Effects of Nigerian Limestone and Superplasticizer on the Hardened Properties of Self Compacting Concrete

Ede, A. N.
Structural Engineering, Department of Civil Engineering,
Colleg of Science and Technology,
Covenant University Ota, Ogun State, Nigeria
E-mail: anthony.ede@covenantuniversity.edu.ng

Adegbite, A. A.
Works and Maintenance Department,
University of Ibadan, Oyo State, Nigeria
E-mail: femadclassics@gmail.com

ABSTRACT

The durability of concrete structures has posed a problem of great significance all over the world and the Nigeria's construction industry is highly plagued by this problem as can be testified by the numerous collapsed concrete structures verified in Nigeria in the past few years. Good concrete works require good production process by skilled workers; however, the inadequacy of the needed skilled workers in Nigeria's construction industry is evidenced in poor quality of concrete construction works and the massive importation of cheap and partially skilled labour from neighbouring countries. This research studies the properties of self-compacting concrete (SCC) at different replacement levels of cement with limestone powder. Theinfluence of Nigerian limestone powder in this SCC is tested and the compressive strength of the SCC compared to that of normal concrete. Results obtained are good and predicts that the use of Nigerian limestone powder can improve the quality of concrete used in Nigeria construction industry and elsewhere in the world.
Keywords*: Self Compacting Concrete, Limestone powder, Compressive Strength.*

INTRODUCTION

Concrete is the most commonly used construction material for buildings and infrastructures worldwide and stands out as the largest consumer of natural resources such as cement, aggregates and water. On the other hand, the durability of concrete structures has posed a great problem all over the world and the Nigeria's construction industry remains a good example of where the effect of poor durability is very rampant. Poor quality building material has been identified as one of the principal causes of building collapse in Nigeria (Ede, 2010). Over 95% of the frequent cases of building and collapse verified in Nigeria affect concrete structures. This makes the desire for durable concrete works very pressing if the nation is ever to attain sustainable development in buildings and infrastructures. Good production process will produce good concrete works. But the difficulty of getting cheap skilled labour

ISSN: 2141 - 6745

for concrete works in Nigeria is a fact that must not be overlooked if good quality must be attained and if the ever increasing cost of construction must be controlled. The inadequacy of the needed skilled workers in Nigeria's construction industry has led to massive importation of cheap and partially skilled labour from neighbouring countries like Benin, Togo, and Niger etc. As skilled workers for the production of quality conventional concrete continues to decrease worldwide, the desire for durable concrete structures will necessitate more advancement in the use of Self-Compacting Concrete and hence the necessity of this research. Over the past recent years, concrete has moved from its conventional nature to a customised material consisting of new constituents to meet the specific needs of the construction industry. The ever growing use of concrete in special construction works and often closely spaced reinforcing bars have made it very important to produce concrete that ensures proper filling ability, good structural performance and adequate durability (Shah et al, 2009).

The required workability for casting concrete depends on the type of construction, degree of congestion of the reinforcement, the complexity of the formwork, placement procedures and consolidation methods (Khayat, 1999). With the increased use of congested reinforced concrete, there is a growing need for highly floodable concrete to ensure proper filling of the formwork and all the hidden angles around the reinforcement (Lambros, 2003).Achieving adequate compaction aroundsome types of reinforcement can be demanding, given the restricted access to the poker vibrators. Skilled labour and strict quality control are required to ensure sufficient compaction and adequate homogeneity of the cast concrete (Khayat, 1999).

Self-consolidating concrete (SCC)is a highly flowable concrete that can spread into difficult places under its own weight and achieve good consolidation in the absence of vibration without exhibiting defects due to segregation and bleeding (Khayat, 1999). The necessity of this type of concrete was proposed by Professor Hajime Okamura in 1986 and first built in 1988. It performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties (Okamura and Ouchi 2003).

Partial replacement of cement by an equal volume of limestone powder with a specific surface area ranging between 500 and 1000 m^2/kg can result in an enhancement in fluidity and a reduction of the yield stress of highly flowable mortar (Yahiaet al., 1999).The basic ingredients to make SCC are the same as those used in making conventional concrete. The main difference is that SCC, in general, has a comparatively high fine to coarse aggregate ratio, a low water-cement ratio, viscosity enhancing additives and good aggregate grading. The main aim of this experimentation is to find out the effect of adding Nigerian limestone on the flow and strength properties of self-compacting concrete containing high range water reducing super plasticiser.

MATERIALS AND EXPERIMENTATION

Cement: the SCC mixes studied in this research were prepared with a Nigerian Portland Cement conforming to BS EN 197 Part 1: Composition, specifications and conformity criteria for common cements.

Mineral additive: the mineral additive used in this study is Limestone powder collected from LarfargeWapco Cement Factory EwekoroOgun State.

Admixtures: the superplasticisers or high range water reducing admixtures adopted is Conplast SP 432 MS conforming to BSEN 934-2 2000. It is a chloride free, superplasticising admixture based on selected sulphonated naphthalene polymers. The admixture was added to the concrete with the mixing water to obtain the best results.

Aggregate: Good quality river sand limited to 4.45mm was used as fine aggregate and crushed granite limited to 20mm was used for this study.

Water: Ordinary potable water available in the laboratory was used.

Mix proportion: The proportions of the concrete mixtures were produced in 5 samples. NC sample is for normal concrete, while SCC samples 1 to 4 are made of the same dosage of aggregates, water and super plasticizer, while diminishing the dosage of cement and increasing that of limestone powder. For all the mixtures, the coarse and fine aggregates were weighed in a room dry condition. The rheological tests of SCC mixes with various % of replacement of cement with limestone powder are determined by conducting tests such as slump flow test, L-box and V-funnel test for each % of replacement.

Slump Test + T_{500}: slump flow and T_{500} timewas used to assess the flowability and the flow rate of SCC in the absence of obstructions. The slump flow test measures the free unrestricted deformability and the T_{500} measures the rate of deformation within a defined flow distance.

L-Box Test: This is used to investigate the passing ability of SCC. It measures the reached height of fresh SCC after passing through the specified gaps of steel bars and flowing within a defined flow distance. With this reached height, the passing or blocking behaviour of SCC can be estimated.

V-Funnel: The flow time of the V-funnel test is to some degree related to the plastic viscosity (Schutter, 2005) and it gives an indication of the filling ability of SCC.

Casting and Curing: Cast iron moulds were used to cast the 150X150X150mm size standard cubes for the determination of compressive strength. The test specimens are stored in moist air for at least 16 hours for 3 days, protected against shock, vibration and dehydration at temperature of 25 °C ± 5 °C (hot climates). After this period the specimens are marked and removed from the molds and kept submerged in clear fresh water at a temperature of 20 °C ± 2 °C and a relative humidity e" 95 % until taken out prior to test. Curing of the (34) cubes specimens of 150x150x150 mm concrete cubes to determine compressive strengths for 7 days, 14 days, 21 days, and 28 days were done according to BS EN 12390-2-2000.

Compressive Strength Test: the cubic test specimen meets the requirements of EN 12350-1. A constant rate of loading within the range 0,6 ± 0,2 MPa/s (N/mm²·s) was applied. After the application of the initial load of approximately 30% of the failure load, the load was increased continuously at the selected constant rate ± 10 %, until no greater load can be sustained.

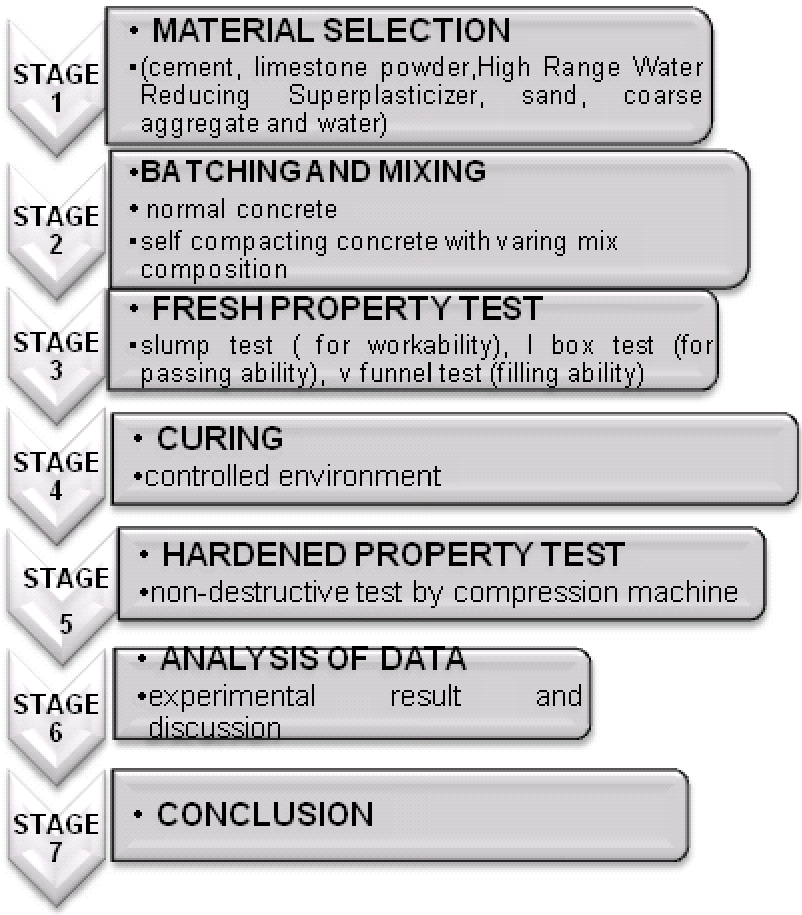

Fig 1: Schematic diagram showing the sequence used in facilitating this research study

RESULTS AND DISCUSSION

In this study, a total of 5 concrete mix samples were analyzed which includes normal vibrated concrete sample and 4 self-compacting concrete (SCC) samples. The fresh and hardened properties of SCC as well as the effect of limestone powder were analyzed using charts and graphs.

Hardened Properties: Each cube samples for various percentage of cement replaced by limestone powder were tested to determine the 7, 14, 21 and 28 day compressive strength using a 2000kN Compression Testing Machine. The test results on cube compressive strengths of normal concrete sampleand the 4 SCC samples are plotted in Fig 2 to 6. Figure 6 shows the compressive strength values at 7, 14, 21, and 28 days of the four SCC samples in comparison with that of NC. At 0.45 water content, the four SCC samples were stronger than the NC at early and later ages. It was found that the cube compressive strength increased with increase in various percentages of Limestone powder. More than 10% replacement of cement by limestone powder showed very slight reduction in the compressive strength of the cubes.

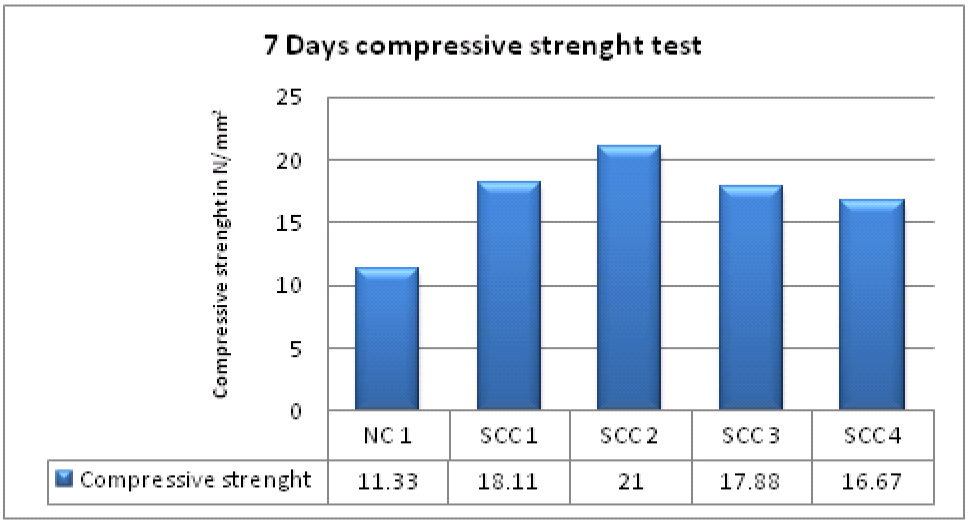

Fig 2: Bar chart showing 7 days Compressive strength of the cube samples

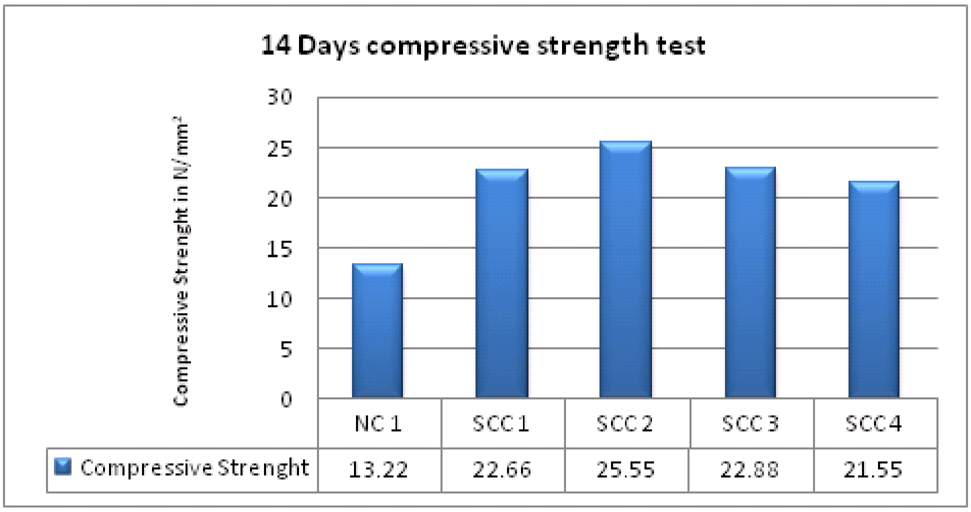

Fig 3: Bar chart showing 14 days Compressive strength of the cube samples.

ISSN: 2141 - 6745

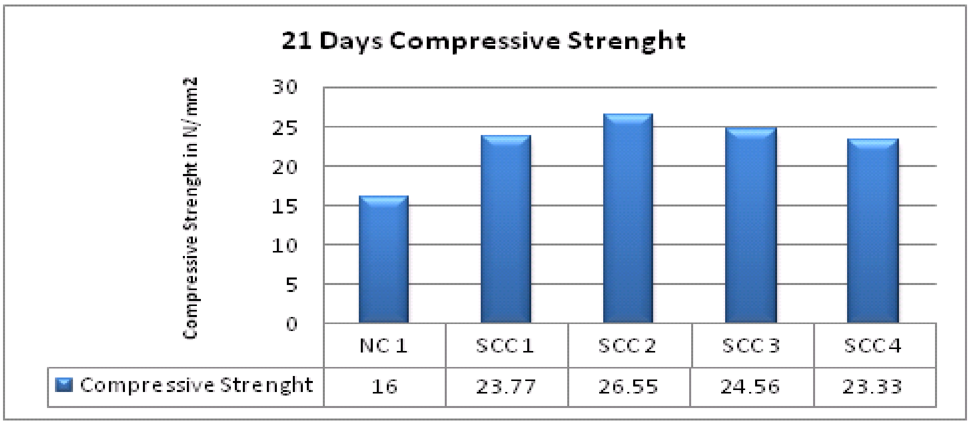

Fig 4: Bar chart showing 21 days Compressive strength of the cube samples.

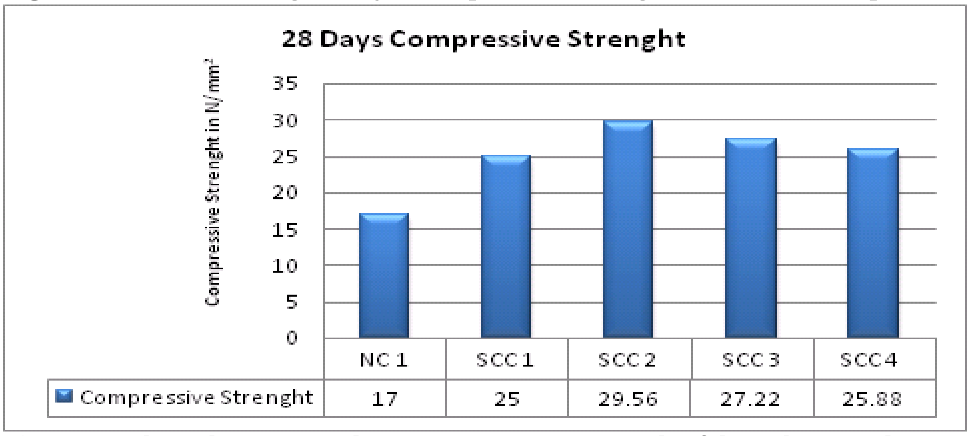

Fig 5: Bar chart showing 28 days Compressive strength of the cube samples.

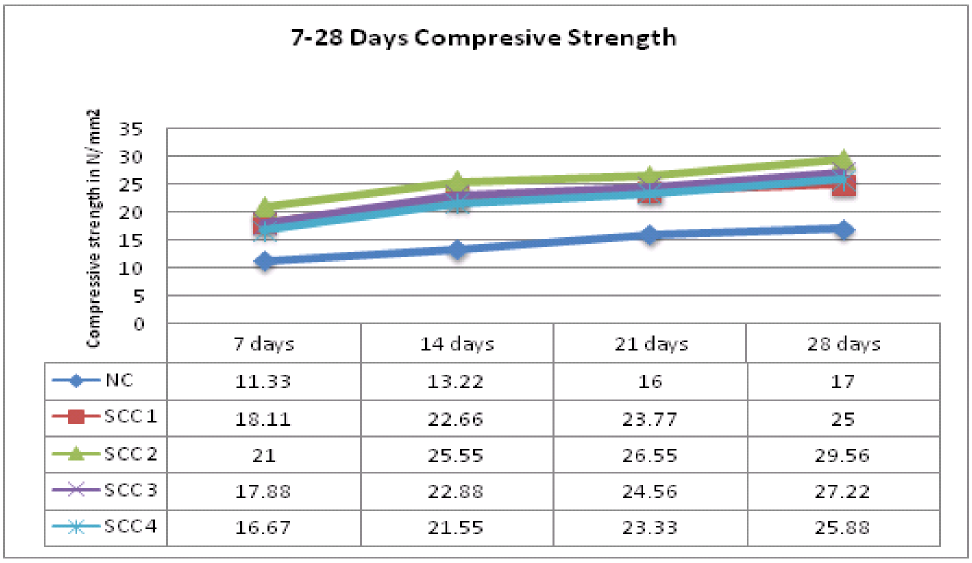

Fig 6: Shows strength development over 28 days curing period for the cube samples.

ISSN: 2141 - 6745

CONCLUSION AND RECOMMENDATIONS

This research work aimed at developing a self-compacting concrete using limestone powder to improve the workability, rheological and strength properties of self-compacting concrete have been achieved. The investigation involved the development of one normal concrete mixture and four SCC models and with different percentage of limestone powder and superplasticiser. The self-compacting ability of the SCC mix were confirmed by testing for the flowability, filling ability, passing ability and segregation resistance using the slump flow test, V funnel test, L box test and V funnel at T_{5min} test respectively. The compressive strength of various concrete samplesare compared. Results obtained confirm that Nigerian limestone powder and superplasticizer can be used to improve the workability and rheological properties of Self-compacting concrete. With a 0.45 w/c ratio the maximum compressive strength of SCC obtained ranges between 25N/mm^2 to 30.33N/mm^2. For all the SCC samples, the compressive strength increased with increases in the content of limestone powder when compared to the normal concrete sample. The optimal increase was obtained for the sample with 10% addition of limestone while other samples showed less increase in strength.

The research has proved that SCC should be given a chance in the Nigerian construction industry and elsewhere in the world as the strength potentials are very encouraging. Further researches should be encouraged with other admixtures in the quest for advancement of alternatives to conventional concrete materials. Finally, this research shows that SCC technology can be used to achieve the construction management triangle of time, cost and quality as the good flowability and enhanced strength will amount to time saving, cost reduction and enhanced quality and durability of concrete structures.

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