

Experimental Investigation and Cost Analysis of Self Compacting Concrete by using Red Mud

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Abstract - Self - compacting concrete (SCC) has widespread use in the prefabricated concrete industry. Nowadays the demand for concrete with high quality is permanent. The production of such mixes often used expensive admixtures and very large quantity of cement. But such concrete was generally of lower strength and difficult to obtain. This lead to the development of Self Compacting Concrete. The workability properties of SCC such as filling ability, passing ability and segregation resistance are evaluated using workability tests such as slump flow, V-funnel and L-Box tests. The flow ability and segregation resistance of SCC ensures a high level of homogeneity, minimal voids and uniform concrete strength providing the potential for a superior level of finish and thus durability of the structure. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. This advantages construction practice and performance with reduced health and environment hazards make SCC a highly acceptable one for both precast and cast in situ construction. This paper deals with the history of SCC development and its basic principle, different testing methods to test high- flow-ability, resistance against segregation, and passing ability, benefits and limitations, usage and applications. The self-compacting concretes developed a 28- day compressive strengths ranging from 26 to 48 MPa. The results show that an economical self-compacting concrete could be successfully developed by using red mud. The present project investigates the making of self-compacting concrete more affordable for the construction market by replacing high volumes of Portland cement by red mud. The study focuses on comparison of fresh properties of SCC containing varying amounts of red mud with that containing commercially available admixture. Test results substantiate the feasibility to develop low cost SCC using red mud.

Keywords - Self Compacting Concrete, passing ability, Red mud, Compressive strength and tensile strength

I. Introduction

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, uniform and has the same property and durability as standard vibrated concrete. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SCC is a high performance concrete that consolidates under its self-weight, and adequately fills all the voids without segregation, excessive bleeding or any other separation of materials, without the need of mechanical consolidation. Filling ability helps SCC to flow through the formwork and completely fill all the spaces within it. Passing ability is the property by which it flows without any blocking. The application of SCC aims at obtaining a concrete of high performance, better and more reliable, improved durability, high strength and faster construction. For SCC it is generally important to use Red mud in order to obtain high mobility. Some volume of powdered materials such as silica fume, fly ash, glass filler, stone powder, etc. is also involved. Self-compacting concrete has been successfully used in Japan, Denmark, France, U.K., etc. It is widely been accepted because of its enhanced properties also it reduces noise pollution, saves time, labor and energy. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction.

II. Literature Review

A review of the literature revealed that various laboratory investigations have been conducted independently either on Red mud. Studies concerning Red mud and different materials for strength in concrete have been conducted in the past years by many investigators like

Ozawa *et al.* (1989) focused on the influence of mineral admixtures, like fly ash and blast furnace slag on the flowing ability and segregation resistance of self-compacting concrete. They found out that on partially replacement of OPC by fly ash and blast furnace slag and strength characteristics 10-20% of fly ash and 25-45% of slag cement by mass. **Cengiz (2005)** used fly-ash with SCC in different proportional limit of 0%, 50% and 70% replacement of normal Portland cement (NPC). He investigated the strength properties of self compacted concrete prepared using HVFA (high volume fly ash). Concrete mixtures made with water-

cementitious material ratios ranged from 0.28 to 0.43 were cured at moist and dry curing conditions. He investigated the strength properties of the mix and developed a relationship between compressive strength and flexural tensile strength. **Kumar (2006)** reported the history of SCC development and its future prospects have also been discussed. Orimet test was performed, the more dynamic flow of concrete in this test simulates better the behavior of a SCC mix when placed in practice compared with the Slump-flow variation. The Orimet/J-ring combination test shows great promise as a method of assessing filling ability. **Sahmaran et al. (2007)** presented a paper on study of fresh and mechanical properties of a fibre reinforced self-compacting concrete and Strength properties as well as the workability, shrinkage, absorption and ultrasonic pulse velocity were studied in this research. From the observations it was concluded that 40% replacement of FA resulted in strength of more than 65 N/mm² at 56 days. **Heba (2011)** presented an experimental study on SCC with two cement contents. It was concluded that higher the percentages of fly ash the higher the values of concrete compressive strength until 30% of FA, however the higher values of concrete compressive strength is obtained from mix containing 15% FA. **Okamura et al [4]** and proposed a mix design method for SCC based on paste and mortar studies for super plasticizer compatibility followed by trial mixes. However, it is emphasized that the need to test the final product for passing ability, filling ability. **Prashant Bhuvra et al [6]** gives in their studies development of Self Compacting Concrete no Specific Method of Mix Design is Available. SCC of Different Strength by Using various ranges of cements and Fly Ash, with appropriate quantity of Super plasticizer.

III. Experimental Program

As the development of SCC started since long ago

Codes and standards are available for SCC particularly in India. SCC is a one type of trial and error method. After 13 to 14 trials decide final proportion.

The following steps are included in this phase:

- Design of concrete mix
- Mixing of concrete
- Test Specimens
- Preparation of Moulds
- Harden Properties of Self Compacting Concrete
- Concrete
- Observations and Test Results

❖ Design of concrete mix

Proportioning of the mix is extremely important in developing an effective Self-Compacting Concrete. The relatively high cost of material used in concrete continues to hinder its widespread use in various segments of the construction industry, including commercial construction. However the productivity economics benefits and works out to be economical in pre-cast industry. The reduction in cement content and increase in packing density of materials finer than 80 µm, like Red mud. The reduction in free water can reduce the concentration of viscosity-enhancing admixture necessary to ensure proper stability during casting and thereafter until the onset of hardening. It has been demonstrated that a total sand content of about 50% of total aggregate is favorable in designing for SCC. to design and control with smaller-sized aggregate. SCC mixtures typically have a higher paste volume, less coarse aggregate, and higher sand-to-coarse aggregate ratio than typical concrete mixtures.

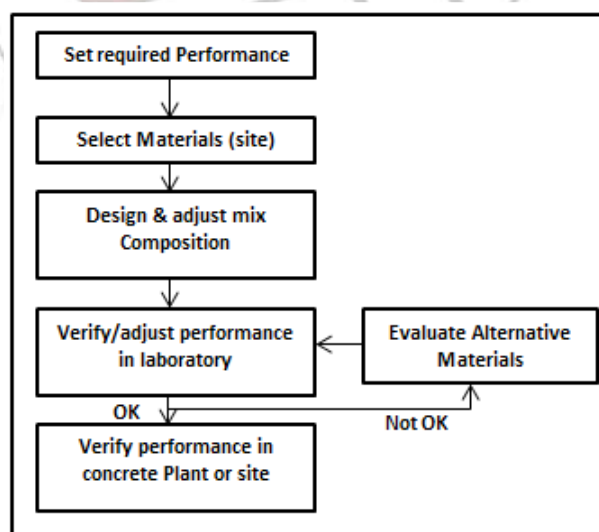


Fig 1. Typical Mix design

1. Slump Flow Test for Measuring Flowability:

The basic equipment used is the same as for the conventional Slump test is shown below in fig.2. The test method differs from the conventional one in the way that the concrete sample placed into the mould has no reinforcement rod and when the slump cone is

removed the sample collapses. The diameter of the spread of the sample is measured, i.e., a horizontal distance is measured as against the vertical slump measured in the conventional test. While measuring the diameter of the spread, the time that the sample takes to reach a diameter of 500 mm (T50) is also sometimes measured. The Slump Flow test can give an indication about the filling ability of SCC and an experienced operator can also detect an extreme susceptibility of the mix to segregation.

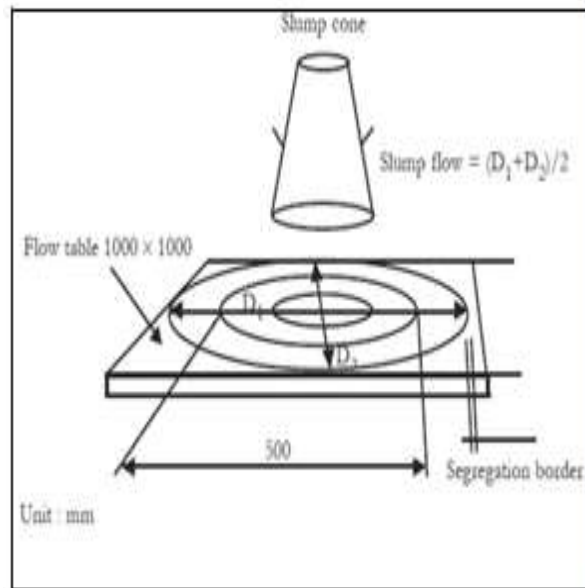


Figure.2(A), Slump Cone Test



Figure.2(B), Slump Cone Test

2. V-funnel Test: The V-funnel test was developed in Japan and used by Ozawa. The equipment consists of a V-shaped funnel, shown in below figure.3. The funnel is filled with concrete and the time taken by it to flow through the apparatus measured. This test gives account of the filling capacity (flowability). The inverted cone shape shows any possibility of the concrete to block is reflected in the result.

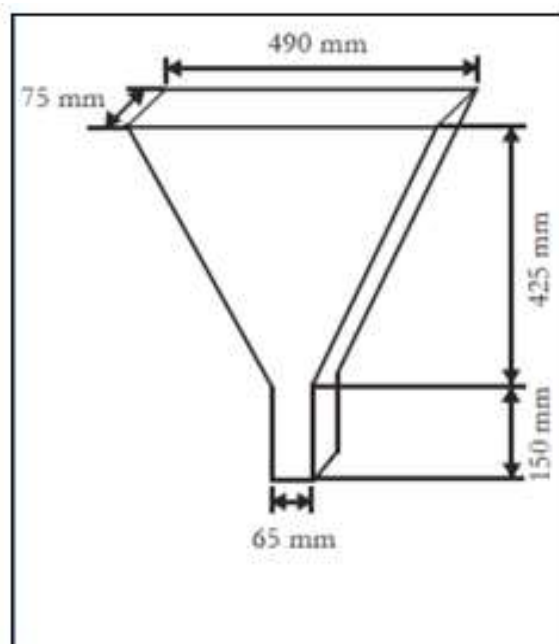


Figure.3(A) V-funnel Test



Figure.3(B) V-funnel Test

3. L-box Test: The L-box test method uses a test apparatus comprising a vertical section and a horizontal trough into which the concrete is allowed to flow on the release of a trap door from the vertical section passing through reinforcing bars placed at the intersection of the two areas of the apparatus, shown in below figure.4. The concrete ends of the apparatus H1 and H2 measure the height of the concrete at both ends. The L-box test can give an indication as to the filling ability and passing ability.

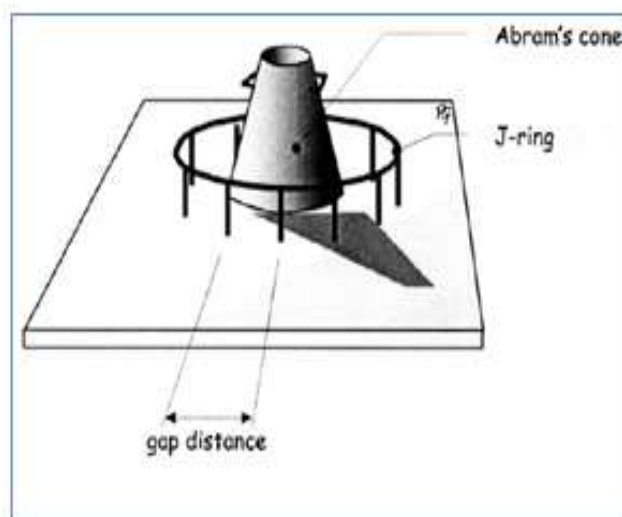


Figure.5(A) Blocking Ring (J-Ring) Test

5. Compressive strength test and split tensile strength test.

Compressive strength test and split tensile strength test are conducted on hardened concrete at 3, 7 and 28 days and results are tabulated in Table -2 & 3. Both the tests are shown in the Figure-



Fig-5 Compressive strength test



Fig-6 Split tensile strength test

IV. Results

The cement, sand and coarse aggregates were weighed according to the mix proportion 1:1:0.5. The fly ash and cement proportion used in the experimentation was 1:3:5. To this dry mix the required quantity of red mud (1%, 2%, 3%, 4%, 5%, 6%, 7%, and 8%) was added and homogenously mixed. To this dry mix the required quantity of water was added and thoroughly mixed. To this the superplasticiser was added at the rate of 700ml/100Kg of cementitious material and mixed intimately. Now the viscosity modifying agent (VMA) was added at the rate of 100ml/100Kg of cementitious material. The entire mix was thoroughly mixed once again. At this stage, almost the concrete was in a flow able state. Now, the flow characteristics experiments for self compacting concrete like Slump flow test, Oriment test, V-funnel test, L-box test and U-box test were conducted. After conducting the flow characteristic experiments the concrete mix was poured in the moulds required for the strength assessment. After pouring the concrete into the moulds, no compaction was given either through vibrated or through hand compaction. Even the concrete did not require any finishing operation. After 24 hours of casting, the specimens were demoulded and were transferred to the curing tank wherein they were allowed to cure for 28 days. For compressive strength assessment, cubes of size 150mmX150mmX150mm were prepared. For tensile strength assessment, cylinders of diameter 150mm and length 300mm were prepared. After 28 days of curing the specimens were tested for their respectively strengths

V. Flow Test Results

The tables give the flow test results of effect of addition of Red mud in various percentages on the properties of self compacting concrete containing an admixtures combination of (SP+VMA)

Table 1. Flow Test Results

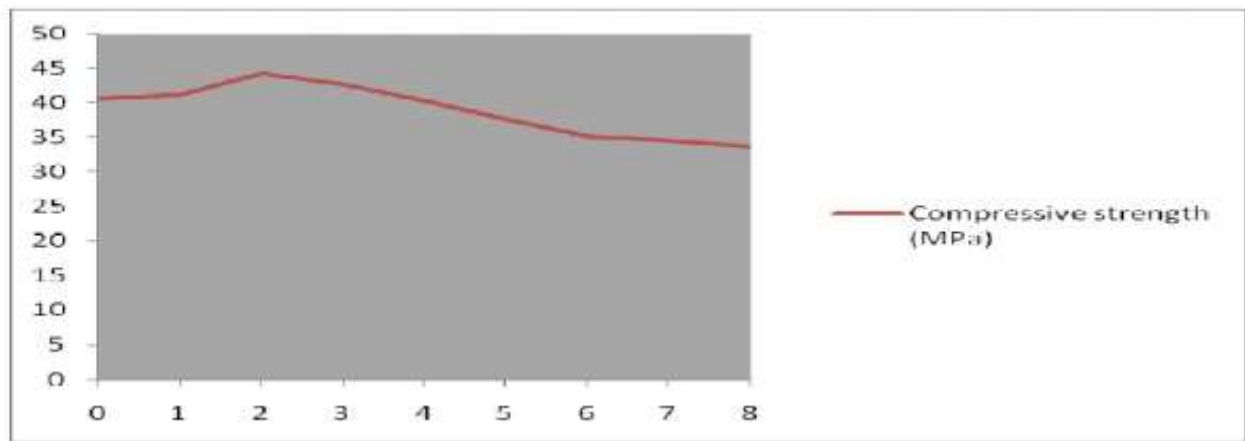
Percentage of red mud	Slump flow (mm)	Slump test (sec)	V-funnel flow time sec	U-box filling height H_1 - H_2 (mm)	L-box		
					Blocking ratio H_2/H_1	(T ₂₀) sec	(T ₄₀) sec
0	680	4.9	33.10	0	0.812	9.24	15.8
1	700	4.7	24.61	0	0.88	6.3	10.2
2	720	4.3	18.70	0	0.96	3.8	6.5
3	710	4.6	32.80	5	0.85	4.6	8.8
4	680	5.3	34.60	5	0.83	5.2	9.2
5	650	5.8	36.80	10	0.78	5.5	11.2
6	630	8.6	42.00	10	0.6	6.3	13.4
7	590	12.4	52.80	15	0.39	7.2	15.6
8	560	13.2	66.54	20	0.16	9.4	25.2

(A) Compressive Strength test results of self compacting concrete containing the combination of admixtures (SP+VMA) with various percentages of red mud

Table 2. Compressive Strength Test

Percentage addition of red mud	Compressive strength (Mpa)	Percentage increase or decrease of compressive strength w.r.t. ref mix
0(Ref)	40.59	-
1	41.18	1.45
2	44.29	9.11
3	42.66	5.10
4	40.29	-0.74
5	37.62	-7.32
6	35.11	-13.50
7	34.51	-14.98
8	33.62	-17.17

The variation of compressive strength can be depicted in the form of graph as shown in graph 1



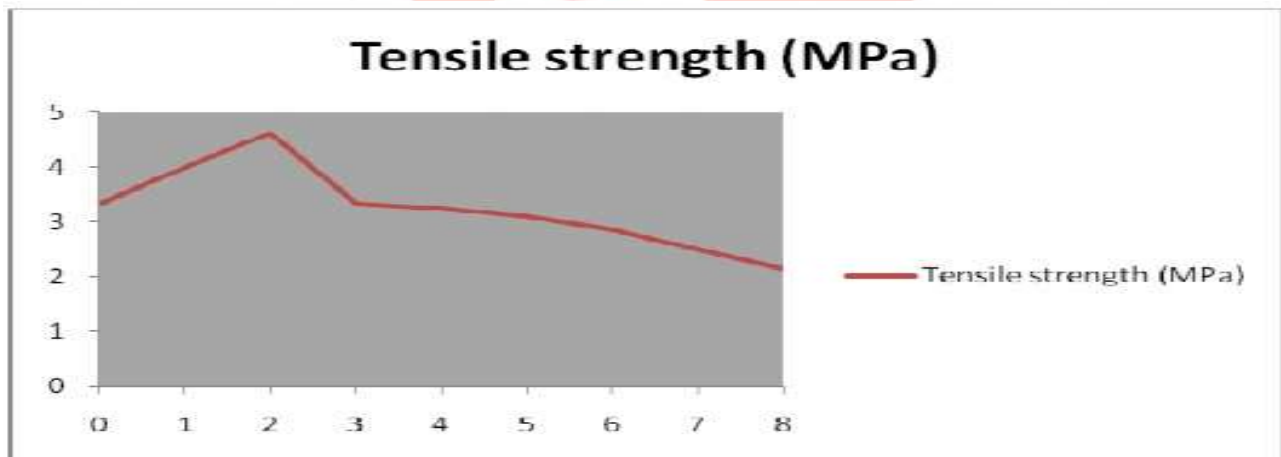
The variation of compressive strength of SCC containing red mud

(B) Tensile strength test results of self compacting concrete containing the combination of admixtures (SP+VMA) with various percentages of red mud

Table 3. Tensile Strength Test

Percentage addition of red mud	Tensile strength (Mpa)	Percentage increase or decrease of tensile strength w.r.t. ref mix
0(Ref)	3.34	
1	4.00	19.76
2	4.62	38.32
3	3.34	0.00
4	3.25	-2.69
5	3.10	-7.19
6	2.87	-14.07
7	2.50	-25.15
8	2.16	-35.33

The variation of tensile strength can be depicted in the form of graph as shown in graph 2



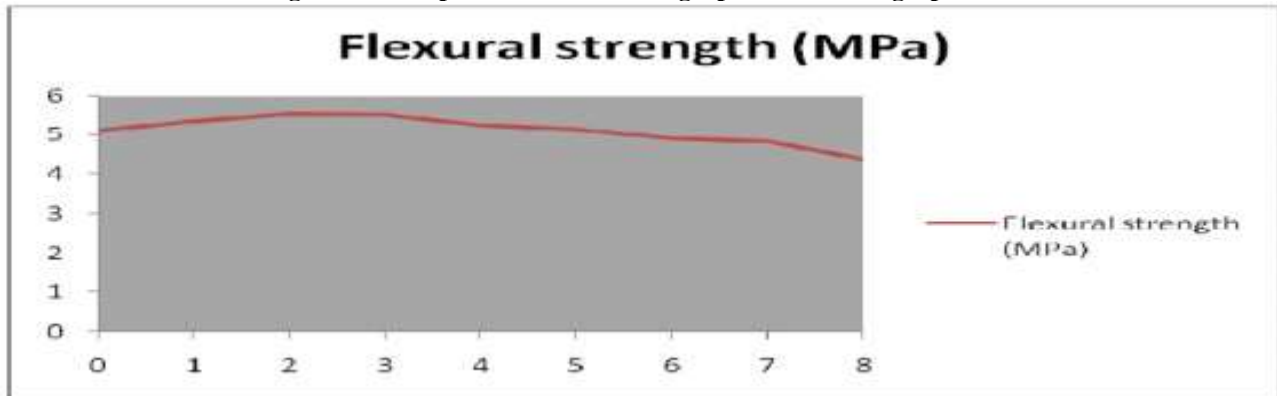
The variation of tensile strength of SCC containing red mud

(C) Flexural strength test results of self compacting concrete containing the combination of admixtures (SP+VMA) with various percentages of red mud

Table 4. Flexural Strength Test

Percentage addition of red mud	Flexural strength (Mpa)	Percentage increase or decrease of flexural strength w.r.t. ref mix
0(Ref)	5.12	-
1	5.36	4.69
2	5.53	8.01
3	5.5	7.12
4	5.26	2.73
5	5.25	0.59
6	4.92	-3.91
7	4.83	-5.66
8	4.4	-14.06

The variation of flexural strength can be depicted in the form of graph as shown in graph 3



The variation of flexural strength of SCC containing red mud

VI. Cost Analysis

Cost comparison between SCC and SCC after blending of cement. From the above results and graph plotted which will give the optimum percentage for the red mud 2%

Table 5 Cost Analysis

Particulars	Rates (Rs)
Rate of Cement per bag	280/-
Sand: Rate/Cum	700/-
12mm aggregate/Cum	500/-
Rate of Superplasticiser/kg	150/-
Rate of VMA/kg	80/-
Red Mud/Ton	300/-
Other	350/-

It observed from the cost analysis the cost of conventional concrete is Rs.4090/cum and the cost of concrete with blending by optimum percentages of red mud are Rs. 4045/cum. respectively. The result concludes that, the SCC with blending by red mud which is industrial wastages causing hazards to the ecosystem enhance the strength and reduces the cost than the normal SCC.

Fig-7 Works photograph



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