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To Study the Effect of Partially Replaced Marble Dust on Strength of SFRC

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ABSTRACT

Concrete is not just a mixture of cement and aggregate but it is synonymous to the strength and durability. Concrete is widely used material in construction due to its uniqueness property. But due to environment concern it is necessary to reduce the factor responsible for climate change. One material used in concrete has major effect on environment, so by reducing the quantity of that material we can approach towards sustainable development. We can do this without compromising the strength.

The thrust nowadays is to produce thinner and green sections of better quality, which can carry the heavy loads. The high strength steel fiber reinforced concrete is a concrete having compressive strength greater than 40MPa, made of hydraulic cements and containing fine and coarse aggregates; and discontinuous, unconnected, randomly distributed steel fibers.

The present study aims at, developing concrete mixtures incorporating marble dust as partial replacement of cement as well as steel fibers. In this study, the flexural, compressive and split tensile strength concrete mixtures for different percentage of steel fibers and replacement of cement with marble dust are reported. It is found out the maximum increase in flexure strength, compressive strength and split tensile strength is for 0% Marble Dust and 1% Steel fibers. Also it has been possible to achieve savings in cement by replacing it with marble dust and adding fibers.

This study also shows that in view of the high flexural strength, high values of compressive strength and high values of split tensile strength, higher load carrying capacity and higher life expectancy, the combination of 10 to 20% marble dust replacement along with addition of 0.5 to 1% steel fibers is ideal for concrete.

Keywords: *High Performance Concrete, Marble Dust, Steel fibers, Super Plasticizer*.

1. Introduction

The definition of high strength concrete (HSC) varies on the geographical basis. In general, HSC may be defined as concrete which attribute the compressive strength properties which is not easy to obtain with the use of local materials and practices. However, the ACI Committee defined HSC of normal weight aggregates having 28 days cylinder compressive strength equal to 41MPa or greater in a uniaxial test (*ACI 363 R-84*). High strength concrete is a relative term which can be defined accordingly to requirement, contemporary and technology.

Concrete is essentially made from five materials, namely, air, water, cement, fine aggregate, and coarse aggregates. The first three constituents, when mixed together, form the binder paste; on adding fine aggregates only to the paste forms mortar; whereas, when all the constituents are mixed together, concrete is formed. An admixture is a material added to the batch of concrete before or during its mixing to modify its freshly mixed, setting or hardened properties. About 80% of concrete produced in North America have one or more admixtures. About 40% of ready-mix producers use fly ash. About 70% of concrete produced contains a water-reducer admixture. One or more admixtures can be added to a mix to achieve the desired results.

In building industry, Marble has been commonly used as a building material since the ancient times. The disposal of the marble powder material, consisting of very fine powder, constitutes one of the environmental problems around the world. Marble blocks are cut into smaller blocks in order to give them the desired smooth shape. In India, marble dust is settled by sedimentation and then dumped away which results in environmental pollution, in addition to forming dust in summer and threatening both agriculture and public health. Therefore, utilization of the marble dust in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment. For instance, certain residues such as marble sludge from stony material manufacturing and cement kiln dust are characterized by an average diameter. This important characteristic makes them potentially candidates for use in the production of self-leveling mortars (SLMs) and self-compacting concretes (SCCs). They can be compacted under their self-weight, with no external action, providing a considerable saving in time and energy. The feasibility of the waste material recovery process is particularly influenced by the simultaneous satisfaction of the economic, technical and normative aspects for each field of use. Once the economic convenience has been assessed, the experimentation must verify that the physicochemical characteristics attained after treatment are suitable to the specific project solutions for which they are intended (Shahul and Sekar 2009)

2. Literature Review

Steel fiber reinforced concrete (SFRC) is concrete containing dispersed steel fibers. The most important regulation of steel fibers in concrete is to control and retard the tensile cracking of the composite material. The steel fiber reinforced concrete improves the strength characteristics like flexural strength, split tensile strength, strain capacity, flexural toughness, compressive strength and crack arrest properties which lead to use in highway and airfield pavements, overlays and bridge deck slabs.

Wang et al. (1996) investigated the fiber reinforced concrete beams under impact loading. Impact tests were carried out on small concrete beams reinforced with different volumes of both polypropylene and steel fibers. The drop height of the instrumented drop weight impact machine was so chosen that some specimens failed completely under a single drop of the hammer, while others required two blows to bring about complete failure. It was found that, at volume fractions less than 0.5%, polypropylene fibers gave only a modest increase in fracture energy. Steel fibers could bring about much greater increases in fracture energy, with a transition in failure modes occurring between steel fiber volumes of 0.5% and 0.75%. Below 0.5%, fiber breaking was the primary failure mechanism and the increase in fracture energy was also modest; above 0.75% fiber pull-out was the primary mechanism with a large increase in fracture energy.

Soulioti(2011), carried out investigation on effect of fiber geometry and volume fraction on the flexural behavior of steel fiber reinforced concrete. In this paper the effect of fiber geometry and fiber volume fraction has been investigated for steel fiber reinforced concretes. Specifically the compression strength, the flexural strength and toughness were studied as a function of the above parameters and compared to unreinforced concrete. The effect of the fiber inclusion on the slump and air content properties of fresh concrete has been also evaluated.

Sekar et al. (2009), carried out investigation on the properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate. In this paper, they accomplished that feasibility of the usage of quarry rock dust and marble sludge powder as hundred percent substitutes for natural sand in concrete. An attempt has been made to durability studies on green concrete compared with the natural sand concrete. It is found that the compressive, split tensile strength and durability studies of concrete made of quarry rock dust are nearly 14 % more than the conventional concrete. *Gupta et al. (2012)*, carried out investigation on the Partial replacement of cement with marble dust powder. In this research, they resulted that with the replacement of 10% of marble dust with cement, the compressive strength increases and further any replacement of marble dust with concrete the compressive strength decreases. Same case in the split tensile strength of cylinder, As 10% replacement of marble dust with cement the split tensile strength increases and further any replacement of marble dust the split tensile strength decreases. Thus they found that the optimum percentage for replacement of marble powder with cement and it is almost 10% cement for both cubes and cylinders.

Katzer(2011),concluded the results of steel fiber reinforced cement composites (SFRCC) modified by super-plasticizers based on different chemical substances. The SFRCC were made on the basis of fine aggregate cement matrix modified by steel fibers of an aspect ratio l/d= 50. Fine aggregate matrix composed of waste aggregate (obtained during hydro classification) was modified by an addition from 0% to 2.8% (by volume) of hooked steel fibers and 1% of super-plasticizer. After establishing basic parameters of fresh mix and hardened fiber reinforced composites, the main tests were a drop-weight test of the SFRCC plates and dynamic harmonic loading of beams. The results specify the influence of the specific super-plasticizer on the behavior of SFRCC subjected to a dynamic force. Super-plasticizers based on polycarboxylate (PC3), Super-plasticizers based on polyether (PE) and Super-plasticizers based on silica fume (CRSP) admixtures; represent three groups of most frequently used Super-plasticizers. The number of impact loading until the appearance of first crack uncrack is the same for all three super-plasticizers. The total number of dynamic loading of all SFRCC plates modified by the CRSP admixture is the highest one. It is nearly four and five times higher than number of dynamic loading of plates modified by the PE and PC3 admixtures, respectively. The total duration of dynamic loading of all SFRCC beams modified by PC3 admixture is the highest one. It is nearly 13% and 24% higher than the duration of a dynamic loading of all the beams modified by the CRSP and PE admixtures, respectively.

3. Material Used for Study

The properties of material used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, fine aggregates, and super-plasticizer, in addition to marble dust and steel fibers.

3.1 Portland Cement

Ordinary Portland Cement (OPC) of 43 Grade (UltraTech cement) from a single lot was used throughout the course of the investigation. It was fresh and without any lumps.

3.2 Aggregate

a) Coarse Aggregates: The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The coarse aggregates may be of following types:-

i) Crushed graves or stone obtained by crushing of gravel or hard stone.

ii) Uncrushed gravel or stone resulting from the natural disintegration of rocks.

iii) Partially crushed gravel or stone obtained as product of blending of above two types.

b) Fine Aggregates: The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. The fine aggregate may be of following types:

i) Natural sand, i.e. the fine aggregate resulting from natural disintegration of rocks.

ii) Crushed stone sand, i.e. the fine aggregate produced by crushing hard stone.

iii) Crushed gravel sand, i.e. the fine aggregate produced by crushing natural gravel.

c) Marble Dust

Marble dust was collected from Maa Santoshi Marbles, M.A. Chowk, Sonepat. It was white in color and it was air dried and powder in form. It was sieved through 4.75 mm sieve so as to find the specific gravity of marble powder was experimentally determined as 2.47. The 90 % particle size of marble powder ranges between 150μ to 600μ.

d) Steel Fiber

Mild steel fibers having 30 mm thickness and 60 mm length i.e. aspect ratio (l/d) 50 which are corrugated and obtained through cutting of steel wires have been used. The fibers have been cut by fiber cutting machine to an accurate size. Three different proportions of fibers i.e. 0%, 0.5% and 1% have been used.

3.2 Super Plasticizer

Super-plasticizers constitute a relatively new category and improved version of plasticizer. They are chemically different from normal plasticizers. Use of super-plasticizer permits the reduction of water to the extent up to 30 percent without reducing workability in contrast to possible reduction up to 15 percent in case of plasticizers. The mechanism of action of super-plasticizer is more or less same as in case of ordinary plasticizer. The super-plasticizers are more powerful as dispersing agents and they are high water reducers. The super plasticizer "GLENIUM™ B233" procured from SIKA India Pvt. Limited was used in present study.

4. Experimental Work

4.1 Compressive Strength of Concrete:

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out from the curing tank at the ages of 28 days and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested. The position of cube when tested was at right angle to that as cast. The load as applied gradually without shock till the failure of the specimen occurs and thus the compressive strength was found.

The quantities of cement, coarse aggregate (20 mm and 10 mm), fine aggregate, marble dust and water for each batch i.e. for different percentage of marble dust replacement was weighed separately. The cement and marble dust were mixed dry to a uniform color separately. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water added to the mix and then super-plasticizer was added. Firstly, 50 to 70% of water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mixer. Super-plasticizer was added in the remaining was and stirred to have uniform mix, added to the mix and then thoroughly mixed for further 2 to 3 minutes in mixer. Then the concrete was filled into the cube moulds and then get vibrated to ensure proper compaction. The surface of the concrete was finished level with the top of the mould using trowel. The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

4.2 Split Tensile Strength of Concrete:

The split tensile strength of concrete is determined by casting cylinders of size 150 mm X 300 mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 28 days of moist curing and tested after surface water dipped down from specimens. This test was performed on Universal Testing Machine (UTM). The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by formula

$T= 0.637P/dl$ Where,
T = Split Tensile Strength in MPa
P = Applied load,
D = Diameter of Concrete cylinder sample in mm.
L =Length of Concrete cylinder sample in mm.

The quantities of cement, coarse aggregate (20 mm and 10 mm), fine aggregate, marble dust and water for each batch i.e. for different percentage of marble dust replacement was weighed separately. The cement and marble dust were mixed dry to a uniform color separately. Fine aggregate was mixed to this mixture in dry form. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water added to the mix and then super-plasticizer was added. Firstly, 50 to 70% of water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mixer. Super-plasticizer was added in the remaining mix and stirred for further 2 to 3 minutes in mixer to have uniform mix. Then the concrete was filled into the cylindrical moulds and then get vibrated to ensure proper compaction. The surface of the concrete was finished level with the top of the mould using trowel. The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

4.3 Flexural Strength of Concrete

Test specimens of beam size 150 mm X 150 mm X 700 mm were prepared for testing the flexural strength of steel fiber reinforced concrete and replacement of cement with marble dust in different percentages.

The beam moulds containing the test specimens were placed in moist air (at least 90% relative humidity) and a temperature of $27^0 \pm 2^0$ C for 24 hours ±1⁄2 hour from the time of addition of water to the dry ingredients. After this the specimens were removed from the moulds and placed in clean fresh water at a temperature of $27^0 \pm 2^0$ C for the remaining curing period. After 28 days of curing the specimens were tested in flexure on a Universal Testing Machine. Loads were applied at the one third points at a constant rate of 30 kg/minute. The distance between the canters of two rollers was kept 20 cm.

If the fracture occurred within the central one-third of the beam, the flexural strength was calculated on the basis of ordinary elastic theory using the following equations:

$F_b = PL/BD^2$, when 'a' is greater than 20 cm for 15 cm specimen

$F_b = 3Pa/BD^2$, when 'a' is less than 20 cm but greater than 17 cm for 15 cm specimen

Where,

F_b = Flexural Strength of the specimen in N/mm^2

B = Width of the specimen (= 150 mm)

D = Depth of the specimen (= 150 mm)

L = Span of the specimen (= 700 mm)

P = Maximum load in Newton (N) applied to the specimen

a = Distance b/w the line of fracture and nearer support, measured on the centre line of the tensile side of the specimen in cm, shall be calculated to the nearest 0.5 kg/cm^2.

If 'a' is less than 17 cm the results of a test shall be discarded.

5. Results and Discussion

5.1 Compressive Strength

For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Test results of compressive strength test at the age of 28 days are given in the Table 4.1. The cube strength results of concrete mix are also shown below.

CUBE STRENGTH (MPa)			
w/c ratio	MD-0%, SF-0%	MD-10%, SF-0.5%	MD-20%,SF-1%
0.3	52.14	54.75	72.26
0.35	45.71	51.83	64.65
0.4	40.71	48.71	54.47

Table 4.1 Compressive Strength Test Results

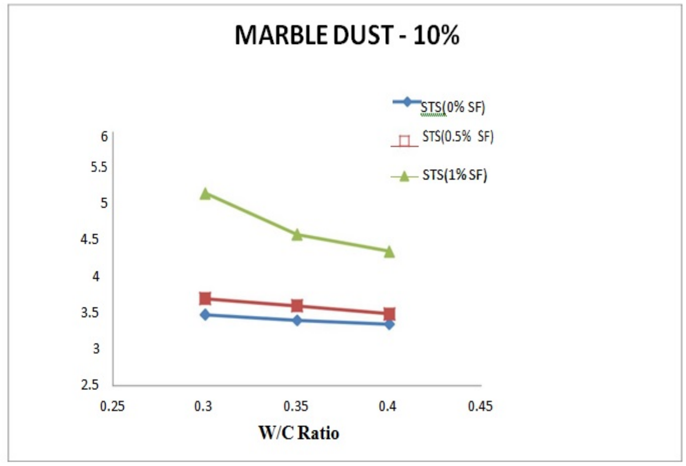

Fig. 4.2 Variation of split tensile strength of concrete with different W/C for 10% M.D and different percentage of S.F.

5.2 Flexural Strength

Test specimens of beam size 150 mm X 150 mm X 700 mm were prepared for testing the flexural strength of steel fiber reinforced concrete and replacement of cement with marble dust in different percentages.

The beam moulds containing the test specimens were placed in moist air (at least 90% relative humidity) and a temperature of $27^O \pm 2^O$ C for 24 hours ±1⁄2 hour from the time of addition of water to the dry ingredients. After this the specimens were removed from the moulds and placed in clean fresh water at a temperature of $27^O \pm 2^O$ C for the remaining curing period. After 28 days of curing the specimens were tested in flexure on a Universal Testing Machine. Loads were applied at the one third points at a constant rate of 30 kg/minute. The distance between the centers of two rollers was kept 20 cm.

If the fracture occurred within the central one-third of the beam, the flexural strength was calculated on the basis of ordinary elastic theory using the following equations:

$F_b = PL/BD^2$, when 'a' is greater than 20 cm for 15 cm specimen

$F_b = 3Pa/BD^2$, when 'a' is less than 20 cm but greater than 17 cm for 15 cm specimen

Where,

F_b = Flexural Strength of the specimen in N/mm^2

B = Width of the specimen (= 150 mm)

D = Depth of the specimen (= 150 mm)

L = Span of the specimen (= 700 mm)

P = Maximum load in Newton (N) applied to the specimen

a = Distance b/w the line of fracture and nearer support, measured on the center line of the tensile side of the specimen in cm, shall be calculated to the nearest 0.5 kg/cm^2.

If 'a' is less than 17 cm the results of a test shall be discarded. Test results of flexural test at the age of 28 days curing are given in Table 4.2. The flexural strength results of concrete mix are also shown

FLEXURAL STRENGTH (MPa)			
w/c ratio	MD-0%, SF-0%	MD-10%, SF-0.5%	MD-20%,SF-1%
0.3	6.10	6.30	6.15
0.35	5.70	5.88	5.90
0.4	4.90	5.16	5.46

Table 4.2 Flexural Strength Test Result

5.3 Split Tensile Strength

The split tensile strength of all the mixes was determined at the ages 28 days for various replacement levels of marble dust and additional percentages of steel fibers in concrete mix. The results of split tensile strength of concrete are reported in Table 4.3. Table 4.3 shows the gain in split tensile strength for different levels of marble dust replacement with concrete and addition of steel fiber at different time. The split tensile strength results of individual concrete mix are also shown graphically. From the results, it is observed that the optimum value of split tensile strength is achieved with addition of 1% of steel fiber in controlled concrete mix. Test results of split tensile strength at the age of 28 days curing are given in Table 4.3

SPLIT TENSILE STRENGTH (MPa)			
w/c ratio	MD-0%, SF-0%	MD-10%, SF-0.5%	MD-20%,SF-1%
0.3	3.60	3.71	4.26
0.35	3.37	3.61	4.00
0.4	3.18	3.50	3.70

Table 4.3 Split Tensile Strength Test Results

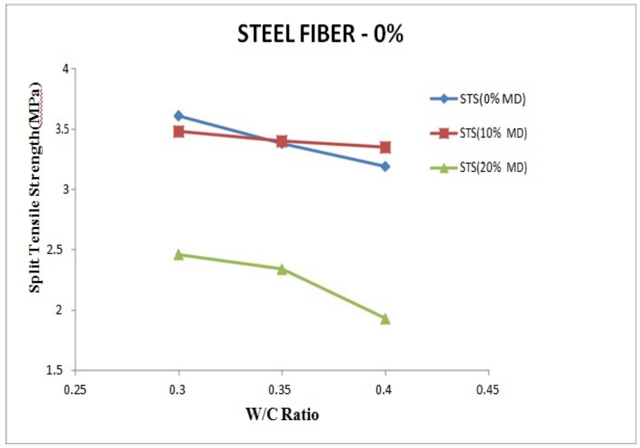

Fig. 4.10 Variation of split strength of concrete with different W/C for 0% S.F and different percentage of M.D.

6. Conclusion

From the experimental results, the following conclusion can be drawn:

Strength Characteristics

➢ Concrete mix with 10 percent marble dust as replacement of cement is the optimum level as it has been observed to show a significant increase in compressive strength at 28 days when compared with nominal mix.

➢ Concrete mixes when reinforced with steel fiber show an increased compressive strength as compared to nominal mix.

➢ The split tensile strength also tends to increase with increase percentages of steel fibers in the mix.

➢ On increasing the percentage replacement of cement with marble dust beyond 10%, there is a slight reduction in the tensile strength value.

➢ The flexure strength also tends to increase with the increase percentages of steel fibers, a trend similar to increase in split tensile strength and compressive strength.

- On increasing the percentage replacement of cement with marble dust beyond 10%, there is decrease in the flexure strength value.

- Maximum strength (flexure, compressive as well as split tensile) of pavement quality concrete incorporating marble dust and steel fibers, both, is achieved for 10% marble dust replacement and 1% steel fibers. However, if the marble dust content is increased to 20%, even with 1% steel fiber, the increase is not very significant.

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