INTERNATIONAL JOURNAL OF LATEST TECHNOLOGY IN ENGINEERING, MANAGEMENT & APPLIED SCIENCE (IJLTEMAS)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VI, June 2026

Fresh State Properties of Self-Compacting Concrete Using Recycled Aggregates

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DOI: https://doi.org/10.51583/IJLTEMAS.2026.150700022

Received: 12 June 2026; Accepted: 17 July 2026; Published: 06 August 2026

ABSTRACT

Self compacting concrete (SCC) is concrete that does not require vibration for placing .It consists of same components as conventionally vibrated concrete which are cement, aggregates and water in addition to mineral and chemical admixtures. This research focused on the fresh state properties of self compacting concrete using recycled aggregates wastes from constructed and demolished structures. Recycled coarse aggregates used in the production of the concrete was in varying percentages of 0%, 20%, 40%, 60%, 80% and 100% as replacement of natural coarse aggregates by volume. Portland cement of 42.5N conforming to BS12 (1996) and superplasticizing admixture was used to maintain a slump of 75mm in all the six mixes used. All mixes exhibited slump flow in the range of 620 – 770mm which ranked them in the SF1 and SF2 slump flow class under EFNARC guidelines. T50 slump flow was between 2.08secs to 3.15secs categorized under vicious flow (VF2) class. V-funnel time was from 6 – 10 secs which is considered adequate under VF1 class while the L-box test was not less than 0.8 indicating deformability and segregation resistance. Self-compacting concrete made with recycled aggregates have achieved the target strength in all the mixes and also satisfied the fresh state properties required for SCC as per EFNARC specification. The work undertaken has demonstrated the suitability of recycled coarse aggregate s(RCA) for use in a range of normal grade concrete applications. Indeed, the results have shown that up to 30% RCA can be used, without any modification in the mix design, in concrete construction with performance similar to natural aggregate concrete

INTRODUCTION

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement (Asmus and Christensen, 2009). The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditionally vibrated concrete (Bonen and Shah, 2005). Self-compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It “flows” like honey and has a very smooth surface level after placing. With regard to its composition, self-compacting concrete consists of the same components as conventionally vibrated concrete, which are cement, aggregates, and water with the addition of chemical and mineral admixtures in different proportions (Buck, 1997). Adoption of self-compacting concrete (SCC) offers substantial benefits in enhancing construction productivity, reducing overall cost, and improving work environment. Cost reduction in building is the primary objective especially in developing countries like Nigeria. Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self-compacting concrete is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances. Self-compacting concrete was developed to improve the durability of concrete structures. Various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. An insightful investigative study of the SCC in view of its applicability in the Nigerian construction industry would boost construction economy and reduce wastage of recourses.

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LITERATURE REVIEW

Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise buildings, defense Installations, environment protection and local/domestic developments. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixture(s). Among these, aggregates, i.e. inert granular materials such as sand, crushed stone or gravel form the major part. There have been two innovative developments in contemporary concrete: self-compacting concrete (SCC) and ultra-high-performance concrete (UHPC). SCC is a type of high-performance concrete. High-performance concrete is a concept developed in the 1980s. It is defined as a concrete that can meet special performance and uniformity requirements, which cannot always be achieved routinely by using only conventional materials and normal mixing, placing, and curing practices. The requirements may involve enhancement of the characteristics of concrete, such as placement and compaction without segregation, long-term mechanical properties, higher early-age strength, better toughness, higher volume stability, or longer service life in severe environments. Self-compacting concrete is a typical example of high-performance concrete that can fill formwork in a compacted manner without the need of mechanical vibration (Fugiwara, 1992). SCC was initially developed by Professor Okamura and his students in Japan in the late 1980s. At that time, concrete construction was blooming everywhere in Japan. Since Japan is in an earthquake zone, concrete structures are usually heavily reinforced, especially at beam–column joints. Hence, due to low flowability, conventional concrete could hardly flow past the heavy reinforced rebars, leaving poor-quality cast concrete and leading to poor durability. Sometimes, the reinforcing steel was exposed to air immediately after demolding. To solve the problem, Professor Okamura and his students conducted research to develop a concrete with high flowability (Shindoh and Matsuoka, 2003). With the help of the invention of the high-range water reducer or plasticizer, such a concrete was finally developed. They were so excited that they called this concrete "high-performance concrete" at the beginning. It was corrected later on to SCC, as HPC covers broader meanings. His investigation found that insufficient compaction was the most common cause of deterioration of concrete structures and suggested an increase in the flowability of the fresh mixture to eliminate compaction, i.e., "self-compacting" concrete mixtures (Kuroiwa et al., 1993). In Europe, a large, industry-led (NCC Sweden, GTM-Vinci France, and six other partners) research project was funded by the European Commission in 1997 (Grauers, 1997). The European SCC project proved that SCC was practical for application using a variety of local materials, and that the expected benefits were obtainable in real construction practice. The fluidity of self-compacting concrete was realized with the invention of high range of water-reducing admixtures or super plasticizers. The alternative approach to raising consistency was to increase the cement paste content Durability is a main requirement of HPC. It has been found that many concrete structures could not fulfill the service requirement, due not to lack of strength, but to lack of durability. For this reason, concrete with high performance to meet the requirement of prolonging concrete service life was greatly needed. SCC is considered an environmentally friendly material. First, the application of SCC on a construction site can eliminate the need for vibration to compact the concrete. The compaction of fresh concrete by vibration is generally recognized as a heavy physical job and an unpleasant activity in the concrete construction process. The vibration can cause high noise levels, up to 90dB, that are not good for public health, especially the health of the operators. Second, the acceleration generated by vibrators can reach 0.70 to $4 m/s^2$ and has potential to injure the vibrator operator. Hence, eliminating the vibration significantly improves health and the environment on a concrete construction site. Thirdly, some skill and experience are needed for vibrator operators in compacting fresh concrete into a satisfactory concrete. Lack of experienced workers in many regions may lead to low quality of concrete. The application of SCC can solve this problem and ensure consistent high quality for concrete structures. The application of SCC also makes automation of construction possible, leading to higher productivity. This is envisaged not only in precast concrete production; but also for in situ concreting operations. The introduction of SCC benefit architects and structural engineers, and ultimately the users of buildings. New types of structural elements, which were not possible with traditional concrete, can be produced using SCC. Such elements include different types of steel–concrete. The flowability of SCC is measured in terms of the reduction in flow of SCC after passing the J-ring as compared to the free slump flow without a J-ring (Brameshuber and Uebachs, 2001; Daczko, 2003; Khayat et al., 2003; ASTM, 2006). The passability of SCC can also be indexed in terms of the difference in the height of concrete between the inside and outside of the J-ring (European Federation of National Trade Associations, 2002; Precast/Prestressed

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Concrete Institute, 2003). Similar to the slump flow test, visual inspection after the J-ring test should be carried out to detect any signs of segregation.

Due to its attractive advantages, SCC has been widely used throughout the world. Full-scale trials and demonstrations were carried out in the early 1990s, and self-compacting concrete was first used in significant practical applications in Japan (Hayakawa et al., 1993). The gradual increase in volume consumption in Japan reached its peak in the construction of the two anchorages of the Akashi–Kaikyo bridge in 1997. A total of 600,000m3 of different varieties of SCC were placed, which remains the most prominent landmark application of SCC and the largest single application to date. In India, large application of SCC was commenced during the Delhi Metro Project in 2003 (Vachhani et al., 2004). However, the annual consumption of SCC in India ranges only from 50,000 to 100,000m3, about 0.1% of the total concrete production (Asmus and Christensen, 2009). In China, due to the booming infrastructure construction in the last few decades, the applications of SCC have been speeded up. A steel fiber-reinforced SCC with compressive strength of 60MPa has been used in the construction of the new China Central TV station.

MATERIALS AND METHODS

The materials used are:

- Ordinary Portland cement(Grade 53) : conforming to BS 12:1996 with specific gravity, specific surface area and 28 days compressive strength of 3.18, 380 m^2/kg, and 56.5 MPa respectively.
- Silica fume: grade 920D having specific gravity 2.3.
- River sand: Locally available river sand was used as fine aggregate. The grading of sand satisfied the BS 882:1992.
- Natural aggregate (NA): crushed basalt of maximum size 12 mm
- Recycled aggregate (RCA) : of 12 mm maximum
- Superplasticizer: polycarboxylic-ether polymer based admixture, commercially branded as Auramix 400.

Method: Six types of concrete mixes were made. In each mix natural coarse aggregate was replaced by recycled coarse aggregate in the ratio of 0%, 20%, 40%, 60%, 80% and 100% by volume. A 42.5N Portland cement (PC) conforming to BS 12 (1996) and superplasticizing admixture- to maintain a nominal slump of 75mm were used throughout the work for concrete production.Test methods as suggested by EFNARC (i.e. European Federation of National Associations Representing for Concrete) were used. Slump-flow test for flowability, V-funnel and T500 for viscosity and L-box test for testing passing ability. The segregation resistance was observed visually during slump flow test. The workability (slump and compacting factor) and stability (bleeding and segregation) of recycled coarse aggregates (RCA) concrete mixes were determined. In addition, in order to assess the effect of RCA on the retention of the workability and maintenance of entrained air content with time, further tests were carried out up to 150 and 60 minutes respectively. In general, results showed a reduction in slump value with increasing RCA content in the mix, but this remained essentially within the specified tolerances of ± 25mm, BS 5328 (1991). In order to assess the effect of RCA content on the maintenance of air content in concrete with time, tests were carried out up to 60 minutes, following alternate mixing and standing for 5 minute periods to simulate transportation and handling conditions in practice. The results obtained, indicate negligible differences in air loss between NA and RCA concretes, suggesting no identifiable effect of RCA characteristics or source. The workability loss, in terms of compacting factor, of both recycled and natural aggregate concrete mixes was measured up to 150 minutes after casting, at 30 minutes intervals. The relationship between workability loss and RCA content was found to be of uniform nature, with RCA concrete exhibiting lower loss compared to control concrete.

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Table 1: Mix proportions for RCA concrete mix (w/c 0.60)

Mix Type	Cement (Kg)	Coarse Aggregate (Kg)		Fine Aggregate (Kg)	Silica Fume (Kg)	Water (Kg)	Dose of SP (Kg)
		Normal	Recycled				
R0	348	804	0	970	115	185	**4.6**
R20	348	644	133	970	115	185	**4.6**
R40	348	483	266	970	115	185	**4.6**
R60	348	322	399	970	115	185	**4.6**
R80	348	161	532	970	115	185	**5.5**
R100	**348**	**0**	**666**	**970**	**115**	**185**	**5.5**

RESULTS AND DISCUSSION

Fresh state properties of self-compacting concrete (SCC)

Mix Type	Slump Flow (mm)	T-50 Slump Flow (sec)	V- Funnel (sec)	L- Box (H1/H2)
R0	670	2.57	6.51	0.92
R20	740	2.08	6.07	0.98
R40	720	2.38	6.19	0.93
R60	765	2.15	6.62	0.95
R80	700	2.81	7.13	0.97
R100	620	3.15	7.86	0.90

All mixes exhibited slump flow in the range of 620-770 mm which ranks all the designed mixtures in the (Slump Flow) SF1 and SF2 class as per EFNARC guidelines which is the most common class in general civil engineering usage and practice. The T50 slump flow is the time for which concrete reaches the diameter of 50 cm and it was measured during execution of slump flow test. It represents the viscosity of mixture. All the mixes recorded the T50 time between 2.08 sec to 3.15 seconds which belong to (Viscous Flow) VF2 class. As per EFNARC specification V-funnel time ranging from 6 to 12 seconds is considered adequate. The test results of V-funnel test for all mixes meet the requirement of flow time for VF1 class which is an indication of good filling ability even with congested reinforcement. The L-box test examined another key property – passing ability (PA). All the mixes meet the criterion that the ration of heights of concrete at the ends of L-box is no less than 0.8, and as the test was conducted with three rebars they were ranked to the PA2 class which is suitable for densely reinforced structures. All the mixes showed horizontal slump flow without any bleeding at the periphery which indicates good deformability and segregation resistance.

CONCLUSION

Self-compacting concrete made with recycled aggregates have achieved the target strength in all the mixes and also satisfied the fresh state properties required for SCC as per EFNARC specification.

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