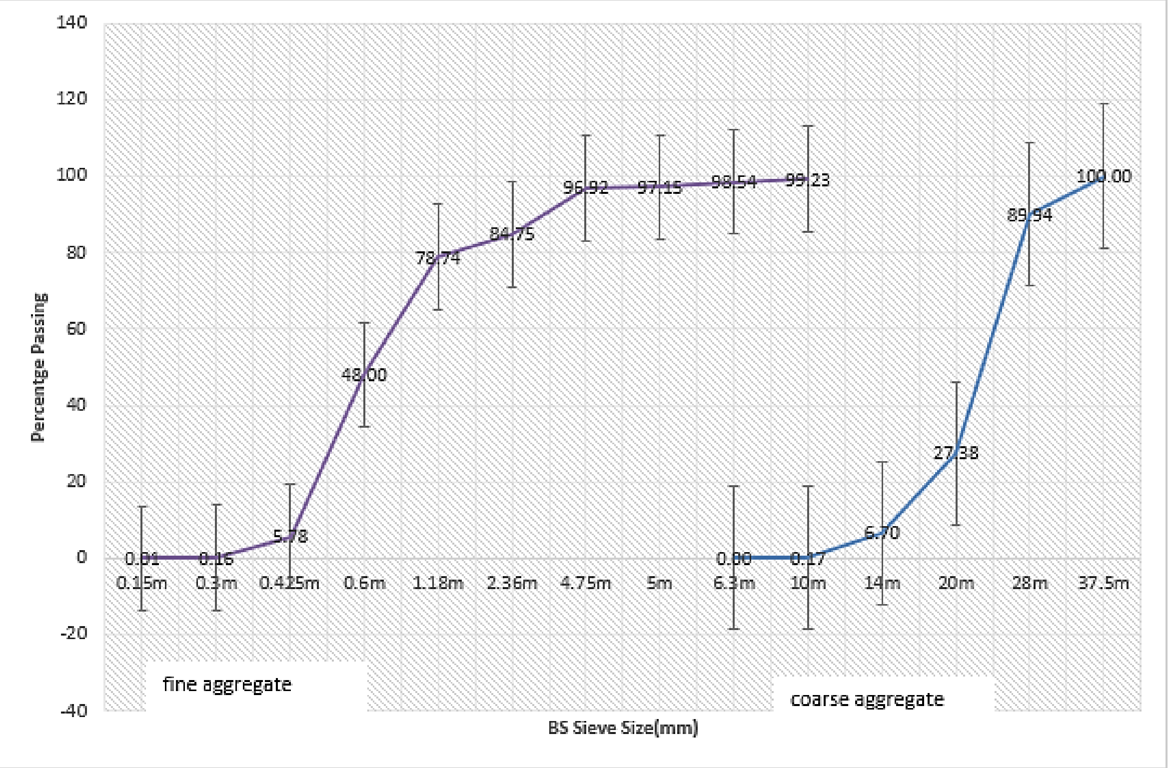


Fig. 4. Particle size distribution of virgin coarse aggregate, and fine aggregates

3.3.2 Slump test for self compacting concrete

Slump test for the Self Compacting Concrete was performed according to IS 1199 (Part 2): [24] and BS EN 12350-8:[25]. The consistency or workability of concrete was gauged by the slump test. The standard slump test was adjusted to account for flow and spread properties for self-compacting concrete (SCC). The slump cone and base plate were ensured that they were clean and free from any previous concrete residue. The slump cone and base plate were lightly moistened to prevent the concrete from sticking. Placing the base plate on a level, stable surface, the slump cone was turned upside down and placed in the centre of the base plate. The slump cone was filled three layers; it was filled with the first layer of SCC up to one-third of its height. It was next filled up to two-thirds of its height for the second layer and finally filled to the brim. No tamping was required for SCC since it was supposed to be self-compacting. The top surface of the concrete was levelled off with a trowel. The cone was lifted vertically and carefully in one smooth motion to allow the concrete to flow out freely. The diameter of the concrete spread in two perpendicular directions was measured and the average of the two measured diameters was calculated. The time taken for the concrete to spread to a diameter of 500 mm (T50 time) using a stopwatch was recorded. This was an indication of the viscosity of the SCC.

The various slump values recorded are shown in Table 4.

3.4 Density

Tables 5-7 presents the findings from the density assessment of the different combinations. The density of concrete rose for all mixes as the curing period extended from seven to twenty-eight days. The percentage changes in mix densities relative to the control are displayed in brackets with (-ve) indicating a drop and (+ve) indicating an increase. The table shows that all of the mixes' densities satisfy the specifications needed for concrete to have a standard weight.

Table 4. Workability

Type of concrete	Mix ratio	Slump value
Self Compacting Concrete	1:3.5:2.5	685mm
Normal Conventional Concrete	1:2:4	79mm

Table 5. Silt content in river sand

Determination of silt content				
Observation Sheet				
Number	**Description**	**Sample No**		
		Sample 1 (ml)	**Sample 2 (ml)**	**Sample 3 (ml)**
1	Level of content (ml)	150	150	150
2	Depth of sand without silt -V1 (ml)	80	80	80
3	Thickness of visible silt V2 (ml)	2	4	2
4	Volume of Water (ml)	70	70	70
5	Percentage by volume of Silt depth to sand thickness (%) $\frac{V2}{V1} \times 100$	2.5%	5%	2.5%
	Average Content	**3.33%**		

Table 6. Density of concrete Cube mixes

Mixes	Average Density (kg/m^3)			
	7 DAYS	**21 DAYS**	**28 DAYS**	**56 DAYS**
Fine Aggregates, coarse aggregate and cement (type A - CONTROL)	2075.36	2255.86	2319.18	2416.58
Fine Aggregates, coarse aggregate, cement and superplasticizer (type B)	2424.9 (+16.84)	2187.73 (-3.02)	2380.68 (+2.65)	2483.52 (+2.77)

(Percentage change from control (Type A) in brackets)

Table 7. Density of concrete Cylinder mixes

Mixes	**Average Density** (kg/m^3)			
	7 DAYS	**21 DAYS**	**28 DAYS**	**56 DAYS**
Fine Aggregates, coarse aggregate and cement (type A - CONTROL)	2298.29	2226.04	2226.04	2279.71
Fine Aggregates, coarse aggregate, cement and superplasticizer (type B)	2300.28 (+0.09)	2330.28 (+4.68)	2330.28 (+4.68)	2600.94 (+14.09)

(Percentage change from control (Type A) in brackets)

Table 8. Density of concrete Prism mixes

Mixes	**Average Density (kg/m^3)**			
	7 DAYS	**21 DAYS**	**28 DAYS**	**56 DAYS**
Fine Aggregates, coarse aggregate and cement (type A - CONTROL)	2410.60	2404.93	2597.67	2558.88
Fine Aggregates, coarse aggregate, cement and superplasticizer (type B)	2604.94 (+8.06)	2604.94 (+8.32)	2617.53 (+19.86)	2644.2 (+3.33)

(Percentage change from control (Type A) in brackets)

Table 9. Average Compressive strengths of concrete mixes

Specimen	**7 Days**	**21 Days**	**28 days**	**56 days**
Type A Control	15.59	17.02	24.28	26.91
Self-compacting concrete	30.00 (+90.44)	33.84 (+98.82)	34.93 (+43.86)	35.81 (+33.07)

Note: Figures in brackets denote the percentage change of mix strength from the control mix (Type 1)

Fig. 5. Compressive strengths of the concrete specimens at different ages

3.5 Compressive Strength

The compressive strength test for concrete measures the load-bearing capacity of the concrete before failure. Concrete compressive strength goes from 15N/mm^2 to 30N/mm^2 for general loading on light structures and beyond for heavily loaded structures.

The average compressive strength data for the different concrete mixtures are shown in Table 9. They show a general increase in strength with increasing curing days, with all combinations showing the highest strength on day 56 as predicted. Fig. 5 presents the results in additional detail. This pattern suggests that the cement matrix in the mixes is continuously hydrating. The percentage changes in the self-compacting concrete's compressive strength from the control mix (Type A) are also shown in the results. The table demonstrates that, out of all the mixes, self-compacting concrete had the highest or best compressive strength.

3.6 Split Tensile Strength

The split tensile test for concrete measures the tensile strength capacity of the concrete. Generally, the direct concrete tensile strength and the split cylinder tensile strength vary from 5 to 13 percent, and the flexural strength from 11 to 23 percent of the concrete cube compressive strength Pacheco-Torgal et al. [26]. These ratios may vary even further depending on the composition of the concrete mix.

The split tensile strength of the concrete generally increased with the curing days as illustrated in Table 10 and Fig. 6. A comparison of the influence of the various aggregate replacements on the concrete mix shows that the Self-Compacting Concrete (Type B) mix which comprises ordinary Portland cement, coarse aggregate, river sand, and superplasticizer provided the best option as the percentage of tensile strength was highest relative to the control mix.

3.7 Flexural Strength

“Flexural Strength or modulus of rapture dictates how a material behaves when bent, whether it will hold or break. This measures the durability and resistance of materials under study.

Generally, flexural strength is a measure of a material’s resistance to deformation under bending forces, hence the deflection and cracking behavior of concrete depend on the flexural tensile strength of concrete” [27]. Standardized testing methods such as 3-point and 4-point bending tests are used to determine a material’s flexural strength, with variations in testing to suit different materials and provide insight into their characteristics under bending loads [28].

Table 10. Average split tensile strengths achieved by concrete specimens

	7 Days	**21 Days**	**28 days**	**56 days**
Type A Control	1.89	2.16	2.97	4.42
Self-compacting concrete	3.25 (+71.96)	3.90 (+80.56)	5.91 (+98.99)	6.61 (+49.55)

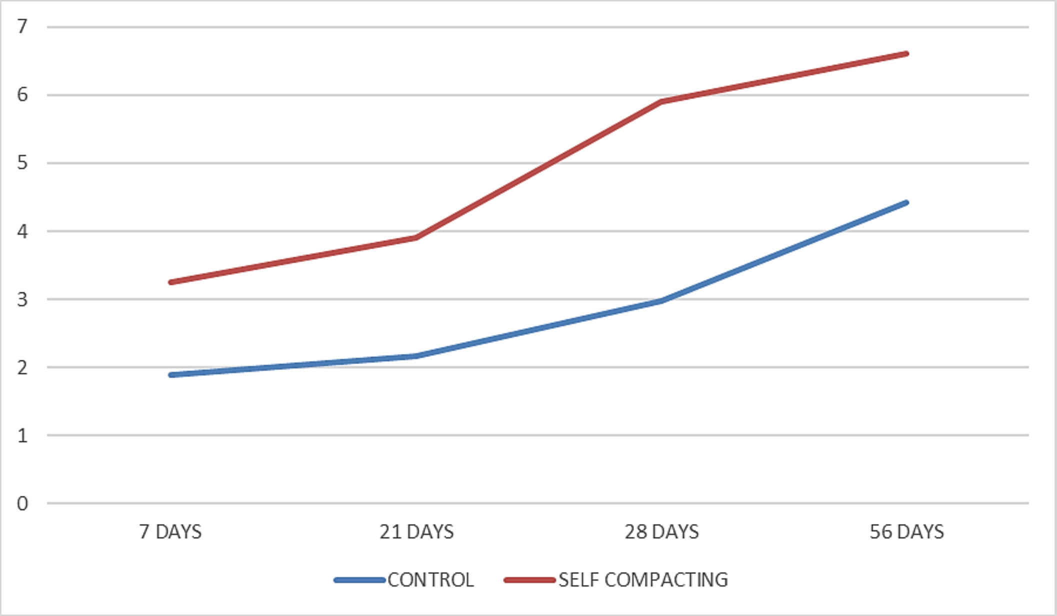


Fig. 6. Split tensile strengths of the concrete specimens at different ages

Table 11. Average Flexural strength achieved by concrete specimens

	7 Days	21 Days	28 days	56 days
Type A Control	4.198	7.4249	8.4302	11.7695
Self-compacting concrete	8.1124 (+93.24)	11.6266 (+56.59)	12.3524 (+46.53)	15.0664 (+28.01)

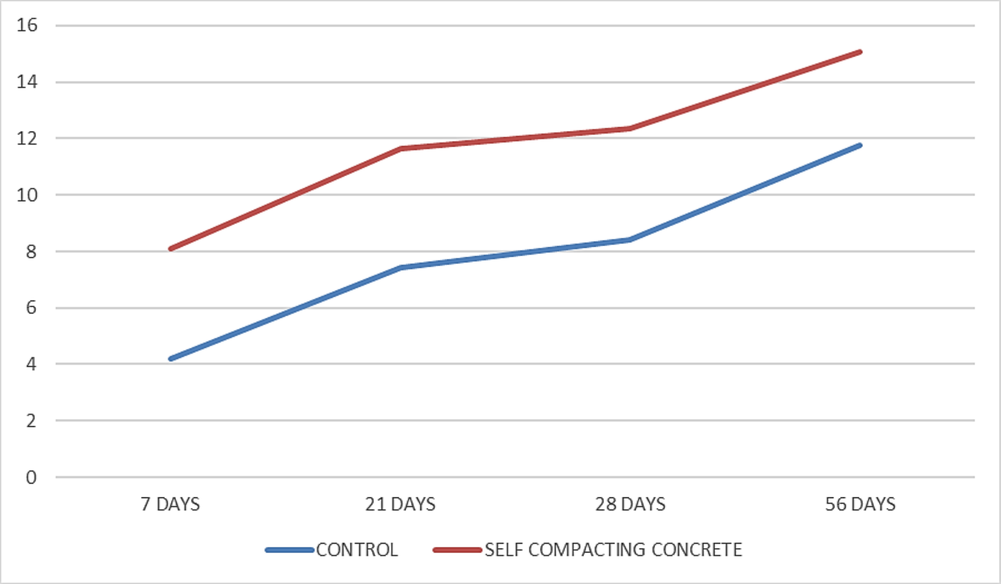


Fig. 7. Flexural strength of the concrete specimens at different ages

As illustrated in Table 11 and Fig. 7, there was a massive percentage increase of (+93.24) on the 7th day, (+56.59) on the 21st day, (+46.53) on the 28th day and (+28.01) on the 56th day. This shows that there was a very high earlier strengths attained by the self compacting concrete on the early ages as compared to its counterpart (normal conventional concrete) but as the ages increased from 21st,28th, and 56th days there was a decline in the percentage increase. This proves that the normal conventional concrete increases significantly in strength as the ages increases as compared to the self compacting concrete even though the self compacting concrete was still higher than the normal concrete [29].

3.8 Discussion

The compressive strength of the self-compacting concrete as compared to the normal concrete (control) offered a percentage increase of 90.44% on the 7th day, a further increase to 98.82% on the 21st day, and reduced to 43.86% on the 28th day and 33.07% on the 56th day. This marginal increase shows that self-compacting concrete offers better compressive strength than conventional concrete even under the same curing parameters and aggregate ratios [30].

For the split tensile strength, the self-compacting concrete showed a percentage increase of 71.96% on the 7th day, 80.56% on the 21st day, the highest being 98.99% on the 28 days and reduced to 49.55% on the 56th day as compared to the normal concrete (control). This shows that the self-compacting concrete has a better tensile capacity than the conventional concrete(control). This means the self-compacting concrete is the least brittle and has a higher tensile strength than the normal concrete (control) [31].

The flexural strength recorded a declining differential percentage increase of 93.24% on the 7th day, 56.59% on the 21st day, 46.53% on the 28th day, and 28.01% on the 56th day. This shows that the self-compacting concrete has a higher ability of composites to resist bending deflection when the force is applied. Hence this was an indirect measure to compare the tensile strength of both the self-compacting concrete and normal concrete(control) and was determined by a third point loading or centre point loading test of the specimen in which the self-compacting concrete specimen proved a higher flexural strength [32,33].

Since the self-compacting concrete does not need any vibration during casting, comparing the densities of both self-compacting concrete and the normal concrete (control), the self-compacting concrete shows a higher percentage increase in densities of all specimens. The self-compacting concrete exhibited a higher percentage increase in densities of all the concrete specimens which indicates good durability and less porosity of the concrete.

4. CONCLUSION

Based on the various test results, it is concluded that self-compacting concrete provides better characteristics in terms of durability, strength, and economy in concrete production, although their use should be dependent on the percentage volume of superplasticizer added to achieve higher strength properties in the utilization to substitute conventional concrete (control). In terms of the compressive, flexural, tensile strength, and density of concrete produced in comparison with both the control and self-compacting concrete, the results still point out clearly that the self-compacting concrete mixes offer the highest percentage increase of (+90.44, +98.82, +43.86, and +33.07) for compressive, (+71.96, +80.56, +98.99, and +49.55) for tensile, (+93.24, +56.59, +46.53, and +28.01) for flexural strength respectively.

5. RECOMMENDATIONS FOR SCC AS PREFERED OPTION

Conventional concrete which uses naturally sourced conventional aggregates devoid of any superplasticizers or admixtures remained the best recommendation for all types of concrete works, regardless of the mix ratio until the emergence of the self-compacting concrete which from research can offer inexpensive alternatives with the inclusion of admixtures/superplasticizers. However, in using these replacement materials it is recommended that:

(i) Self-compacting concrete offered higher compressive strengths of about 35.81 N/mm² at 56 days than the normal concrete of 26.91 N/mm², split tensile strength of about 6.61 N/mm² for self-compacting concrete, and 4.42 N/mm² for normal control concrete indicating a percentage increase of (+49.55%) and a flexural strength of 15.07N/mm² at 56 days for self-compacting concrete and 11.77N/mm² for normal concrete representing 28.01 percent increase which means the self-compacting concrete must be recommended for heavy load bearing reinforced concrete structures.

(ii) Since self-compacting concrete offers higher strengths in terms of compressive, tensile, and flexural using similar aggregate volumes, self-compacting concrete is deemed to be very economical and less expensive and lightweight to heavy structures and mass concrete. However, the concrete ratios can be increased accordingly using the same volume of superplasticizer dosage and volume of cement to give an average strength for such works.

(iii) Since self-compacting concrete attained very high strengths at the earlier ages, 7 and 21 days, the formwork can be removed earlier days than the normal control concrete which needs more time to cure and attain its required strengths.

(iv) Self-compacting concrete must be recommended as quality concrete for heavy-duty structures and those exposed to the weather since it has very low permeability and minimized voids due to its high density recorded.

(v) Self-compacting concrete should be recommended because of its easy-to-use requirements as the elimination of internal or external vibration for compaction, better flowability, workability, and pumpability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. Chat gpt 4.0 was used in editing the references to an updated versions within the last 10 years as required by the review.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/119020