International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Assessment on Workability and Strength Properties of SCC using Quarry Rock Dust and different bases of Super Plasticizers & VMA

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Abstract*: SCC is a concrete which has the ability to flow like liquid. This flowability of concrete is achieved by limiting the size of coarse aggregate content. Also 20% of the coarse aggregate is replaced by utilizing flyash inorder to increase the percentage of powder content..And due to the scarcity and unavailability of sand, an alternate is choosen to measure the rate of workability of SCC using quarry rock dust. The main property and strength of SCC depends on its workability[1] Hence workability tests and its relative compressive strength have been conducted to measure SCC specimens with fine aggregate and quarry rock dust. Fluidity of the paste can be improved by increasing the content of water-powder ratio and by adding super plasticizers. Segregation and blockages can be avoided by reducing the coarse aggregate content. A viscosity modifying agent (VMA) helps to reduce the changes in concrete properties[2]. Thus, relative proportions of ingredients need to be carefully determined to impart self leveling and self compacting properties to SCC in the fresh stage. Thus SCC specimens have been casted with quarry rock dust and fine aggregate using three different bases of superplasticizers(HRWRA) such as polycarboxyl, naphthalene and melamine bases and VMA. And its workability and strength properties have been evaluated by conducting different tests.

Keywords* : CVC- Conventional Concrete, HRWRA-High Range Water Reducing Admixture, NMS-Nominal Maximum Size, QRD – Quarry Rock Dust, RC-Reinforced Concrete, SCC-Self Compacting Concrete, VMA-Viscosity Modifying Agent

I. INTRODUCTION

SCC is the concrete which has the ability to flow under its own self weight to completely fills the formwork by itself without any usage of compacting accessories.[3] There are two types of inorganic additions, nearly inert additions (Type I) and pozzolanic or latent hydraulic additions (Type II). Nowadays, the main difficult in construction practice is unavailability of sand. Hence fine aggregate is replaced with quarry rock dust to SCC specimens for its easy availability and to reduce the cost of construction. Chemical admixture is added during mixing of concrete in minimum quantity with respect to the mass of powder content.

Revised Manuscript Received on January 30, 2020.
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Here powder content refers to the addition of cement and flyash helps to modify and enhance its strength properties in all aspects.. The most important admixtures are the superplasticizers which are added to improve both aspects of concrete both in strength and durability. Also superplasticizers helps the concrete in to flowable nature by reducing water content. The addition of VMA reduces problems like segregation of concrete and blends the concrete into uniform mix. The workability of SCC can be characterized by the following three properties: Filling ability, Passing ability and Segregation resistance of fresh concrete.[4]Thus a concrete mix can be defined as Self-Compacting Concrete only if all the above mentioned three characteristics are fulfilled. Other test methods developed to characterize the properties of SCC are tabulated in Table.I

Table-I: Test methods for workability

SI.No	Method	Property
1.	Slump-flow by Abrams Cone	Filling ability
2.	T50cm slump flow	Filling ability
3.	J-ring	Passing ability
4.	V-funnel	Filling ability
5.	V-funnel at T5 minutes	Segregation resistance
6.	L-box	Passing ability
7.	GTM screen stability test	Segregation resistance

II. MATERIAL PROPERTIES

Fly ash: As per ACI Committee 116,flyash is the finely divided inorganic residue or pulverized fuel ash resulting from the combustion of ground or powdered coal. There are two types of fly ash such as class F and class C [5] .Class F and Class C fly ash are classified depends on the CaO content present .Class C typically gives very good strength results at 28 days compared to Class F fly ash.

Coarse aggregate: Graded coarse aggregates are used with maximum size of 12.5mm.The coarse aggregate shall confirm to IS: 383-1970. The test procedures for the determination of the physical properties, shall be in accordance with IS: 2386-1963.Coarse aggregate sizes of 20 mm and 12.5 mm shall be used in suitable proportions to satisfy the grading requirements for IS 20mm size.

Fine Aggregate: Fine aggregate shall be free from particles such as clay, shale, loam, cemented particles, mica, organic and other foreign matters. Test procedures for the determination of the physical properties, shall be in accordance with IS: 2386-1963 (Part1-8). All the material properties are shown in Table.II

Physical Tests	Cement	Fly ash	Fine Aggregate	Quarry Rock Dust	Coarse Aggregate
Specific Gravity	3.08	3.16	2.6	2.64	2.7
Fineness Modulus	-	-	3	2.86	6.08
Bulk Density	-	-	-	-	1602 kg/m^3
Bulking of Sand	-	-	20%	22%	-

Quarry Rock Dust: Concrete plays an important role in the construction industry and on the other hand, river sand; one of the essential materials has become very expensive which is a scarce material. Depletion of sand is a hectic issue due to increased usage of sand in construction [6]. All the physical properties of all materials are tabulated in Table. II

Table-II: Physical Properties of all Materials

Chemical Admixtures: Requirement of higher workability is the main essence of SCC concrete.[8] Higher workability can be achieved without compromising the strength by adding chemical admixtures into the concrete without adding excess of water. The use of chemical admixtures have become almost a universal practice allover to reduce water-cement ratio for the required workability, which excellent increase in strength[9].

In this study, three different types of admixtures have used for evaluating hardened properties of SCC concrete. They are

- Glenium Super plasticizer and Glenium VMA - Polycarboxyl Base.
- R550 MC and Stabilizer 4R - Melamine Base
- Conplast SP337 and Diutan gum - Napthalene Base.

III MIX DESIGN

Grade of Concrete = M35
Cement used = Ordinary Portland Cement (OPC)
Max Aggregate Size = 12.5 mm
Water Cement Ratio = 0.5

Since there is no standard code for self compacting concrete yet, **EFNARC** code and IS code are referred to satisfy various requirements of good SCC and to design the mix respectively.

In SCC, characteristics such as high fluidity, adequate viscosity and high resistance to segregation should coexist. Fluidity of the paste can be increased by the adding super plasticizers [9]. The viscosity of the paste is increased by use of large quantities of powder material and by addition of a Viscosity Modifying Agent (VMA).Segregation and blocking can be avoided by reducing the coarse aggregate content [3].VMA helps to reduce the changes in concrete properties that can be caused by the variations of specific gravities of ingredients of concrete. Thus relative proportions of ingredients need to be carefully determined to import self leveling and self compacting properties to SCC in fresh stage [8].

Numbers of trials were conducted to achieve the fresh workability characteristics of SCC by replacing 20% of coarse aggregate with fly ash. Mix proportion for SCC is shown in Table.III

Table-III: Mix Proportion for SCC

Ingredients	Quantity	Ingredients	Quantity
SCC-1		**SCC-2**	
w/c	0.5	w/c	0.5
Water	220 liters	Water	220 liters
Cement	440 kg/m^3	Cement	440 kg/m^3
Fly ash	168.29 kg/m^3	Fly ash	168.29 kg/m^3
Fine Aggregate	**794.27 kg/m^3**	**Quarry Rock Dust**	**816.03 kg/m^3**
Coarse Aggregate	673.19 kg/m^3	Coarse Aggregate	673.19 kg/m^3
Mix Proportion: 1: 0.38 : 1.80 :1.52		**Mix Proportion** : 1: 0.38 :1.85 : 1.52	

Admixture Dosages: Various admixture dosages are shown in Table.IV

Table-IV: Admixture dosages of different superplasticizers

Admixture Base	Super plasticizers (%)	VMA (%)
Polycarboxyl Base	0.65% of powder content	1% of powder content
Napthalene Base	1% of powder content	1% of powder content
Melamine Base	1.5% of powder content	0.75% of powder content

Where,

Powder content = Cement + Fly ash
= 440+168.29
= 608.29 kg/m^3

IV METHODOLOGY

The following tests are to be carried out for finding out the filling ability, passing ability, segregation resistance and the results are tabulated and discussed in this chapter.

- Slump flow test
- T 50cm slump flow
- V-funnel
- V-funnel at T5 min
- L-box test

All the mixes of different admixtures satisfies all the EFNARC standards and flow properties.

The main characteristics are well within the standards. Super plasticizer and VMA used should be selected in such a manner that, it should be compatible with each other[9]. Hence in this study three different superplasticizers and its compatible VMA has been used.

The admixtures used are given below

- Glenium Super plasticizer and Glenium VMA
- R550 MC and Stabilizer 4R - Melamine Base
- Conplast SP337 and Diutan gum

V-FUNNEL TEST

The equipment was designed in Japan to determine the flowable capacity of concrete. Since the shape of the equipment is designed in the shape of V shape it is named as "V-Funnel" test.

The funnel is designed to carry 12 liters of concrete and the time taken by the concrete to flow through the apparatus and to fill the bucket kept at the bottom is measured. After this step, again the funnel will be refilled by the concrete and left for 5 minutes to settle down.

L-BOX TEST

The apparatus consists of a rectangular box in the shape of 'L', which consists of both vertical and horizontal sections, separated by a movable gate, vertical length of reinforcement bars are fitted infront of the entry gate. The vertical section is filled with concrete, and the gate is lifted to let the concrete move into the horizontal section [3].

The level of concrete at the end of the horizontal section is measured as the proportion of that remaining concrete in the vertical section. It refers to the slope of the concrete at rest. This is an indication of passing ability of concrete. The horizontal section of the box can be marked at 200mm and 400mm from the gate and the time taken to reach these points are measured.

V RESULTS AND DISCUSSION

A. FRESH PROPERTIES TEST

The fresh properties have been achieved for all the mixes using three different admixtures by keeping fly ash percentage and mix proportions constant but only by varying the dosages of SP and VMA. At water-cement ratio 0.5 all the fresh properties of SCC are well satisfied and tabulated in Table.V

Table-V: Test results of fresh properties of SCC

SCC with Fine aggregate (SCC-1)			
W/C-0.5	**Glenium**	**SP337**	**R550 MC**
V-Funnel (Sec)	8	7	8
V-Funnel T5 min (Sec)	9	9.5	10
L-Box (h2/h1)	0.88	0.9	0.85
Slump flow T50cm (Sec)	3	4	4
Slump Flow (mm)	695	680	655
SCC with Quarry Rock Dust (SCC-2)			
W/C-0.5	**Glenium**	**SP337**	**R550 MC**
V-Funnel (Sec)	6	6	7
V-Funnel T5min (Sec)	7	7.5	8
L-Box (h2/h1)	0.7	0.85	0.8
Slump flow T50cm (Sec)	3	3	4
Slump Flow (mm)	737	705	686

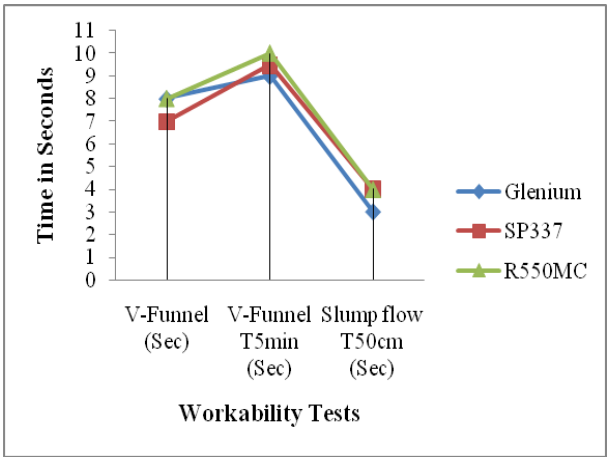

Fig.1.Workability test results of SCC-1

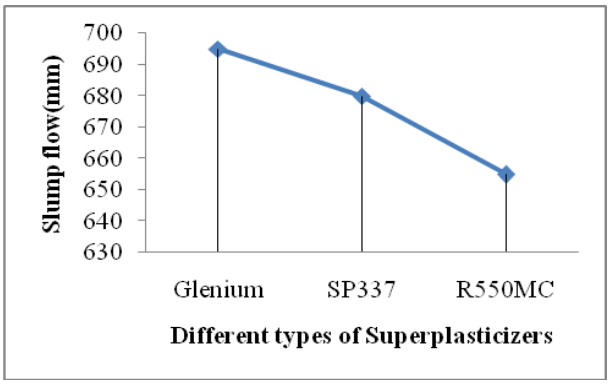

Fig.2.Slump Value of SCC-1

Even though the workability test results are found to be similar, it was clearly observed that only by adding 1% of powder content of SP and 1% of powder content of VMA in naphthalene base produce almost similar results to 0.65% of powder content of SP and 1% of powder content of VMA in polycarboxyl base.

And to the maximum of 1.5% of powder content of SP and 0.75% of powder content of VMA produce almost similar workability test results to polycarboxyl base. The "Fig.1"and "Fig.2" shows that more percentage of SP content requires to enhance the results of naphthalene based SP. And when adding more content of SP the compatible % of VMA have to be determined to achieve the best workability properties in SCC-1. Thus percentage of super plasticizer and VMA plays a vital role in enhancing the basic strength properties of SCC-1. Thus relative proportions of ingredients of super plasticizer and VMA need to be carefully determined to impart the self levelling and self compacting properties of SCC in fresh stage. At W/C ratio 0.5 all the fresh properties of SCC-1 are well satisfied.

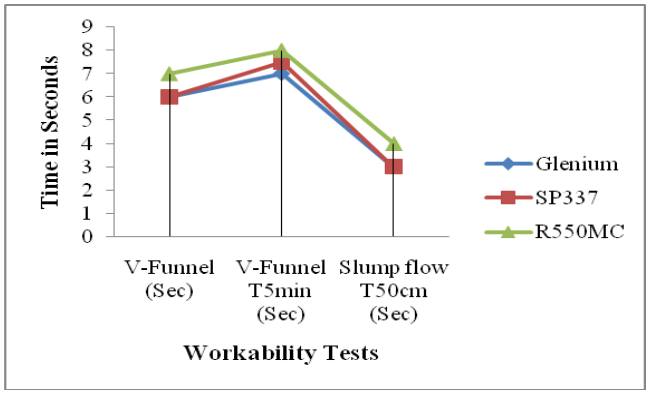

Fig.3.Workability test results of SCC-2

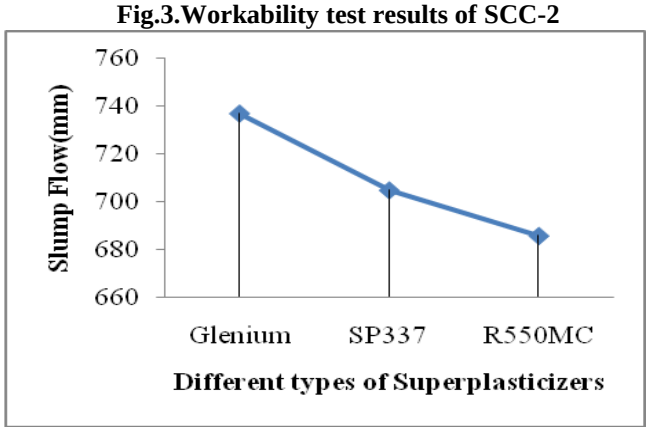

Fig.4.Slump Value of SCC-2

The "Fig.3" and "Fig.4" shows that the fresh properties have been achieved for all the mixes using three different admixtures by keeping fly ash percentage and mix proportions constant but only by varying the dosages of SP and VMA. Compared to all super plasticizers all workability test results in SCC-2 mix with quarry rock dust was found to be more compared to SCC mix with fine aggregate. Thus all the characteristics of flowability concrete are well within the standards [7]. Even compared with SCC mix of fine aggregate SCC mix with QRD shows enhanced results in workability tests. The workability is high since the fineness modulus of QRD is more compared to fine aggregate. This results in achieving more workability nature of SCC when mixed with QRD. Thus super plasticizer and VMA used in SCC-2 is found to be compatible with each other. All these three super plasticizers and VMA results with almost similar test results. Out of all the three mixes, glenium super plasticizer has the best tendency to give a stable mix with high slump flow values. And the workability test results in slump flow test clearly reveals that melamine base super plasticizer and naphthalene base super plasticizer shows less workability compared to polycarboxyl based super plasticizer.

B. MECHANICAL PROPERTY TEST

The tests were carried out for finding out the compressive strength and flexural tensile strength of concrete. The mechanical properties test results are shown in Table.VI

Table-VI: Mechanical Strength Properties of SCC

Mix: M35	SCC-1		SCC-2	
Super plasticizers	7^{th}day Compressive Strength (MPa)	28^{th}day Compressive Strength (MPa)	7^{th}day Compressive Strength (MPa)	28^{th}day Compressive Strength (MPa)
Glenium	39.07	53.36	41.25	55.89
SP337	36.10	48.81	37.67	49.06
R550MC	32.59	44.35	34.21	43.17

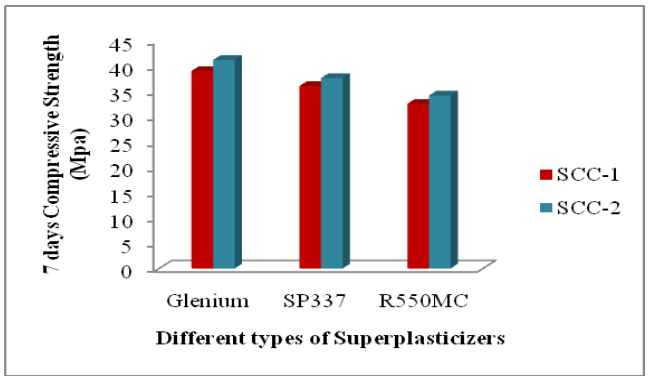

Fig.5. Compressive Strength of SCC-1 and SCC-2 at 7 days

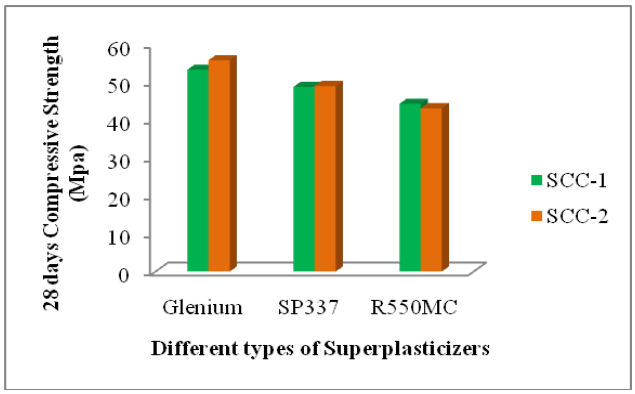

Fig.6. Compressive Strength of SCC-1 and SCC-2 at 28 days

Since the workability of glenium based admixture is more the compressive strength test results of glenium super plasticizer under polycarboxyl base produce better results compared to R550MC super plasticizer and Conplast SP337 super plasticizer.

Thus from "Fig.5" and "Fig.6", compared to melamine base and naphthalene base, polycarboxyl base chemical admixtures produce enhanced results of compressive strength in both SCC mixes. Compared to both mixes of SCC-1 and SCC-2,Self Compacting Concrete with quarry rock dust shows better results compared with SCC with fine aggregate. It was clearly observed that when workability increases compressive strength increases. Thus SCC-2 mix reveals better compressive strength results.

VI CONCLUSION

- Workability of SCC blended with quarry rock dust shows high value compared to SCC blended with fine aggregate.
- Slump flow of glenium superplasticizer with polycarboxyl base produce better workability in both SCC mixes compared to melamine base and naphthalene based superplasticizers.
- Other workability tests such as L-box and V-funnel for passing ability and segregation resistance of almost all bases of superplasticizers shows similar results in SCC-1 and SCC-2.
- Compared to different bases of superplasticizers, polycarboxyl base superplasticizer such as glenium shows better compressive strength results in both mixes of SCC.
- Compressive strength of quarry rock dust blended SCC mix produce enhanced results compared to strength of SCC mix with fine aggregate.
- Compared to addition of dosage of percentage of super plasticizers, melamine based super plasticizer require more addition in percentage of powder content of SP and VMA in both mixes.
- VMA helps to blend the concrete into paste to enhance the workability and strength properties.

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