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Experimental Study to Improve the Durability of Self Compacting Concrete Using Waste Marble Dust and Fly Ash

Virendra Singh[1], Pratik Gajjar[1], Parth Thaker[2]

[1]*M.Tech. Scholar, Department of Structural Engineering Design, CEPT University, Ahmedabad, Gujarat, India*
[2]*Assistant Professor, Faculty of Technology, CEPT University, Ahmedabad, Gujarat, India*

Abstract —*This paper investigates the study of workability and durability characteristics of Self-Compacting Concrete (SCC) with waste marble dust and containing Class F fly ash. The process of the development of the concrete for durability aspects in various proportions varying from 0%, 10%, 15%, 20% and 25% marble dust as a replacement of cement along with fly ash. The main aim of the investigation was to identify the best proportion of marble dust with fly ash, which can be replaced with cement to get the desired durability. The proportion of fly ash was taken as 30% by weight of cement decided from previous studies published in various Studies. 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.*

Keywords-*Durability; Fly Ash, Marble Dust, Self-Compacting Concrete, Workability Test*

I. INTRODUCTION

Self Compacting Concrete (SCC) has remarkably affected the concrete development industry, particularly the precast concrete industry. Since its first advancement in Japan in 1988, SCC has increased more extensive acknowledgment in Japan, Europe and USA because of its natural particular points of interest. SCC gives structures that are more tasteful while giving quality strength and durability execution, giving designers greater adaptability to create complex designs, and permitting constructors more choices in development systems. There is no standard strategy for SCC mix design, and numerous scholastic organizations and additionally admixture, ready-mixed, precast and contracting companies have built up their own particular mix proportioning strategies. According to EFNARC Guidelines for SCC mix design, a standout amongst the most vital contrasts amongst SCC and regular concrete is the use of a mineral admixture. Along these lines, many investigations on the impacts of mineral admixtures on the properties of SCC have been directed. These examinations demonstrate the upside of mineral admixture utilization in SCC, for example, enhanced workability with diminished cement content (Poppe and Shutter, 2005; Ye et al., 2007). Since cement is the most costly segment of concrete, lessening cement content is a sparing arrangement. Furthermore, the mineral admixtures can enhance molecule packing and decrease the penetrability of concrete. Thus, the durability of concrete is likewise improved (Assie et al., 2007). Industrial byproducts or waste materials, for example, limestone powder, fly ash and granulated blast furncae slag are for the mostly utilized as mineral admixtures in SCC (Felekoglu et al., 2006; Unal et al., 2006). Accordingly, the workability of SCC is enhanced and the utilized amount of by-products or waste materials can be increased. Other than the temperate advantages, such employments of by-products or waste materials in concrete diminish natural contamination (Bosiljkov, 2003).
Placement of concrete for the most part requires compaction by vibration in the structures. Self Compacting concrete has been characterized as 'a profoundly flowable, yet stable concrete that can spread promptly into the right spot and fill the formwork with no compaction and without experiencing any noteworthy separation', (Khayat). An other option suggest self compacting concrete as 'a flowing concrete without segregation and bleeding, capable of filling spaces and dense reinforcement or out of reach voids without obstacle or blockage'.
The composition of SCC must be designed all together not to separate, e.g. to make excessive bleed-water and settle out the coarse division (sedimentation). Air entrainment is additionally workable for SCC to build the concrete's protection from ice or ice defrosting salts.
The utilization of SCC in the genuine structure has consistently increased in the current years and presents a brilliant contrasting option to traditional concrete for high-density or complicated reinforced segments and placement in limit molds. SCC can likewise be pumped from the base of a form or dropped from the top with a suggested greatest fall stature of 6 feet.
Marble has been usually utilized as a building material since the old times. The industry's disposal of the marble powder material, comprising of fine powder, today constitutes one of the natural issues far and wide (Corinaldesi et al., 2010). Marble blocks are cut into smaller pieces so as to give them the coveted smooth shape. Amid the cutting procedure around 25% the first marble mass is lost as dust. In Turkey marble dust is settled by sedimentation and after that dumped away which brings about natural contamination, in addition to forming dust in summer and undermining both farming and general wellbeing. In this way, use of the marble dust in different industrial segments particularly the development, horticulture, glass and paper industries would secure nature.

The by-product of thermal power plants is fly ash, which is the remains after the burning of coal in power plants. The need for developing new materials for building arose, since a large scarcity of raw materials for construction and an urgent need to safe guard the environment against the pollution caused by the industrial waste product generated from coal used in thermal power plants creating unmanageable disposal problems due to their potential to pollute the surrounding environment. Fly ash, when used as a mineral admixture in concrete, it improves the strength and durability properties. It can either be used as an admixture or as a binding agent in concrete replacing cement. It can be also used as a partial replacement of fine aggregates, as a complete replacement of fine aggregates and as an additional content to achieve various properties of concrete (jino et al., 2012).

II. LITERATURE REVIEW

The purpose for development of SCC is the social problem on durability of concrete structures that arose around 1983 in Japan. Due to a gradual decrease in the number of skilled workers in Japan's construction industry, a similar decrease in the quality of construction work took place. As a result of this fact, one solution for the achievement of durable concrete structures independent of the quality of construction work is the implementation of SCC. Development of the first practicable SCC by researchers Okamura and Ozawa, around 1986, at the University of Tokyo and the large Japanese contractors (e.g. Kajima Co., Maeda Co., Taisei Group Co., etc.) quickly took up the idea.

2.1 Marble Dust

These days the construction materials are greatly judged by their ecological characteristics and this is because of an acute scarcity of quarried aggregates. Use of improper technology and unscientific methodology of quarrying minerals like marble generates a huge quantity of waste of this valuable mineral in India. Directly dumping the waste materials and exposing it to the vulnerable environment can be a serious cause of environmental hazard. On top of that this marble quarry industry produces a high amount of waste (about 20% of marble quarried). Recent advancements on the study to utilize marble waste has showed that it can be effectively be used as a construction material.

Due to increased awareness of ill effects from pollution, utilization and safe disposal of marble waste generated from marble quarries and marble processing industries has become as urgent and challenging task. Use of marble dust in construction industry will help industry making more eco-friendly concrete with the waste being utilized efficiently.

Using marble dust as partial replacement of cement not only helps to reduce the cement content which reduces costs but marble dust can help in improving strength of concrete, improves durability and also effectively enhances the rheological properties of both mortar and concrete. Only shortcoming of using marble dust in concrete is that it does not take part in hydration process.

Apart from marble dust there are other materials which have been actively used in the construction industry and they are silica fume, fly ash, pumice powder and ground granulated blast furnace slag (GGBFS) replacing cement (Demirel and Yazicioglu, 2008, 2006, 2007). Marble dust can be used in many ways of which the main objective is to spare the mother earth from the dumpsites of the marble squander it can be utilized to make new products or can be used as an admixture (Hameed and Sekar, 2009). Numerous experimentation have been carried out on utilization of waste marble dust or waste marbel aggregate, such as its addition in self-compacting concrete as an admixture or sand (Corinaldesi et al., 2010; Alyamac and Ince, 2009; Guneyisi et al., 2009; Unal and Uygunoglu, 2003), as well as its use in the asphaltic concrete (Karasahin and Terzi, 2007; Akbulut and Gurer, 2007; Binici et al., 2008) and also its use in production of cement (Aruntas et al., 2010).

(Tanver Kavas)Studied the properties of cement and mortar joining marble dust and squashed brick. The cementitious materials utilized as a part of this investigation were plain cement, gypsum, natural pozzolona, marble dust and squashed brick. The mortars were thrown into 40 x 40 x 160 mm moulds for strength tests. The tests were completed at 2, 7 and 28 days. In result it was reasoned that substitution of cement by marble dust and squashed brick impacts strength of the mortar essentially. The strength of the mortar containing waste materials was lower than the control mortar.

A Study has been led by (P. A. Shirulea) Described the likelihood of utilizing the marble dust in concrete generation as partial substitution of cement. 3 cubes and 3 cylinders were casted for 7 days and 28 days for every rate supplanting of marble dust with cement. Marble dust was supplanted by 0%, 5%, 10%, 15% and 20%. Final strength of cubes and cylinders were inspected following 7 days and 28 days of curing. They directed the tests utilizing pressure testing machine to test the compressive strength of cubes and splitting tensile strength of cylinders. They reasoned that the ideal rate for supplanting of marble powder with cement is almost 10% cement for the both cubes and cylinders. Consequently a basic advance to limit the expenses for construction with use of marble powder which is openly or cheaply accessible.

2.2 Fly Ash

The major by-product of the thermal power plants after the combustion of coal at high temperature is fly ash, all power stations produces different types of fly ash. The ash is carried upwards with the other flue gases and is captured before it reaches the atmosphere by highly efficient electro static precipitators. The captured waste is called Pulverized Fuel Ash (PFA) or Fly Ash. It looks like cement and is made of very fine, glassy spheres. In India, around 165 million tons of fly ash is produced annually. It is claimed by the industries that fly ash is neither toxic nor poisonous which is disputed, but to dump this material requires lot efforts and can pose threat to surrounding soil and water bodies. Research and experiment worldwide confirms that fly ash owning to its pozzolanic properties it can replace cement in relatively large proportions and can compose sound and durable concrete.

Fly Ash can be used to produce durable concrete structures in combination with cement. Fly ash particles being far smaller than cement and spherical in shape fill the voids between cement particles in the concrete matrix, hence increasing the density of concrete. Concrete produced with fly ash can gain strength over a longer period, also it produces lower heat of hydration and lower temperature rises. Use of fly ash can notably reduce the risk of damages caused due to sulphate attacks and provides resistance against chloride ingress.

(Carolyne Namagga)Research was completed (with no fly ash, 15%, 20%, 25%, 30%, 35%, 40%, 45% and half fly ash individually) to advance the advantages of utilizing High Lime fly ash in concrete as a replacement for vast extents of cement. A 25% - 35% fly ash replacement gives the most ideal strength results. Past 35% fly ash replacement, the rate gain of compressive strength diminishes yet keeps up its strength over the coveted strength.

(Narendra) studied that the early strengths (up to 28 days) of concrete blends (with 20%, 35% and half fly ash replacements) for various evaluations of concrete (i.e. M30, M40 and M50) were equivalent or lower than that of ordinary cement concrete blends. By 56 days, the strength of 20%, 35% and half Fly Ash blends surpassed that of the Portland cement mix. (G. Zhi) studied the conduct of concrete produced using both-fly ash and ground granulated blast furnace slag combined.

(Thomas)Discusses the effect of fly ash on the properties of concrete with a view to streamlining the level of fly ash utilized for a given application. The ideal measure of fly ash differs with application, as well as with composition and productions of the considerable number of materials in the concrete blend (particularly the fly ash), the conditions amid putting (particularly temperature), construction practices (for instance, completing and curing) and the exposure conditions. Subsequently, the ideal fly ash content will shift on a case-by-case premise. Fly ash content of up to 50% might be reasonable.

2.3 Self Compacting Concrete

Self Compacting concrete (SCC) is a newly innovated concrete type, which has ability to self compacting and placing without any vibration. SCC has an advantage over normal concrete which offers a faster rate of concrete placement, with rapid construction and ease to flow around congested reinforced areas. The flowability and segregation resistance of SCC ensures a high level of homogeneity, minimum concrete voids and uniform strength properties, providing best potential for a superior level of finish and durability of the structure. SCC is mainly formed with low water cement ratio, providing the prospective for high early strength, earlier demoulding and faster construction. SCC is very important and vigorously used concrete in current construction practices in India.

(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.

(EFNARC) Gives different helpful rules for the mix design of the SCC, likewise it gives itemized depiction for the tests to be performed on SCC and furthermore it gives determinations of the different basic materials and admixtures. Alongside that, it gives rules for the blending and placing of the self compacting concrete.

(Surabhi C.S.) Carried out a test ponder on concrete substance in the SCC blend is supplanted with different level of limestone powder and the fresh and hardened properties were contemplated. It was watched that limestone powder can be successfully utilized as a mineral admixture in SCC. It was watched that, aftereffects of the 7 day and 28 day compressive strength increments with increment in substance of limestone powder up to 20%. The change in compressive strength at 28 day was around 20% for a supplanting of 20% of cement with limestone powder. In any case, advance addition of limestone powder lessens the strength. All the hardened properties like cylinder compressive strength, split tensile strength, flexural strength and modulus of elasticity enhances with the addition of limestone powder.

(Felekoglu B.) Has done research on effect of w/c ratio on the fresh and hardened properties of SCC. According to the author, adjustment of w/c ratio and super plasticizer dosage is one of the key properties in proportioning of SCC mixtures. In this research, fine mixtures with different combinations of w/c ratio and super plasticizer dosage levels were

investigated. The results of this research show that the optimum w/c ratio for producing SCC is in the range of 0.84-1.07 by volume. The ratio above and below this range may cause blocking or segregation of the mixture.
As per a study conducted by (C. Yalcinkaya), effect of high volume GGBFS replacement on mechanical performance of self compacting steel fiber reinforced concrete was studied. Within the scope of this study, eight self compacting concrete mixtures were prepared. After detailed study it was concluded that 50% replacement of cement by GGFS can effectively increase harden properties of the self compacting concrete.

III. TEST PROGRAM AND METHODS

The process of the development of the concrete for strength aspects in various proportions varying from 0%, 10%, 15%, 20% and 25% marble dust as a replacement of cement along with fly ash. The main aim of the study was to identify the best proportion of marble dust with fly ash, which can be replaced with cement to get the desired strength. The proportion of fly ash was taken as 30% 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. Tests of these specimens were conducted at 7, 28 and 56 days after casting.

4.1. Methodology

Methodology followed for the experimental work is as follows.

- Test of various materials to be used.
- Concrete mix design for M30 grade of concrete.
- Tests for fresh properties of concrete.
- Casting of concrete specimens and curing.
- Testing of specimens and acquisition of data.
- Analysis, result and discussion.
- Conclusion.

4.2. Workability Test

4.2.1 V-Funnel Test

A V-funnel made to the dimensions (tolerance ± 1 mm) as shown in the fig., fitted with a quick release watertight gate at its base and supported in such a way that 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.

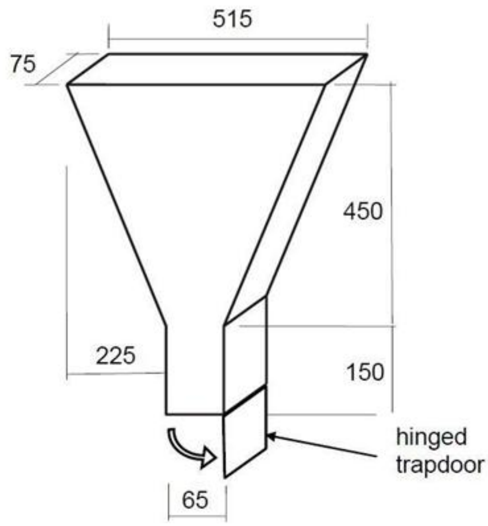

Figure 1 V-Funnel test Apparatus

4.2.2 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.

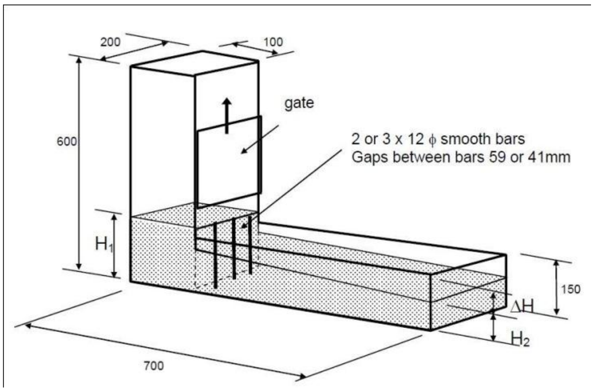

Figure 2 L-Box test Apparatus

4.2.3 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

4.3 Durability Test

4.3.1 Salt Ponding Test

Chloride attack is particularly important because it primarily causes corrosion of reinforcement; statistics have indicated that over 40 percent of failure of structures is due to 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

4.3.2 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. RESULT DISCUSSION

5.1 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	7	0.9	660
3	F30Md10	7.5	0.945	675
4	F30Md15	8	1	675
5	F30Md20	8.5	0.9	660
6	F30Md25	8	0.8	655

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.
Above test results for L Box test represent that passing ability of the self compacting concrete for different mixes depends on the fly ash and marble dust contents. Results shows that passing ability of the SCC increases up to replacement of cement by 30% fly ash 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 675 mm for control mix and F30Md15 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.

5.2 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	F0Md0	6.57	40.54
2	F30Md0	5.83	47.25
3	F30Md10	5.48	47.45
4	F30Md15	6.12	39.01
5	F30Md20	6.37	29.20
6	F30Md25	7.74	25.38

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	F0Md0	9.18	35.86
2	F30Md0	7.81	45.44
3	F30Md10	7.47	45.09
4	F30Md15	7.28	36.76
5	F30Md20	9.48	25.93
6	F30Md25	11.46	21.26

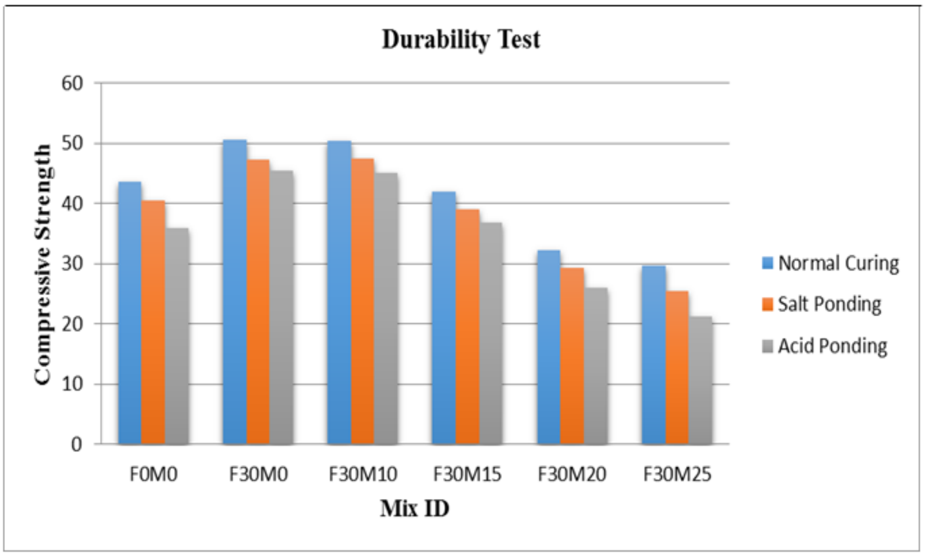

Figure 6 Durability Test Results for Different Mixes of SCC

Results from the durability test on the different mixes shows that presence of fly ash and Marble dust in SCC noticeably reduces the effect of Acid and Alkaline chemicals on concrete. Based on the test results data, it was noticed that both strength reduction and weight loss were lower than the control mix for the replacement of cement by upto 30% fly ash and 15% marble dust. It was also noticed that further increase in marble dust content does noticeably increases both strength loss and weight loss.

V. CONCLUSION

A few generalized conclusions are summarized below:

- The present study was carried out for M30 grade of self compacting concrete mix with replacement of cement with different proportions of marble dust (10%, 15%, 20% and 25%) and 30% of fly ash.
- It is recommended that, at least the following 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 fly ash for replacement upto 20% by marble dust show slightly better performance of fresh SCC than control mix.
- 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.

One can extend the work in this area by taking concrete grade other than M30 and by taking marble dust from the different region. The properties studied in this experimental work were compressive strength, tensile strength and Durability test of self compacting concrete. Other properties such as flexural strength, modulus of elasticity and abrasion resistance etc. can also be studied in detail.

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