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Experimental Investigation on Strength Characteristics of Self-Compacting Concrete Using Superplasticizer

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Abstract-This paper deals with the results of an experimental research on Self-Compacting Concrete (SCC) with superplasticizer. Superplasticizers are commonly known as High Range Water Reducers because it permits low water cement ratio as well as the workability also affected. In this study, the local materials and Sika Viscocrete-10 are used and their properties are determined. All tests are performed according to ASTM standard. The mix proportions and testing methods for flow characteristics of self-compacting concrete are different from conventional vibrated concrete. Various trial mixes with different superplasticizer of 0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, 1.4% and 1.5% are conducted to satisfy the workable properties of SCC. The fresh properties of SCC such as slump flow test, slump flow T500mm test, V-funnel test, V-funnel T5minutes test and L-box test are carried out and checked according to ACI 237R-07 guideline. Harden properties of compressive strength of SCC is determined at the age of 3 days, 7 days and 28 days. Mix design is calculated for the target strength M34.2 (4959psi). The results of the present investigation indicate that the performance and compressive strength of SCC with admixture 0.8% was observed to be much better than other four successful mixes.

Keywords- *Compressive Strength, Self-Compacting Concrete (SCC), Superplasticizer, Workability*

I. INTRODUCTION

Self-Compacting Concrete represents one of the most significant advances in concrete technology. SCC is able to flow under its own weight due to its highly fluid nature and achieving a full compaction even in a formwork with complicated shapes and dense reinforcement. It provides better quality especially in the members having reinforcement congestion or decreasing the permeability and improving durability of concrete [5]. The property of SCC in hardened state is dense, homogeneous and has the same engineering properties and durability as normal concrete.

Self-Compacting concrete consist of similar components as conventionally vibrated concrete: cement, coarse aggregate, fine aggregate and water with the addition of chemical admixtures in different proportion [6]. The main purpose of using superplasticizer is to produce flowing concrete with very high slump that is to be used in heavily reinforced structures and in places where adequate consolidation by vibration cannot be readily achieved [7].

The objectives of the study are to find the flowability of Self-Compacting Concrete with various dosage of superplasticizer and to evaluate the compressive strength of Self-Compacting Concrete.

II. PHYSICAL PROPERTIES OF MATERIAL

In this study, the physical properties and chemical composition of Crown cement with and without superplasticizer is tested. Then, the physical properties of fine and coarse aggregates are tested. The properties test results of cement, fine aggregate, coarse aggregate and superplasticizing admixture used in this research are shown in Table I to V.

A. Cement

Ordinary Portland cement, Crown cement (52.5 Grade) from a single batch is used through the course of project work.

The properties of Crown cement used are shown in Table I.

TABLE I. THE PHYSICAL PROPERTIES OF CROWN CEMENT

Properties		Results	Standard Range
Fineness (%)		8.6	< 10
Specific Gravity		3.16	3.15 ~ 3.2
Normal Consistency (%)		27.5	26 ~ 33
Setting Time	Initial (min)	50	>45
	Final (min)	110	< 375
Soundness (mm)		0.7	< 1

B. Physical Properties of Fine and Coarse Aggregates

Aggregate significantly affects the performance of SCC by influencing its flowing ability, passing ability and segregation resistance as well as its strength. The fine aggregate used in this investigation is river sand which is locally available and coarse aggregate used in this study is crashed stone with a maximum size of 20 mm. The physical properties of fine and coarse aggregates are shown in Table II.

TABLE II. TEST RESULTS FOR PHYSICAL PROPERTIES OF FINE AND COARSE AGGREGATE

Section	Fine Aggregate	Coarse Aggregate	Standard Range
Fineness Modulus	2.08	7.17	2~3.1
			5.5~8
Specific Gravity	2.67	2.74	2.5~2.9
			2.6~3
Water Absorption (%)	0.92	0.73	<3%
			<2%

C. Superplasticizer or High Range Water Reducer

Superplasticizing Admixture used in this study is Sika Viscocrete-10. It is a liquid admixture that is suitable for the production of ready mixed concrete. And it is especially suited for applications which require high quality concrete, concrete with high water reduction to meet low w/c ratio requirements, high performance concrete and self-compacting concrete [6]. It has been developed in accordance to ASTM-494 Type F. Test results for physical properties of cement with different percentages of superplasticizer are shown in Table III and IV.

TABLE III. NORMAL CONSISTENCY OF CROWN CEMENT WITH DIFFERENT PERCENTAGE OF HIGH RANGE WATER REDUCING ADMIXTURE

Percentage of Admixture by Weight of Cement (%)	Weight of Water (g)	Normal Consistency (%)	Percentage of Water Reduction (%)
0	108.9	27.5	-
0.2	104	26	4.4
0.5	98	24.5	9.9
1.0	90	22.5	17.3
1.5	80.5	20.125	26

TABLE IV. DENSITY OF SUPERPLASTICIZER (SIKA VISCOCRETE-10)

Test No.	I	II	III
Wt. of flask (g)	153	153.70	153.30
Wt. of (flask + water) (g)	650.10	650.10	649.90
Wt. of water to calibration mask (g)	497.10	496.40	496.60
Volume of water (cm3)	498.78	498.13	498.40
Wt. of admixture (g)	526.50	525.50	526
Wt. of (flask + admixture) (g)	679.50	679.20	679.30
Density of water (g/cm3)	0.997	0.997	0.997
Density of admixture (g/cm3)	1.056	1.055	1.055
Average Density of admixture (g/cm3)	1.06		

The density of admixture is 1.06.

The more percentages of superplasticizer, the more amount of water can be reduced also the less value of normal consistency.

D. Water

Water used for mixing in the present work was potable tap water.

III. MIX PROPORTION OF SELF-COMPACTING CONCRETE

In order to determine self-compacting concrete on the properties of fresh and hardened concrete, the proportion of cement, find and coarse aggregate are calculated by using ACI mix design. To get flow-ability and the mix proportions for field mix design of self-compacting concrete, ACI 237R-07 guideline proportions parameters for SCC are considered. The w/c ratio 0.32 is used in the mix design according to ACI 237R-07 with various superplasticizer. Fine and coarse aggregates must adjust to obtain the fresh self-compacting concrete properties. Table V shows required amount of materials per m3 for normal concrete and self-compacting concrete with various superplasticizer.

TABLE V. MIX PROPORTIONS

No	Admixture (%)	Cement (kg)	Fine agg; (kg)	Coarse agg; (kg)	Water (kg)
NC	-	637.96	486.96	1127.23	204.15
SCC1	0.2	625.19	818.98	809.22	200.06
SCC2	0.4	612.44	841.12	809.22	195.98
SCC3	0.6	567.78	918.59	809.22	181.69
SCC4	0.8	529.50	979.46	809.22	169.44
SCC5	1.0	491.22	1045.87	809.22	157.19
SCC6	1.2	478.47	1068	809.22	153.11
SCC7	1.4	459.33	1087.37	823.42	146.98
SCC8	1.5	440.19	1120.57	823.42	140.86

The mix proportions are calculated based on the ACI 237R-07 guidelines.

IV. PROPERTIES OF FRESH CONCRETE

After mixing the materials, tests are conducted to ACI 237R-07 guidelines. Slump flow test, T500mm test, V-funnel test, V-funnel T5minutes test and L-box test are used to evaluate the fresh concrete properties of SCC. A concrete mix is called SCC if it fulfils the requirement of filling ability, passing ability and resistance to segregation. The results of air content and fresh properties of self-compacting concrete values are shown in Table VI and VII.

A. Slump Flow and T_{500mm} Slump Flow Test

Slump flow is the most commonly used test and gives a good assessment of filling ability. The slump cone is held down firmly. The cone is then filled with concrete. Tamping is not required. Any surplus concrete is removed from around the base of the concrete. After this, the cone is raised vertically and the concrete is allowed to flow out freely. The diameters of concrete in two perpendicular directions are measured. The average of two measured diameters is calculated [3]. The T500mm time is secondary indication of flow. The T500mm test is determined during the slump flow test. It is simply the amount of time the concrete takes to flow to a diameter of 500 millimeters.

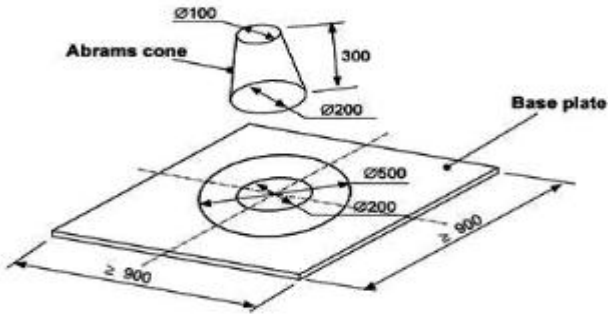

Figure 1. Slump Flow Test

B. L-box Test

L-box test assesses passing ability of SCC. The vertical section is filled with concrete and then gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height H1 and H2 are measured. Closer the unit volume of ratio H2/H1 indicates better flow of concrete [3].

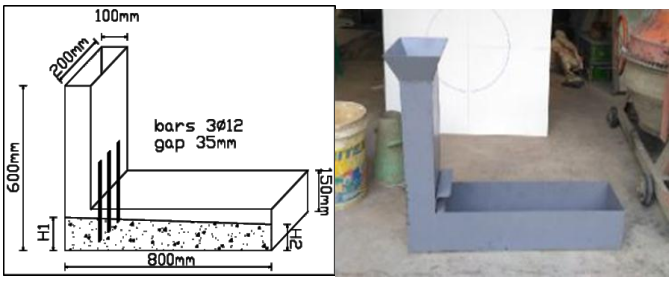

Figure 2. L-box Test

C. V-funnel and V-funnel $T_{5minutes}$ Test

V-funnel test measures the flow-ability of concrete. The test assembly is set firmly on the ground and the inside surfaces are moistened. The trap door is closed and a bucket is placed underneath. Then the apparatus is completely filled with concrete without compacting. After filling the concrete, the trap door is opened and the time for the discharge is recorded [3]. To measure the flow time T5minutes, the trap door is closed and V-funnel is refilled immediately. The trap door is opened after 5minutes and the time for the discharge is recorded. This is the flow time at T5minutes.

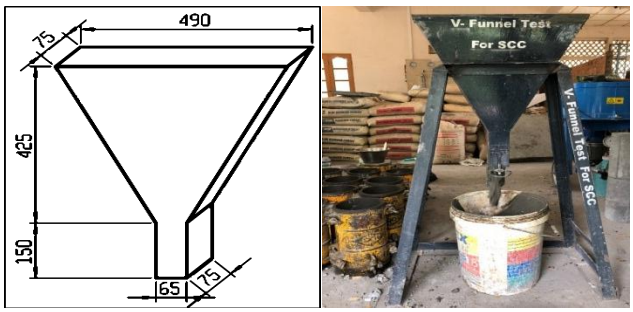

Figure 3. V-funnel Test

D. Air Content Test

The purpose is to determine the air content of freshly mixed concrete made with relatively dense aggregates by observing the change in volume of the concrete with a change in pressure.

TABLE VI. PERCENTAGE OF SUPERPLASTICIZER AND AIR CONTENT RESULTS

Mix	w/c	Admixture (%)	Air Content (%)
NC	0.32	-	2
SCC1		0.2	2.1
SCC2		0.4	2.1
SCC3		0.6	2.2
SCC4		0.8	2.3
SCC5		1.0	2.5
SCC6		1.2	2.75
SCC7		1.4	2.9
SCC8		1.5	3.2

TABLE VII. TEST RESULTS ON FRESH PROPERTIES OF SELF-COMPACTING CONCRETE

No	Admixture (%)	Slump flow (mm)	T500mm Slump Flow (sec)	V-funnel (sec)	V-funnel at T5mimutes	L-box (H2/H1)
NC	0	-	-	-	-	-
1	0.2	-	-	-	-	-
2	0.4	325	-	-	-	-
3	0.6	610	4.24	11.62	14.51	0.82
4	0.8	728	3.84	11.31	14.13	0.9
5	1.0	640	4.53	11.7	14.72	0.80
6	1.2	555	4.95	11.82	14.86	0.8
7	1.4	485	6.62	13.25	17.54	0.63
8	1.5	445	7.56	15.63	18.23	0.43
ACI 237R-07		450 -760	2-5	6-12	0-15	0.8-1

V. MECHANICAL PROPERTIES OF HARDENED CONCRETE

The compression test is the most common test conducted on hardened concrete, partly because it is easy test to perform and partly because of the desirable characteristic properties of concrete is qualitatively related to its compressive strength. This test is performed on 3days, 7days and 28days. The specimens are tested under a compressive axial load. Three cylinders with and without superplasticizer are tested at each period interval and average compressive strength of the three cylinders are taken as the compressive strength. The result compressive strength values are shown in Table VIII.

TABLE VIII. COMPRESSIVE STRENGTH VALUES WITH DIFFERENT DOSAGES OF SUPERPLASTICIZER AND W/C = 0.32

Mix	Admixture (%)	Air Content (%)	Compressive Strength (Mpa)		
			3Days	7Days	28 Days
NC	-	2	31.53	37.95	40.28
SCC1	0.2	2.1	35.8	39.7	46.71
SCC2	0.4	2.1	36.19	43.79	46.9
SCC3	0.6	2.2	42.03	47.87	49.24
SCC4	0.8	2.3	44.76	50.59	54.88
SCC5	1.0	2.5	31.72	37.36	37.51
SCC6	1.2	2.75	28.99	33.86	34.45
SCC7	1.4	2.9	28.32	30.94	31.14
SCC8	1.5	3.2	25.3	25.59	27.73

VI. DISCUSSION AND CONCLUSION

In this study, the mix design proportions of compressive strength of self-compacting concrete are done according to the guidelines of ACI 237R-07. Using w/c ratio at 0.32 and various superplasticizer such as 0.2%, 0.4%, 0.6%, 0.8%, 1.0%, 1.2%, 1.4% and 1.5%, the compressive strengths of self-compacting concrete are tested at the age of 3 days, 7days and 28 days.

It can be seen that only four mixes with admixture 0.6, 0.8, 1.0 and 1.2 percentages are categorized as successful mixes because they met SCC acceptance criteria. From the strength point of view, the strengths are increased up to admixture 0.8% mix and then significantly decreased. For normal vibrated concrete, the compressive strength is 40.28Mpa at 28days which is more than the target strength 34.2Mpa. For successful mix SCC with the more percentages of superplasticizer from 0.6% to 1.0%, the more amount of the 28days strength of SCC than that of the target strength. But the admixture 1.2% can nearly give the target strength at 28 days.

The air content results are increased with an increase of superplasticizer. But these results are within the allowable limits (3.5 ± 1.5%). As a conclusion, out of four successful mixes, the performance and compressive strength of SCC with admixture 0.8% was observed to be much better than the others.

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