

# Effects of limestone and super-plasticizer on the fresh properties of self-compacting concrete

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## Abstract.

The free flow ability of fresh self-compacting concrete (SCC), capable of overcoming obstacles and penetrating into difficult joints is one of the special properties that differentiate SCC from normal concrete. It can then be rightly said that the fresh property of self compacting concrete (SCC) is the most important factor that distinguishes SCC from conventional concrete. Due to the importance of this property to the overall performance of self-compacting concrete, the tests of fresh SCC must be gotten right since any mistake will compromise the essence of recurring to SCC in place of normal concrete.

This research attempts to enhance the flow-ability of SCC via replacement of cement with varying dosage of limestone and super-plasticizer. To validate the improvement of SCC fresh properties, slump test is used to assess workability, L-box test for passing ability and V-funnel test for filling ability. Test results analyzed with statistical tools confirmed that the workability and rheological properties of self-compacting concrete can be improved through the adoption of various dosages of limestone powder.

**Keywords:** Self-Compacting Concrete, Limestone powder, Fresh properties.

## 1. Introduction

The durability of concrete, the most widely used construction material in the world has been of great concern to researchers all over the world. Problems related to the strength and poor quality concrete appear to be very severe in the developing nations where most of their buildings are realized in reinforced concrete. For instance, in Nigeria, over 95% of frequent cases of building collapse verified affect concrete structures and poor quality material has been identified as one of the principal causes of collapse in Nigeria [1]. To circumvent the concrete durability and strength issues, scientists have labored to improve the quality of normal concrete and to create alternative products capable of serving as matrix in the construction industries. One of such improvements on the quality of normal concrete is self-compacting concrete, capable of occupying various forms of spaces under the influence of gravity without segregation with the ability to fill the formworks and the spaces between the reinforcement without vibration and rodding. Review of past works on SCC can be found in [2, 3, 4, 5, 6, 7, 8]. The special properties of the fresh self-compacting concrete are the ability to flow naturally, overcoming obstacles and the capacity of self-compacting. These special properties, difficult to obtain in normal concrete are achieved only by systematic optimization of both the individual constituents and of the composition [9]. It can then be rightly said that the fresh property of self compacting concrete (SCC) is the most important factor that distinguishes SCC from conventional concrete. Therefore it is important that the tests of fresh SCC is gotten right because any mistake will compromise the essence of using SCC in place of normal concrete.

For these reasons, this research studies the fresh properties of self-compacting concrete. This work aims at using limestone powder to improve the workability and rheological properties of fresh self-compacting concrete. The influence of limestone powder and High Range Water Reducing Super plasticizer on the fresh properties of SCC is considered. For the flow-ability, slump test was adopted, for passing ability, L-box test is used and for the viscosity/fluidity, V-funnel test is executed.

## 2. Materials and Methods

The main aim of this experimentation is to find out the effects of addition of limestone on the flow properties of self-compacting concrete containing High range water reducing super-plasticizer. The research procedure consisted of material selection, batching and mixing, fresh property tests.

## 2.1. Constituent materials

The materials adopted are cement, limestone powder, high range water reducing super-plasticizer, sand, coarse aggregate and water.

Cement: The cement adopted for the test conformed to BS EN 197 Part 1: Composition, specifications and conformity criteria for common cements.

Additive: The mineral additive used in this study is a Nigerian Limestone powder.

Admixtures: Conplast SP 432 MS conforming to BSEN 934-2 2000 served as super-plasticizers or high range water reducing admixtures. This is a chloride free, super-plasticizing admixture based on selected sulphonated naphthalene polymers which enables the water content of the concrete to perform more effectively.

Aggregates: Good quality river sand limited to 4.45mm was used as fine aggregate and crushed granite limited to 20mm was used for this study. These aggregates were weighed in a room dry condition.

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

## 2.2. Mix proportion

In this study, 5 concrete mixture samples are analyzed. The samples are labeled as **SCC<sub>1</sub>** for conventional concrete mix for reinforced concrete with 50% water/cement ratio and extra 20ml of super-plasticizer; and **SCC<sub>2</sub>**, **SCC<sub>3</sub>**, **SCC<sub>4</sub>** and **SCC<sub>5</sub>** for self-compacting concrete with 45% water/cement ratio and 5%, 10%, 15% and 20% cement replacement with limestone powder respectively.

The batching and mixing with varying mix compositions are summarized in table 1.

**Table 1:** mix proportion of SCC samples

Materials	<b>SCC<sub>1</sub></b>	<b>SCC<sub>2</sub></b>	<b>SCC<sub>3</sub></b>	<b>SCC<sub>4</sub></b>	<b>SCC<sub>5</sub></b>
Portland Cement (Kg)	10	9.5	9	8.5	8
Limestone Powder (Kg)	0	0.5	1	1.5	2
Fine Aggregate (Kg)	20	20	20	20	20
Coarse Aggregate (Kg)	20	20	20	20	20
Water cement ratio (%)	0.5	0.45	0.45	0.45	0.45
Superplasticiser (ml)	120	100	100	100	100

## 2.3. Tests procedures

The fresh property tests consisted of slump test (for workability), L-box test (for passing ability), V-funnel test (filling ability). The fresh SCC's tests' apparatus and execution processes are shown in figures 1 and 2.

### 2.3.1 Slump test and T<sub>500</sub> time test

Slump flow and T<sub>500</sub> time test are used to assess the fluidity and the flow rate of SCC in the absence of obstructions. The slump flow test measures the free unrestricted deformability and the T<sub>500</sub> test measures the rate of deformation within a defined flow distance.

Apparatus: the equipments used [5] were made up of base plate of size of 900 × 900 mm, made of impermeable and rigid material (steel or plywood) with smooth and plane test surface, a 300mm high Abram's cone with the internal upper/lower diameter equal to 100/200 mm, a stopwatch with the accuracy of 0.1 second for recording the slump flow time T<sub>500</sub>, a graduated ruler for measuring the diameters of the flow spread, bucket and moist

sponge or towel for wetting the inner surface of the cone and the test surface of the base plate. The slump flow time  $T_{500}$  is the period of time between removal of the cone from the base plate and the arrival of the SCC at the circle of diameter 500mm.

Test Procedure: after placing the cleaned base plate in a stable and level position, the bucket is filled with 6-7 litres of fresh SCC before pre-wetting the inner surface of the cone and the test surface of the base plate using the moist sponge or towel and finally placing the cone in the centre of the 200 mm circle of the base plate. The cone is then filled with the sample from the bucket without any external compacting action such as rodding or vibrating. After a short rest (no more than 30 seconds for cleaning and checking the moist state of the test surface), the cone is lifted perpendicular to the base plate in a single movement, in such a manner that the concrete is allowed to flow out freely without obstruction from the cone, and the stopwatch is started the moment the cone loosed contact with the base plate. The stopwatch is stopped when the front of the concrete first touches the circle of diameter 500 mm. The stopwatch reading is recorded as the  $T_{500}$  value. The test continued until concrete flow has ceased. The largest diameter of the flow spread on the base plate,  $d_{max}$ , is measured together with the one perpendicular to it,  $d_{perp}$ , using a ruler (reading to nearest 5 mm). The slump flow spread  $S$  (figure 1a) is the average of diameters  $d_{max}$  and  $d_{perp}$ , and is expressed in mm to the nearest 5 mm:

$$S = \frac{d_{max} + d_{perp}}{2} \quad (1)$$

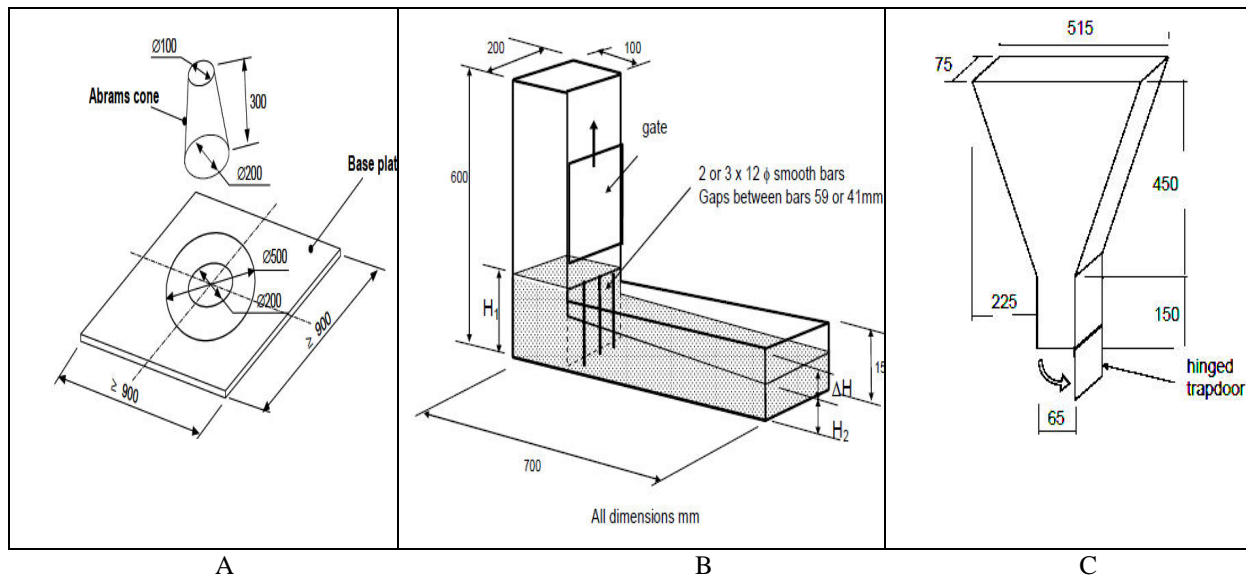


Figure 1: fresh SCC test apparatus. A) Base plate and Abrams cone; B) L-box test and C) V-funnel test.



Figure 2: fresh SCC test execution. A) slump spread; B) L-box test and C) V-funnel test.

### 2.3.2. L-box test

The method aims at investigating 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 the reached height, the passing or blocking behaviour of SCC can be estimated.

Apparatus: the apparatus consisted of an L-box with the possibility of using two types of gates: one with 3 smooth bars and one with 2 smooth bars with gaps of 41 and 59 mm, respectively. A suitable tool for ensuring that the box is level i.e. a spirit level and buckets for taking concrete sample [5] are made available.

Test Procedures: after placing the L-box in a stable and level position, the vertical part of the L-box is filled with 12.7 litres of fresh SCC. The concrete is allowed to rest in the vertical part for one minute ( $\pm 10$  seconds) to verify whether it is stable or not (existence of segregation). The sliding gate is lifted to let the concrete flow out of the vertical part into the horizontal part of the L-box. When the concrete stops moving, the average distance, noted as  $\Delta h$  between the top edge of the box and the concrete that reached the end of the box, at three positions, one at the centre and two at each side are measured [5].

The passing ratio  $P_L$  or blocking ratio  $B_L$  are dimensionless quantities expressed to the nearest 0.01:

$$P_L = \frac{H}{H_{max}} \quad (3)$$

$$B_L = \frac{H}{1 - H_{max}} \quad (2)$$

### 2.3.3. V-funnel test

The V-funnel flow time is the period of time a defined volume of SCC needs to pass a narrow opening and gives an indication of the filling ability of SCC provided that blocking and/or segregation do not take place; the flow time of the V-funnel test is to some degree related to the plastic viscosity [5].

Apparatus: V-funnel is a v-shaped funnel made of steel, with a flat, horizontal top and placed on vertical supports, and with a releasable, watertight opening gate. A stopwatch with the accuracy of 0.1 second is needed for recording the flow time. A straight edge for leveling the concrete, buckets for taking concrete sample and moist sponge or towel for wetting the inner surface of the V-funnel form part of the apparatus.

Test procedure: the cleaned and wet V-funnel with the top opening horizontally positioned and the hinged door closed is placed vertically on a stable and flat ground. The funnel is filled completely with a sample of SCC without applying any compaction or rodding. The funnel is then lifted and placed above a container before opening the hinged door and starting the stopwatch. The stopwatch is stopped at the end of the SCC flow and the reading is recorded as the V-funnel flow time  $t_v$ .

The V-funnel flow time  $t_v$  is the period of time from releasing the gate to the end of flow, expressed to the nearest 0.1 second.

## 3. Results and Discussion

The main aim of this experimental research is to find out the effects of addition of limestone on the flow properties of self-compacting concrete containing high range water reducing super-plasticizer. The data gotten from the tests are hereby analyzed. The analyses are carried out through statistical tools by using tables, charts and graphs.

The fresh properties of Self-compacting concrete with varying percentage of limestone powder are analyzed. The rheological properties of SCC mixes with various percentage of replacement of cement with limestone powder are determined by conducting tests such as slump flow test, L-box test and V-funnel test for the five samples considered for this research.

### 3.1. Slump flow and $T_{500}$ results

The SCC mixtures presented a slump flow between 658mm and 685mm which is an indication of a good deformability. The slump flow and the  $T_{500}$  time varied in response to the dosage of super-plasticizer and percentage of the limestone powder. The **SCC<sub>5</sub>** sample with 20% lime stone replacement had the highest slump

flow and the least  $T_{500}$  time followed by **SCC<sub>1</sub>** with extra dosage of super-plasticizer as can be seen in figures 3 and 4 respectively.

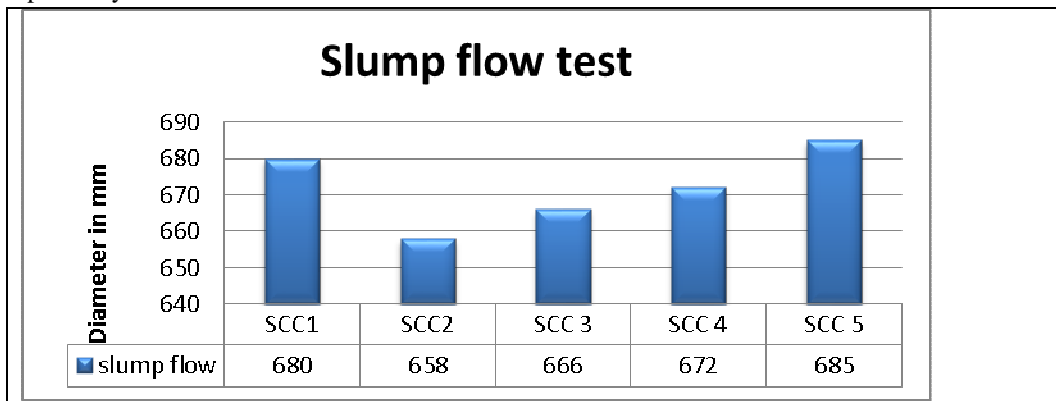


Figure 3: Bar chart showing slump flow diameter of samples

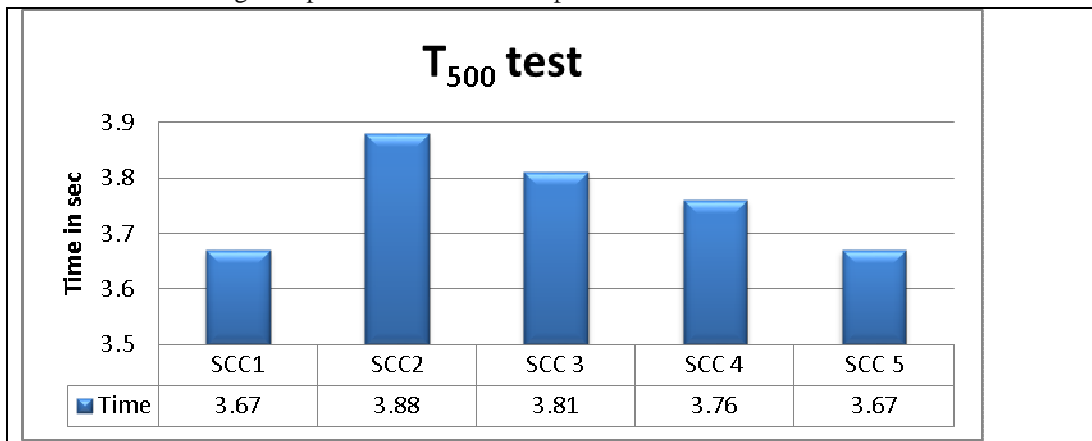


Fig 4: bar chart showing  $T_{500}$  time of each sample

### 3.2. L-Box results

From figure 5, the blocking ratio of the SCC samples are in the range of 0.87s to 0.95s which is an indication of a good passing ability between congested reinforcement. The passing ratio seems to increase in proportion to the percentage of limestone powder without any increase for the high dosage of super-plasticizer. It can be seen that up to 20% of cement can be replaced by limestone powder without affecting the passing ratio of SCC.

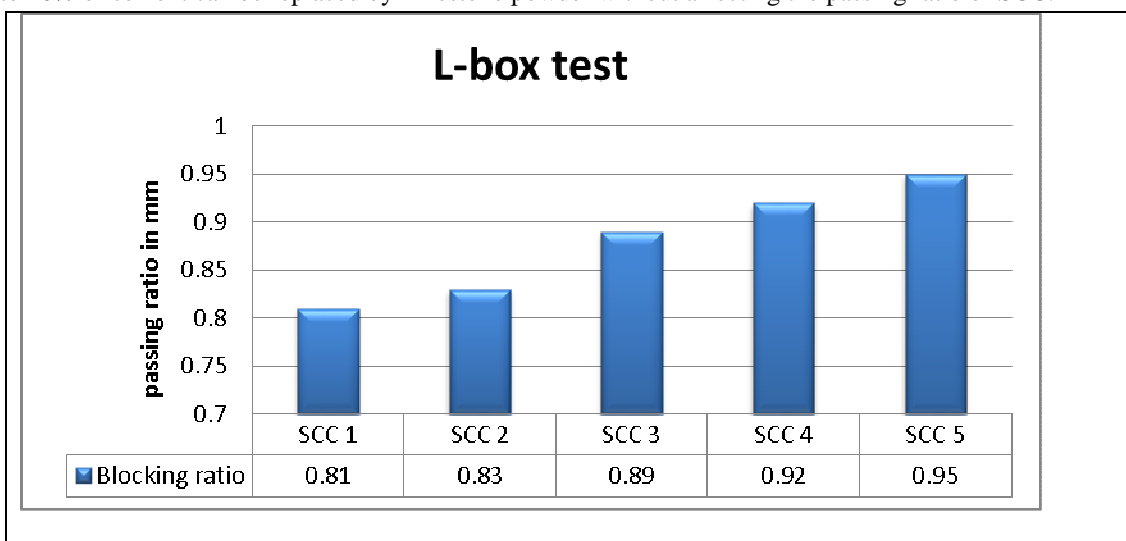


Figure 5: Bar chart showing passing ratio of samples

### 3.3. V-funnel test results

From figure 6, the flow time of the SCC samples are in the range of 10.05 to 11.52s which is an indication of a good flow-ability. The SCC5 sample with 20% limestone content had the fastest flow time, followed by SCC 1 with 0% limestone and 20ml extra dosage of super-plasticizer.

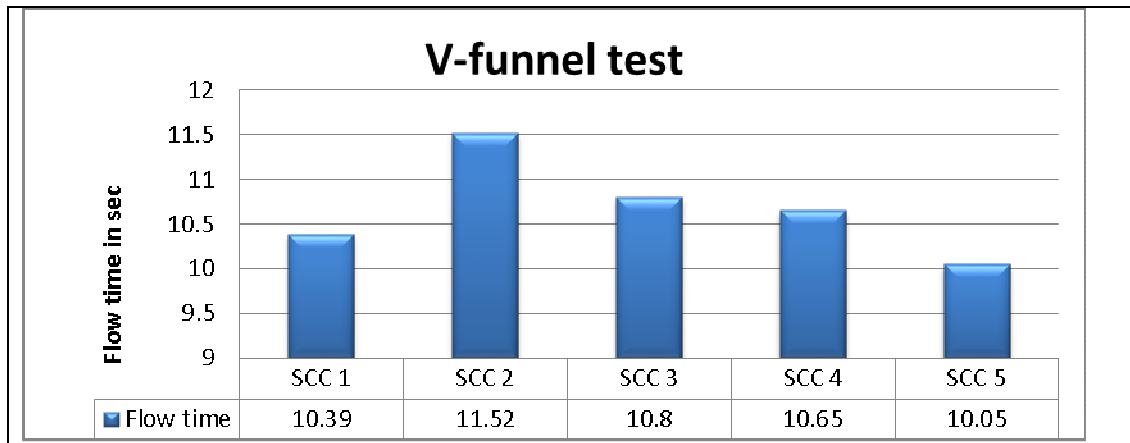


Figure 6: Bar chart showing Flow time of samples

### 4. Conclusion

This research work aimed at verifying the workability and rheological properties of self-compacting concrete developed using various dosages of limestone powder and super-plasticizer. The self-compacting ability of the SCC samples were confirmed by testing for the flow-ability, 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 results obtained confirmed that a concrete mixture that flows under its own weight, passes through congested reinforcement and resists segregation can be made using Limestone powder and super-plasticizer. It was also confirmed that limestone powder can be used to enhance the workability and rheological properties of Self-compacting concrete.

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