American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-2 pp-43-47
www.ajer.org

Research Paper Open Access

Workability and strength characteristics of self compacting concrete containing fly ash and dolomite powder

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Abstract: - Advancements in technology demand many improved properties to the concrete like workability, flow ability, higher strength, durability etc. To overcome the difficulties like low workability and low flow ability, a new form of concrete designated as Self Compacting Concrete (SCC) was developed in 1988 by Okamura in Japan. Self compaction is described as the ability of the fresh concrete to flow under its own weight over a distance without segregation and without using vibrators to achieve proper compaction. Sufficient number of investigations is necessary to get a clear idea about the factors affecting the strength, durability and long term behavior of SCC with additives like fly ash and dolomite powder. In this paper, high volume fly ash self compacting concrete was produced with 12.5percent , 18.75percent , 25percent , and 37.5percent of the cement (by mass) replaced by fly ash and 6.25percent , 12.5percent and 25percent of the cement replaced by dolomite powder. For these mixtures compressive strength (cube) was studied at 7thday, 28th day and 90th days with same water powder ratio (0.33). The test results for acceptance characteristics of self compacting concrete such as slump flow test, J-ring test, V-funnel test and L-box test are presented. The mixes were then tested for other mechanical properties like, cube compressive strength at 7th day, 28th day, and 90th day, cylinder compressive strength at 28th day, split tensile strength, and flexural strength at 28th day. For all levels of cement replacement concrete achieved superior performance in the fresh and mechanical tests compared with the reference mixture.

Keywords: - *Dolomite powder, fly ash, self-compacting concrete, super plasticizer, viscosity modifying admixture.*

I. INTRODUCTION

The invention of self compacting concrete (SCC) can be considered as a major evolution in the construction industry. Self compacting concrete is a concrete which has little resistance to flow so that it can be placed and compacted under its own weight without any external vibration [1]. SCC offers many advantages compared to ordinary concrete. The main advantage is in the elimination of mechanical compaction. There are many more advantages in terms of technology, working environment and health monitoring [3]. The high fluid nature of SCC makes it suitable for placing in difficult conditions and also in slender sections with congested reinforcement. SCC can also help in easier placement of concrete, better surface finish, uniform consolidation etc [5]. The present study focuses on the workability characteristics and strength parameters of SCC containing fly ash and dolomite powder. The cement used for the study was 53 grade ordinary Portland cement which has been partially replaced by fly ash and dolomite powder, based on the guidelines of European Federation of producers and contractors of specialist products for structures (EFNARC)[2]. The mix proportions were chosen and the cement content alone was varied without varying the aggregate content. The water powder ratio was kept at 0.33 throughout the study. Water Reducing Admixture (WRA) and viscosity modifying admixture (VMA) were used to improve the workability characteristics [4].

II. MATERIALS AND METHODS

The ingredients used for the study were the same as those used for conventionally vibrated concrete except the usage of mineral and chemical admixture. In order to achieve SCC, optimum proportions of ingredients were selected considering the characteristics of cementitious materials, aggregate quality, paste proportions, aggregate-paste interaction, and type of admixtures, dosage and mixing. For this study ordinary Portland cement of 53 grades with specific gravity 2.93 has been used. River sand passing through 4.75mm sieve with fineness modulus of 2.89 and specific gravity 2.49 which falls under grading zone II has been used as fine aggregate. The coarse aggregate used was crushed granite with a maximum nominal size of less than

12.5 mm, bulk density 1400 kg/m3 and specific gravity 2.85.

Mineral admixture

Generally, fly ash added to SCC for providing increased cohesion and reduced sensitivity to changes in water content. However, high levels of fly ash may produce a paste, which is so cohesive that it becomes resistant to flow. Fly ash (class F) specific gravity is 1.9407 obtained from Mettur Thermal Station was used as a partial replacement of cement up to 37.5 percent. The dolomite powder added to SCC for changing the viscosity and influencing the rheological properties of the mix. The dolomite powder which is a natural form of calcium magnesium carbonate [Ca Mg (Co3)2], with specific gravity 2.89 obtained from Rajasthan has been used as a partial replacement of cement up to 25 percent.

Chemical admixture

A high performance concrete Superplasticizer (SP) based on modified polycarboxylic ether to reduce water-powder ratio for the required workability was considered suitable for the present investigation. Glenium B233 obtained from BASF construction chemicals having relative density 1.09 and pH value 7 has been used. Glenium B233 is a ready to use admixture that can added to the concrete. The water reduction was maximum when Glenium B233 was added after the addition of 50 to 70 percent of the water. VMA has been added along with SP for control mix, which was more robust than the mix without VMA. Glenium Stream 2 having relative density 1.19, and pH 8 was used along with Glenium B233 to improve its performance.

III. EXPERIMENTAL PROGRAM

To study the workability characteristics of SCC Slump flow test, Associated time (T500) that the SCC requires to flow to a diameter of 500 mm, V-funnel test, L-box test and Slump flow with J-ring combination tests were conducted . Compressive strength, Split tensile strength and Flexural strength test were carried out on the hardened SCC. The mix proportions taken for the investigation were based on the EFNARC guidelines. 12.5, 18.75 and 37.5 percentage replacement of cement with fly ash and 6.25, 12.5 and 25 percentage replacement of cement with dolomite has been used in the present investigation. The total powder content was kept 600 kg/m^3. Table1 gives the details of the mix compositions.

Table 1. Mix composition per cubic meter of concrete

Materials	$100F_0 D_0$	$75F_{12.5} D_{12.5}$	$50F_{25} D_{25}$	$50F_{37.5} D_{12.5}$	$75F_{18.75} D_{6.25}$
Cement (kg)	600	450	300	300	450
Flyash (kg)	0	75	150	225	112.5
Dolomite Powder (kg)	0	75	150	75	37.5
Total powder content (kg)	600	600	600	600	600
Fine aggregate (kg)	869	869	869	869	869
Coarse aggregate (kg)	706	706	706	706	706
Water (kg)	198	198	198	198	198
Water powder ratio	0.33	0.33	0.33	0.33	0.33
Superplasticizer (%)	0.82	0.82	0.82	0.82	0.82
VMA (%)	0.2	0	0	0	0

IV. RESULTS AND DISCUSSION

Fresh properties

The results of the various tests that were conducted to study the fresh properties of SCC are discussed in the subsequent sections.

Slump flow

The slump flow test was conducted to assess the horizontal free flow of SCC in the absence of obstructions. It indicates the filling ability of the concrete and also its resistance to segregation. It has been observed that the slump flow characteristics of the mixes are in the range of 690 and 720 mm, and T500 slump flow time of the mixes is between 2 and 5 seconds, which satisfy the recommended values of EFNARC. Slump flow improves with the increase in fly ash content and decreases with the increase in dolomite content. The slump spread test setup is shown in Fig. 1. The workability test results with recommended values given in the Table. 2.

Table 2. Workability tests results with recommended values

Method	Mix designation					Recommended Values	
	100F0 D0	75F 12.5 D12.5	50F25 D25	50F37.5 D12.5	75F18.75 D6.25	Min	Max
Slump flow(mm)	720	695	675	700	690	650	800
T500 slump flow (Sec)	2	5	3	5	5	2	5
V-Funnel (Sec)	6	10	11	12	12	6	12
V-Funnel, at 5 minutes(sec)	8	10.5	11	14	15	-	+3
L-Box ratio, H2/H1	0.84	0.82	0.82	0.87	0.8	0.8	1
J-ring height(mm)	8	10	5	7.5	5	3	10

Fig 1 Slump spread test

Fig 2 V-funnel time test

Fig 3 L-box ratio test

Fig 4 J-ring height test

V- funnel

The filling ability of the fresh concrete was tested with V-funnel, whereby the flow time is measured. The V-funnel flow time increases from 6 to 12 seconds with increase in dolomite content indicating increase in viscosity of concrete. The results of V-funnel test confirms to the standard requirements. The values are given in Table 2 and the test setup is shown in Fig.2.

V-funnel, at 5 minutes

The segregation resistance of the fresh concrete was tested with the V-funnel, at 5 minutes. The test results showed an increased flow time due to the reduction in flow characteristics i.e., the reduction in the passing ability of the mix. The percentage reduction in the passing ability of the mix was observed as 17 percent for addition of fly ash and 12.5 percent for dolomite powder. The results of V-funnel at 5 minutes test are given in Table 2.

L-Box, H2/H1 ratio

The L-box test was conducted to assess the filling and passing ability of SCC and serious lack of stability (segregation). No significant changes were observed for the five mixes. The blocking ratios in the L-box test were as per the requirement of SCC mixes as laid down by EFNARC guidelines. The L-box ratio test setup is shown in Fig. 3 and the values are given in Table 2.

J-ring

J-ring test was conducted to assess the passing ability of the concrete. The accepted difference in height between inside and outside should be between 3 and 10 mm. The results of J-ring test satisfy the EFNARC guidelines. The setup for J-ring test is shown in Fig. 4. The values are given in Table 2.

Hardened Properties

The results of the various tests that were conducted to study the hardened properties of SCC are discussed in the subsequent sections.

Compressive strength

The compressive strength of cubes at 7th, 28th and 90th days and 28th day cylinder compressive strength of the concrete mixes have been observed for different percent replacement of cement with fly ash and dolomite powder. From the results obtained, has been observed that the compressive strength of concrete increased with increase in the replacement levels up to 18.75percent. Beyond that, the compressive strength reduces. This is attributable to the amorphous nature of fly ash and filling ability of dolomite powder. The maximum compressive strength obtained has been for a mix prepared with 25 percentage replacement of cement with fly ash and dolomite powder (12.5 percent fly ash and 12.5 percent dolomite powder). This mix has been taken as the optimized mix. The 28th day compressive strength showed an increase of 8 percent while the 90 day compressive strength showed an increase of 9 percent with that of the control mix. This shows the strength development may be due to the pozzolanic action of the fly ash at later ages. From the results of the 28th day cylinder compressive strength of the concrete mixes, it has been observed that the cylinder compressive strength of concrete has decreased with increase in the percentage replacement of cement with fly ash and dolomite powder. It has also been noticed that the compressive strength of the optimized mix showed a decrease of only about 6 percent than that of the control mix. The compressive strength results are reported in Table 3.

Table 3 Compressive strength properties of concrete mixes

Mix designation.	Compressive strength (cube) N/mm^2		Compressive strength (Cylinder) N/mm^2	
	7 days	28 days	90 days	28 days
100D0D0	57.77	59.26	60.73	38.87
75F12.5D12 .5	45.19	49.62	54.36	36.42
50F25D25	20.74	31.85	42.96	21.7
50F37.5D12 .5	27.41	38.21	43.55	28.91
75F18.75$_D$6. 25	32.59	48.88	50.36	31.96

Split tensile strength

From the experimental investigation it has been observed that the split tensile strength showed a decreasing trend with the increasing percentage replacement of fly ash and dolomite powder. It has also been noticed that the split tensile strength of SCC is greater than that of the control mix. For the mixes 75F12.5 D12.5 and 75F 18.75D6.25 SCC the values are respectively 7 and 4 percent greater than that of control mix. 12.5 to 18.75percent replacement of cement with fly ash and 6.25percent to 12.5percent replacement of cement with dolomite powder resulted in the increase in the split tensile strength values. It is noticed that the increase in split tensile strength has been due to the pozzolanic reactivity of fly ash and filling ability of the dolomite filler. The split tensile strength of concrete mixes are given in Table 4.

Flexural strength

The flexural strength test has been conducted on beam specimen subjected to two points loading and it has been observed that the flexural strength of mix 75F12.5D12.5 was 2.2 percent greater than that of control concrete. For other SCC mixes there is only a slight difference with control concrete. It is found that the flexural strength of SCC increased with an increase in replacement of cement with 12.5 percent of fly ash and 12.5 percent of dolomite powder. The higher flexural strength, has been due to the better microstructure, especially the smaller total porosity and the more even pore size distribution within the interfacial transition zone of SCC. Further the higher content of ultra fines of fly ash and dolomite particles which resulted in dense cement matrix also resulted in the increase in flexural strength. The flexural strength values of concrete mixes are given in Table 4.

Table 4 Tensile strength properties of concrete mixes at 28days

Mix designation.	Flexural strength N/mm^2	Split tensile strength N/mm^2
100F0D0	5.73	2.76

75F12.5D12.5	5.86	2.97
50F25D25	5.49	2.64
50F37.5D12.5	5.3	2.74
75F18. D6.25	5.72	2.87

V. CONCLUSIONS

Based on the results of this investigation, it has been observed that the use of fly ash in SCC mixes reduces the possibility of bleeding and segregation, and increases the filling and passing ability of concrete, whereas dolomite powder imparts viscosity to the concrete and improves the segregation resistance of the concrete mix. The major findings of the study are:-

- Better mechanical and physical properties of concrete can be obtained with the replacement of cement with fly ash from 12.5 percent to 18.75 percent.
- Further it has been observed that SCC could be prepared using dolomite powder instead of VMA. The use of dolomite powder in self compacting concrete mixes reduces the possibility of segregation.
- Better fresh properties of SCC can be obtained with the replacement of cement with dolomite powder from 6.25 percent to 12.5 percent.
- The best self compacting properties were obtained by replacing the cement with the fly ash in 37.5 percent and fine aggregate content to 55 percent of the total aggregate, using a 53 grade ordinary Portland cement and the water powder ratio remained as 0.33.

From this experimental study it can be inferred that fly ash and dolomite powder blend well to improve the overall workability, which is the prime characteristics of SCC. The present study promotes the use of fly ash, which is otherwise considered as waste material. Hence the fly ash–dolomite based SCC is a sustainable material for future construction works. However, design methodologies are to be developed for this concrete prior to actual use in worksite.

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