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Characterization of self-Consolidating Concrete for Tensile Strength and Bonding Characteristics

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ABSTRACT

Self-compacting concrete, also referred to as self-consolidating concrete, is able to flow and consolidate under its own weight and is desecrated almost completely while flowing in the formwork. It is cohesive enough to fill the spaces of almost any size and shape without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily-reinforced concrete members or in complicated work forms.

Present-day self-compacting concrete can be classified as an advanced construction material. As the name suggests, it does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete. These include an improved quality of concrete and reduction of on-site repairs, faster construction times, lower overall costs, facilitation of introduction of automation into concrete construction. An important improvement of health and safety is also achieved through elimination of handling of vibrators and a substantial reduction of environmental noise loading on and around a site. The composition of SCC mixes includes substantial proportions of fine-grained inorganic materials and this gives possibilities for utilization of mineral admixtures, which are currently waste products with no practical applications and are costly to dispose.

The objectives of this research were to compare the Splitting Tensile Strength and Compressive Strength values of self-compacting and normal concrete specimens and to examine the bonding between the coarse aggregate and the cement paste using the Scanning Electron Microscope Cylinder specimens (8” by 4”) were tested for Splitting Tensile and Compressive Strength after 28 days of standard curing, in order find out if self-compacting concrete would show an increase in these strengths and a better bonding between aggregate and cement paste, compared to normal concrete.

Keywords : Concrete, Admixture, Compressive Strength, Tensile Strength

I. INTRODUCTION

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. The concept of self-compacting concrete was proposed in 1986 by professor Hajime Okamura (1997), but the prototype was first developed in 1988 in Japan, by professor Ozawa (1989) at the University of Tokyo. Self-compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix-design method and self-compact ability testing methods have been carried out from the viewpoint of making it a standard concrete. 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 usually, the chemical admixtures used are high-range water reducers (super plasticizers) and viscosity-modifying agents, which change the rheological properties of concrete. Mineral admixtures are used as an extra fine material, besides cement, and in some cases, they replace cement. In this study, the cement content was partially replaced with mineral admixtures, e.g. fly ash, slag cement, and silica fume, admixtures that improve the flowing and strengthening characteristics of the concrete.

The introduction of "modern" self-levelling concrete or self-compacting concrete (SCC) is associated with the drive towards better quality concrete pursued in Japan around 1983, where the lack of uniform and complete compaction had been identified as the primary factor responsible for poor performance of concrete structures (Dehn et al., 2000). Due to the fact that there were no practical means by which full compaction of concrete on a site was ever to be fully guaranteed, the focus therefore turned onto the elimination of the need to compact, by vibration or any other means. The SCC were used under trade names, such as the NVC (Non-vibrated concrete) and SQC (Super quality concrete). Modern application of SCC is focused on high performance, better and reliable and uniform quality.

II. METHODS AND MATERIAL

2. Methodology

Self-compacting concrete (SCC) is a fluid mixture, which is suitable for placing in difficult conditions and in structures with congested reinforcement, without vibration. In principle, a self-compacting or self-consolidating concrete must:

Have a fluidity that allows self-compaction without external energy, Remain homogeneous in a form during and after the placing process, and* Flow easily through reinforcement The technology of SCC is based on adding or partially replacing Portland cement with amounts of fine material such as fly ash, blast furnace slag, and silica fume without modifying the water content compared to common concrete. This process changes the rheological behaviour of the concrete.

2.1 Existing Tests for Fresh SCC Mixes

Fresh SCC must possess at required levels the following key properties:

2.1.1 Filling ability: this is the ability of the SCC to flow into all spaces within the formwork under its own weight.

2.1.2 Passing ability: this is the ability of the SCC to flow through tight openings such as spaces between steel reinforcing bars, under its own weight.

2.1.3 Resistance to segregation: the SCC must meet the required levels of properties A & B whilst its composition remains uniform throughout the process of transport and placing. Many tests have been used in successful applications of SCC. However, in all the projects the SCC was produced and placed by an experienced contractor whose staff has been trained and acquired experience with interpretation of a different group of tests. In other cases, the construction was preceded by full-scale trials in which a number, often excessive, of specific tests was used. The same tests were later used on the site itself. Below is a brief summary of the more common tests currently used for assessment of fresh SCC.

2.1.3.1 U-type test: Of the many testing methods used for evaluating self-compact ability, the U-type test (Figure) proposed by the Taisei group is the most appropriate, due to the small amount of concrete used, compared to others. In this test, the degree of compact ability can be indicated by the height that the concrete reaches after flowing through obstacles. Concrete with the filling height of over 300 mm can be judged as self-compacting. Some companies consider the concrete self-compacting if the filling height is more than 85% of the maximum height possible.

2.1.3.2 Slump Flow test: The basic equipment used is the same as for the conventional Slump test. The test method differs from the conventional one by the fact that the concrete sample placed into the mold is not rodded and when the slump cone is removed the sample collapses. The diameter of the spread of the sample is measured, i.e. a horizontal distance is determined as opposed to the vertical distance in the conventional Slump test. The Slump Flow test can give an indication as to the consistency, filling ability and workability of SCC. The SCC is assumed of having a good filling ability and consistency if the diameter of the spread reaches values between 650mm to 800mm.

2.1.3.3 L-Box test: This method uses a test apparatus comprising of a vertical section and a horizontal trough into which the concrete is allowed to flow on the release of a trap door from the vertical section passing through reinforcing bars placed at the intersection of the two areas of the apparatus. The time that it takes the concrete to flow a distance of 200mm (T-20) and 400mm (T-40) into the horizontal section is measured, as is the height of the concrete at both ends of the apparatus (H1 & H2). The L-Box test can give an indication as to the filling ability and passing ability.

2.1.3.4 Orimet test: The test is based on the principle of an orifice rheometer applied to fresh concrete. The test involves recording of time that it takes for a concrete sample to flow out from a vertical casting pipe through an interchangeable orifice attached at its lower end. The shorter the Flow-Time, the higher is the filling ability of the fresh mix. The Orimet test also shows potential as a means of assessment of resistance to segregation on a site.

2.1.3.5 V-funnel test: Viscosity of the self-compacting concrete is obtained by using a V-funnel apparatus, which has certain dimensions in order for a given amount of concrete to pass through an orifice. The amount of concrete needed is 12 litres and the maximum aggregate diameter is 20 mm. The time for the amount of concrete to flow through the orifice is being measured. If the concrete starts moving through the orifice, it means that the stress is higher than the yield stress; therefore, this test measures a value that is related to the viscosity. If the concrete does not move, it shows that the yield stress is greater than the weight of the volume used. An equivalent test using smaller funnels (side of only 5 mm) is used for cement paste as an empirical test to determine the effect of chemical admixtures on the flow of cement pastes.

2.1.3.6 Slump Flow/J-Ring combination test : This test involves the slump cone being placed inside a 300mm diameter steel ring attached to vertical reinforcing bars at appropriate spacing (the J-Ring itself). The number of bars has to be adjusted depending on the maximum size aggregate in the SCC mix. Like in the Slump Flow test, the diameter of the spread and the T-50 time are recorded for the evaluation of SCC viscosity. The Slump Flow/J-Ring combination test is an improvement upon the Slump Flow test on its own as it aims to assess also the passing ability of the fresh mix. In this respect, the SCC has to pass through the reinforcing bars without separation of paste and coarse aggregate.

2.4 Existing Tests for Hardened SCC Mixes

Testing of harden concrete plays an important role in controlling and confirming the quality of cement concrete works. Systematic testing of raw material, fresh concrete and hardened concrete are inseparable part of any quality control programmed for concrete, which helps to achieve higher efficiency of the material used and greater assurance of the performance of the concrete with regard to both strength and durability. One of the purposes of testing hardened concrete is to confirm that the concrete used at the site has developed the required strength.

2.4.1 Compressive Strength Test : Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. The cube specimen is of the size 15x15x15 cm.

2.4.2 Tensile Strength Test: It is used to test the tensile strength of briquettes. The m/c used in laboratory has a compound lever system for applying tensile force. The briquette under test is held vertically between two jaw these jaw are to be well greased before filling the briquette. The machine is provided with a pan c just below this pan, another pan is hung for re-echoing the lead shots. The specimen is of the size is 2.5 x2.5 cm.

The following step to be follow for design procedure

3. Analysis and Design

Conventional concrete tends to have a difficulty regarding the adequate placing and consolidation in thin sections or areas of congested reinforcement, which leads to a large volume of entrapped air voids and compromises the strength and durability of the concrete. Using self-compacting concrete (SCC) can eliminate the problem, since it was designed to consolidate under its own weight. Therefore, it is important to verify the mechanical properties of SCC before using it for practical applications.

This research was conducted to find out if self-compacting concrete would show an increase in splitting tensile strength and compressive strength and a better bonding between aggregate and cement paste, in order be used as a replacement for conventional concrete in the construction industry. The experimental program was divided into two phases.

3.1 Aggregate – cement bonding characteristics:

Bonding between aggregate and cement paste is an important factor in the strength of concrete, especially the tensile strength, and regarding the fracture properties of concrete. Bond is due, in part, to the interlocking of the aggregate and the paste owing to the roughness of the surface of the former. A rougher surface, such as that of crushed particles, results in a better bond, usually obtained with softer, porous, and mineralogical heterogeneous particles. Generally, texture characteristics, which permit no penetration of the surface of the particles, are not conducive to good bond. In addition, bond is affected by other physical and chemical properties of aggregate, related to its mineralogical and chemical composition. So, aggregate shape, surface structure and hardness are all factors affecting the strength of the aggregate-matrix bond. However, today little is known about these phenomena, and relying on experience is still necessary in predicting the bond between the aggregate and the surrounding cement paste.

The determination of the quality of bond of aggregate is rather difficult and no accepted tests exist. Generally, when bond is good, a crushed concrete specimen should contain some aggregate particles broken right through, in addition to the more numerous ones pulled out from their cavities. An excess of fractured particles, however, might suggest that the aggregate is too weak. Because it depends on the paste strength, as well as on the properties of aggregate surface, bond strength increases with the age of concrete. Thus, providing it is adequate, the bond strength may not be a controlling factor in the strength of concrete. Most often, concrete fracture occurs according to a pattern, which follows the contact surface zone representing the weakest link. This very thin zone surrounding the aggregate consists of a matrix layer and an adjacent aggregate layer, the two layers being separated by a contact surface or aggregate-matrix interface (physical interface) as shown in Figure 3.2 (i) Between the two phases, i.e. the matrix and the aggregate, physical forces and interactions may exist, generated by the adhesive and interlocking forces, as well as by matrix-aggregate interpenetration subsequent to cement-paste shrinkage. That such treatment may provide a more economical means of achieving better bonding.

3.2 Self-compacting Concrete Mix Design

The self-compacting concrete mix design used in the study was based on previous work done in Japan, US, Canada. All the mixes were prepared in 100 lbs batches (for 6 specimens – 4 by 8 inches cylinders and U-type test) using an electrical mixer. The mix proportions for casting the concrete specimens are given in Table. 3.2

The type I Portland cement was replaced by blast furnace slag (25%), fly ash (15%), and silica fume (5%). The water-cement ratios have been varied from 0.3 to 0.6 while the rest of the components was kept the same, except the chemical admixtures, which were adjusted for obtaining the self-compact ability of the concrete.

Table 3.1 Self-compacting concrete mix design.

Water/Cement ratio	0.3	0.4	0.45	0.5	0.6
Water (lbs)	6.6	8.8	9.9	11	13.2
Cement (lbs)	12.1	12.1	12.1	12.1	12.1
Slag Cement (lbs)	5.5	5.5	5.5	5.5	5.5
Fly Ash (lbs)	3.3	3.3	3.3	3.3	3.3
Silica Fume (lbs)	1.1	1.1	1.1	1.1	1.1
Fine Aggregate.(lbs)	26	26	26	26	26
Coarse Aggregate.(lbs)	46.4	46.4	46.4	46.4	46.4
HRWR (ml)	340	100	80	50	20
VMA (ml)	0	15	25	50	100

3.3 Normal Concrete Mix Design

Normal concrete mixes were prepared in 62 lbs batches (for approx. 6 specimens - 4 by 8 inches cylinders) using the electrical mixer. The mix proportions for casting the concrete specimens are given in Table

Table 3.2 Normal concrete mix design

Water/Cement ratio	0.3	0.4	0.45	0.5	0.6
Water (lbs)	4.1	5.5	6.2	6.8	8.2
Cement (lbs)	13.6	13.6	13.6	13.6	13.6
Fine Aggregate.(lbs)	16.1	16.1	16.1	16.1	16.1
Coarse Aggregate.(lbs)	28.2	28.2	28.2	28.2	28.2

3.4 Batching Procedure

A total of 11 (eleven) batches based on the above mix designs have been prepared in this research. The procedure used for the batches was as follows:

(A) Predetermined quantities of fine and coarse aggregate were added to the mixer and mixed for 30 seconds.

(B) Predetermined quantities of cement, fly ash, slag cement and silica fume were added to the mixer and mixed together with the aggregates for 1 minute

(C) Various amounts of water, super plasticizer and viscosity admixture were added and mixed thoroughly.

D) Different mixtures obtained were used to carry out the slump flow test, the U-type test, and to cast cylindrical specimens.

No vibration or compaction has been applied to the self-compacting concrete specimens, whereas compaction on normal concrete specimens was applied, for approximately 30 seconds, using a tamping rod. All concrete specimens have been cast and cured according to ASTM C 192-95 “Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory”.

Compressive and splitting tensile strengths of concretes were performed according to ASTM C 39-94 “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens” and ASTM C 496-96 “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens”, respectively.

III. RESULTS AND DISCUSSION

4.1 Object of testing the main objective of testing was to know the behaviour of concrete with replacement of ordinary sand with stone dust at room temperature. The main parameters studied were workability and compressive strength. The materials used for concrete samples are tested in laboratory and results are tabulated.

4.2 Test Results of Materials Used In Present Work

4.2.1 Cement

Birla-1cement (OPC), [W-50,M-04, Y-2015] IS:455,was used for all concrete mixes. The cement used was fresh and without any lumps. Testing of cement was done in lab. The various tests results conducted on the cement are reported in Table 4.1.

Table 4.1 : Properties of cement

S. No.	Characteristics	Obtained Standard value
1.	Normal Consistency	29.5%
2.	Setting time :	
3.	Compressive Strength:	
3.	Fineness (%)	3.5% <10
5.	Specific Gravity	3.12
6.	Soundness	

4.2.2 Coarse Aggregates

Locally available coarse aggregates having the maximum size of 20mm were used in the present work. Testing of coarse aggregates was done. The 20mm aggregates were firstly sieved through 20mm sieve. They were then washed to remove dust and dirt and dried to surface dry condition. The results of various tests conducted on coarse aggregate are given in Table 4.2, Table 4.3 & Table 4.4.

Table 4.2 : Fineness Modulus / Grading of Coarse Aggregates

S. No.	Sieve Size	Mass Retained	Cumulative mass Retained	Cumulative Percentage Retained (%)	Percentage Passing (%)
1	40mm	00	00	0.0	100.0
2	20mm	110 g	110 g	2.2	97.8
3	10mm	3675 g	3785 g	75.7	24.3
4	4.75mm	1190 g	4975 g	99.5	0.5
5	Pan	25 g	5000 g	-	0.0
Total ∑ C				177.4	

Fineness Modulus of Coarse aggregate = ∑C +500/100 = 177.4 + 500/100 = 6.77

Table 4.3 : Properties of Coarse Aggregates

S. No.	Characteristics Value	
1.	Type	Crushed
2.	Maximum size	20mm
3.	Specific Gravity	2.65
4.	Moisture Content	0.0%
5.	Water Absorption	0.2%
6.	Bulk Density : (a) Loose (b) compacted	 1404.4 Kg/m^3 1648.8 Kg/m^3

Table 4.4 : Sieve Analysis of Coarse Aggregate

Sieve Size	40mm	20mm	10mm	4.75mm
% Passing	100.0	97.8	24.3	0.5

4.2.3 Fine Aggregate-Sand

The Sand used for the experimental programme was locally available river sand. Properties of the fine aggregate used in the experimental work are tabulated in Table 4.5 & Table 4.6 and Table 4.5

Table 4.5 : Fineness Modulus / Grading of Fine Aggregate (Sand)

S. No.	Sieve Size	Mass Retained	Cumulative Mass Retained	Cumulative Percentage Retained (%)	Percentage Passing (%)
1	4.75 mm	4 g	4 g	0.4	99.6
2	2.36 mm	7 g	11 g	1.1	98.9
3	1.18 mm	236 g	247 g	24.7	75.3
4	600 mic	266 g	513 g	51.3	48.7
5	300 mic	385 g	898 g	89.8	10.2
6	150 mic	94 g	992 g	99.2	0.8
7	Pan	8 g	1000 g	--	--
Total ∑C				266.5	--

Fineness Modulus of Fine Aggregate (Sand) = ∑C / 100 = 266.5 / 100 = 2.665

Table 4.6 : Properties of Fine Aggregate (Sand)

S. No.	Characteristics Value	
1.	Specific Gravity	2.63
2.	Moisture Content	0.1%
3.	Water Absorption	0.5%
4.	Bulk Density : (a) Loose (b) Compacted	 1549.6 Kg/m^3 1679.4 Kg/m^3

Table 4.7 : Sieve Analysis of Sand

Sieve Size	4.75 mm	2.36 mm	1.18 mm	600 µ	300 µ	150 µ	75 µ
% Passing	99.6	98.9	74.3	48.7	10.2	0.8	0.05

4.2.5 Plasticizer

Glenium - super plasticizer was used in this project/experiment. It is a High range, water addition super plasticizer for self-compacting concretes.

Fig. 4.1: Performing compressive strength test for 28 days

Table 4.8 compressive strength test for 28 days

w/c	0.3	0.4	0.45	0.5	0.6
N.C.	32.39	30.23	30.00	28.59	28.00
S.C.C	42.50	41.39	40.10	38.12	38.00

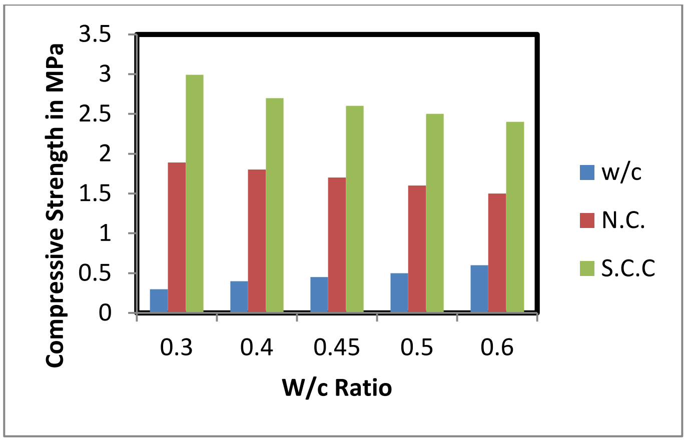

Fig. 4.2: Compressive Strength for 28 days

Fig. 4.3: Performing tensile strength test for 7 days

Table 4.9 tensile strength test for 7 days

w/c	0.3	0.4	0.45	0.5	0.6
N.C.	1.89	1.80	1.70	1.60	1.50
S.C.C	2.99	2.70	2.60	2.50	2.40

Fig. 4.4: Performing tensile strength test for 28 days

Table 4.10 tensile strength test for 28 days

w/c	0.3	0.4	0.45	0.5	0.6
N.C.	3.34	3.30	3.20	3.10	3.00
S.C.C	4.74	4.5	4.0	3.59	3.34

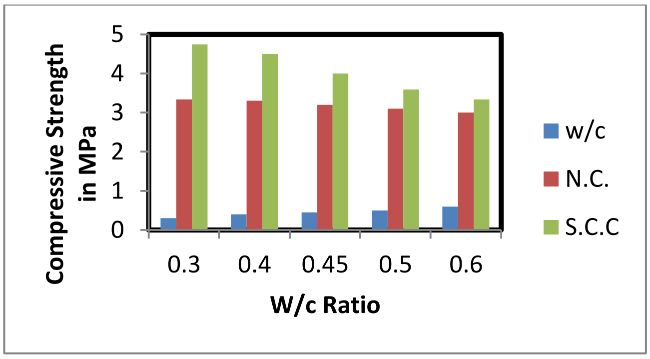

Fig. 4.5 tensile strength test for 28 days

4.3 Slump Flow Test

The consistency and workability of self-compacting concrete were evaluated using the slump flow test. Because of its ease of operation and portability, the slump flow test is the most widely used method for evaluating concrete consistency in the laboratory and at construction sites. In this study, the diameter of the concrete flowing out of the slump cone was obtained by calculating the average of two perpendicularly measured diameters for determining the above mentioned properties of concrete. The results from Table 4.1 show that the self-compacting concrete was complying with the requirements found in the literature. Thus, self-compacting concrete was assumed to having a good consistency and workability after gradually adjusting the chemical admixtures in the mix.

Table 4.11 Slump flow test results.

W/C Ratio	0.3	0.4	0.45	0.5	0.6
Spread diameter (mm)	655	670	685	700	740

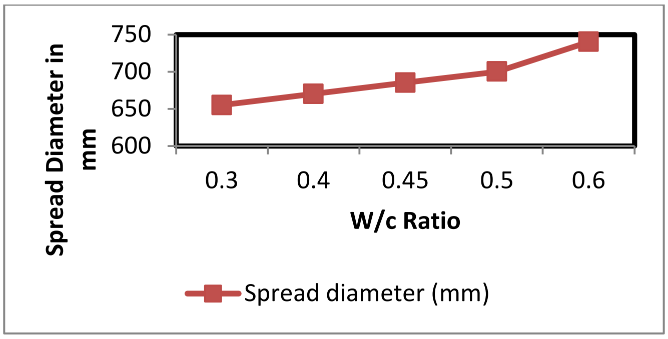

Fig. 4.6 Slump flow Spread diameter

4.4 U-type test

The U-type test was used to assess the self-compact ability of concrete. The results presented in Table 4.2 show that the concrete can be considered self-compacting due to the fact that after opening the sliding gate SCC rose in the other half of the U-tube to a height greater than 85% of the maximum possible height, which is 340 mm.

Table 4.12 U-type test results

W/C Ratio	0.3	0.4	0.45	0.5	0.6
U-tube filling height (mm)	300	305	320	320	330

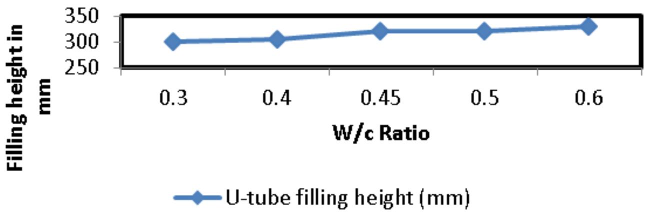

Fig. 4.7 U-type Filling Height

4.5 Concrete Density

Densities of both types of concretes were determined by weighing the cylindrical specimens, after remoulding them. The volume of a mould (8” x 4”) is 0.00165 m3 (0.058 ft3). The final densities for each type of concrete have been calculated by averaging the densities of all five water-cement ratios. Results regarding the densities and the weights for both types of concrete are presented in Table.

Table 4.13 Normal and self-compacting concrete densities.

W/C Ratio	0.3	0.4	0.45	0.5	0.6
NC* - Weights (kg)	3.91	3.88	3.86	3.85	3.83
SCC** - Weights (kg)	4.12	4.09	4.07	4.03	3.98
NC - Density (kg/m3)	2370	2352	2339	2333	2321
SCC - Density (kg/m3)	2497	2479	2467	2442	2412

4.6 L-Box test: This method uses a test apparatus comprising of a vertical section and a horizontal trough into which the concrete is allowed to flow on the release of a trap door from the vertical section passing through reinforcing bars placed at the intersection of the two areas of the apparatus (Dietz and Ma, 2000). The time that it takes the concrete to flow a distance of 200mm (T-20) and 400mm (T-40) into the horizontal section is measured, as is the height of the concrete at both ends of the apparatus (H1 & H2). The L-Box test can give an indication as to the filling ability and passing ability.

Table 4.14: L-Box Test

W/C Ratio	0.3	0.4	0.45	0.5	0.6
Ht. H1	80	70	65	60	50
Ht. H2	65	60	55	45	35
Blocking ratio H2/H1	0.812	0.857	0.846	0.75	0.7
time taken for conc. to reach a dist.of 200mm T20	9.24	9.00	8.34	8.00	7.50
time taken for conc. to reach a dist. of 400mm T40	15.8	15.00	14.67	14.00	13.12

4.7 Orimet Test :

The test is based on the principle of an orifice rheometer applied to fresh concrete (Bartos, 2000). The test involves recording of time that it takes for a concrete sample to flow out from a vertical casting pipe through an interchangeable orifice attached at its lower end. The shorter the Flow-Time, the higher is the filling ability of the fresh mix. The Orimet test also shows potential as a means of assessment of resistance to segregation on a site

Table 4.15 : Orimet Test Result

W/C Ratio	0.3	0.4	0.45	0.5	0.6
Time in sec	40.05	35.03	33.02	30.00	28.08

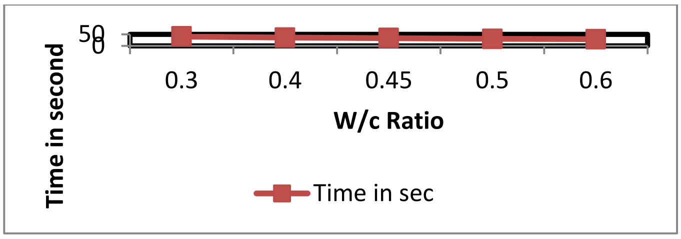

Fig. 4.8 : Orimet Test (Flow Time in second)

Fig. 4.9 : Performing Orimet Test (Flow Time in second) and V-funnel test

4.8 V-funnel test:

Viscosity of the self-compacting concrete is obtained by using a V-funnel apparatus, which has certain dimensions (Figure 1.4), in order for a given amount of concrete to pass through an orifice (Dietz and Ma, 2000). The amount of concrete needed is 12 litres and the maximum aggregate diameter is 20 mm. The time for the amount of concrete to flow through the orifice is being measured. If the concrete starts moving through the orifice, it means that the stress is higher than the yield stress; therefore, this test measures a value that is related to the viscosity. If the concrete does not move, it shows that the yield stress is greater than the weight of the volume used. An equivalent test using smaller funnels (side of only 5 mm) is used for cement paste as an empirical test to determine the effect of chemical admixtures on the flow of cement pastes.

Table 4.16: V-funnel Test

W/C Ratio	0.3	0.4	0.45	0.5	0.6
Time in sec	35	34	33.10	31	30

4.9 Combination test:

This test (Figure 1.5) involves the slump cone being placed inside a 300mm diameter steel ring attached to vertical reinforcing bars at appropriate spacing (the J-Ring itself) (Kosmatka et al., 2002). The number of bars has to be adjusted depending on the maximum size aggregate in the SCC mix. Like in the Slump Flow test, the diameter of the spread and the T-50 time are recorded for the evaluation of SCC viscosity. The Slump Flow/J-Ring combination test is an improvement upon the Slump Flow test on its own as it aims to assess also the passing ability of the fresh mix. In this respect, the SCC has to pass through the reinforcing bars without separation of paste and coarse aggregate.

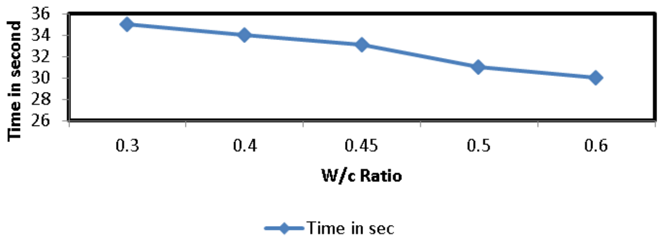

Fig. 4.10: V-funnel Test Slump Flow/J-Ring

Fig. 4.11: Performing Slump Flow/J-Ring combination test

Table 4.17: Slump Flow/J-Ring combination test

W/C Ratio	0.3	0.4	0.45	0.5	0.6
Spread diameter (mm)	650	665	675	700	720
Avg ht. in mm	15	13	12	10	8

IV. CONCLUSION

Taking into account the findings from this study, previously presented, the following conclusions can be drawn: It has been verified, by using the slump flow and U-tube tests, that self-compacting concrete (SCC) achieved consistency and self-compact ability under its own weight, without any external vibration or compaction. Also, because of the special admixtures used, SCC has achieved a density between 2400 and 2500 kg/m3, which was greater than that of normal concrete, 2370-2321 kg/m3. Self-compacting concrete can be obtained in such a way, by adding chemical and mineral admixtures, so that its splitting tensile and compressive strengths are higher than those of normal vibrated concrete. An average increase in compressive strength of 60% has been obtained for SCC, whereas 30% was the increase in splitting tensile strength.

Also, due to the use of chemical and mineral admixtures, self-compacting concrete has shown smaller interface micro cracks than normal concrete, fact which led to a better bonding between aggregate and cement paste and to an increase in splitting tensile and compressive strengths. A measure of the better bonding was the greater percentage of the fractured aggregate in SCC (20-25%) compared to the 10% for normal concrete.

In addition, self-compacting concrete has two big advantages. One relates to the construction time, which in most of the cases is shorter than the time when normal concrete is used, due to the fact that no time is wasted with the compaction through vibration. The second advantage is related to the placing. As long as SCC does not require compaction, it can be considered environmentally friendly, because if no vibration is applied no noise is made.

V. FUTURE SCOPE

Further investigations have to be carried out regarding the self-compacting concrete. One major topic, which has to be studied, is related to the influence of cement type and aggregate shape and surface properties on the bonding between cement paste and coarse aggregate. Also, a thorough investigation has to be carried out in order to obtain an appropriate relationship between the water-cement ratio and the aggregate-cement physical interface.

VI. REFERENCES

[1]. Atkins, H. N., “Highway Materials, Soils, and Concretes”, 4th Edition, Prentice Hall, pp.277-330 (2003).

[2]. Barksdale, R. D., “The Aggregate Handbook”, National Stone Association” (1993).

[3]. Bartos, J. M., “Measurement of Key Properties of Fresh Self-compacting Concrete”, CEN/PNR Workshop, Paris (2000).

[4]. Dehn, F., K. Holschemacher, and D. Weisse, “Self-Compacting Concrete - Time Development of the Material Properties and the Bond Behavior”, LACER No. 5, pp.115 123 (2000).

[5]. Detwiler, R. J., R. Wenk, and P. Monteiro, “Texture of calcium hydroxide near the aggregate cement paste interface”, Cement and Concrete Research Journal, Vol. 18, Issue 5, pp.823-829 (1988).

[6]. Dhir, R. K. and T. D. Dyer, “Modern Concrete Materials: Binders, Additions and Admixtures”, Thomas Telford Publishing, London, UK (1999).

[7]. Dietz, J. and J. Ma, “Preliminary Examinations for the Production of Self-Compacting Concrete Using Lignite Fly Ash”, LACER No.5, pp.125-139 (2000).

[8]. Dodson, V., “Concrete Admixtures”, VNR Structural Engineering Series (1990).

[9]. Duval, R. and E. H. Kadri, “Influence of Silica Fume on the Workability and the Compressive Strength of High-Performance Concretes”, Cement and Concrete Research Journal, Vol. 28, Issue 4, pp.533-547 (1998).

[10]. Ferraris, C. F., L. Brower, J. Daczko, C. Ozyldirim, “Workability of Self-Compacting Concrete”, Journal of Research of NIST, Vol. 104, No. 5, pp.461-478 (1999).

[11]. Ferraris, C. F., “Measurement of the Rheological Properties of High-Performance Concrete”, J. Res. Natl. Inst. Techn., Vol. 104, No. 5, pp.461-477 (1999).

[12]. Ferraris, C. F., “Concrete Mixing Methods and Concrete Mixers: State of the Art”, NIST Journal, Vol. 106, No. 2, pp.391-399 (2001).