IMPROVING THE DURABILITY OF SELF COMPACTING CONCRETE USING WASTE MARBLE DUST AND GROUND GRANULATED BLAST FURNACE SLAG

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Abstract*—One of the major environmental concerns is the disposal of the waste materials and utilization of industrial by products. Marble quarries will produce millions of tons waste dust powder every year. Having considerable high degree of fineness in comparison to cement this material may be utilized as a partial replacement to cement. For this purpose an experiment is conducted to investigate the possibility of using marble dust powder in the production of self compacting cement with combined use ground granulated blast furnace and how it affects the fresh and mechanical properties of self compacting concrete. As primarily, waste marble has been used as a replacement of cement and marble sand as a replacement of sand. M30 mix of self-compaction concrete was opted for experimental purpose. The effect of marble dust is evaluated by performing the different tests on the cubes and cylinders to know its durability, durability tests (compressive strength of cubes after cured in sodium chloride and sulphuric acid for 56 days). Tests of these specimens were conducted at 7, 28 and 56 days after casting. Finally, different results of all the tests will guide me to identify the appropriate percentage use of waste marble dust and marble sand for achieving the best result.

***Index Terms*—Durability, Ground Granulated Blast Furnace, Marble Dust, Self Compacting Concrete, Workability Test**

I. INTRODUCTION

In Japan, many concrete structures are constructed to satisfy the growth of the infrastructure in 1970s. These structures have major durability issues. It has been found that concrete used for the construction is not properly compacted by skilled labors. To resolve this problem, self-compacting concrete is developed in Japan. The quality of concrete is vastly improved by use of self-compacting concrete (SCC). Therefore, SCC becomes extremely important material on construction sites. Superplasticizers and powder or viscosity modifying agents are extremely important ingredients of SCC. Superplasticizer in mix increases the flowability of material with low yield value while powder or viscosity modifying agents help to maintain the viscosity of the mix. Therefore, use of these two reduces the segregation and bleeding. Limestone powder, pulverized fuel ash (PFA), and granulated ground blast furnace slag are used as powder materials for SCC. To reduce the risk of blocking of concrete flow by congested reinforcement and narrow opening in the formwork, coarse aggregate content in SCC mix is much lower than the nominal mix. Industrial by product such as Marble Powder (MP) is obtained by shaping, sawing, polishing of marbles. MP used as inert material in the concrete mix and it is reported that use of it enhances the fresh and hardened performance of self-compacting concrete (SCC).

The use of SCC had steadily increased in the recent years on construction site, looking to advantages of the SCC on over the normal vibrated mix concrete composition. Self-compacting concrete is a very innovative concrete which can easily placed in congested reinforced section. It saves time of construction for large construction sites. SCC gives more homogeneous mix and good quality concrete across the entire concrete cross section. SCC has many advantages such as reduced noise pollution; Improve the surface finishes, conventionally high early strength of the concrete, and reduced the labour requirements on construction site.

Therefore, use of these types of mineral additives in SCC will make it possible, not only to decrease the cost of SCC but also to increase its long-term performance. To assess the effectiveness of GGBS in SCC some of the parameters like chemical composition, hydraulic reactivity, and fineness have been carefully examined earlier It was seen that among these, the reactive glass content and fineness of GGBS alone will influence the cementitious/ pozzolanic efficiency or its reactivity in concrete composites significantly.

Blast furnace slag is a by-product obtained in the manufacture of pig-iron. It is a product formed by the combination of the earthy constituents of iron-ore with the limestone flux at high temperature in the blast furnace (about 15000 c). The molten slag is rapidly quenched by a hose of water to yield a glassy granular product called granulated blast furnace slag. Hydrated slag's, granulated or palletized, give the same hydrates as Portland cement i.e., C-S-H and AF1 phases. As they react more slowly with water than Portland cement, they can be activated by different ways: chemically in presence of lime and sulphate activators, physically by grinding or thermally. Slag, which is obtained by grinding the granulated blast furnace slag, is highly pozzolanic in nature. Cement replacement levels of slag can be much higher than that of other pozzolanic materials, such as, Fly ash and silica fume. Generally, GGBS has higher 'CaO' content than other pozzolanas.

Therefore it is advisable to use this type of admixtures in self-compacting concrete.

II. LITERATURE REVIEW

A work conducted by N R Gaywala, D B Raijiwala (2011) [5] they discussed the different hardened properties of self-compacting concrete with OPC, fly ash from Birla glass, Kosamba, Gujarat, as a binder material in concrete for design mix. And the hardened properties are compared with an M25 grade of concrete. They used crushed stones as coarse aggregate passing through 12.5 mm IS sieve but retained on 10 mm sieve, fine aggregates of maximum size 4.75 mm, the cement of 525kg/m3, and high-performance superplasticizer named GLENIUM SKY 78. After performing all the tests they concluded that maximum compressive strength, flexural strength, pull out strength, tensile strength attained at 15% fly ash mixing with cement, and a concrete mix with 35% fly ash gives nearer result in compressive strength, flexural strength, pull out strength, tensile strength in comparison with M25 mix.

Paratibha Aggarwal, Yogesh Aggarwal, S M Gupta, R Siddiqu (2005) [6] they discussed on the existing research works about SCC and materials and mixture design, test methods such as V funnel test, L-Box test, J-ring etc., Tribological behavior of SCC, performance of SCC for underwater applications, in basement walls, columns, beams etc., fresh concrete properties, performance of SCC mixtures using an “artificial neural network”, developed models that can be used as economical tools which reduced the number of mix trials for SCC and can be used to generate future results using other material. On the review, they concluded that Workability parameters, the properties of SCC in the hardened state are similar to those of conventional concrete, high strengths, and adequate durability can be obtained using SCC. SCC has better internal frost resistance as compared to normal concrete. Different design methodologies like ANN, factorial design method etc. for SCC have been suggested to develop models that can be used as economical tools for the optimized design of SCC mixtures with desired properties.

P, Jeeva. S, Dhinesh.A, Manoj Kumar. R, Subramanian. M (2013) [7] they studied a review on the development of self-compacting concrete with mineral admixture silica fume. Silica fume is added at 10%, 12.5%, and 15% of cement weight. They have performed slump test, v funnel test, J-ring test, L-box test and U-box test on the fresh properties of SCC, and some NDT tests on thehardened properties of SCC ultrasonic pulse velocity test and compressive strength test by rebound hammer test. They suggested not to use more than 6% silica fume in the concrete mix, and SCC gives resistance against corrosion, freeze-thaw actions, and sulfate attack due to reduced porosity.

Kennouche .S, Zelizer .A, Benmounah .A, Hami .B, Mahdad .M, Bernoulli .H and Bijou .S (2013) [8] they studied the various properties of SCC mixing silica fume in 15% weight of the cement, Portland cement of two different type, polycarboxylates and plynaphtalen two types of admixtures, 3/8 mm and 8/15 mm aggregates are used coarse and fine sand of fineness modulus 3.2 and 1 are used and French association of civil engineering’s recommendations are used for the mix design. After performing the tests for both the fresh and hardened concrete they concluded that fixing the dosage of silica fume at 15% the fresh properties of SCC has given a good result, but the mechanical properties show that the compressive strength is higher 25 Mpa which shows very low porosity, which is because of silica fume as filler material, they studied that the viscosity of the cement paste is inversely proportional to the percentage of superplasticizer.

Biswadeep Bharali (2015) [9] he studied about the fresh and hardened properties of SCC where Ground Granulated Blast Furnace Slag and Fly Ash was used as the filler material for cement with a various percentage for M30 concrete. They carried their strength test, flexural strength, and split tensile strength on the samples where the cement is replaced by 30% GGBS (Ground Granulated Blast Furnace Slag), 20% both GGBS and FA (Fly Ash), 40% of GGBS, 15% both GGBS and FA, 40% of FA, and 30% fly ash and Superplasticizer GLENIUM B233. After all the tests he concluded that FA has the ability to reduce the content or demand of admixture, it has been observed that 30% replacement of cement by FA gives a slump of 710 mm which is best compared to all the specimens, it also improves the fresh concrete properties, but when the cement is replaced by 40% GGBS the slump flow test value decreased compared to the test value of cement replaced by FA, it shows that concrete with 30% GGBS gives compressive strength 39 Mpa which nearer to the SCC (100%) cement 41.2 Mpa, the test result suggested that a concrete with 60% OPC, 20% FA, 20% GGBS has compressive strength 34.9 Mpa and flexural strength 7.0 Mpa.

Er.Ranjodh Singh, Er.Rohin Kaushik, Er.Gurniwaz Singh (2013) [12] they had tried to achieve SCC with high fluidity and cohesiveness by replacing the fine aggregates with brick dust and marble powder, both are waste materials in industry and harmful to the environment so they tried to use these byproducts to replace the fine aggregates in SCC. They used OPC 43 grade cement, with 37% standard consistency and 3.15 specific gravity, fine and coarse aggregates both with specific gravity 2.65 and fineness modulus 2.2 and 7.87 respectively. After conducting the tests they concluded that SCC can be obtained using both brick dust and marble powder, concrete with 25% marble dust possessed well-hardened properties, under certain conditions both marble dust and brick dust increase the strength of SCC.

Aravinth S. N. (2014) [14] he tried to develop high strength self-compacting concrete of M60 with ordinary Portland cement 53 grade, silica fume, and superplasticizer GLENIUM B233 and tried to achieve SCC by trial mixes. He worked on EFNARC -2005 guidelines. After conducting the test for both fresh and hardened properties of SCC he concluded that reduction of w/p ratio (water powder ratio) increases the compressive strength, optimum dosage of chemical admixture is 1.5%-2%, below 1.5% of SP would affect the workability and over dosage would affect setting time, dosage of SP would vary linearly with the weight of cementitious materials, water content should be selected carefully before adding VMA because rheological behavior is more sensitive to water, results shows that concrete with 15-17.5% silica fume gives compressive strength 60.75 Mpa to 70.92 Mpa for w/p ratio 0.368 to 0.334.

N. Bouzoubaâ and M. Lachemib (2001) [15] they had studied an experimental program on SCC made with a high volume of fly ash. They performed their studies on 9 SCC samples and one control concrete. They had used 400kg/m3 cementitious material, with water-cementitious material ratio 0.35 to 0.45, SCC mixes are made by replacing cement 40, 50 and 60% of Class F fly ash, sulphonated, naphthalene-formaldehyde superplasticizer and a synthetic resin type air-entraining additives were used, they used coarse aggregates of maximum size 19mm, their studies showed that it is possible SCC with high volumes of class F fly ash, they studied that the slum flow of SCC using high volume of class F fly ash varies between 500 to 700 mm, flow time of 3 to 7 minutes, segregation was 1.9 to 14%, and water bleeded from 0.025 to 0.129 mL/cm2, temperature rise of SCC is 5 to 10 ºC lower than ordinary concrete, and setting time is 3 to 4 hours longer than ordinary concrete, and SCC gained 15 to 31 Mpa, and 26 to 48 Mpa at 7 and 28 days, and it was observed that SCC with 50% class F fly ash replacement gives 35 Mpa compressive strength with water-cementitious ratio 0.45 which cost is similar to normal M35 concrete.

A Study has been conducted by (P. A. Shirulea) Described the probability of using the marble dust in concrete production as partial replacement of cement. 3 cubes and 3 cylinders were casted for 7 days and 28 days for each percentage replacement of marble dust with cement. Marble dust was replaced by 0%, 5%, 10%, 15% and 20%. Final strength of cubes and cylinders were examined after 7 days and 28 days of curing. They conducted the tests using compression testing machine to test the compressive strength of cubes and splitting tensile strength of cylinders. They concluded that the optimum percentage for replacement of marble powder with cement is almost 10% cement for both cubes and cylinders. Hence a simple step to minimize the costs for construction with usage of marble powder which is freely or cheaply available.

(CarolyneNamagga)Research was carried out (with no fly ash, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50% fly ash respectively) to optimize the benefits of using High Lime fly ash in concrete as a replacement for large proportions of cement. A 25% - 35% fly ash replacement provides the most optimal strength results. Beyond 35% fly ash replacement, the rate gain of compressive strength decreases but maintains its strength above the desired strength.

(Narendra)studied that the early strengths (up to 28 days) of concrete mixes (with 20%, 35% and 50% fly ash replacements) for different grades of concrete (i.e. M30, M40 and M50)were equal or lower than that of normal cement concrete mixes. By 56 days, the strength of 20%, 35% and 50% Fly Ash mixes exceeded that of the Portland cement mix.(G. Zhi)Studied the behavior of concrete made from both- fly ash and ground granulated blast furnace slag combined.

(Hajima Okamura) addressed the two major issues faced by the international community in using SCC, namely the absence of a proper mix design method and proper testing method. They proposed a mix design method for SCC based on paste and mortar studies for super plasticizer compatibility followed by trial mixes. However, it was emphasized that the need to test the final product for passing ability, filling ability, and flow ability and segregation resistance was more relevant.

(Druta) completed a test concentrate to analyze the Splitting Tensile Strength and Compressive Strength estimations of self-compacting and ordinary concrete samples and to look at the holding between the coarse aggregates and the cement paste utilizing the Scanning Electron Microscope. This examination utilized mineral admixtures like Blast Furnace Slag, Fly Ash and Silica Fume and synthetic admixtures Super plasticizers and Viscosity-Modifying Admixtures, It has been checked by utilizing the slump flow and U-tube tests, that self-compacting concrete (SCC) accomplished consistency and self-similarity under its own weight, with no outer vibration or compaction. Self-compacting concrete can be gotten in such a manner, by including chemical and mineral admixtures, with the goal that it's splitting tensile and compressive strengths are higher than those of typical vibrated concrete. A normal increment in compressive strength of 60% has been gotten for SCC, while 30% was the increment in splitting tensile strength. Additionally, because of the utilization of chemical and mineral admixtures, self-compacting concrete has demonstrated fewer micro cracks than typical concrete, certainty which prompted a superior holding amongst aggregate and cement past and to an increment in splitting tensile and compressive strengths. A measure of the better holding was the more prominent level of the fractured aggregate in SCC (20-25%) contrasted with the 10% for typical concrete.

III. Materials Used in Present Study

The constituent materials, used for the production of Self Compacting Concrete shall generally comply with the requirements of IS 456: 2000. The materials shall be suitable for the intended use in concrete and not contain harmful ingredients in such quantities that may be detrimental to the quality of the durability of the concrete, or cause corrosion of the reinforcement.

Cement

General suitability is established for cement conforming to IS 12269: 1987. The cement used for experiment was Ordinary Portland Cement of grade 53. The properties of cement are found out by lab testing such as chemical constituents and physical properties such as fineness specific surface and specific gravity etc. The tests were carried out as per the Indian Standards and its results are shown in Table 2. (Courtesy: Hathi Cements PVT LTD)

Table 1 Properties of Cement

Particulars	Test Results
Magnesia (% by mass)	3.79
Sulphuric Anhydride (% by mass)	2.49
Total loss on ignition (% by mass)	1.49
Total Chloride (% by mass)	0.037
Al_2O_3/Fe_2O_3	1.16
Insoluble Residue (% by mass)	0.54

Table 2 Physical Analysis Data

Test	Test Result
Fineness Specific Surface	315
Initial Setting Time (min)	175
Final Setting Time (min)	280

Ground Granulated Blast-Furnace Slag

Ground granulated blast-furnace slag provides reactive fines with a low heat of hydration. GGBFS is either available separately and added during dry mixing as per requirements or presents in some cements. It is very important to select appropriate proportion of GGBFS in mix so that concrete mix becomes stable and risk of segregation should be reduced. (Courtesy: GURU Metachem)

Table 3 Properties of GGBFS

Characteristic	Test Results
Magnesia content (%)	8.25
Sulphide Sulphur (%)	0.68
Sulfate content (%) as SO_3	0.15
Manganese content (%)	0.32
Chloride content (%)	0.001
Glass content (%)	91.73
Moisture content (%)	0.02
Loss on Ignition (%)	0.36
Insoluble Residue (%)	0.25

Table 4 Physical Analysis Data

Test	Test Result
Fineness Specific Surface	362
Initial Setting Time (min)	205

Aggregates

Aggregates are used for the mix shall conform to IS 383: 1970. The maximum size of the aggregates majorly depends on the spacing of reinforcement bars, concrete cover and thickness of the elements. The maximum size of aggregate is usually kept to 20mm or less for the SCC. If particle size is less than 125 micron then it contributes to the powder content of the mixture.

Aggregates were used in our experimental work were same as they were used in normal construction work and purchased from a local dealer.

Both coarse and fine aggregates were in Saturated-Surface-Dry (SSD) condition. The maximum size of coarse aggregate was 20mm, and fine aggregates are in the form of Sand.

Marble Dust

Marble dust used for experimental work was acquired from a quarry of marble dust at Palanpur. The properties of marble dust are found out by lab testing such as chemical constituents and physical properties such as fineness specific surface and specific gravity etc. The tests were carried out as per the Indian Standards.

Table 5 Properties of Marble Dust

Oxides	**%weight**
CaO	50.87
SiO_2	7.27
Al_2O_3	0.11
MgO	0.84
SO_3	0.37
Na_2O, K_2O	-
Loss by Ignition	39.76
Total Chloride	-
Fe_2O_3	0.45

Table 6 Physical Analysis Data

Test	**Test Result**
Fineness Specific Surface	128
Specific Gravity	2.69

Mixing Water

Suitability is established for mixing water and for recycled water from concrete production conforming to IS 456: 2000.

Admixtures (Superplasticiser)

Admixtures used shall be complying with IS 9103: 1999, when appropriate. Superplasticizers are an essential component of SCC to provide the necessary workability. Other types may be incorporated as necessary, such as Viscosity Modifying Agents (VMA) for stability, air entraining admixtures to improve freeze-thaw resistance, retarders for control of the settings, etc.

The admixture should bring about the required water reduction and fluidity but should also maintain its dispersing effect during the time required for transport and application. The required consistence retention will depend on the application. Precast concrete is likely to require a shorter retention time than for concrete that has to be transported to and placed on site. Superplasticiser used in experiment was based on second generation polycarboxylic ether polymers. (Provided in Product Manual: BASF)

Table 7 Performance Test Data for Superplasticiser

Aspect	**Light Brown Liquid**
Relative Density	1.10 ± 0.01 at 25˚C
pH	≥ 6
Chloride ion content	$<0.2\%$

Viscosity Modifying Agent

Admixtures which are used to modify the cohesiveness of the SCC mix without significantly altering the fluidity of mix are called as a viscosity modifying agents (VMA). These types of admixtures are reduce the effect of moisture content variations, fine aggregate fineness or its grading and also help to make SCC tougher and less sensitive to slight variations in mix proportions, ingredients and condition of sites. Although, a noble mix design process and proper selection of other SCC constituents should not be avoided by adding the VMA.

Table 8 Performance Test Data for VMA

Aspect	**Colourless free flowing liquid**
Relative Density	1.10 ± 0.01 at 25˚C
pH	≥ 6 at 25˚C
Chloride ion content	$<0.2\%$

Additions (including mineral fillers and pigments)

SCC requires special rheological characteristics; both passive and reactive accompaniments are commonly used to enhance and sustain the fresh properties such as workability, as well as reduce the heat of hydration by controlling the cement content.

Typical additions are: Stone powder, Fly ash, Silica Fume, Ground Granulate Blast-Furnace Slag, Ground Glass Filler, Pigments and Fibers can also be effectively use.

IV. Experimental Investigation and Procedure

The process of the development of the concrete for strength and durability aspects in this investigation in various proportions varying from 0%, 10%, 15%, 20% and 25% marble dust as a replacement of cement along with ground granulated blast-furnace slag. The main aim of the study was to identify the best proportion of marble dust with ground granulated blast-furnace slag, which can be replaced with cement to get the desired strength and durability. The proportion of ground granulated blast-furnace slag was taken as 40% by weight of cement decided from previous studies published in various journals. The effect of marble dust is evaluated by performing the different tests on the cubes and cylinders to know its compressive strength at different intervals of days, splitting tensile strength and durability tests (compressive strength of cubes after cured in sodium chloride and sulphuric acid for 56 days). Tests of these specimens were conducted at 7, 28 and 56 days after casting.

Workability Test

V-Funnel Test

A V-funnel apparatus is shown in the Figure 1. It is fitted with a quick release watertight gate at its base. It is leveled so the top of the funnel is horizontal. The V-funnel apparatus shall be made of metal and the surfaces of the metal be smooth, and not be such that it is not readily attacked by cement paste or be susceptible to rusting.

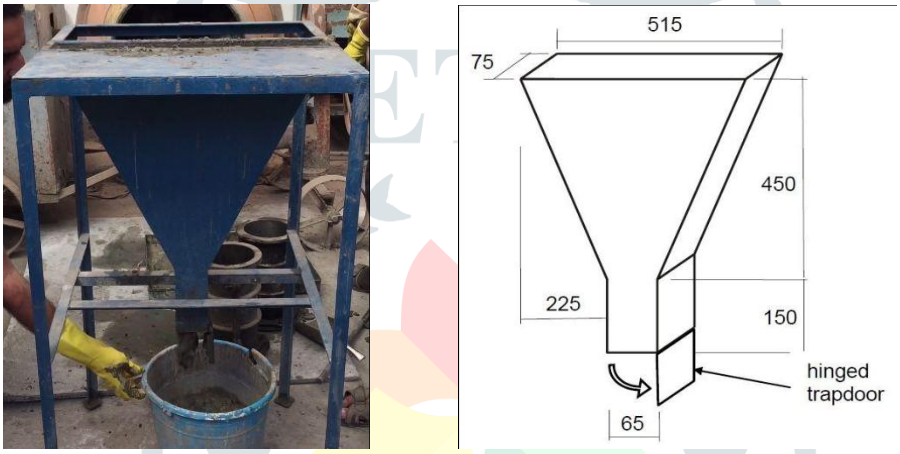

Figure 1 V-Funnel test Apparatus

L-Box Test

L box, general dimensions are shown in the figure number. L box device is made by such material so it gives smooth and flat surface. L box device should be made by rust free. For ease of cleaning, vertical hopper may be required to remove; therefore its assembly should be easily removable. The required volume should be poured inside the L-box by closing the vertical hopper.

There are two arrangements which represent the reinforcement bars of elements. First arrangement has two 12 mm diameter bars having 59mm of spacing between them and second arrangement has three 12 mm diameter bars having 41mm spacing. These two arrangements are interchangeable.

L box test is used to measure the different properties of the concrete such as flowability, segregation, and blocking. Concrete is poured into the vertical shaft of L box and one minute time is given to rest the concrete in vertical shaft. Afterwards, concrete has allowed to flow by opening the vertical hopper. Concrete will pass from the reinforcement arrangement and it reaches to the other end. The time is recorded for concrete to reach to the other end. Once concrete is settled down, the distances H1 and H2 are measured.

The ratio of H2/H1 should be in between 0.8 to 1.0. Concrete stability and blocking ability can be measured by visual observation. If aggregates are placed in all the parts of horizontal shaft then concrete is stable.

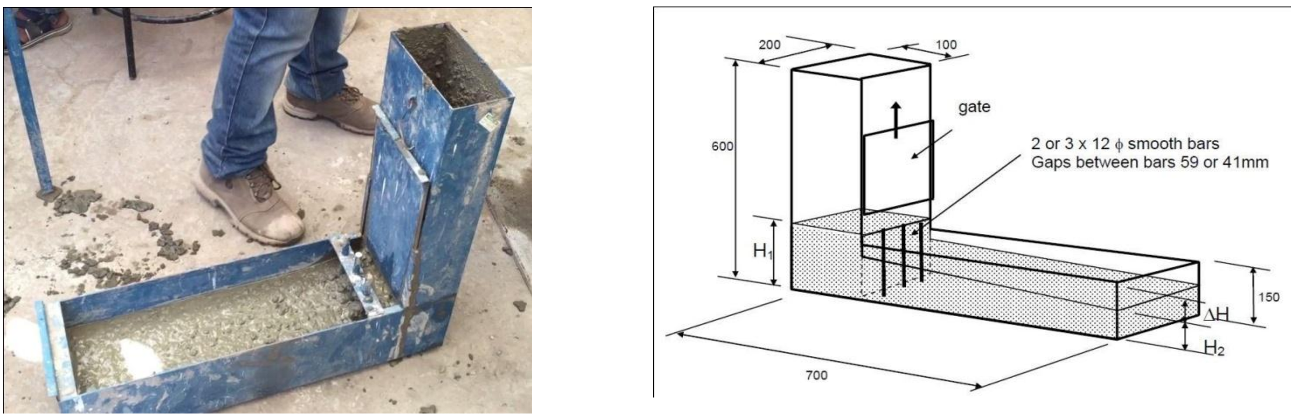

Figure 2 L-Box test Apparatus

Slump-Flow Test

To determine the flowability and the stability of self-compacting concrete slump-flow tests are performed. The equipment is constructed of one flow table and one slump cone. The table is circular in shape on which a concentric diameter of 50cm is marked. The slump cone is kept in the center of the table and pressed against it while pouring concrete in the cone. Next, the cone is lifted vertically and the stop watch is started to note the time. Time foe the concrete to reach the 50cm diameter is recorded. After the concrete has stopped flowing, the final diameter to which the concrete has flowed and if necessary any segregation border at the concrete periphery is measured.

Figure 3 Slump Flow Test

Durability Test

Salt Ponding Test

Corrosion of reinforcement in the reinforced cement concrete structures is common defects and statistics show that over 40 percent structures are failed due to corrosion of reinforcement. Chloride attack is one of the prime reasons for the corrosion of reinforcement. To evaluate the chloride resistance of concrete and mortar Salt Ponding Test has been used. In involves the ponding of salt solution on concrete cube specimens. After curing of specimen for 28 days in water, the specimens were submerged into 2.5% NaCl solution in a tank up to 56 days. Every 2 weeks the chloride solution was renewed by same chloride solution. After 56 days the specimens were removed from the tank and weighted and tested for compressive strength in CTM Machine.

Figure 4 Salt Ponding Test

Acid Ponding Test

The effect of different exposure condition will be different on concrete. To study the effect of exposure to acidic environment, specimens were immersed in 2.5% of solution of Sulphuric Acid (H_2SO_4), after curing for 28 days in normal water, up to 56 days. The acidic solution is refreshed after 8 weeks with the same solution. After 56 days the specimen removed from tank and weighted and tested for compressive strength in CTM machine.

Figure 5 Acid Ponding Test

V. LABORATORY TEST RESULTS

Workability Test Results

The results of V-Funnel test for different percentage of ground granulated blast-furnace slag and marble dust as a replacement of cement are shown in table below. Based on the results from V Funnel test it can be observed that, filling ability of the self compacting concrete with replacements by fly ash and marble dust are consistence with the result for control mix.

Table 1 Workability Test Result

Sr. No	Mix ID	V-Funnel (S)	L-Box	Slump Flow (mm)
1	F0Md0	7	0.8	650
2	F30Md0	8	0.9	655
3	F30Md10	8	0.91	655
4	F30Md15	7.5	0.98	670
5	F30Md20	8	0.9	665
6	F30Md25	10	0.8	650

Based on the results from V Funnel test it can be observed that, filling ability of the self compacting concrete with replacements by GGBFS and marble dust are consistence with the result for control mix, except in case of G40Md25 it can be seen that V Funnel time increases by 2 seconds which shows that for that SCC mix filling ability is slightly decreases. Here it can be noticed that increase in content of GGBFS and marble dust slightly reduces filling ability of SCC.

Above test results for L Box test represent that passing ability of the self compacting concrete for different mixes depends on the GGBFS and marble dust contents. Results shows that passing ability of the SCC increases upto replacement of cement by 40% GGBFS and 15 % marble dust, further increase in marble dust content passing ability of SCC starts to reduce mainly because of the lumps formed in the SCC mix.

Based on the above test results, it can be observed that Slump flow in case of self compacting concrete increases effectively from 650 mm to 670 mm for control mix and G40Md15 respectively, further increase in marble dust content reduces the slump flow of the SCC, it was observed during testing that reduction in slump flow mainly happen due to formation of lumps and segregation of aggregates.

Durability Test Results

The results of compressive strengths for different percentage of ground granulated blast-furnace slag and marble dust as a replacement of cement after 56 days of curing in Alkaline Solution are shown in table below.

Table 2 Durability Test Results for Alkaline Solution

S. No.	Mix ID	Durability (Alkaline Ponding)	
		% weight loss	Strength (N/mm²)
1	G0Md0	6.57	40.54
2	G40Md0	5.52	41.87
3	G40Md10	5.32	41.78
4	G40Md15	5.60	35.41
5	G40Md20	6.51	27.96
6	G40Md25	7.46	25.06

The results of compressive strengths for different percentage of ground granulated blast-furnace slag and marble dust as a replacement of cement after 56 days of curing in Acid Solution are shown in table below.

Table 3 Durability Test Results for Acid Solution

S. No.	Mix ID	Durability (Acid Ponding)	
		% weight loss	Strength (N/mm²)
1	G0Md0	9.18	35.86
2	G40Md0	7.04	38.78
3	G40Md10	7.13	39.72
4	G40Md15	7.53	32.14
5	G40Md20	8.86	24.11
6	G40Md25	10.24	21.59

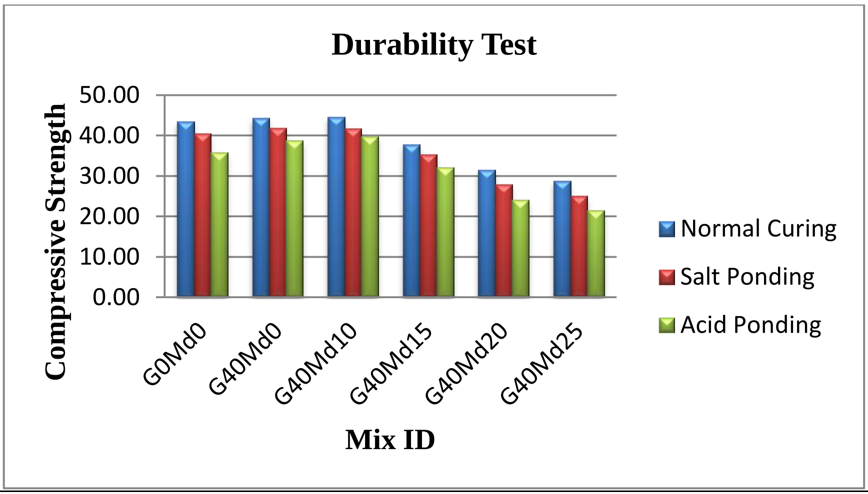

Figure 6 Durability Test Results for Different Mixes of SCC

Results from the durability test on the different mixes shows that presence of GGBFS and Marble dust in SCC noticeably reduces the effect of Acid and Alkaline chemicals on concrete. Based on results, it was noticed that both strength reduction and weight loss were lower than the control mix for the replacement of cement by upto 40% GGBFS and 15% marble dust. It was also noticed that further increase in marble dust content does noticeably increases both strength loss and weight loss.

VI. CONCLUSIONS

A few generalized conclusions are summarized below:

- The present study was performed for M30 grade of self compacting concrete mix with replacement of cement and having different proportions of marble dust (10%, 15%, 20% and 25%) and 40% of ground granulated blast-furnace slag.
- It is recommended that, at minimum, Slump test, L-Box test and V-Funnel should be performed for the laboratory verification tests.
- Test performed on fresh concrete (i.e. Slump test, L-Box and V-Funnel) resulted in almost similar result for all different mix proportions. SCC with marble dust and GGBFS for replacement upto 20% by marble dust show slightly better performance of fresh SCC than control mix.
- The study reveals that cement replacement by 10% and 15% of marble dust and 40% of GGBFS achieves required compressive strength at 7 and 28 days.
- The test results shows that cement replacement by 10% of marble dust and 40% of fly ash gain required splitting tensile strength at 28 and 56 days.
- In durability aspect there are no significant weight loss is observed and compressive strength loss is about average 8% for salt ponding and 17% for acid ponding.

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