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Development of High Strength Self Compacting Concrete Using Mineral And Chemical Admixture

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Abstract:Self compacting concrete(SCC) can flow and consolidate under its own weight and de-aerated almost completely while flowing in the formwork. The use fine materials such as silica fume and Viscosity Modified Agent(VMA) can ensure the required properties of SCC that involved in this research work. The high strength SCC obtained by using 53 grade OPC, silica fume and Superplasticizer GLENIUM B233. Mix proportion of the constituents are arranged by many trials to obtain compressive strength above 60 MPa. Mix proportions were checked for workability tests.

1. INTRODUCTION

The development of new technology in the material science is progressing rapidly. In last three decades, a lot of research was carried out throughout globe to improve the performance of concrete in terms of strength and durability qualities. Self compacting concrete witness for the research and study work.

Self compacting concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of form work under its self weight. It eliminates the need for vibration either external or internal for the compaction of concrete without compromising its engineering properties.

SCC is flowable and deformable without segregation, in order to maintain deformability along with flowability in paste, a super plasticizer is considered indispensable in the concrete to maintain W/C ratio. With super plasticizer, the paste can be made from flowable with little concomitant decrease in viscosity. An optimum combination of water-to-cementitious material ratio and super plasticizer for achievement of self-compactibility can be derived for fixed aggregate content concrete through laboratory trial mixture proportioning.

Use of high content powder materials (<80 µm, from 450 to 600 kg/m^3) that necessitates the replacement of up to 50% of the powder content by supplementary cementitious materials and/or fillers.

Use of Viscosity- enhancing admixture in some cases when the water content is not low enough to promote sufficient viscosity of the paste.

SCC is being studied worldwide, with papers presented at almost every concrete-related conference, but there is no universally adopted standardized methodology for evaluation of self-compactibility of this concrete. Currently self-compactibility is being rapidly adopted in many countries. However there is a need for conducting more research and development work for the standardization of the methods of self-compacting characteristics of SCC.

2.BASIC PRINCIPLE FOR SCC PRODUCTION

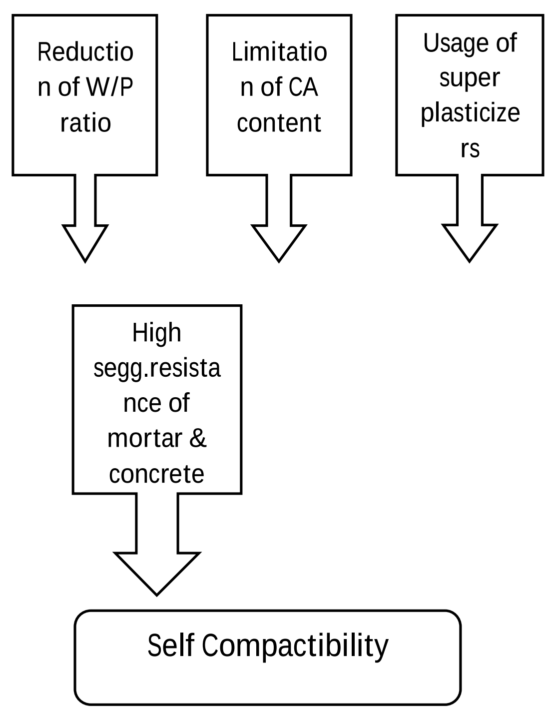

Chart 1 Principle for SCC Production

3. GUIDELINE REFERENCE

This work was carried out as per the European guidelines EFNARC-2005. The following table shows the specific ranges for concrete ingredients.

Constituent	Typical Range By Mass (Kg/M^3)	Typical Range By Volume (Lit/M^3)
Powder	380-600	
Paste		300-380
Water	150-210	150-210
Coarse Agg.	750-1000	270-360
Fine Agg.	Content balances the volume of other constituents, typically 48-55% of total agg weight.	
Water/Powder ratio by volume		0.85-1.10

Table 1 Typical Range of Mix Composition

Limitations for Workability tests as per EFNARC guidelines.

Test Method	Range
Slump flow (mm)	650 - 800
T-50 Slump flow (Sec)	0 - 5
L-Box (h_2/h_1)	0.8 – 1.0
V-Funnel (Sec)	0 – 10
U box (h_2-h_1)	0 – 30

Table 2 Limitation for Workability Tests

4. INGREDIENT MATERIALS

The concrete ingredients materials were tested for for their physical properties according to the guidelines.

4.1. Cement– Ordinary Portland Cement(OPC) of 53 grade from Jaypee cements of specific gravity 3.15

4.2. Coarse Aggregate– Crushed Granite aggregate with nominal size < 12.5mm having bulk density – 1540 Kg/m^3 and specific gravity – 2.75

4.3. Fine Aggregate– Zone III Sand passing through 4.75mm sieve of specific gravity 2.56

4.4. Water– Ordinary potable water of pH ranging from 7 to 8.5

4.5. Mineral Admixture-Silica Fume

Silica fume (very fine amorphous silica particle < 1 µm) and superplasticizer are complementary materials to manufacture self levelling concretes with great cohesion of fresh mix.

Due to this special behavior silica fume in the presence of superplastisizer can compensate the absence of fine materials such as fly ash or ground limestone in relatively lean cement mixtures (300 kg/m^3)

Silica fume is produced in conformance with the ASTM C 1240 specifications. Silica fume having specific gravity of 2.24 is used in this study. The following table shows the properties of silica fume.

Properties	Limits
State	Amorphous-Sub micron powder
Colour	Gray to medium gray powder
Specific Gravity	2.10 – 2.40
Solubility	Insoluble
Bulk Density -Densified	608 – 720 kg/m^3
Bulk Density - Undensified	192 – 320 kg/m^3

Table 3 Properties of Silica fume

4.6. Chemical Admixture-GLENIUM B233

GLENIUM B233 is an admixture of new generation based on modified polycarboxylic ether. The addition of this superplasticizer to dry aggregate or cement is not recommended and forced action for 60 seconds in mixers is recommended after addition of GLENIUM B233.

This is based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. At the start of mixing process the electrostatic dispersion occurs but the presence of lateral chains, linked to the polymer backbone, generate a seric hindrance which stabilizes the cement particle to separate and disperse.

The physical properties of GLENIUM B233 obtained from BASF construction chemicals is shown below in the table.

Properties	Limits
Colour	Light Brown liquid
Relative density	1.09 ± 0.01
pH	>6
Chloride ion content	<0.2%

Table 4 Properties of GLENIUM B233

Dosage – GLENIUM B233 dosage ranges from 500ml to 1500ml per 100 kg of cementitious material is normally recommended. Figure 1 shows the manufacture pack of GLENIUM B233 from BASF Chemicals.

Figure 1 GLENIUM B233

4.7. GLENIUM STREAM 2

GLENIUM STREAM 2 is a premier ready-to-use, liquid, organic, viscosity-modifying admixture (VMA) specially developed for producing concrete with enhanced viscosity and controlled rheological properties. Concrete containing GLENIUM STREAM 2 admixture exhibits superior stability and controlled bleeding characteristics ,thus increasing resistance to segregation and facilitating placement.

Glenium stream 2 is a viscosity modifying admixture which is used in combination with the GLENIUM B233 in order to guarantee maximum efficiency. Glenium stream 2 comprises mixture of water-soluble polymer which is absorbed onto influence the rheological properties of mix.

It has dual play as it decrease viscosity - maintains internal cohesion of the concrete during casting and the polymer chains of the admixtures arrange themselves in the direction of flow of the mix, on the second action it resists segregation due to the polymer chain when the concrete is not moving.

The rheological behavior induced by stream 2 is optimized by using it in combination with GLENIUM B233 to enhance SCC properties. Below mentioned table shows the properties of Glenium stream 2.

Properties	Limits
Colour	Colourless liquid
Relative density	1.01 ± 0.01
pH	8 ± 1

Table 5 Properties of Glenium Stream 2

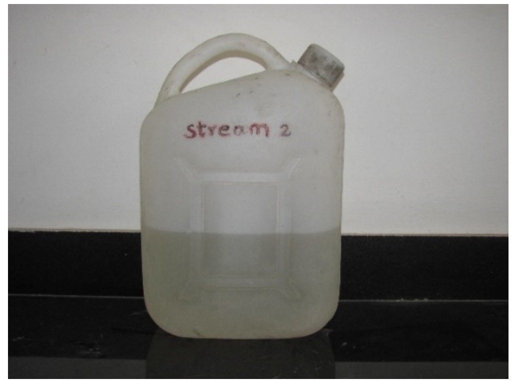

Figure 2 GLENIUM Stream 2

4.8. Viscosity Modified Admixtures (VMA)

A self compacting concrete should have high workability and viscosity. The fluidity of the mix increases as there is no internal friction between the particles and the concrete flows freely. Reaching a right balance between fluidity and the resistance to segregation is essential for SCC. This balance is lacking when the fluidity of the concrete is obtained by adding water.

Even though super plasticizer gives high fluidity, the required property of the SCC is not ensured. This introduce to Viscosity Modifying Agent(VMA) to attain the required property.

5. TRIAL MIX PROPORTIONS – VMA

Mix design procedure were followed from the EFNARC (May 2005) guidelines. Recommended range for W/P ratio by volume is 0.85 to 1.1 and for coarse aggregate it is 50 to 60% iin net volume of concrete. The following table shows mix proportioning values in Kg/m^3.

ID	W/P Ratio	Fine Agg.	Coarse Agg.	Water
1	0.368	901.56	788.56	175
2	0.361	890.18	792.33	175
3	0.354	878.49	796.10	175
4	0.348	866.50	799.88	175
5	0.341	854.17	803.65	175
6	0.334	841.48	807.42	175

Table 6.1 Mix proportioning 1

ID	Cement	Silica Fume	Super Plasticizer	VMA
1	413.44	62.64	7.62	2.38
2	421.09	63.80	7.76	2.42
3	429.04	65.01	7.90	2.47
4	437.29	66.26	8.06	2.52
5	445.86	67.56	8.21	2.57
6	454.78	68.91	8.38	2.62

Table 6.2 Mix proportioning 2

Trial mix proportions for mix without VMA addition is to be calculated as same procedure by including the SP dosage alone.

6. CONCRETE CASTING

After preparing the materials and arriving at the mix design ratio, the specimens such as cubes and cylinders are cast.

Specimen Details – For compression test cubes are cast in in size 150 mm. Split tensile strength test cylinders of size 150mm in diameter and 300mm height.Concrete is cast in prisms for flexural strengthtest.

7. EXPERIMENTAL INVESTIGATIONS

7.1.1 Results on Fresh Concrete - VMA mix

Workability test are carried out for fresh concrete the following shows the unit for the result values.

Slump Flow Test : mm

U - Box Test : mm

L – Box Test : mm

V – Funnel Test : Sec

J – Ring : mm

ID	Slump flow	U - Box	L - Box	V - Funnel	J - Ring
1	735	10	0.98	6.9	1
2	725	13	0.96	7	2
3	710	15	0.93	7.32	4
4	700	17	0.9	7.58	5
5	690	19	0.88	8.02	6
6	685	21	0.86	8.96	7

Table 7 Results on VMA mix

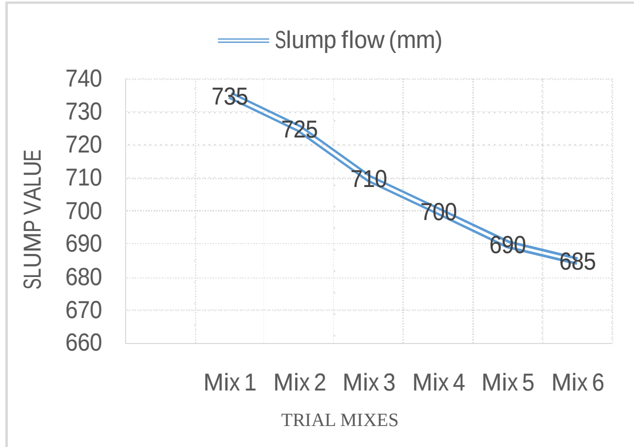

Chart 2 Slump Value for VMA mix

7.1.2 Results on Fresh Concrete –Mix without VMA Addition

ID	Slump flow	U - Box	L - Box	V - Funnel	J - Ring
1	765	3	0.94	7.32	0
2	753	5	0.93	7.43	1.5
3	742	8	0.92	7.66	3
4	730	10.5	0.9	7.88	4
5	720	13	0.84	8.09	5.5
6	712	15	0.81	8.25	6.5

Table 8 Results on mix Without VMA

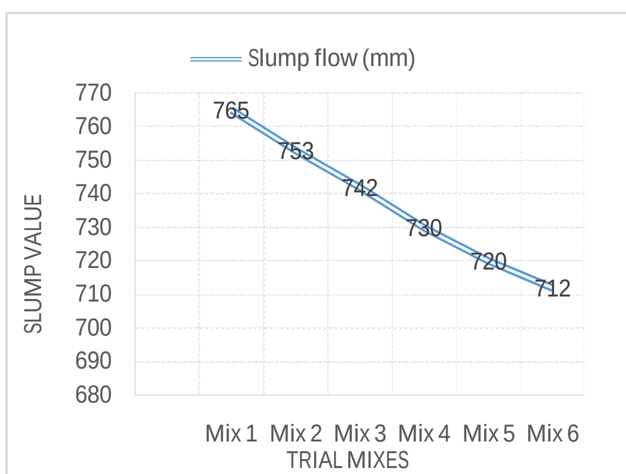

Chart 3Slump Value mix without VMA.

7.2.1Test Results on Hardened Concrete VMA mix

ID	Compressive Strength N/mm^2			Flexural Strength test
	7 Days	14 Days	28 Days	28 Days
1	42.15	50.87	61.33	6.8
2	45.34	55.23	64.24	6.92
3	50.58	59.42	66.22	7.29
4	53.63	61.04	68.02	7.52
5	54.06	61.48	69.32	8
6	54.5	63.22	72.96	8.43

Table 9 Compressive and Flexural strength test result

The following chart is drawn for Compressive strength against W/C ratio for VMA added mixes

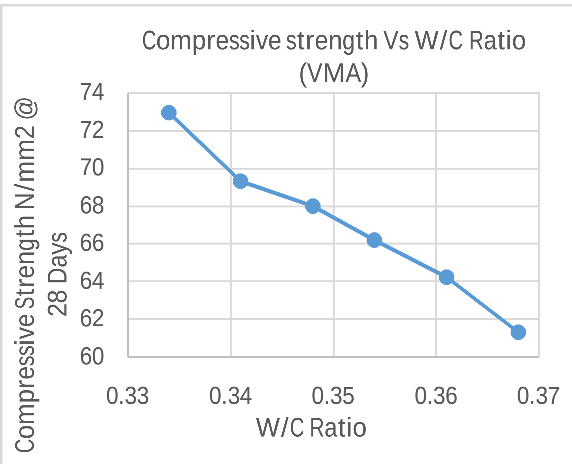

Chart 4 Compressive strength Vs W/C Ratio

Split Tensile test was carried out by cylinder specimen of diameter 150mm, height 300 mm.

ID	Split Tensile test N/mm^2		
	7 Days	14 Days	28 days
1	1.25	2.64	3.89
2	1.67	3.05	4.58
3	2.08	3.19	4.72
4	2.22	3.33	5.14
5	2.5	3.47	5.28
6	2.64	3.89	5.42

Table 10 Split tensile test results (VMA mixes)

7.2.2 Test result for mix without VMA Addition

ID	Compressive Strength N/mm^2			Flexural Strength test
	7 Days	14 Days	28 Days	28 Days
1	41.86	47.96	60.75	7.52
2	43.02	49.12	63.07	7.73
3	44.47	50.29	65.98	7.88
4	45.34	52.61	66.85	8.05
5	47.38	54.06	68.89	8.15
6	48.83	55.81	70.92	8.32

Table 11 Compressive and flexural strength test results

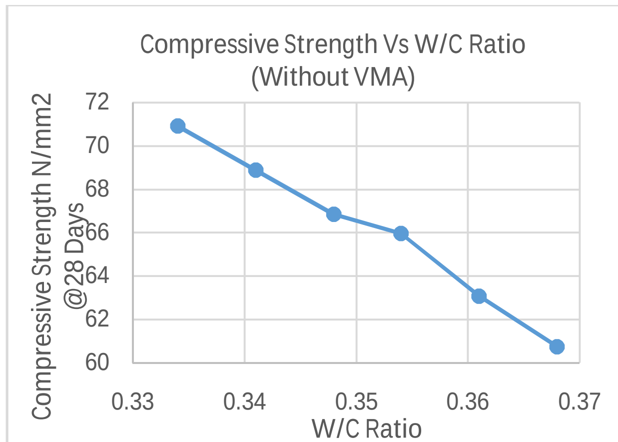

Chart 5 Compressive Strength Vs W/C ratio

ID	Split Tensile test N/mm^2		
	7 Days	14 Days	28 days
1	1.94	2.64	3.82
2	2.08	2.78	4.02
3	2.2	2.91	4.16
4	2.44	3.05	4.3
5	2.58	3.19	4.58
6	2.74	3.47	4.86

Table 12 Split tensile test results

CONCLUSION

Test results on fresh concrete are within the limits of, and follows EFNARC guidelines. Reduction of W/P ratio increases compressive strength. Optimum dosage of chemical admixture is 1.5-2%. Dosage of SP below 1.5% affects workability, over dosage affects setting time. Dosages ofplasticizers require maintaining the self-compactibility of concrete, increased linearly by weight of cementitious materials. Attention need at selecting water content for SCC without adding VMA,since rheological behaviour is more sensitive for water. Test results on fresh concrete with replacement of silica fume as 15-17.5% are within the limits of SCC. Compressive strength was obtained from 60.75 MPa to 70.92MPa for W/P ratio 0.368 to 0.334.

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