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Strength and Durability Studies on Steel Fibre Reinforced Concrete with Marble Dust as Partial Replacement of Cement

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Abstract:
Adjustments to traditional mix designs and the use of super plasticizers create this concrete that can meet flow performance requirements. Use of dangerous manufacturing wastes in concrete construction will leads to greener environment. This paper presents the viability of the replacement of waste marble powder for cement and steel fibres to attain economy and surroundings saving. The self-compacting concrete is ideal to be used for casting heavily reinforced sections or be placed where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible to cast, giving a far superior surface to conventional concrete. Self-compacting concrete, also referred to as self-consolidating concrete, is able to flow and consolidate under its own weight and is deaerated almost completely while flowing in the formwork. It is cohesive enough to fill the spaces of almost any size and shape without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily-reinforced concrete members or in complicated work forms.This study aims to focus on the possibility of using partial replacement of Marble dust and steel fibres in self compacting concrete (SCC) for M30 Grade prepared using additives of super plasticizer and viscosity modifying agent. The fresh and hardened properties in SCC (M30) are studied in laboratory experiments by replacing cement by using steel fibre of 0.2% by weight of concrete and marble dust with varying percentage of 0%, 25%, 50%, 75% and100%. There is an enlarge in the strength of the concrete fashioned from waste marble powder as partial replacement of cement.
Key Words: Self-Compacting Concrete, Super Plasticizers, Steel Fibres, Marble Dust, Cement.

1.0 Introduction

Present-day self-compacting cement can be delegated a propelled development material. As the name recommends, it doesn't require to be vibrated to accomplish full compaction. However, concrete technology has reduced use of energy and natural resources which further reduces pollutants. But, due to rise in its cost waste should be used as constituents which will decrease the cost. The organization of SCC blends incorporates significant extents of fine-grained inorganic materials and this gives conceivable outcomes for usage of mineral admixtures, which are right now squander items with no useful applications and are exorbitant to discard (St John, 1998). Self-compacting cement expands the likelihood of utilization of different mineral results in its assembling and with the densification of the grid, mechanical conduct, as estimated by compressive, ductile and shear quality, is expanded. Then again, the utilization super plasticizers or high range water reducers, improves the hardening, undesirable air entrainment, and streaming capacity of the solid. Self-compacting concrete is the highly flow able, non-segregating concrete that can spread into place, fill formwork, and encapsulate even the most congested reinforcement by means of its own weight, with slight or no vibration. It deliversthis striking settlement while maintain or ornamental all of expected mechanical and sturdinessuniqueness of concrete. In this specific situation, steel filaments are exhibited as an answer for this issue, since because of fiber fortification instruments the solid malleability and post-breaking opposition can be altogether improved. SCC does not utilize a high extent of water to end up liquid - in actuality SCC may contain less water than standard cements. Rather, SCC gains its liquid properties from a strangely high extent of fine total, for example, sand (regularly half), joined with super plasticizers (added substances that guarantee particles scatter and don't settle in the liquid blend) and consistency improving admixtures (VEA). SCC was conceptualized in 1986 by Prof. Okamura at Ouchi University, Japan, when gifted work was in constrained supply, causing troubles in cement related businesses. The original of SCC utilized in North America was portrayed by the utilization of generally high substance of cover just as high measurements of synthetic substances admixtures, more often than not super plasticizer to upgrade flow ability and strength. Such superior cement had been utilized generally in fix applications and for throwing concrete in confined zones. The original of SCC was accordingly portrayed and indicated for specific applications. K. Vardhan, S. Goyal, R. Siddique, and M. Singh, (2015), Marble is a metamorphic rock which results from the transformation of pure limestone. Chemically, calcite, dolomite, or serpentine materials are the major components of marble as crystalline rocks. Dr. Anurag Mishra, Mr. Rajesh Gupta (2014), there are several wastes being released from the industries which leads to many environmental and health problems and so it becomes necessary to find an appropriate solution to the emission of these wastes. Marble powder is an inert material which is procured as an industrial by-product during sawing, grinding, and polishing of marble is a cause to various environmental problems. These wastes can be used as the constituents of concrete by partially replacing the cement which makes it economical and also conserves our natural resources. The possibility of utilizing marble powder in concrete production which includes different types of concrete mixes of M25 by replacing the cement with marble powder in various proportions (0%, 5%, 10% & 15%) by weight to determine the optimum percentage of replacement. The testing for Compressive strength of these Concrete mixes is done at 7 and 28 days and the results are then compared with the normal conventional Concrete. Ali Ergun (2011), the increase in the strength of mortar can be attributed to the calcium carbonate content of Marble Powder & the additional surface area provided by the calcium carbonate in Marble Powder may provide sites for the nucleation and

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growth of hydration products that leads to further increase in strength.Alyamac KE, Ince R, (2009) Marble dust can be used either to produce new products or as an admixture so that the natural sources are used more efficiently and the environment is saved from dumpsites of marble waste. Sarsby, R.W. (2001), Aggregate extraction process damages the land, making it derelict land which is incapable of beneficial use without treatment. It is not acceptable to leave large areas of land in a blighted and unusable state. Besides environmental degradation, considerable energy is consumed in mining or quarrying operations and transportation of aggregate materials. Utilization of waste or recycled materials in concrete helps in conserving natural resources, mitigates environment pollutions, reduces cost of concrete manufacturing, reduces landfill demand and its cost, and saves energy.This study focus on the likelihood of with Marble dust and steel fibres in self compacting concrete (SCC) for M30 Grade concrete prepared using additives of super plasticizer and viscosity modifying agent. The fresh and hardened properties in SCC (M30) are studied in laboratory experiments by replacing cement by using steel fibre of 0.2% by weight of concrete and marble dust with varying percentage of 0%, 10%, 20%, 30% and 40% with 0.6% super plasticizer added by weight of cement.

2.0 MATERIAL PROPERTIES

Collection of material used in the course of the laboratory tests are described in the subsequent segment.

2.1 Cement: Ordinary Portland cement of 53 grade from the neighborhood market was utilized and tried for physical and substance properties according to Seems to be: 4031 – 1988and observed to acclimate different determinations according to May be: 12269-1987. The physical properties of cement are Normal Consistency: 30%, Initial Setting Time: 35 min, CompressiveStrength 7 days: 37 N/mm^2, 14days: 47 N/mm^2, 28days: 53 N/mm^{2}and Specific Gravity: 3.15

2.2Fine Aggregates: In the present examination fine aggregates is characteristic sand from nearby market is utilized. The physical properties of fine total like explicit gravity, mass thickness, and degree and fineness modulus are tried as per IS: 2386. Physical properties of coarse fine are Fineness Modulus = 2.72, Specific Gravity = 2.61, Loose Bulk Density (kg/m^3) = 1585, Compact Loose Bulk Density (kg/m^3) = 1690 and Fineness Modulus of Coarse Aggregate = 2.72.

2.3 Coarse Aggregate: The crushed aggregates of 12.5 mm greatest size adjusted got from the nearby pounding plant, Robo silicon, Keesera Gutta, Hyderabad is utilized in the present investigation. The physical properties of coarse total like explicit gravity, mass thickness, degree and fineness modulus are tried as per IS; 2386.Physical properties of coarse aggregates are Fineness Modulus = 6.15, Specific Gravity = 2.68, Loose Bulk Density (kg/m^3) = 1475, Compact Loose Bulk Density (kg/m^3) = 1690 and Fineness Modulus of Coarse Aggregate = 6.15

2.4 Marble Dust: Marble powder was collected from the waste deposit of marble factory during shaping and dressing of stones. It was sieved by IS-90 micron sieve before mixing in concrete. Thus, utilizing this marble waste in construction industry itself would help to protect the environment from dumpsites of marble and also limit the excessive mining of natural resources of sand.Physical Properties of marble dust are Specific Gravity 2.210, Dry Moisture Content (%) =1.58, Bulk Density (kg/m^3) = 1118 4 Fineness Modulus = 2.03 and the chemical properties are SiO_2= 01.38, $Al2O_3$= 00, Fe_2O_3= 00.24, CaO= 53.12 and MgO = 00.38

2.5 Steel Fibers: Tempered steel wire of 0.5 mm separation crosswise over has been used as a piece of the game plan of SFRC. The steel fiber of length 40 mm and of point of view extent 80 has been used as a piece of this exploratory work. All the steel fibers are secured, trapped, broke down alive and well. The common separation crosswise over lies in the extent of 0.25-0.75 mm catch end steel strands are being used as a piece of this endeavor. Length of these strands is 30 mm and the edge extent of 55. Thickness of steel fiber is 7900 kg/cum

Fig. 1Steel Fibers

2.6 Super Plasticizer: The super plasticizer utilized in solid blend makes it exceedingly functional for additional time with a lot lesser water amount. It is perceptive that with the utilization of huge amounts of better material (fine total + bond + fly fiery remains) the solid is much firm and requires more water for required functionality henceforth, in the present examination SP430 is utilized as water lessening admixture.The optimum dosage is best determined by site trails with the concrete mix, which enables the effect of workability as a guide, the rate of addition is in the range of 2.5% of power value.

2.7 Water: This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete , should be clean and free from harmful impurities such as oil, alkali, acid, etc., in general, the water, which is fit for drinking should be used for making concrete.

2.8 Sodium Chloride (NaCl): Sodium chloride regularly known as salt is an ionic compound with the synthetic equation NaCl, speaking to a 1:1 proportion of sodium and chloride particles with a molar masses of 22.99 and 35.45 g/mol separately. 100 g of NaCl contains 39.34 g Na and 60.66 g Cl. In its eatable type of table salt which is regularly utilized as a topping and sustenance additive. Enormous amounts of sodium chloride are utilized in numerous mechanical procedures, and also stabilization of soils.

2.9 SulphuricAcid (H_2So_4): Sulfuric acid is called hostility is a mineral corrosive made out of the components sulfur, oxygen and hydrogen, with sub-atomic recipe H_2SO_4. Its destructiveness can be mainly credited to its solid acidic natureandif at a high fixation of its drying out and oxidizing properties. It is likewise hygroscopic and promptly retaining water vapor from the air. Sulfuric corrosive is a significant ware compoundand a country's sulfuric corrosive creation is a decent marker of its modern quality. It is most normally utilized in compost make, but at the same time is significant in mineral handling, oil refining, wastewater preparing, and substance combination.

3.0 DESIGN OF M30 GRADE MIX (IS: 10262:2009)

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining with the object of producing concrete of certain minimum strength and durability as economically as possible.

Maximum size of aggregate = 12 mm; Degree of workability = 0.90; Degree of workability = Good; Type of exposure = Mild; Test data for materials:Specific gravity of cement = 3.15; Specific gravity of fine aggregate = 2.61, Specific gravity of coarse aggregate = 2.68

Determine the target mean strength fck' = fck+1.65(S) = 30+1.65*5= 38.65 N/mm²

Selection of water –cement ratio (W/C) = 0.42, Max water content = 186liters

Cement content from W/C = 186/0.42, Cement = 440 kg/m^3

Calculation of Coarse aggregates= $\frac{\text{Bulk density of Coarse aggregates}}{\text{Specific Gravity of Coarse aggregates}} = \frac{1265}{2.68} = 472$ kg/m^3

Calculation of Fine aggregates= $\frac{\text{Bulk density of fine aggregates}}{\text{Specific Gravity of fine aggregates}} = \frac{1595}{2.61} = 611.11$ kg/m^3

Final Mix of Concrete

W	Cement	Fine aggregates	Coarse Aggregates
186	440	472	611.11
0.42	1	1.07	1.38

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4.0 WORKABILITY AND DURABILITYSTUDIES

A time schedule for testing of specimens is maintained to ensure their proper testing on the due date and time. Durability of Concrete of concrete to defy weathering exploit, chemical attack, and abrasion while maintaining its preferred engineering property. The fresh and hardened properties in SCC (M30) are studied in laboratory experiments by replace cement by adding steel fibre(SF) of 0.2% by weight of concrete and marble dust with varying percentage of 0%, 10%, 20%, 30% and 40% with 0.6% super plasticizer added by weight of cement. Acid attack and Sulphate Attack tests were conducted by using Sulphuric Acid (H_2So_4) and Sodium Chloride (NaCl) under durability studies. The cast specimens are tested as per standard procedures, immediately after they are removed from curing tubs and wiped off the surface water, as per IS 516-1959. The details of the tests are mentioned below.

4.1 Compressive Strength

Compression is the test commonly conducted for concrete with the size of the cube 15cm × 15cm × 15cm was cast to test various concrete mixtures for compressive strength test. After molding, kept for curing for 7, 14, 28, 56 and 28 days and the compressive strength was calculated. The water and grit on the cubes was removed before testing the cubes. The test was carried as per IS: 516-1959. The compressive Strength of the Specimens was calculated as follows: Compressive Strength =P/A, Where P= Maximum load Applied (N) and A= Area of the Load applied face ($mm^{2)}$

		
Fig.2 Compressive Strength	**Fig.3Splitting Tensile Strength**	**Fig.4 Flexural Strength**

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4.2 Split Tensile Test

Tensile strength of concrete is much lower than its compressive strength (that's why steel is used to carry the tension forces). It has been estimated that tensile strength of concrete equals roughly about 10% of compressive strength. This test was conducted as per IS516-1959. The measured splitting tensile strength *fsp* of the specimen was calculated using the following Formula: $Fsp = 2P/(\pi DL)$; Where P= maximum load applied to the specimen (N), D = cross sectional diameter of the specimen (mm) and L = length of the specimen (mm).

4.3 Flexural Strength

Flexural strength is an indirect measure of the tensile strength of concrete is a measure of the maximum stress on the tension face of an unreinforced concrete beam or slab at the point of failure in bending. It is measured by loading 150 x 150 mm (or (100 x 100 mm) concrete beams with a span length at least three times the depth.Where Fr is the MR; F'c is the specified compressive strength. When MR is critical to design, the best estimate is established from laboratory tests for specific mixtures and materials used.The Flexural strength of the specimens was calculated as follows: Modulus of Rupture (MR, $fb=PL/bd^2$, Where P = Maximum load applied (N), L = Supported length of the specimen (mm), b = Measured width of the specimen (mm), d = Measured depth of the specimen at the point of failure (mm).

4.4 Acid Attack Test: The solid 3D square examples of different solid blends of size 150 mm were thrown what's more, following 28 days of water restoring; the examples were expelled from the relieving tank what's more, permitted to dry for one day. The loads of solid 3D shape example were taken as W1.The corrosive assault test on solid 3D shape was directed by submerging the blocks in the corrosive water for 90 days following 28 days of relieving. Hydrochloric corrosive (NaCl) with pH of around 2 at 10% load of water was added to water in which the solid 3D squares were put away. The pH was kept up all through the time of 90 days. Following 90 days of inundation, the solid 3D shapes were removed from corrosive water. At that point, the examples were tried for compressive quality. The obstruction of cement to corrosive assault was found by the % loss of weight of example and the % loss of compressive quality on submerging solid 3D squares in corrosive water.

4.5 Sulphate Attack Test: The opposition of cement to sulfate ambushes transformed into concentrated with the guide of making sense of the loss of compressive power or form in compressive quality of solid blocks drenched in sulfate water having 5% of Sulfuric acid (H_2SO_4) by method for weight of water and individuals which aren't submerged in sulfate water. The solid 3D squares of 150mm size after 28days of water restoring and dried for later on have been drenched in 5% Na_2SO_4 and 5% H_2SO_4conveyed water for 90 days. The consciousness of sulfate water changed into kept up sooner or later of the period. After 90days drenching period, the solid 3D shapes had been dispensed with from the sulfate waters and in the wake of clearing out the water and girt from the outside of 3D squares tried for compressive vitality following the techniqueendorsedinIS:516-1959.

5.0 RESULTS AND ANALYSIS

Experiments were carried out by adopting partial replacing with cement by different percentages of Marble Dust 10%, 20%, 30% and 40% and also 2% steel fibres and with 0.6% super plasticizer added by weight of cement by way to find the optimum percentages and its outcome on strength properties and durability of concrete and the results are furnished below.

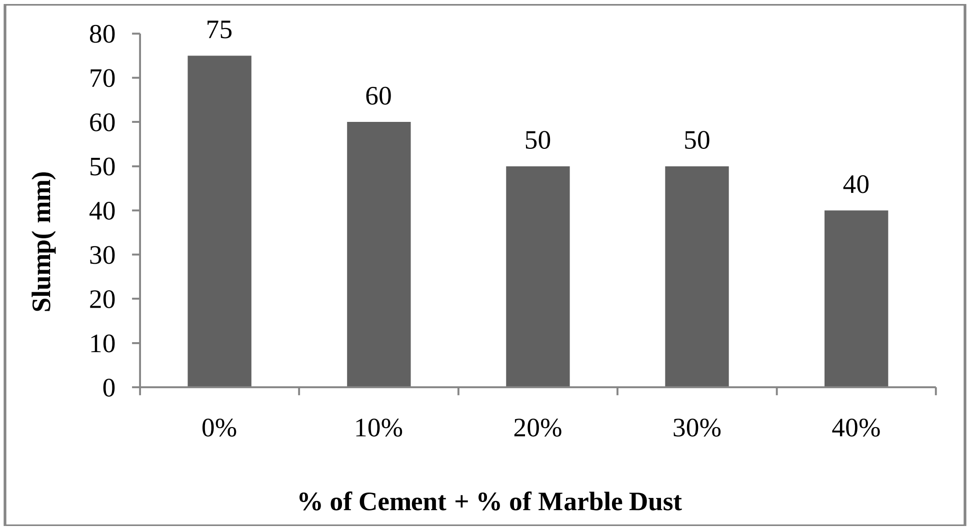

Fig.5. Variation of Slump Values for Partial Replacement of Cement with Marble Dust

From the above Fig. 5 Slump Values are decreasing with increasing percentage of adding Marble powder.

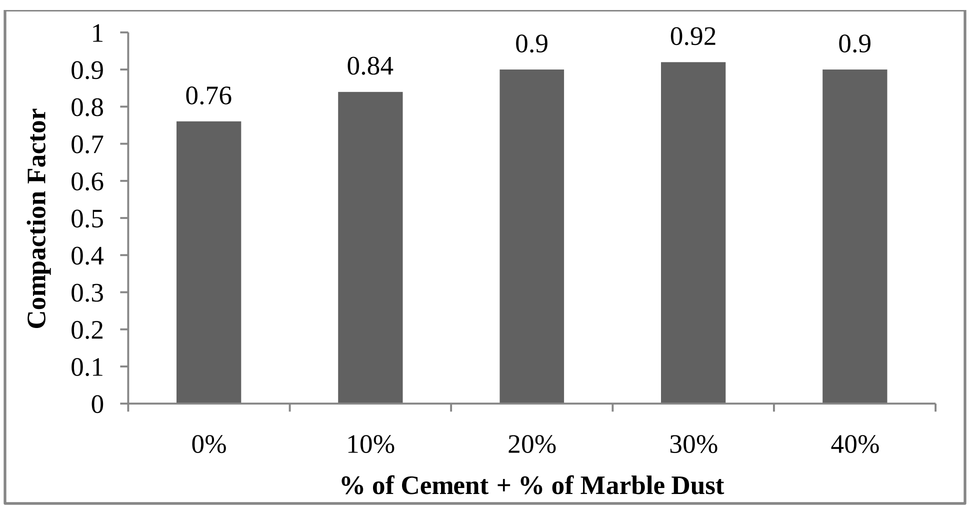

Fig.6. Variation of Compaction Factor Values for Partial Replacement of Cement with Marble Dust

From the above Fig.6 compaction factor values are increases with increasing of percentage of adding Marble powder.

5.1 Compressive Strength: Result representing the compressive strength values from 3,7 and 28 days curing at a range of replacement 10%,20% 30% and 40% marble dust in place of OPC 53 grade cement by considering the M 30 grade mix proportions and the compressive strength test results are presented in the Fig.7. From the result it was observed that the compressive strength of the concrete increases with increase in the replacement level of cement by Marble Dust up to 30 % and further addition it there was a decrease in the strength of the concrete and also compressive strength increases with curing.

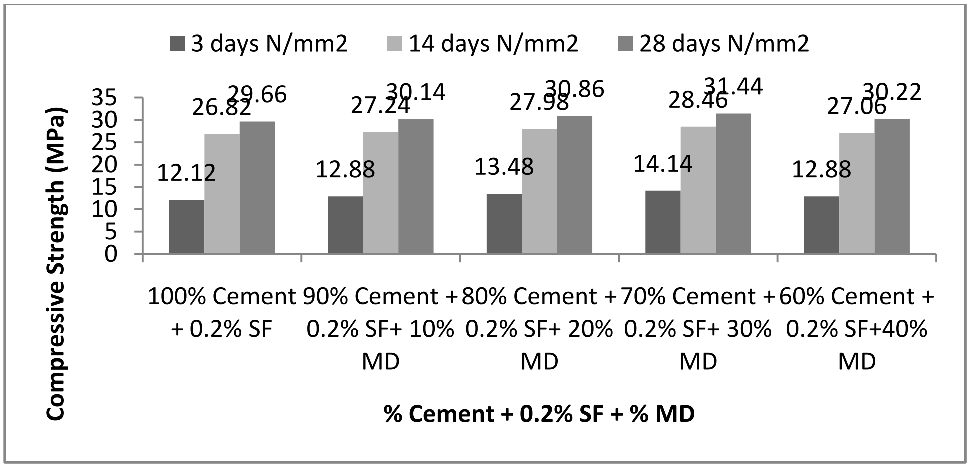

Fig. 7. Variation of Compressive Strength for 0.2% Steel FibresBlend with Partial Replacement of Cement with and % Marble Dust at Various Days of Curing

5.2 Split Tensile Strength: From the Fig. 8, Split Tensile Strength values at different curing periods of 3, 7 and 28 days it increases by replacement of marble dust 10%, 20% 30% and 40% in place of OPC 53 grade cement by designed M30 grade mix, the Split Tensile Strength results are increases with increase in the replacement level of cement by Marble Dust up to 30 % and further addition it there was a decrease in the strength of the concrete.

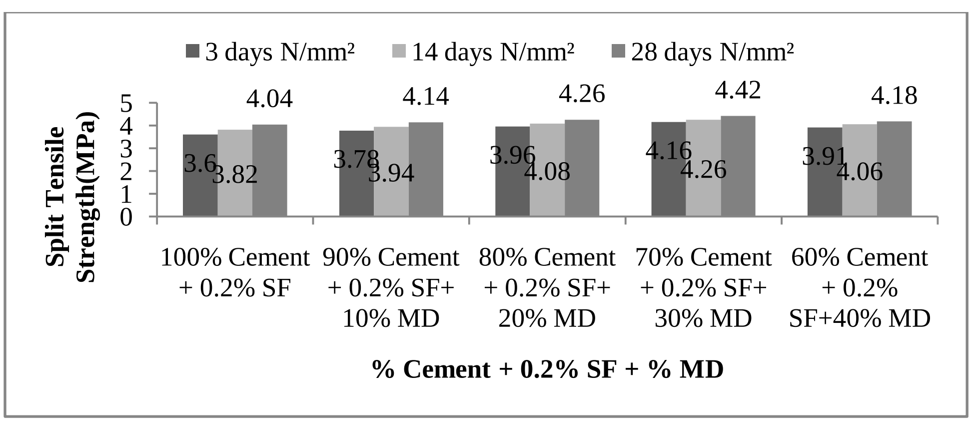

Fig. 8. Variation of Split Tensile Strength for 0.2% Steel FibresBlend with Partial Replacement of Cement with and % Marble Dust at Various Curing Periods

5.3 Flexural Strength: Flexural Strength results shows that there is an increase in strength upto 30% blending of marble dust in place of cement and further addition it decreases as presented in the Fig.9.from the above 30% of marble dust found to be optimum percentage as compared to other percentages tried in this investigation.

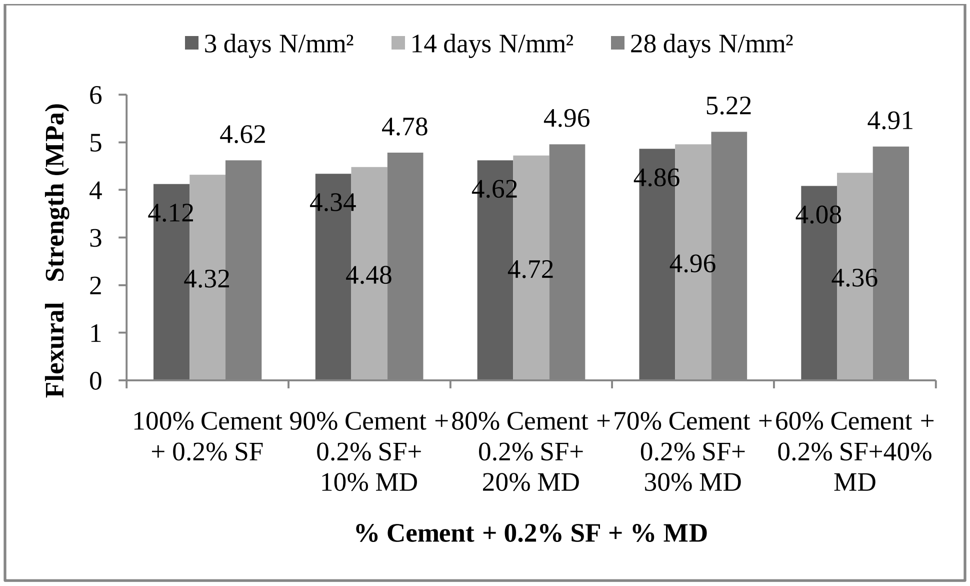

Fig. 9. Variation of Flexural Strength for 0.2% Steel FibresBlend with Partial Replacement of Cement with and % Marble Dust at Various Curing Periods

5.4 Acid and Sulphate Attack: The cubes of size blends of size 150×150×150 mm casted with different proportions of marble dust replace with cement following 28 days of water restoring and dry for one day. After that submerging these cubes in the corrosive water Sodium Chloride (NaCl) for 90 days following 28 days of relievingwith pH of around 2 at 10% and were dried and weighted. From the Figs. 10 and 11, it is found that there is a continuous reduction in weight due to breakdown of concrete. 5% of Sulfuric acid (H_2SO_4) mixed in water and submerged the cubes for 90 days.After 90days curing period, the solid cubes had been dispense with on or after the sulfate waters and in the wake of clearing out and tried for compressive test ,the results found that loss f compressive strength observed as compared to normal curing presented in the Figs.12 and 13 respectively.

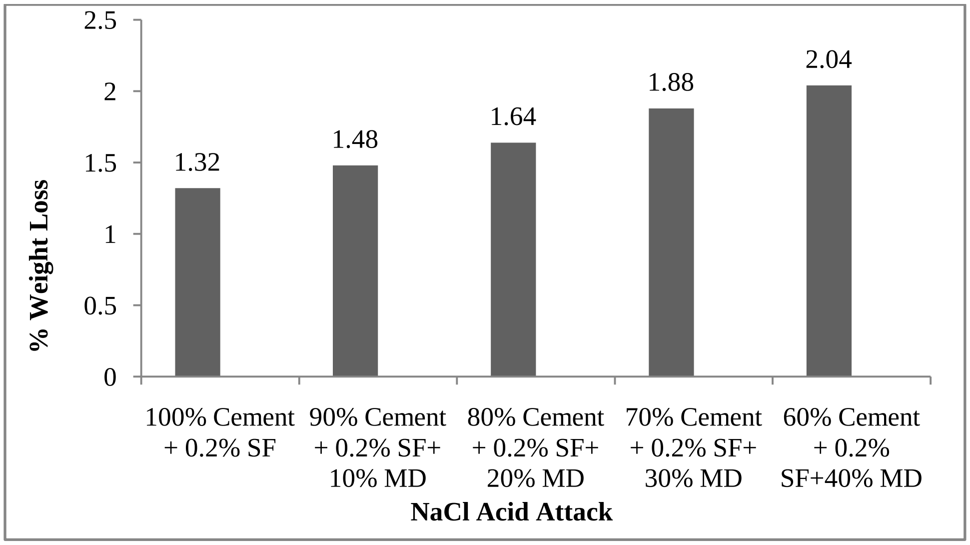

Fig. 10. Variation of % of loss of Weight for 0.2% Steel FibresBlend with Partial Replacement of Cement with and % Marble Dust at 90 Days of Curing of NaCl Acid Attack

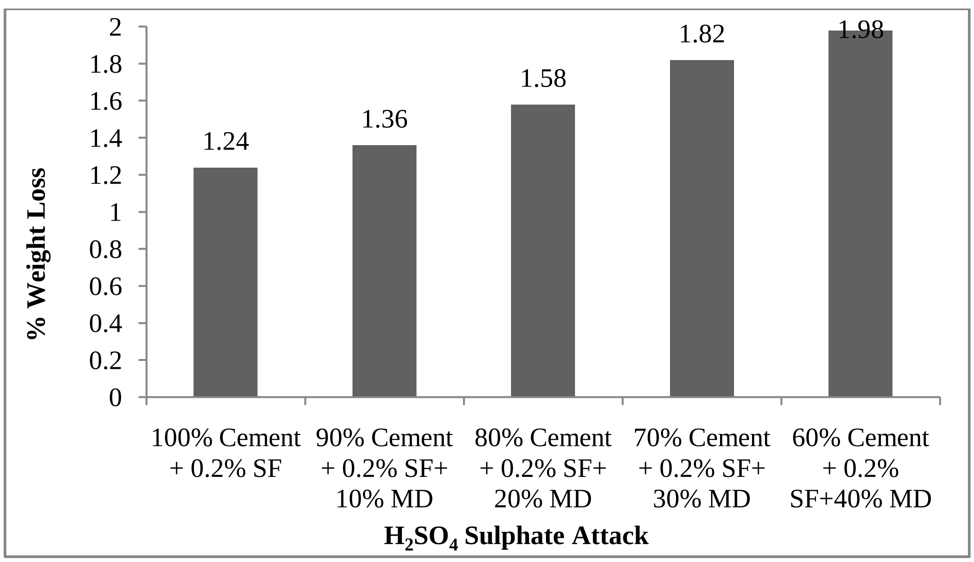

Fig. 11. Variation of % of loss of Weight for 0.2% Steel Fibres Blend with Partial Replacement of Cement with and % Marble Dust at 90 Days of Curing of H_2SO_4Sulphate Attack

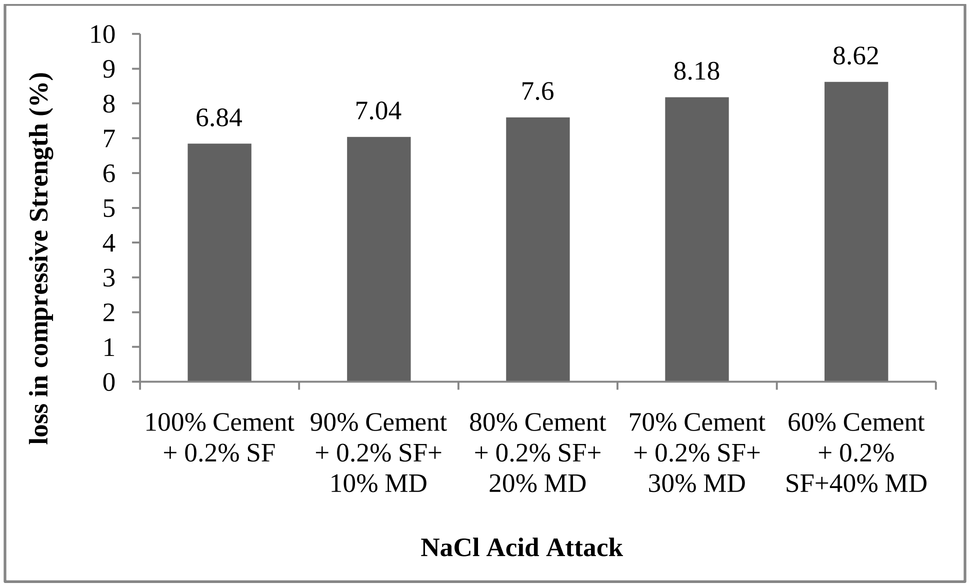

Fig. 12. Variation of % of loss of compressive Strength Values for 0.2% Steel FibresBlend with Partial Replacement of Cement with and % Marble Dust at 90 Days of Curing of NaCl Acid Attack

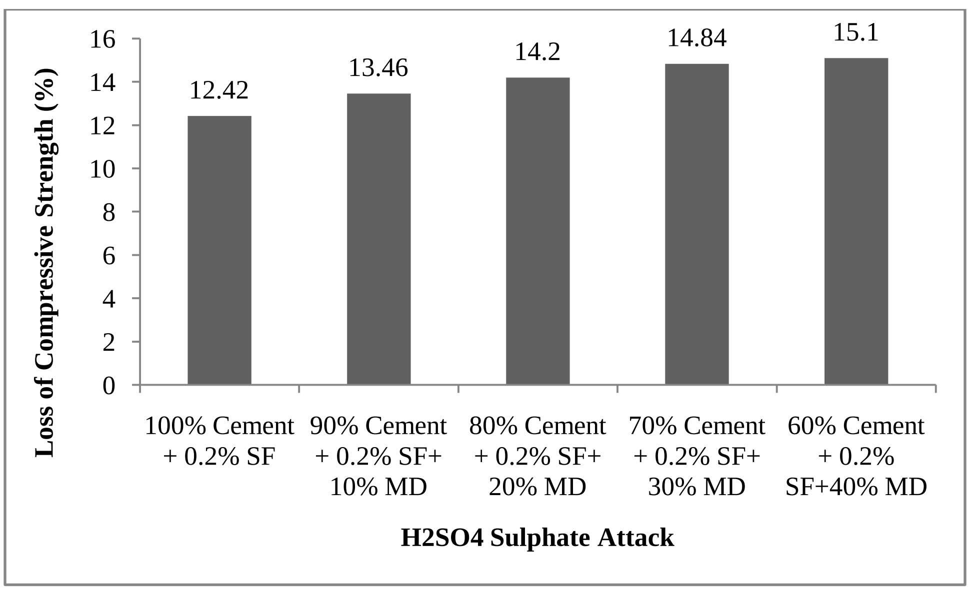

Fig. 13. Variation of % of Loss of compressive Strength Values for 0.2% Steel Fibres Blend with Partial Replacement of Cement with and % Marble Dust at 90Days of Curing of H_2SO_4Sulphate Attack

Conclusions

The following outcomes were made based on the experimental investigation carried out in the laboratory as per IS standards by partial replacing marble dust in place of cement along with 0.2% steel fibres and o.6% super plasticizer.

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- Self-compacting concrete can be obtained in such a way, by adding chemical and mineral admixtures, so that it's splitting tensile and compressive strengths are higher than those of normal vibrated concrete.
- The slump flow value for the SCC by mixing marble powder decreases and compaction factor for the SCC by blend marble powder increases with increasing the percentage.
- The optimal value of compressive strength, split tensile strength and flexural strength of SCC was observed at 30% of marble powder. The value of strengths increases with increase in the percentage of marble powder up to 30%.
- In addition, self-compacting concrete has two big advantages. One relates to the construction time, which in most of the cases is shorter than the time when normal concrete is used, due to the fact that no time is wasted with the compaction through vibration.
- The second advantage is related to the placing. As long as SCC does not require compaction, it can be considered environmentally friendly, because if no vibration is applied no noise is made.
- Due to effect of acid and sulphate on concrete by using marble dust the value of percentage loss of weight, and percentage loss of compressive strength increases.
- From the above study, it is accomplished that the marble dust can be used as a substitution material for cement upto 30% which gives an outstanding result in strength characteristic and quality portion. The outcome prove that this industrial waste is capable of improving hardened concrete performance up to 30%, attractive fresh concrete behavior and can be used in plain concrete.

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