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REVIEW OF SELF-CONSOLIDATE CONCRETE

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ABSTRACT

The self-consolidating concrete possess quality of achieving full compaction and flowing based on its own weight even in congested reinforcement. In this study, the self-consolidating concrete is investigated by its qualities. The material used in the study included fine aggregate, coarse aggregate, cement, superplasticizer, marble powder, and silica fume. There were 5 specimen beams used in the current study based on cement, silica fume, and marble powder combination. The test included slump flow test, V-funnel test, and L-box test. The results show that for the five samples, the 7 days' compressive strength was about 29.94 on average; and for 28 days' compressive strength, the strength was 41.65 on average. The results show that self-consolidate concrete has satisfactory qualities.

Keywords: Self-Consolidate Cement, Concrete, Durability.

INTRODUCTION

With increased use of concrete in modern era, there are new types of concrete are developed which have different qualities and used in variety of settings. One innovative concrete is self-consolidating concrete which is free from compaction and vibration for placement. The self-consolidating concrete possess quality of achieving full compaction and flowing based on its own weight even in congested reinforcement. The resulting self-consolidating concrete is as hard as traditional vibrated concrete and possess all the qualities of traditional vibrated concrete. The use of self-consolidating concrete is started in Europe since 1970s however, the improved version was developed in 1980 by Japan. Currently, the self-consolidating concrete is heavily used in industrial and constructions context. The self-consolidating concrete provide a good alternative of traditional method since it provides rapid rate of concrete placement with speedy construction times and easy flow in congested areas. The structure which is based on self-consolidating concrete shows good features including higher durability, superior finishing, uniform concrete strength, minimal concrete voids and higher level of homogeneity. Mostly, low water to cement ratio is used for producing the self-consolidating concrete which gives higher strength and earlier demolding. The other benefits of self-consolidating concrete include safer working environment, less level of noise, no vibration, thinner concrete sections, greater freedom in design, improved durability, easier placement, higher surface finishing, reduction in site manpower and faster construction. Given these desirable qualities of self-consolidating concrete, it is not surprising that many experts consider it as the most revolutionary product among the concrete products. Based on the self-consolidating concrete technology, superior plasticisers for concrete is also developed. Now self-consolidating concrete is using heavily in precast concrete work and the site concrete work.

Key Features of Self-Consolidating Concrete

For obtaining the higher workability on concrete, it is required that good spacing between the aggregates as to minimize the friction between them. Concrete sample based on good space between the aggregates is covered by cement paste, the aggregates can be compacted and squeeze out for excess cement paste surrounding it. The left over is the top layer with just the paste itself and below is a compact state of aggregates having enough cement paste to fill the void spaces. The cement paste in the voids is labelled as ‘compact paste’; whereas the cement paste which wraps around the aggregates is called ‘excess paste’. Easier and homogeneous dispersion is possible because of this excess paste in the matrix.

Figure 1: Self-Consolidating Concrete

Figure 2: Self-Consolidating Concrete Use

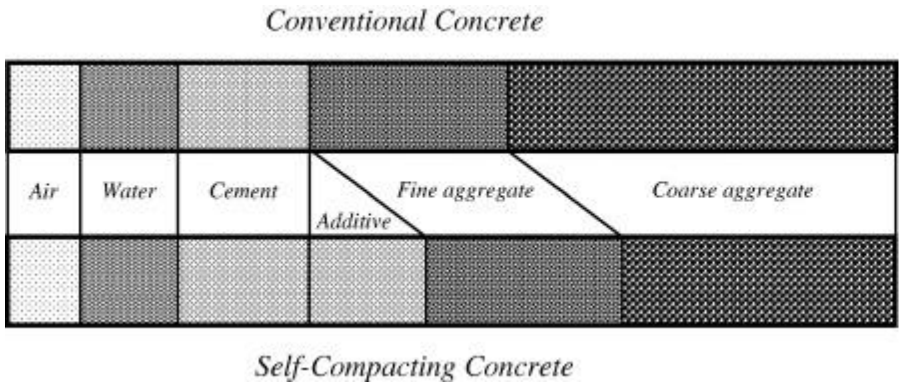

Figure 3: Difference between Conventional and Self-Consolidating Concrete

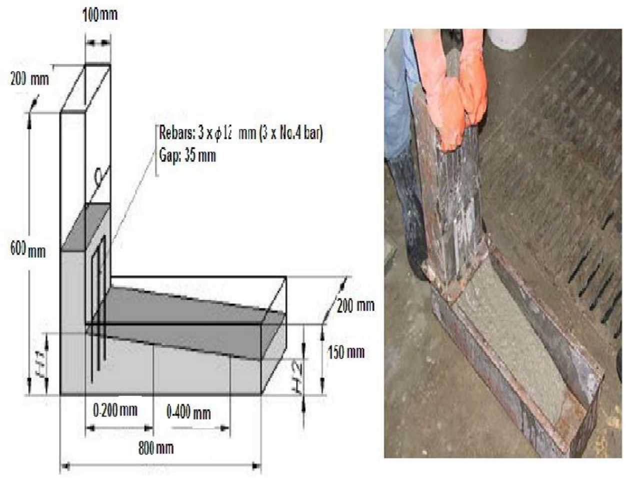

Figure 4: Test Method

REVIEW OF PAST LITERATURE

Various studies report experiments or different test-based studies related to the self-consolidating concrete. For example, study by Felekoglu (2008) was about self-consolidating concrete. The study showed that for producing self-consolidating concrete and achieving consistency, some physical properties of sand used need to be changed. When comparing between self-consolidating concrete and CLS sand. The comparison showed that CLS sand increased the admixture demand while losing the strength. Based on increased admixture contents, setting times of self-consolidating concrete prepared with CLS sand was also increased. The test showed guidelines for selecting suitable sand quantity and type.

The study by Siddique (2008) was about self-consolidating concrete in a fluid mixture suitable for placing in structures with congested reinforcement without vibration. The findings are that a good balance between stability and deformability is required. Based on material and mix proportion, the compact ability is also influenced. The author also proposed an experimental procedure for the design of self-consolidating concrete mixes. The test results are based on acceptance characteristics such as L-Box, V-funnel, J-ring.

A study about self-consolidating concrete conducted by Okamura and Ozawa (1995). The study showed that aggregate movements in self-consolidating concrete can be increased by using the transparent polymer leads. Furthermore, the study reported that by adjusting the coarse control, super plasticizer, w/c ratio, the filling ability and shear stress can be improved. A procedure for making such adjustment is also proposed in the study. Accordingly, mortars, the ratio of slump flow index to funnel flow index to almost constant with respect to volume of water to cement ratio for a given value of super plasticizer to cement ratio.

Another study by Okamura and Ozawa (1995) was based on fill ability using the U box test, L box test, funnel flow, and slump flow. The study findings are that self-compatibility is influenced by w/c ratio and must be decided based on strength requirements.

Collepardi (1980) conducted experiments related to the self-consolidating concrete. The findings show that self-consolidating concrete is the most important cementations material. In particular, it was suggested that the ingredients of these mixtures including silica fume, ground limestone, fly ash, cement, and super plasticizer, etc. Their properties are studies based on resistance to segregation and sustainable progress.

MATERIAL AND METHODS

Table 1: Fine Aggregate

S. No	Properties	Values
1	Bulk Density	1.8
2	Fineness Modulus	1.9
3	Specific Gravity	1.3

Clean river sand is used as a fine aggregate in the study. 5.85mm sieve is used for first sieving for removing any greater particles. Particles smaller than 0.105 mm were considered as fine which contribute to the powder content.

Coarse Aggregate

Table 2: Coarse Aggregate

S. No	Properties	Values
1	Bulk Density	8.32
2	Fineness Modulus	2.35
3	Specific Gravity	1.9

Crush stone aggregate is used as a coarse aggregation which were passed through 15mm sieve. Normal concrete constitute of about 85% of total aggregate. However, the self-consolidating concrete only constitute of about 50% of total volume of concrete.

Table 3: Cement

S. No	Properties	Values
1	Consistency	42%
2	Specific Gravity	2.93
3	Initial Setting time	40 min
4	Final Setting Time Test	340 min

Cement has certain cohesive and adhesive properties which enable bonding material fragments into a compact mass. Among concrete, cement is considered as highly important ingredient. There are various types of cement based on their qualities and usage. In present study, the Portland cement is used.

Superplasticizer

For self-consolidating concrete, the superplasticizer is considered as an essential component for necessary workability. In this study, the Conplast SP440 is utilized. This type of superplasticizer is considered as chloride free based on sulphonated naphthalene polymers. The solution f superplasticizer is instantly mixed with water. It produces the fine particles in the concrete mix which enables the water contents of the concrete to perform more effectively. This leads to the increased strength.

Marble Powder

The marble natural stones create a large amount of dust which leads to the pollution in the cities. However, with the use of marble powder, the dust can be reduced which has favorable environmental consequences. The gravity of marble powder used in this study related experiment was about 1.963.

Silica Fume

Table 4: Chemical Composition of Silica Fume

S. No	Constituents	Quantity (%)
1	LOI	3.23
2	CAO	1.7
3	FE_2O_3	1.93
4	$Ai_2\,O_3$	0.42
5	SiO_2	90.69

The silica fume when added to the concrete provides favorable chemical properties such as durability of the concrete, reinforcement of the microstructure through filler effects and reduction of bleeding and segregation. Higher earlier strength is also achieved by using the silica fume. In the present study related experiment, specific gravity of the silica fume used is 2.45.

Specimen Description

Five beam specimens were used in the current study related experiment. The specimen's details are provided in the table below.

Table 5: Specimen Description

Specimen	Description
SP1	Control Specimen
SP2	75% of cement, 5% of silica fume, 20% of marble powder
SP3	70% of cement, 10% of silica fume, 20% of marble powder
SP4	65% of cement, 15% of silica fume, 20% of marble powder
SP5	60% of cement, 20% of silica fume, 20% of marble powder

The Proportion Mix of self-consolidating concrete is as follows.

Table 6: Proportion Mix of Self-Consolidating Concrete

S. No	Materials	Quantity (Kg/m^3)
1	Super Plasticizer	1.50% of powder
2	Water	187
3	Coarse Aggregate	690
4	Fine Aggregate	1030
5	Cement	420

Tests for Fresh Properties of self-Consolidating Concrete

The first test is slump flow test which is normally used for the assessment of the horizontal flow and flow rate of self-consolidating concrete in the absence of obstructions. Originally, the test was about measuring the underwater concrete.

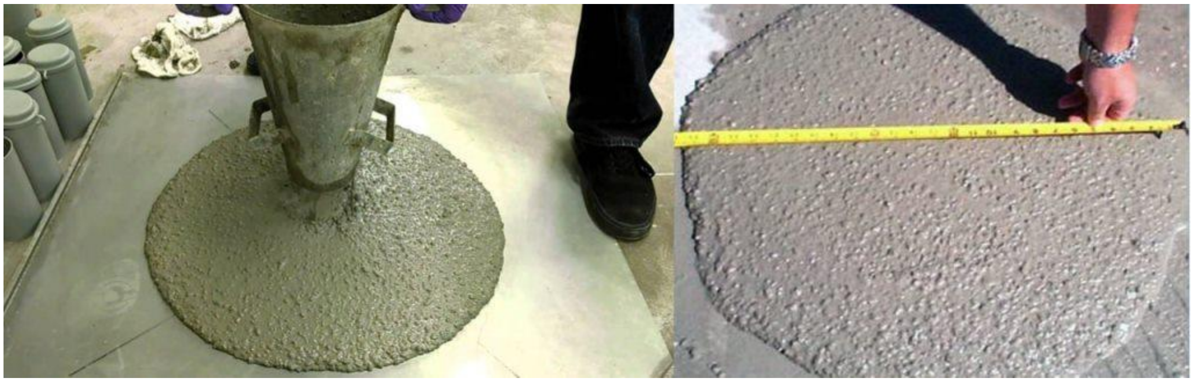

Figure 5: Slum Flow Test

If the test value is higher, it shows that the concrete is able to fill formwork under its own weight. Based on the guidelines by EFNARC, the SCC required at least 650mm value. Generally, there is no universal guidelines regarding the tolerance acceptance however, ± 50 mm is considered as rule of thumb. A secondary indication of flow is the T500 time. Lower time corresponds with higher flowability and higher time corresponds with lower flowability. If minor segregation is there, it will coarse aggregation can occur at the edge of the pool of the concrete. It if it does not occur, it does not mean that segregation is not occurred since it is a time related aspect and can occur later on.

V Funnel test is used for assessment of the filling ability of the concrete with a maximum aggregate size of 20 mm. Ozawa is credited with development of the test at first place. A V-shaped funnel is used in this test. The test procedure is that the funnel is filled with concrete and the time is measured for its flowing through the apparatus. The funnel can be refilled with concrete and left for 5 minutes to settle. In case of segregation, the flow time will be increasing.

Figure 6: Funnel Test

The concrete ease of flow is measured and shower flow time is an indication of greater flowability. Based on the guidelines by EFNARC, the flowability for self-consolidating concrete is about 10 seconds. Prolonged flow time means there is some susceptibility of the mix to blocking while inverted cone shape restricts flows. Based on 5 minutes' time for settlement, segregation of concrete will indicate a less continuous flow with an increase in flow times.

L Box Test for self-consolidating concrete assess its concreteness and its extent to blocking by reinforcement. The apparatus consists of a rectangular section box in the shape of an L with a horizontal and vertical section which are separated by a movable gate in front of which the vertical lengths of reinforcement bars are fitted.

Figure 7: L-Box Test

Concrete is filled in vertical section and gate is lifted for permitting the concrete flow into the horizontal section. By the time, the flow is stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section. The slope of the concrete is indication when at rest. It shows its extent to which the passage of concrete through the bars is restricted or its passing ability. Different intervals and diameters based bars can be used based on normal reinforcement considerations. These bars can be set at any spacing to impose a more or less severe testing conditions related to the passing ability of the concrete. The obvious blocking of coarse aggregate behind the reinforcing bars can be detected visually.

Requirements of Self-Consolidate Cement

The main properties of self-consolidate cement are the properties of the fresh state. Ideally speaking, the mix design should be flowing under its own weight without vibration and able to flow through heavily congested reinforcement. The basic requirements for a concrete to be considered as self-consolidate are filling ability and compressive strength. The details are as follows.

The filling ability is about self-consolidate cement is flowing freely in all type of spaces within the formwork based on its own weight without any external energy and leaving no voids. It is also about how quickly the self-consolidate cement flows under its own weight without losing its stability.

Compressive strength is about compression test carried on concrete cubes based on the standard guidelines. In this study, the concrete cubes specimen was tested under 2200 KN capacity compression testing machine. Concrete cube crushing strength is assessed by applying compressive load at the rate of 150 KN/min until the specimen fails.

Figure 8: Compressive Strength Test

Table 7: Results

S. No	Types of Sample	7 Days compressive Strength (N/mm^2)	28 Days compressive Strength (N/mm^2)
1	SP1	31.50	39.59
2	SP2	32.57	42.33
3	SP3	29.72	44.59
4	SP4	28.63	41.11
5	SP5	27.29	40.67
	Average	**29.942**	**41.658**

The results show that mostly, for the 7-day compressive strength, the specimen ranged from 27.29 to 32.57 with average of 29.942. Similarly, for the 28-day compressive strength, the specimen ranged from 39.59 to 44.59 with average of 41.65.

CONCLUSION

Experiment was conducted to test the self-consolidating cement with various ratio of silica fume and marble powder for their flow and strength testing. The results based on the slump flow test, v-funnel test, and L box test shows that strength of the sample is increased as the silica fume is added with higher proportion. Overall, results show that self-consolidate cement has satisfactory qualities.

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