Effect Of Carbon Fiber In Rigid Pavement Partially Replacing Cement With Marble Dust

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Abstract: As the concrete industry is growing day by day, it may be certain that increasing demand may create burden on core substances like cement, sand and aggregates. In this study, a substitute material (marble dust) has been taken which will partially replace cement in concrete pavement. Marble dust is a waste product which comes from marble industry during cutting process, leaving it as it is will create environment issues. Also for increasing strength carbon fiber is introduced in concrete pavement. Carbon fiber is having a low body to weight ratio and high strength, So a long lasting pavement can be obtained. Keeping in view the strength parameters, reinforcement of concrete will multiple pavement properties greatly. Unlike steel reinforcement which is prone to rust and deteriorate concrete properties with age. In present study M40 grade of concrete is designed for rigid pavement having water- cement ratio 0.40, it was found that the compressive strength, tensile strength and flexural strength increases compared to concrete without fibers.

Index Terms: carbon fiber, compressive strength, Marble dust, split tensile strength and flexural strength.

1. INTRODUCTION

Rigid pavement is the technical term used for any concrete road surface. Concrete roads are called rigid, while flexible roads are made by using asphalt. Such terms refer to the amount of deformation that happens when in use and over time in the road surface itself. The strength and ability to hold shape are the main benefits of using concrete pavement. Due to increasing traffic density, axel load on pavement increases which results in cracking of pavement. So there was gap which must be filled by introducing such material which will overcome it. In this study carbon fiber is used in little amounts of weight of concrete volume (0.50%, 1% & 1.50%). Addition of carbon fibers makes concrete an isotropic material and changes its brittle behavior to ductile behavior. Effect of carbon fiber will be long enough than steel fiber, which is prone to rust and also than glass fiber which deteriorate in high alkaline environment of cement. Carbon fibers are proven to be medically safe and also have greater strength than steel fibers. These are also more stable than glass fibers. Besides this carbon is having a very low weight to body ratio and low density. These have high specific strength and stiffness than the available metallic fibers and because of that they are making their way in concrete industry. Marble dust is an industrial by product and leaving it as it is can create environmental pollution. So steps must be taken to put this on efficient use. It is white in colour if major composition of limestone is of Calcite (100% $CaCO_3$). A large quantity of marble dust gets produced during cutting process of marble. The result is that the mass of marble waste is 20% of total marble quarried.

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This huge mass of waste also consists of fine particles, which nowadays is one of the environmental problems around the world. The demand of natural cement is too high due to its extensive use in concrete and rapid construction in developing countries, which leads to its scarcity. To overcome from this crisis, partial replacement of cement with marble dust might be economical alternative and a step towards sustainable development. The use of M40 design mix for pavement concrete will be carried for tests.

2. METHODOLOGY

The materials used for the study are OPC-43, Coarse aggregate, fine aggregates, water, carbon fiber & marble dust.

2.1 Materials used

a) Cement: The 43 grade (Khyber cement) ordinary portland cement (OPC) from a single lot was used throughout the investigation. It was fresh and there were no lumps, initial and final setting time of 50 min & 257 min. the specific gravity was 3.15.

b) Coarse & Fine aggregate: the nominal size of coarse aggregate used was 20mm with fineness modulus of 7.023 & specific gravity of 2.73. The fine aggregates was of zone-II having fineness modulus of 2.346 & specific gravity of 2.67.

c) Water: For the mixing and curing from cement, drinking water is generally considered adequate. Accordingly, potable water was used in the Product Testing Laboratory to make concrete usable. This was free of any harmful substances and a good quality of drinking.

d) Carbon fibers: Carbon fiber used in this study are short pitch chopped carbon fibers, these were bought from Bhat engineering works from Batamaloo Srinagar. The properties of carbon fiber used are tabulated below

***Fig -1** carbon fiber*

***Table 1** carbon fiber specifications*

Carbon fiber chopped	GC-700T-PU6
Chop length	6mm
Carbon content	95%
Electric resistivity	1.6×10^{-3} Ωcm
Elongation	1.7%
Tensile strength	4300MPa
Tensile modulus	230GPa
Density	1.8 g/cm^3

e) Marble dust: Marble dust from Haryana Marbles, Bagi-Mehtab, Srinagar. It was white in color, dry air and powder in shape. As shown in Table 3.6, it was sieved through 4.75 mm sieve to find the percentage fineness. Marble powder's specific gravity was determined experimentally as 2.80.

***Fig-2** marble dust*

2.2 Test methods

a) Sieve Analysis: sieve analysis of coarse aggregates fine aggregates and marble dust was done as per IS: 2386 (PART I) – 1963. 3000g of coarse aggregate was sieved through 80mm- 4.75mm sieves also fine aggregates (1500g) and marble dust (200g) was sieved through 4.75mm - 150µ. Finesses modulus and grade of fine aggregates was obtained.

b) Compression Strength Test: cube specimens of 150 mm x 150 mm x 150 mm are prepared and are dried for 24 hours. Then these are put in water tank. At the age of 28 days samples are taken out and surface water is wiped off. The load is then applied gradually to sample in compression testing machine.

***Fig 4** Preparation of moulds*

***Fig 5** Compression Test*

c) Flexure Strength Test: Test samples of 150 mm ×150 mm× 700 mm beam length were prepared to test the flexural strength of reinforced concrete from carbon fiber and substitute 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 after water was added to the dry ingredients. After that, the specimens were removed from the molds and placed for the remaining healing period in clean fresh water at a temperature of $27^0 \pm 2^0$C. On a Universal Testing Machine, the specimens were tested in flexure after 28 days of curing. Loads were applied at a constant rate of 400 kg/minute at one-third points. The distance between the two roller centers was held at 20 cm.If the fracture occurred in the central one-third of the tube, the flexural force was determined using the following equations based on the ordinary elastic theory:

$F_b = PL/BD^2$

When 'a' > 20 cm for 15 cm specimen

Fig 6 *Flexure Strength Of Beam*

d) Split Tensile Strength Test: Through casting cylinders of length 150 mm X 300 mm, the split tensile strength of concrete is determined. By positioning them evenly, the cylinders are checked. At the age of 28 days of moist healing, samples are extracted from the healing tank and examined after surface water dipped from specimens. On the Universal Testing Machine (UTM) this experiment was carried out.). The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by the formula:

T= 0.637P/DL

Fig 7 *Split Tensile Strength*

3. CONCRETE MIX DESIGN AND MIX PROPORTION

M40 grade of concrete was designed as per IS 10262-2019. Quantity of material used per cubic meter of concrete are tabulated below.

Table 1 *Mix Proportion of Concrete Mix*

Mix ID	Wt .of M.D kg/m^3	Wt. of C.F kg/m^3	Wt. of cement kg/m^3	Wt. of F.A kg/m^3	Wt. of C.A kg/m^3	Wt. of water kg/m^3
M1	0	0	460	593.91	1221.83	184
M2	45.67	9	411.07	591.25	1216.36	183
M3	45.36	18	408.24	588.59	1210.89	182
M4	45.04	27	405.45	585.93	1205.42	181

M2- 10% marble dust & 0.5% carbon fiber
M3- 10% marble dust & 1% carbon fiber
M3- 10% marble dust & 1.5% carbon fiber

4. RESULT & DISCUSSION

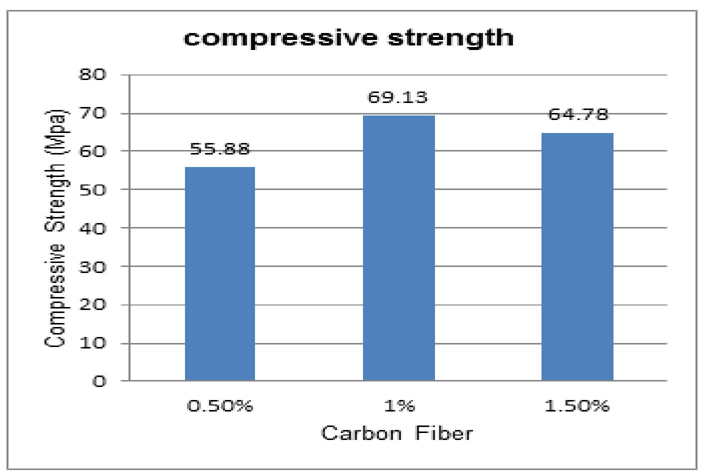
4.1 Compressive Strength Test

At the age of 28 days, cube specimens of 150 mm x 150 mm x 150 mm were removed from the healing tank and tested immediately after removal from the water. Compressive strength of different dosages of carbon fiber and marble dust @ 10% are tabulated below:

Table 2 *shows compressive strength at 28 days with varying carbon fiber percentage and marble dust @ 10%*

Mix ID	Marble dust	Carbon fiber	Compressive strength (MPa)
M1	0	0	49.10
M2	10%	0.5%	58.88
M3	10%	1%	69.13
M4	10%	1.5%	64.78

Graph 1 *Variation of compressive strength of concrete with varying C.F and M.D @ 10%.*



4.2 Flexure Strength Test

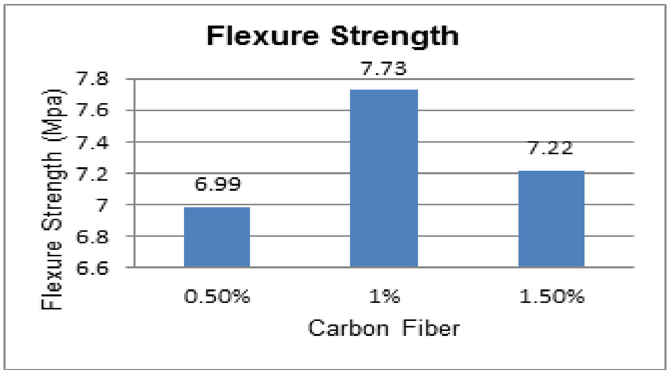
Test samples of 150 mm ×150 mm× 700 mm beam length were prepared to test the flexural strength of reinforced concrete from carbon fiber and substitute cement with marble dust in different percentages

Table 3 *Shows Flexural Strength At 28 Days With Varying Carbon Fiber Percentage And Marble Dust @ 10%*

Mix ID	Marble dust	Carbon fiber	Flexural strength (mpa)
M1	0	0	4.63

M2	10%	0.5%	6.99
M3	10%	1%	7.73
M4	10%	1.5%	7.22

Graph 2 *Variation of flexural strength of concrete with varying C.F and M.D @10%,*



4.3 Split tensile Strength Test

Through casting cylinders of length 150 mm X 300 mm, the split tensile strength of concrete is determined. By positioning them evenly, the cylinders are checked. At the age of 28 days of moist healing, samples are extracted from the healing tank and examined after surface water dipped from specimens.

Table 4 *Shows Split Tensile Strength At 28 Days With Varying Carbon Fiber Percentage And Marble Dust @ 10%*

Mix ID	Marble dust	Carbon fiber	Split Tensile strength (mpa)
M1	0	0	3.5
M2	10%	0.5%	4.91
M3	10%	1%	5.55
M4	10%	1.5%	5.17

Graph 3 *Variation of Split Tensile strength of concrete with varying C.F and M.D @10%.*

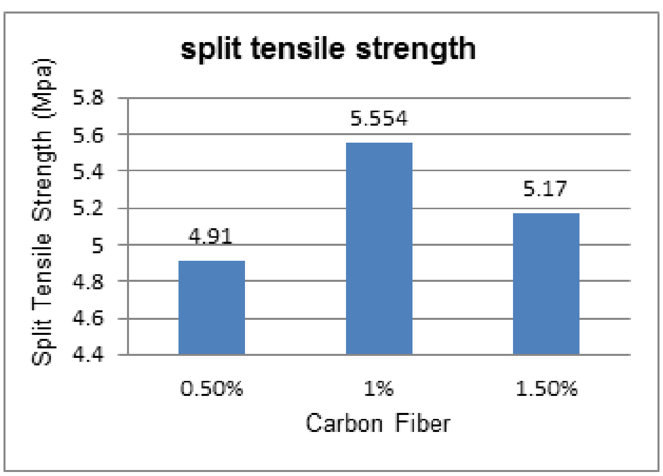
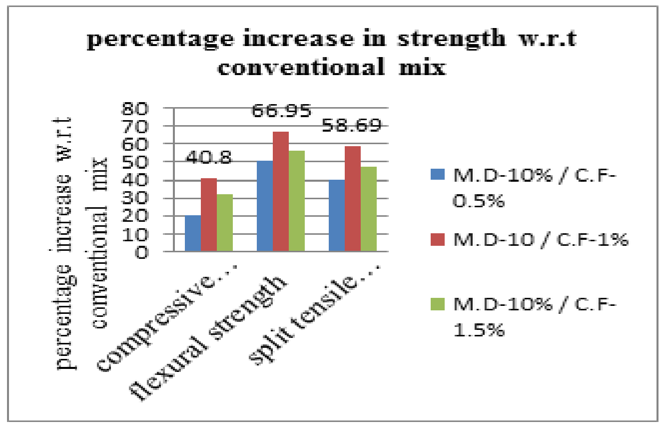


Table 6 *Shows Percentage Increase In Compressive, Flexural And Split Tensile Strength With Respect To Conventional Mix*

Marble dust	Carbon fiber	%agem increase/ decrease in compressive strength	%age increase/ decrease in flexural strength	%age increase/ decrease in split tensile strength
10%	0.50%	19.92%	50.90%	40.39%
10%	1%	40.80%	66.95%	58.69%
10%	1.50%	31.93%	55.93%	47.73%

Graph 4 *Percentage Increase In Compressive, Flexural And Split Tensile Strength With Respect To Conventional Mix.*



5 CONCLUSION

The following conclusion can be drawn from the experiments carried:

(a) The compressive strength of concrete pavement increases up to 1% of carbon fiber of volume of concrete having marble dust @ 10% replacement to weight of cement. The variation of compressive strength with different percentages of carbon fiber (0.5%, 1% & 1.5%) is 19.92%, 40.80% & 31.93% respectively. So it is clear that reduction in strength is achieved beyond 1% of carbon fiber. The upper value achieved is (1%- C.F & 10% - M.D) is 69.13 MPa.

(b) The flexure strength of concrete designed for pavement varies with levels of carbon fiber percentage. The percentage change in flexure is 50.90%, 66.95 & 55.93% for (0.5%,1% &1.5%) of carbon fiber having marble dust @10% replacement to cement. The best result is observed at 1% (7.73 MPa) of carbon fiber beyond which reduction in strength was observed.

(c) The split tensile also showed maximum results at 1% (5.55 MPa) of carbon fiber having marble dust @10% replacement to cement. The percentage change in split tensile strength is 40.39%, 58.69% & 47.73% for (0.5%, 1% &1.5%) of carbon fiber of volume of concrete.

(d) Thus it is conclude that carbon fiber can be used only up to 1% of volume of concrete. The decrease in strength beyond 1% is due to its low body to weight ratio and high permeability. So the optimum percentage observed is 1% C.F and 10% marble dust.

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