EXPERIMENTAL STUDY TO ENHANCE THE STRENGTH PROPERTIES OF SELF COMPACTING CONCRETE USING WASTE MARBLE DUST AND FLY ASH

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Abstract*— Supplementary materials (SMs) have been widely used all over the world in ready-mixed concrete due to their economic and environmental benefits; hence, they have drawn much attention in recent years. Due to growth in construction industry and demand of Concrete, there is a scarcity of the different resources, used in making concrete. So in my research work, I aim to understand and examine the appropriate material and percentage of waste materials to be used as a replacement of the same in concrete as supplementary materials. 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. 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. In this experimental investigation three different tests were conducted on fresh concrete and two tests on cured concrete cubes to understand its strength. 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. Judicious selection of materials, appropriate mixing methods, proper curing, and appropriate dosage of superplasticizer will enable the production of high performing high volume fly ash and marble self-compacting concrete.

***Index Terms*—Fly Ash, Marble Dust, Self Compacting Concrete, Strength Test, Workability Test**

I. INTRODUCTION

Construction industry has been very progressing and promising industry in India ever since. Evidently now, construction industry contributes more than 10% of India’s GDP (Gross Domestic Product). Patently, per capita cement consumption in India was about 185 kg while per capita steel consumption was about only 57.8 kg, this figure proves that in India, cement contributes more in construction industry than steel. Demand for cement was about 265.9 million tonnes in end of year 2013; with a greater anticipation of market grow at 10.2%.

For Indian Cement Industry, availability of raw materials are in abundance, in fact in India, the present status of the total reserves of the cement grade limestone are about 123829.64 million tonnes in year of 2014 (National Inventory of Cement Grade Limestone Reserves, NCB India – March 2014), this ensures cement manufacturing for a long forthcoming future. But the fact that cement manufacturing is a very energy intensive process and emits around 0.9 kg of green house gas (i.e. CO2) for per kg production of cement, which is now governing concern for sustainability and pollution control. Cement production industries are also familiar with this issues and constantly trying to minimize their carbon footprint by adopting dry process for cement manufacturing and researching and developing cement with waste industrial products like ground granulated blast-furnace slag, fly ash, silica fume and many other promising materials.

Self Compacting concrete is a recently advanced concrete, which has capacity to self compacting and putting with no vibration. Self compacting concrete has preference over ordinary concrete which offers a quicker rate of concrete placement, with fast rate of construction and ease to stream around congested fortified regions of reinforcement. The flowability and segregation resistance of self compacting concrete guarantees a high state of homogeneity, least voids and uniform strength properties, giving best potential to a prevalent level of finish and strength of the structure. Self compacting concrete is fundamentally formed with low water cement proportion, giving the prospects for high early quality, prior demoulding and speedier construction. Self compacting concrete is critical and enthusiastically utilized cement in current development hones in India.

Fly ash is a major by-product/waste generated by combustion of pulverised coal at high temperatures at power stations. 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.

In India, marble processing industries generates about 7 million tonnes of waste annually in form of powder during sawing and polishing process, which can be narrowed down to 20% of the total marble quarried. Usually this waste generated during sawing and polishing process is dumped into nearby pit or some vacant spaces. This results into hazardous environmental pollution. The waste marble dusts generally get airborne and get deposited on nearby fertile land, crops and vegetation. Waste marble dust also contaminates the ground and surface water bodies. Marble waste can prove as a very important environmental management tool for achieving sustainable and economic development. Marble dust can be used as a supplementary of cement in concrete, as it has ability to fill voids present in the concrete, possible bondage and hence will give sufficient strength to concrete.

II. Literature Review

Literature Review for Marble Dust

A work directed by (Ahmed N. Bdour) proposed a productive usage of waste marble dust as a section substitute of limestone in a cement plant. This exploration portrays endeavors to characterize the arrangements of waste-based mixtures and the relating handling conditions appropriate to the generation powder based cements. Likewise, this examination evaluates the properties of the last product after incorporating waste marble powder, Waste Marble Dust samples. Taking everything into account, it was discovered that the Waste Marble samples were found to contain the normal cementitious stages and a decent understanding was acquired between the characterizations techniques utilized. Test outcomes demonstrate that this waste marble dust based cement is fit for enhancing solidified concrete performance up to 16%, improving fresh concrete behavior.

(V.M. Shelke. Prof. P.Y Pawde) studied the impact of fractional supplanting of cement with marble dust and compare it with the compressive strength of ordinary M30 concrete. And furthermore to discover the level of marble powder and silica fume supplanted in concrete that makes the strength of the concrete maximum. In this examination a progression of compression tests were led on 150mm cube and 150mm x 300mm cylindrical samples utilizing a changed test strategy that gave the entire compressive strength, utilizing silica fume of steady 8% with and without marble powder of volume parts 0, 8, 12, and 16% on Ordinary Portland cement concrete.

A Study has been directed by (Hanifi Binici) found that marble dust concrete has higher compressive strength than that of the relating lime stone dust concrete having equal water-cement and mix proportion. The outcomes showed that the Marble dust concrete would likely have lower water penetrability than the lime stone concrete. Ordinarily, concrete made with marble dust got amid polishing and cutting of marble in production lines will accomplish higher strength than ordinary concrete for 28 days curing period. Marble waste concrete is likewise anticipated that would be similarly durable when contrasted with ordinary concrete. Marble waste when utilized as a part of concrete expands the measure of water required for producing given slump, this might be because of expanded surface area in dust compared to sand. The general workability estimation of marble dust concrete is less compared to ordinary concrete.

(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.

Literature Review for Fly Ash

(Amit Mittal)The impact of fly ash on workability, setting time, thickness, and air content, and compressive strength, modulus of elasticity, shrinkage and permeability by Rapid Chloride Permeability Test (RCPT) are contemplated. In view of this examination, compressive strength versus W/C curves have been plotted so concrete mixes of grade M15 to M45 with various level of fly ash can be specifically composed.

It is genuinely settled that fly ash can enhance numerous properties of fresh and hardened concrete and additionally decrease the ozone harming substance footprint related with the utilization of Portland cement. (Thomas M. D.) This paper talks about how the ideal the level of fly ash is reliant on the properties of the fly ash, the execution prerequisites for the fresh and hardened concrete, the climatic conditions amid construction and the exposure conditions and durability requirements during service. By and large, the ideal level of fly ash might be at least 40%.

(Dale P. Bentz)A new approach of streamlining the molecule sizes of the cement and fly ash for accomplishing wanted execution in a mixed item was finished. By suitably choosing the particle size distribution of cement with fly ash, proportionate 1 day and 28 day strengths might be accomplished with around 35% volumetric replacement of cement with fly ash while keeping up a similar volume division of water in the mixture, along these lines giving a real 35% decrease in cement content. Erosion of reinforcement installed in concrete causes the vast majority of the disappointments in concrete structures.(M. F. Montemor)The corrosion process of steel installed in concrete with different measures of fly ash (up to half of the aggregate cover) was tried under entire and incomplete submersion, in sodium chloride arrangement. The erosion procedure was trailed by checking of open circuit potential (OCP) and electrochemical impedance spectroscopy (EIS). Fly ash addition has prompted a raise of concrete resistivity and of the time for erosion initiation and to decrease the erosion rate.

(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.

Literature Review for Self-Compacting Concrete

(Persson) completed a trial and concentrate on mechanical properties, for example, strength, elastic modulus, creep and shrinkage of self-compacting concrete and the relating properties of typical concrete. The examination included eight blend extents of sealed or air-cured samples with water binder proportion (w/b) differing in the vicinity of 0.24 and 0.80. 50% of the blends were SCC and rest was ordinary concrete. The age at stacking of the concrete in the creep study differed in the vicinity of 2 and 90 days. Strength and relative humidity were additionally found. The outcomes demonstrated that elastic modulus, creep and shrinkage of SCC did not vary essentially from the comparing properties of typical concrete.

(Nan Su) proposed another mix design technique for self-compacting concrete. To start with, the measure of aggregate required was resolved, and the paste of binders was then filled into the voids of aggregate to guarantee that the concrete hence got has flowability, self-compacting capacity and other wanted SCC properties. The measure of aggregate, binders and blending water, and in addition sort and dose of super plasticizer to be utilized are the major point impacting the properties of SCC. Slump flow, V-funnel, L-box, U-box and compressive strength tests were done to look at the execution of SCC, and the outcomes demonstrated that the proposed technique could be utilized to effectively create SCC of high caliber. Contrasted with the strategy created by the Japanese Ready-Mixed Concrete Association (JRMCA), this technique is less difficult, less demanding for execution and less tedious, requires a littler measure of binders and spares cost.

(N. Bouzoubaa) did a trial examination to assess the execution of SCC made with high volumes of fly ash. Nine SCC blends and one control concrete were made amid the investigation. The substance of the cementitious materials was looked after consistent (400 kg/m3), while the water/cementitious material proportions extended from 0.35 to 0.45. The self-compacting blends had a cement substitution of 40%, 50%, and 60% by Class F fly ash. Tests were completed on all blends to get the properties of fresh concrete regarding consistency and solidness. The mechanical properties of hardened concrete, for example, compressive strength and drying shrinkage were likewise found. The SCC blends created 28-day compressive strength going from 26 to 48 MPa. They revealed that conservative SCC blends could be effectively created by joining high volumes of Class F fly ash.

(Dr. R. Sri Ravindrarajah) made an endeavor to build the dependability of new concrete (cohesiveness) utilizing increased measure of fine materials in the blends. They announced about the improvement of self-compacting concrete with diminished segregation potential. The orderly exploratory approach demonstrated that partial substitution of coarse and fine aggregate with finer materials could create self-compacting concrete with low segregation potential as evaluated by the V-Funnel test. The aftereffects of bleeding test and strength improvement with age were featured by them. The outcomes demonstrated that fly ash can be utilized effectively in creating self-compacting high-strength concrete with diminished segregation potential. It was additionally detailed that fly ash powder in self-compacting concrete aides in enhancing the strength past 28 days.

(Hajima Okamura) tended to the two noteworthy issues looked by the international community in utilizing SCC, to be specific the nonappearance of a legitimate mix design technique and appropriate testing strategy. They proposed a mix design technique for SCC based on paste and mortar studies about super plasticizer compatibility after by trial mixes. Notwithstanding, it was accentuated that the need to test the last product for passing ability, filling ability, and flow ability and segregation protection was more pertinent.

(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 self compacting concrete, likewise it gives itemized depiction for the tests to be performed on self compacting concrete 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.

III. Experimental Investigation and Procedure

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.

Workability Test

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

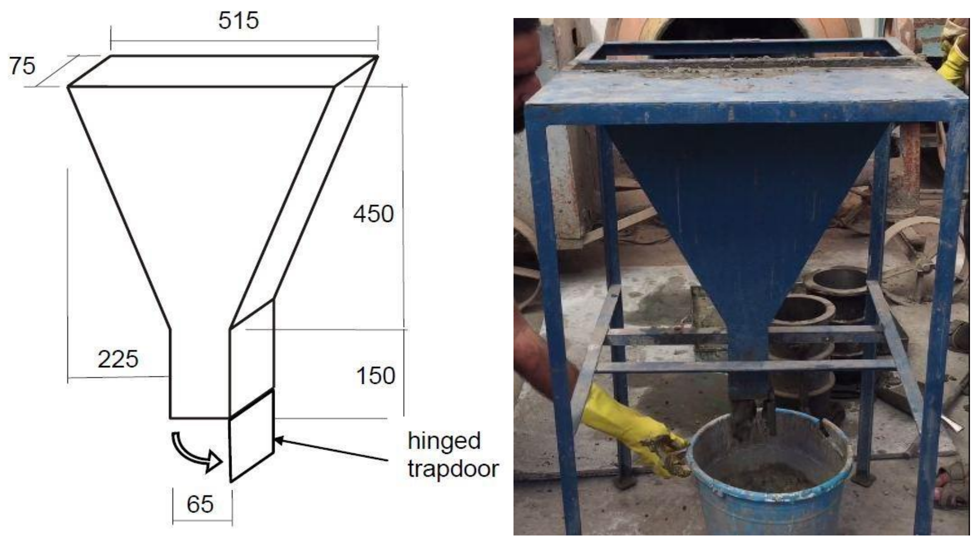

Figure 1 V-Funnel test Apparatus

L-Box Test

L-box, having the general arrangement as shown in fig. and the dimensions (tolerance ± 1 mm) are as shown in the fig. The L-box might be of inflexible construction with surfaces that are smooth, level and not promptly assaulted by cement paste or be at risk to rusting. The vertical hopper might be removable for simplicity of cleaning. With the entryway shut, the volume of the vertical hopper should be (12, 6 – 12, 8) l when filled level with the best.

The assemblies holding the reinforcement bars shall have 2 smooth bars of 12 mm diameter with a gap of 59 mm for the two bar test and 3 smooth bars of 12 mm diameter with a gap of 41 mm for the three bar test. These assemblies shall be interchangeable and locate the bars in the L -box so that they are vertical and equidistant across the width of the box.

The principles of the L- shaped box are shown in figure. With the L-shaped box, it is possible to measure different properties, such as flowability, blocking and segregation. The vertical part of the box, with the extra adapter mounted, is filled with concrete. After the concrete has rested in the vertical part for one minute, the sliding gate is lifted. The concrete will now flow out of the vertical part into the horizontal part of the L-box. On its way, it has to pass the layer of reinforcement. After the sliding gate is removed, the time for the concrete front to reach marking is recorded. When the concrete has stopped; the distances H1 and H2 are measured.

Acceptable values of the so-called blocking ratio, H2/H1, can be 0.80 – 1.0. Both blocking and stability can be detected visually. If the concrete builds a plateau behind the reinforcement layer, the concrete has either blocked or segregated. Blocking usually displays itself by coarse aggregates gathered between the reinforcement bars. If coarser aggregates are distributed on the concrete surface all the way to the end of the horizontal part, the concrete can be regarded as stable.

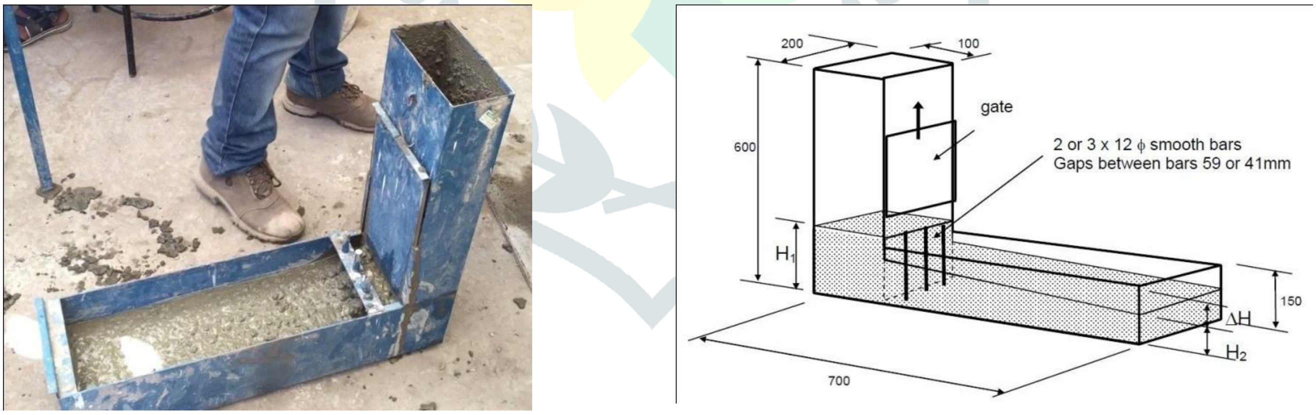

Figure 2 L-Box test Apparatus

Slump-Flow Test

Slump-flow tests are used to determine flowability and stability of SCC. The equipment consists of one slump cone and one flow table. A concentric diameter of 500 mm is marked on the table. The slump cone is filled with concrete while pressing the slump cone to the table. Next, the slump cone is lifted vertically and time measurement is started. Time for the concrete diameter to reach 500 mm is recorded. When the concrete has stopped flowing, the final diameter of the concrete and if necessary any segregation border at the concrete periphery is measured.

Strength Test

Compressive Strength Test

Compression tests were conducted to investigate the ultimate strength of concrete with ground granulated blast-furnace slag and Marble Dust as replacement of cement in various proportions. Compression tests were conducted on three 150mm x150mm x 150mm concrete cubes after 7, 28 and 56 days of casting. The tests were done on Compressive Testing Machine (CTM).

The compressive strength of a sample was calculated using,

$C = P/A$

Where,

C = Compressive Strength (N/mm^2)
P = Total load on specimen at point of failure (N) A =Area of the specimen (mm^2)

Splitting Tensile Test

Tensile strength is measured by this particular test by using Compressive Testing Machine. The concrete cylinder specimens are being tested at 28th and 56th days. A concrete cylinder of size 300mm height and 150mm diameter is subjected to the action of compressive force along two opposite edges. For the uniform distribution of loads two steel plates were placed at those two particular edges only to transfer the compressive force, it doesn't take part into load carrying capacity of cylinder. The cylinder is placed with its axis horizontal between the plates of the testing machine, and the load is increased until the failure takes place along the length of cylinder and splits the cylinder in two.

The tensile strength is found out by using equation,

$T=2P/\pi LD$

Where,

T= Tensile strength of concrete (N/mm2)
P= Compressive load on the specimen at the time of failure (N)
L= Length of the specimen (mm)
D= Diameter of the specimen (mm)

Figure 3 Compressive Strength test Machine with Specimen

IV. Laboratory 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.

Table 2 Compressive Strength Test Result

S. No.	Mix ID	Compressive Strength (N/mm²)		
		7th Day	28th Day	56th Day
1	F0Md0	27.76	38.01	43.57
2	F30Md0	28.52	39.72	50.37

3	F30Md10	28.67	41.79	50.53
4	F30Md15	21.31	33.59	41.94
5	F30Md20	21.07	27.24	32.19
6	F30Md25	17.94	25.01	29.69

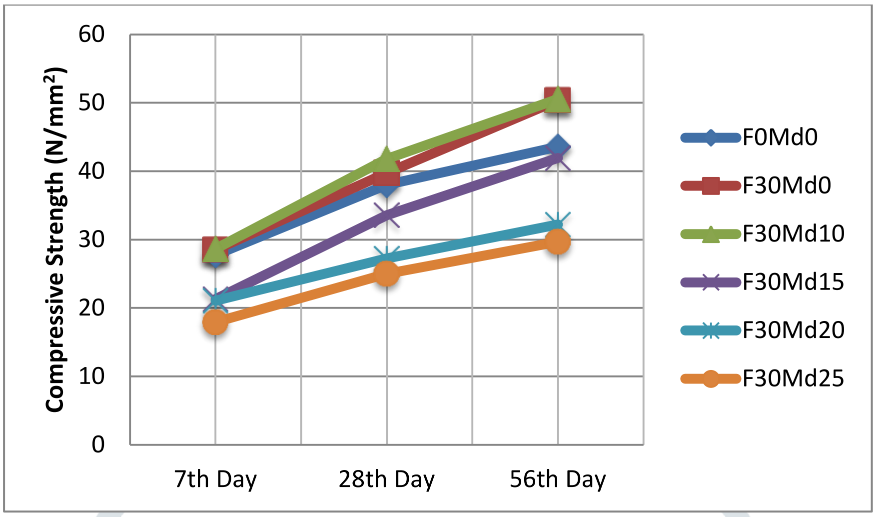

Figure 4 Compressive Strength test results for different mixes of SCC

Results from the compressive test represent that for replacement of cement by marble dust up to 10%, compressive strength of the SCC gives comparatively higher results than Control mix.

Table 3 Splitting Tensile Strength Test Result

Sr. No	Mix ID	28th Day	56th Day
1	F0Md0	3.78	3.8
2	F30Md0	3.76	3.79
3	F30Md10	3.79	3.80
4	F30Md15	3.03	3.12
5	F30Md20	2.81	2.95
6	F30Md25	2.23	2.49

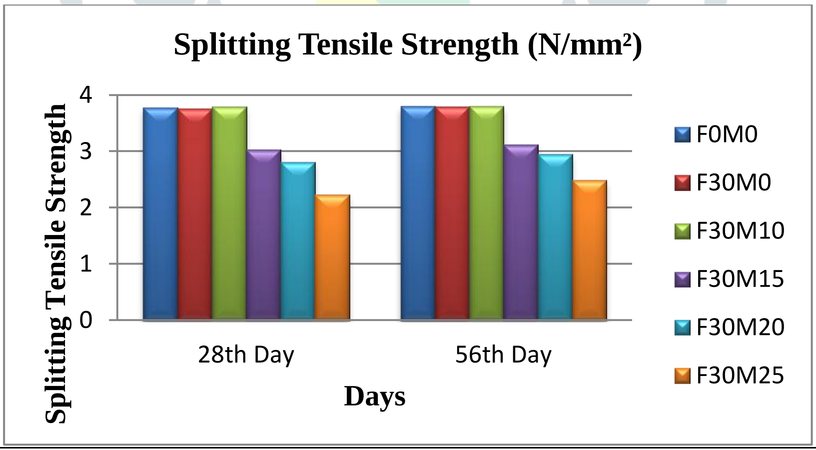

Figure 5 Splitting Tensile test results for different mixes of SCC

Results for the splitting tensile strength shows that tensile strength of the SCC for the replacement of cement by 30% GGBFS and 10% marble dust gives almost same results as control mix at both 28th day and 56th day. Further increase in the marble dust content reduces the splitting tensile strength of the concrete.

V. CONCLUSIONS

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 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 fly ash for replacement up to 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 30% of fly ash achieves required compressive strength at 7 and 28 days.
- The test results shows that cement replacement by 10% of marble dust and 30% of fly ash gain required splitting tensile strength at 28 and 56 days.
- From compressive strength test and splitting tensile strength test it can be concluded that the best proportion of marble dust and fly ash are 10% and 30% respectively with 28 days of curing.

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