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Comparative study of Effects of Viscosity Modifying Agents on Self Compacting Concrete

Ashwin Venkataraman and V Vasugi

***Abstract*—This projects aims at bringing out the role of Viscosity Modifying Agents and how various VMAs affect the properties of self-compacting concrete differently. The main reason behind this study is to find out which VMA is best suited for the particular cement being used in the manufacture of SCC. In this project, two different viscosity modifying agents are used namely Glenium Stream 2 and Rheomac VMA 358. The quantity of the VMA added is the same for both the test conditions and their properties are checked as per standard SCC tests. Comparative study is done between the test mixes and the results are drawn to bring out the more optimum VMA for the cement used. Only fresh concrete tests are done so as to attain the workability related results. There was variation in the fluidity based on the dosage of the VMA provided**

***Keywords*— Glenium Stream 2, Rheomac VMA 358, Self Compacting Concrete (SCC), Viscosity Modifying Agent (VMA) and Workability**

I. Introduction

Self-Compacting Concrete (SCC) is a type of special concrete that has high workability and self-compacting property, i.e. the compaction occurs due to its high flowing property and the need for external vibrators are not required. The concrete is cohesive enough to avoid bleeding or segregation. For the making of self-compacting concrete for high strength purpose the water cement ration should be kept to the minimum. In order to increase the flow property and high workability, chemical admixtures are used in order to increase the workability of the concrete without compromising on the water cement ratio and strength of the concrete.

This project aims to study the properties of SCC when various Viscosity Modifying Agents (VMAs) are added to the same mix of concrete and how various VMAs affect the self-compacting properties of SCC.

A. *Viscosity Modifying Agents*

Viscosity Modifying Agents are added to increase the viscosity of the concrete so as to avoid bleeding and segregation as chemical admixtures increase the flow ability of the concrete. To make sure that the concrete is not too runny, has a long setting period and loses its bonding VMAs are used. The addition of VMA depends on the cement being used. Result of VMA addition may vary from cement to cement. Each cement has one particular VMA which acts best with it. This project aims to draw a result based on this for Birla Cement OPC 53 grade.

The main function of VMA is to modify the rheological properties of concrete, namely the yield point and plastic velocity.

- The yield point is the force needed to start the flow of concrete. It is related to workability of the concrete and can be assessed by the Slump Cone test
- The plastic velocity is the resistance to flow under external pressure. Viscosity as we know is the resistance to flow caused by internal friction in the material. The speed of flow in concrete is related to the plastic velocity and can be asses by the T_{500} during slump cone test or the V-Funnel test.

Ashwin Venkataraman
PG Student, Structural Engineering
SMBS, VIT University
Chennai, India

Prof V Vasugi
Department of Civil Engineering, SMBS
VIT University
Chennai India

B. *Scope and Objectives*

In this project, it is proposed to study

- Mix proportion for high strength self-compacting concrete
- The comparative study of different VMAs for the same mix proportion and Superplasticizer content
- Study of workability of SCC using
    - Slump cone test
    - U-box test
    - L-box test
    - V-funnel test

The scope of this project is limited to the availability of VMAs. The superplasticizer used is Glenium B 233. The study is conducted to see which of the two VMAs complements the superplasticizer better.

II. Literature Review

- 2013, *Asian Journal of Civil Engineering (BHRC) Vol 14, No 1, pp 71-86,* "Optimization of Superplasticizer and Viscosity Modifying Agent in Self-Compacting Concrete". J Guru Jawahar, I V Ramana Reddy, C Sashidhar, J Annie Peter.
  They concluded that the use of VMA imbibes the water so as to resist bleeding and make the paste cohesive. VMA doesn't affect the saturation point of superplasticizer dosage. The increase in sand content affects decreases the spread while increasing the viscosity of the mix.
- 2012 March, *International Journal of Emerging Trends in Engineering and Development, Issue 2, Vol. 2, ISSN: 2249-6149,* "Strength and Workability Character of Self Compacting Concrete with GGBS, FA and SF". Dr P Muthupriya, P Nandhini Sri, Mr P Ramanathan and Dr. P Venkatasubramani.
  They conclude that the use of mineral admixtures improved the performance of SCC in fresh state and avoided the use of VMAs. The optimum w/p ratio was found to be 0.35.

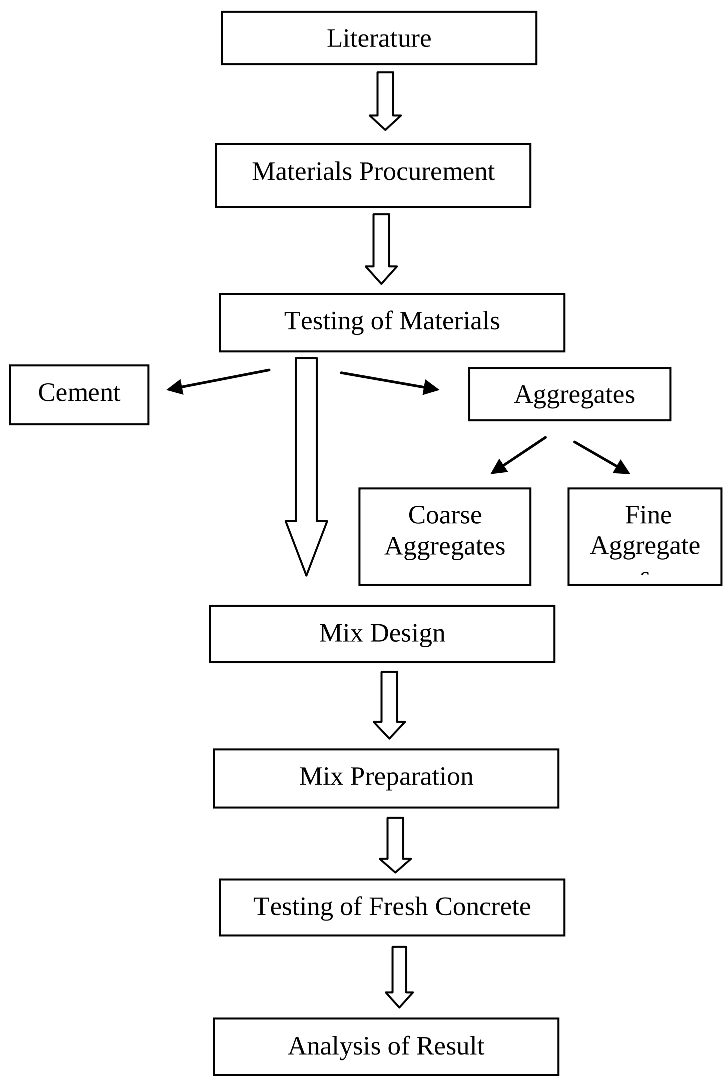
- 2012, *International Journal of Civil and Structural Engineering, Vol 3. No. 2, ISSN: 0976-4399,* "Effect of superplasticizer dosage on compressive strength of self-compacting concrete". Rahul Dubey and Pradeep Kumar.
  They found that the optimum dosage was found to be 2% by mass of cementitious materials. Beyond 2% up to 8% the increase in strength was marginal. Beyond 10% the mix did not set even after 10 days.

- August 2010, *35th Conference on Our World in Concrete and Structures held in Singapore,* "Effect of Viscosity Modifying Admixtures on the Rheological Properties and Stability of Self Consolidating Cementitious Materials". Mohammad Vahdani, Iman Mehdipour, Saeed Yousefi
  They concluded that the VMAs are sensitive to minimum w/c ratio. VMAs influence the bleeding of the concrete mixes, but their influence doesn't arise a high effect on the stability of the mix.
- March 2006, *The Indian concrete journal, vol 80, no 3, pp 13-20.* "Effect of maximum Size and Volume of Coarse Aggregate on properties of SCC". D Das, V K Gupta and S K Kaushik
  It was concluded based on experimental results that to achieve the self-compacting properties the mix should contain a lower volume of coarse aggregate. It is difficult to develop self-compacting concretes with a coarse aggregate content higher than 45% or lower than 15% of the total aggregate

- June 2004, *The Indian concrete journal, vol 78, pp 30-34.* "Use of SCC in Pump House at TAAP 3 and 4, Tarapur. A Mittal, M B Kaisare and R G Shetti
  The methodology adopted for the design of SCC mix, test methods to qualify SCC and method adopted for concreting of walls and other structures of a condenser cooling water pump house was described in brief.

- August 2003, *Proceedings of the 3rd International RILEM Symposium , Reykjavik, Iceland, 17-20, 1 Vol., 1048 pp., ISBN: 2-912143-42-X.* "Properties of flowing concrete and self-compacting concrete with high-performance superplasticizer" It was concluded that the bleeding capacity for SCC is influenced by the superplasticizer dosage. Also the flow ability of SCC is reduced with the elapsed time, superplasticizer dosage and presence of reinforcement. Vibrations were found to increase the later age strength of SCC. Mix proportions, superplasticizer dosage and binder material type used were responsible for the variations found in the concrete properties of SCC.

III. Methodology



The materials procured and the concrete mix design is computed. The mix is made and the tests on SCC fresh concrete is conducted. Based on the results got, the comparison is made and the results are drawn.

IV. Materials

A. *Materials for the SCC mix*

Cement : 53 grade OPC Birla Cement

Fly Ash : Class F fly ash

Aggregates : Fine Aggregates well graded conforming to IS 383
Coarse aggregates 20 mm passing with max size 12.5mm for SCC

Chemical Admixture : Carboxylic Ether based Glenium B 233 superplasticizer

VMA : Glenium Stream 2
Rheomac VMA 358

B. *Material Testing*

1. ***Cement***
    a. Fineness of Cement
    b. Consistency of Cement
    c. Initial Setting Time
    d. Specific Gravity of Cement
    e. Compressive Strength

Test Results

TABLE I. RESULTS FOR CEMENT TESTING

Test	IS Standard	Test Result
Fineness Test	< 10%	8%
Consistency Test	30% to 40%	34.5%
Initial Setting Time	>30 minutes	68 minutes
Final Setting Time	< 10 hours	10 hours 45 minutes
Specific Gravity	3.1 to 3.5	3.38
Compressive Strength	53 N/mm^2 (cement grade 53)	54 N/mm^2

2. ***Fine Aggregates***
    a. Specific Gravity
    b. Sieve Analysis
    c. Fineness Test
    d. Test for Silt and Clay

Test Result

TABLE II. FINE AGGREGATE TEST RESULTS

Test	IS Standard	Test Result
Specific Gravity	>2.55	2.65
Fineness		2.89
Test for Silt and Clay	< 7%	4%

TABLE III. SIEVE ANALYSIS

IS Sieves	% Passing
4.75 mm	100
3.35 mm	94.3
2.36 mm	57.3
1.68 mm	38.4
1.18 mm	32.7
600 µm	15.3
300 µm	5
150 µm	1.3

3. ***Coarse Aggregates***
    a. Specific Gravity
    b. Crushing Test
    c. Impact Test
    d. Absorption Test

Test Results

TABLE IV. RESULT FOR COARSE AGGREGATE TESTING

Tests	IS Standard	Test Result
Specific Gravity	> 2.6	2.84
Crushing Test	< 30%	28.93%
Impact Test	< 30%	20.32%
Absorption Test	< 3%	1.2%

4. ***Superplasticizer***
    a. Superplasticizer used is Glenium B 233
    b. Recommended dosage of Glenium B 233 is 1500 ml per 100 kg of cement
    c. The specific gravity of SP is 1.08
    d. Additional properties of SP
        i. Non Corrosive
        ii. Works best with Glenium Stream 2 VMA
        iii. Concrete remains workable beyond 45 minutes

C. *Mix Design*

According to studies for a good Self-Compacting concrete, the ratio of CA to FA, i.e. CA/FA should be between 0.86 and 1. Keeping this in mind, the mix is designed a s a normal concrete and this recommendation is applied in the end of the design. The design code followed is IS 10262 – 2009 (revision).

Data for M30 Grade Concrete

f_{ck} required @ 28 days = 30 N/mm^2

Max size of aggregate = 20mm

Degree of workability = 0.9 compaction factor

Degree of quality control = good

Type of exposure = mild

Cement used = Birla 53 – 0PC

Fine Aggregate = confirming to zone II

Coarse Aggregate = 20mm passing

Specific gravity of

a. Cement = 3.38

b. Coarse Aggregate = 2.84

c. Fine aggregate = 2.65

1. *Target Mean Strength*

Target mean strength for mix design

$$\bar{f}_{ck} = f_{ck} + t \times S$$

Where,

f_{ck} = Characteristic Compressive Strength at 28 days in N/mm^2

t = a statistical value depending on expected proportion

S = Standard Deviation

$\bar{f}_{ck}$ = 30 + (1.65 X 5)

= 38.25 N/mm^2

2. *Selection of Water Cement Ratio*

From IS: 10262 2009, Table 2, the water-cement ratio for target mean strength of 38.25 N/mm^2

Water cement ratio = 0. 39

3. *Selection of Water Content and Fine Aggregate \Ratio*

For change in value in water cement ratio, and compacting factor, following adjustment required by using Table 6 of IS: 10262-2009.

TABLE V. INCRESE IN WATER CONTENT

Sl. No.	Change in Condition	Adjustment in Water Content
1	Increase in w/c (0.6-0.44), i.e. 0.16	0
2	Increase in compacting factor (0.9-0.8), i.e. 0.1	+ 3%
Total		+ 3%

Water = $186 + \frac{186 \times 3}{100}$

= 191.6 liter/m^3

4. *Calculation of Cement Content*

Cement = $\frac{191.6}{0.39}$

= 491.3 kg/m^3

Due to addition of fly ash, cementitious materials is increased by 10%

Total cementitious materials

= 1.1x491.3 kg/m^3

= 540.43 kg/m^3

Adding 30% fly ash,

Fly ash content = 0.3 X 540.43 kg/m^3

= 162.13 kg/m^3

Cement Content = 540.43 – 162.13 kg/m^3

= 378.3 kg/m^3

Saving of cement = 491.3 – 378.3

= 113 kg/m^3

Water-cement ratio = 191.6 / 378.3

= 0.5

Water-cementitious material ratio

= 191.6 / 540.43

= 0.35

5. *Calculation of Aggregate Content*

Total Volume of Concrete = 1 m^3

Cement Content = 378.3 kg/m^3

Volume of Cement = $\frac{378.3}{3.38*1000}$

= 0.112 m^3

Water Content = 191.6 lt

Volume of water = 191.6/1000

= 0.191 m^3

Volume of Superplasticizer = (mass/specific gravity)*(1/1000)

Mass of superplasticizer (2% of

Cementitious materials) = 0.02*540.43

= 10.806 kg

Volume = $\frac{10.806}{1.08*1000}$

= 0.010 m^3

Volume of Fly ash = $\frac{162.13}{2.24*1000}$

= 0.072 m^3

Total volume of aggregates = 1 – (0.112+ 0.191+0.010+0.723)

= 1 – 0.3853

= 0.6147 m^3

Assuming a ratio CA/FA of 0.86 by mass

For W/C ratio of 0.5 CA = 0.6. For every ±0.05 change in w/c -/+ 0.01 applies in CA

Therefore CA for w/c 0.39 = 0.622

For pump able concrete CA is reduced by 10%

Therefore CA = 0.622*0.9

= 0.5598

FA = 1 – 0.5598

= 0.4402

Mass of CA = 0.6147 x 0.5598 x 2.84 x 1000

= 977.26 kg/m^3

Mass of FA = 0.6147 x 0.4402 x 2.65 x 1000

= 717.065 kg/m^3

Actual Quantities Required for the Mix

TABLE VI. ACTUAL QUANTITY REWUIRED FOR REGULAR CONCRETE

Water	Cement	Fine Aggregates	Coarse Aggregates
191.6 litres	378.3 kg	717.065 kg	977.26 kg

Mix Ratio – *1: 1.89: 2.58*

SCC is largely affected by the characteristic of materials and mix proportions. Applying the CA/FA ratio that defines the aggregate proportioning for Self Compacting Concrete,

Coarse Aggregate required = 0.86 X 717.065

= 617.18 kg/m^3

Modified Mix Proportion

TABLE VII. QUANTITY REQUIRED FOR SELF COMPACTING CONCRETE

Water	Cement	Fine Aggregates	Coarse Aggregates
191.6 litres	378.3 kg	717.065 kg	617.18 kg

Mix Ratio – *1: 1.89: 1.63*

Similarly for other mixes the proportion is calculated

TABLE VIII. MIX PROPORTIONS FOR OTHER TEST MIXES

f_{ck} N/mm^2	SP Content	Water Content	Cement Content	FA Content	CA Content	Mix Proportion
M 30 (Glenium Stream 2)	2%	191.6	378.3	717.065	617.18	1:1.89:1.63
M 35 (Glenium Stream 2)	2%	191.6	398.4	703.9	601.47	1:1.76:1.51
M 30 (Rheomac VMA 358)	2%	191.6	378.3	711.23	611.66	1:1.88:1.61
M 35 (Rheomac VMA 358)	2%	191.6	398.4	699.56	601.62	1:1.75:1.51

V. Tests on Fresh Concrete

Various tests were conducted on fresh concrete. Tests done on fresh concrete are:

- Slump Cone Test
  - Slump Flow (cm)
  - Slump Flow Time T50 (sec)
- L-Box Test
  - Blockage Ratio
  - T200 mm
  - T400 mm
- U-Box Test
- V-Funnel Test
  - V-Funnel Test
  - V-Funnel T5 min

VI. Results

The consolidated table of the results is shown below in Table IX. This shows how the Glenium Stream 2 is better than Rheomac VMA 358.

TABLE IX. RESULTS

Tests	M30 2% (Glenium Stream2)	M35 2% (Glenium Stream2)	M30 2% (Rheomac VMA358)	M35 2% (Rheomac VMA358)	Range	
					Min	Max
Slump Flow (cm)	70	72	74	75	65	80
Slump Flow Time (sec)	3	3	4	5	2	5
V Funnel (sec)	9	9	10	11	8	12
U Box (% Passing)	0.95	0.95	0.93	0.91		
L Box Blockage Ratio	0.9	0.9	0.9	0.89	0.8	1

VII. Conclusion

We can draw to a conclusion from this project that each SP has a particular VMA which complements it and enhances the workability and stability of the SCC. In this particular case Glenium B233 SP is well complemented by the Glenium Stream 2 VMA rather than the Rheomac VMA 358.

But it was noticed that upon over dosage undesirable effects take place making the concrete less workable and rapid setting. The dosage of the VMA shouldn't exceed 1% by mass of the cementitious material at all times. Optimum range ranges from 0.2% to 0.4% for best effects.

Acknowledgment (Heading 5)

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