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A Study on Strength Properties of Rigid Pavement Concrete with Use of Steel Fibers and Marble Dust

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Abstract
Due to high strength, durability, economy and better serviceability there is a growing interest in the construction of concrete pavement. The main concentration nowadays is towards the production of thinner and green pavements of good quality which can sustain much heavier loads. High strength steel fibre concrete is a concrete that possesses strength greater than 40 MPa and is made of hydraulic cement, fine and coarse aggregates and unconnected, discontinuous, randomly distributed steel fibres. The aim of this study was to develop pavement quality control mixture including marble dust as a partial replacement of cement as well as admixtures. In this study, the flexural, compressive and split tensile strength for pavement quality concrete mixture for different percentage of steel fibre and replacement of cement with marble dust were reported. For 1% steel fibre and 0% marble dust, increase in compressive strength, flexural strength and split tensile strength is maximum. Also is has been made possible to achieve savings in cement by its replacement with marble dust and additional fibres. This study also reveals that in view of higher values of split tensile strength, flexural strength, compressive strength, higher life expectancy and higher load carrying capacity, the combination of 20% marble dust with addition of 0.5%-1% steel fibre is ideal for a rigid pavement that has the above mentioned characteristics.

Keywords
Steel fibre, marble dust, split tensile strength, compressive strength, flexural strength

I. Introduction
As we know Concrete is a versatile construction material. Firstly it was innovated as protective cover of steel members, after that it was revised and now a day's concrete is used as a structural member and steel is provided to modify its properties and give better strength to the concrete. Concrete has benefits like fire resistance, excellent resistance to water, has ability to mould into various shapes and sizes easily as per requirement, economic and readily available material on the job site. It was observed that the normal concrete have many inadequacy such as low value of strength to weight ratio as compared to steel. So as to overcome this inadequacy resulted in the development of high strength concrete (HSC). Now a day, with the excessive use of admixtures and widely distributed application of concrete technology, it is easy to attain cylinder strength of 50MPa in 12 to 18 hours and near to 70Mpa or above at 28 days. As per economic point of view, it is very important to design a higher proportion of the available strength of concrete with efficiency and effectively rather than a smaller proportion of much higher strength.
The environmental influence or effect of concrete is a complex mixture having not entirely negative effects; while concrete is a major donor to greenhouse gas emissions, recycling of concrete is highly common in structures that have reached the extent of their life. Structures built of concrete can have a long serving life. As concrete possesses a high thermal mass and very less permeability, it can be used for making energy efficient housing.
As we know Concrete is a gifted construction material. Firstly it was introduced as protective cover of steel members, after that it was modified and now a day's concrete is used as a structural material comprehensively and steel is reinforced to modify its properties and give better strength to the concrete. Concrete can yield benefits like excellent resistance to water, fire resistance, has ability to mould into various sizes and shapes easily as per requirement, economic and readily available material on the job site. It is noticed that the normal concrete has many drawbacks like low value of strength to weight cement ratio as compared to steel. So as to overcome this weakness, development of high strength concrete (HSC) came into existence.
Now a days, with the excess use of admixtures and widely distributed application of concrete technology, it is easy to achieve cylinder strength of 50.00 MPa in 12 to 18 hours and near to 71Mpa or above at 28 days of curing. As per economic point of view, it is very necessary to design a higher proportion of the available strength of concrete with efficiency and effectively rather than a lesser proportion of much higher strength.

II. Steel Fibre Reinforced Concrete

A. Definition
Fibre reinforced concrete represented by combination of four different phases, like cement, water, coarse aggregate, fine aggregate and a dispersion of discontinuous, steel fibre. It can also contain admixtures and pozzolans which are commonly used with the conservative concrete. All admixtures under the ASTM specifications for use in concrete are desirable for use in Steel Fibre Reinforced Concrete (SFRC).

B. Fibre Content
Various amount of fibre is added in concrete which is generally measured as a fraction of total volume of mortar. Practically four ranges of Volume fractions (Vf) can be identified as shown in Table 1

C. Types of Fibres
Fibre is manufactured from various materials in various shapes and sizes. The numerical parameter representing a fibre is its aspect ratio i.e. l/d ratio which means fibre length divided by diameter. Typical aspect ratio is used which have ranges from 30-150 for length dimensions of 1.0 to 76.2 mm. Various properties of commonly used steel fibres as shown in
Table 2.

Table 1 Typical Practical Ranges of Fibre Reinforcement of Concrete

Approx. Vol. Fraction of Fibre	Matrix	Example
Vf< 0.5%	Concrete	PP in pipe caps
0.5 <Vf< 3%	Concrete (smaller size agg.)	Pavements, Joints
3 <Vf< 8%	Mortar	Cement sheets, repairs
8 <Vf< 20%	Paste, Slurry	Asbestos cement sheets, slurry

Table 2: Physical and Mechanical Properties of Fibres

Fibre	Diameter (μm)	Specific Gravity	Young`s Modulus (KN/mm2)	Tensile Strength (KN/mm2)	Elonga-tion at break
Asbestos	0.02-20	2.55	165	3-3.5	2-3
Glass	9-15	2.60	70-80	2-4	2-3.5
Steel	5-500	7.84	200	1-3	3-4
Polypro-pylene	20-200	0.91	6-7	0.5-0.7	20
Rayon	20-200	1.5	7-8	0.4-0.6	10-25
Polyeth-ylene	20-200	0.95	0.14-0.42	0.7	10
Cotton	-	1.5	5	0.42-0.70	3-10

III. Materials

The properties of material used for manufacturing concrete mix are found out in laboratory as per relevant codes of practice. Materials used in present study were cement, coarse aggregates, fine aggregates, and super-plasticizer, in addition to marble dust and steel fibres. The purpose of studying of various properties of material in checking the appearance with codal requirements and enabling an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below:

A. Cement

The physical properties of the cement as found out from various tests conforming to Indian Standard IS: 8112:1989 are listed in Table 3. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture.

Table 3 : Test Results of Cement Sample

S. No.	Characteristics	Experimental value	Requirements as per IS: 8112-1989
1.	Consistency (%)	28	-
2.	Specific gravity	3.15	3.15
3.	Initial setting time (min)	95	>30
4.	Final setting time (min)	215	<600
5.	Fineness (%)	5	10
6.	Soundness (mm)	2.55	<10
7.	Compressive strength		
(i)	3 days (MPa)	26.10	≥23
(ii)	7 days (MPa)	36.69	≥33
(iii)	28 days (MPa)	46.56	≥43

B. Aggregates

1. Coarse Aggregates

Locally available crushed stone of sizes 20 mm and 10 mm size in 70:30 proportion were used in the concrete mixture. The aggregates were rinsed to remove dirt, dust and then dried to surface dry condition. Physical properties of coarse aggregates are given in Table 4.

Table 4 Physical properties of coarse aggregate

Particulars	Properties
Specific gravity	2.67
Fineness modulus	6.52
Bulk density(Loose),kg/m³	1460
Bulk density(compacted),kg/m³	1650
Maximum size, mm	20
FM (20mm)	7.01
FM (10mm)	6.66

2. Fine aggregates

The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. The physical properties of fine aggregates as shown in table no. 5

Table 5 : Physical properties of fine aggregate

Particulars	Properties
Specific gravity	2.67
Fineness modulus	2.20
Bulk density (loose), Kg/m³	1590
Bulk density (compacted), Kg/m³	1780
FM	2.203

C. Marble Dust

Marble dust was collected from locally vendors. 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 percentage fineness as shown in Table 6. The specific gravity of marble powder was experimentally determined as 2.47.

Table 6 : Sieve Analysis of Marble Dust

Weight of sample taken =100 gm.					
Sr. No	IS-Sieve	Wt. Retained (gm)	%age Wt. Retained	% age passing	Cumulative % retained
1	4.75 mm	0	0	100	0
2	2.36 mm	0	0	100	0
3	1.18 mm	0	0	100	0
4	600 µ	8	8	92	8
5	300 µ	11	11	81	19
6	150 µ	81	81	0	100
7	PAN	0	0	SUM = 127	F.M. = 1.27

D. Steel fibres

Mild steel fibres 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 fibres have been cut by fibre cutting machine to an accurate size. Three different proportions of fibres i.e. 0%, 0.5% and 1% have been used. Properties of steel fibre used are tabulated in 7.

Table 7 : Properties of Steel Fibres

Average Thickness	30 mm
Length	60 mm
Density	7850 kg/m3
Tensile Strength	8500 kg/m3
Shape	Crimped steel fibre

E. Admixture

As an admixture, “GLENIUM™ B233”, a prominent super plasticizer, from SIKA India, was acquired, and was used in present study. The technical data availed by manufacturer is given in Table 8

Table 8 : Properties of Super plasticizer

Sr. No.	Characteristics	Value
1.	Type	Polycarboxylic ether (PCE)
2.	Form	Liquid
3.	Colour	Light Brown
4.	Specific Gravity	1.09
5.	Relative density	1.09 0.01 at 250C
6.	pH Content	>6
7.	Setting Time	There may be mild extension of initial or final

F. Water

The potable water is a general consideration for mixing and curing of concrete. Hence in accordance this potable water was used for manufacturing concrete available in Material Testing laboratory. The water was considerably free from any dangerous toxics and hence was fit for use in the concrete mixture.

IV. Experimental Program

The experimental program included the following:

- Properties of materials used for making concrete were tested.
- Design of mixes for pavement quality concrete and steel fibre reinforced concrete was achieved by making trials.
- Casting and curing of specimens.
- Tests to determine the flexural strength, compressive strength and Split Tensile strength of high strength steel fibre reinforced concrete.

V. Results and Discussions

1. Compressive test

Test results of compressive strength test at the age of 28 days are given in the Table 8.

Table 9 Compressive Strength Test Results

CUBE SRENGTH (MPa)									
w/c ratio	MD-0% / SF-0% (MF00)	MD-10% / SF-0% (MF10)	MD-20%/SF-0%(MF20)	MD-0%/ SF-0.5% (MF01)	MD-10%/SF-0.5% (MF11)	MD-20%/SF-0.5% (MF21)	MD-0%/SF-1% (MF02)	MD-10%/ SF-1% (MF12)	MD-20%/ SF-1% (MF22)
0.3	52.13	48.44	24.21	58.37	54.76	49.28	93.15	85.16	72.25
0.35	45.70	46.24	21.90	56.85	51.84	46.51	72.56	68.57	64.64
0.4	40.70	44.89	14.90	50.98	48.72	38.89	64.12	59.86	54.46

2. Split Tensile strength

The results of split tensile strength of concrete are reported in Table 10 shows the gain in split tensile strength for different levels of marble dust replacement with concrete and addition of steel fibre at different time.

Table 10 : Split Tensile Strength Test Results

SPLIT TENSILE SRENGTH (MPa)									
w/c ratio	MD-0% / SF-0%(MF00)	MD-10% /SF-0%(MF10)	MD-20%/SF-0%(MF20)	MD-0%/ SF-0.5% (MF01)	MD-10%/SF-0 .5%(MF11)	MD-20%/SF-0 .5%(MF21)	MD-0%/SF-1-%(MF02)	MD-10%/ SF-1-%(MF12)	MD-20%/SF-1-%(MF22)
0.3	3.61	3.48	2.46	3.82	3.70	3.51	5.55	5.15	4.25
0.35	3.38	3.40	2.34	3.77	3.60	3.41	5.12	4.58	4.02
0.4	3.19	3.35	1.93	3.57	3.49	3.11	4.64	4.35	3.69

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3. Flexural strength

Test specimens of beam size 150 mm 150 mm 700 mm were prepared for testing the flexural strength of steel fibre reinforced concrete and replacement of cement with marble dust in different percentages. Results as shown in table no 11

Table 11 : Flexural Strength Test Results

FLEXURAL SRENGTH (MPa)									
w/c ratio	MD-0% / SF-0-%(MF00)	MD-10% /SF-0-%(MF10)	MD-20%/ SF-0-%(MF20)	MD-0%/ SF-0.5% (MF01)	MD-10%/ SF-0 .5%(MF11)	MD-20%/SF-0.5%(MF21)	MD-0%/ SF-1-%(MF02)	MD-10%/ SF-1-%(MF12)	MD-20%/ SF-1-%(MF22)
0.3	6.10	5.89	5.45	6.14	6.30	5.86	7.27	6.73	6.14
0.35	5.70	5.69	4.78	6.00	5.88	5.67	6.68	6.21	5.89
0.4	4.90	4.60	4.18	5.87	5.16	4.89	6.10	5.69	5.45

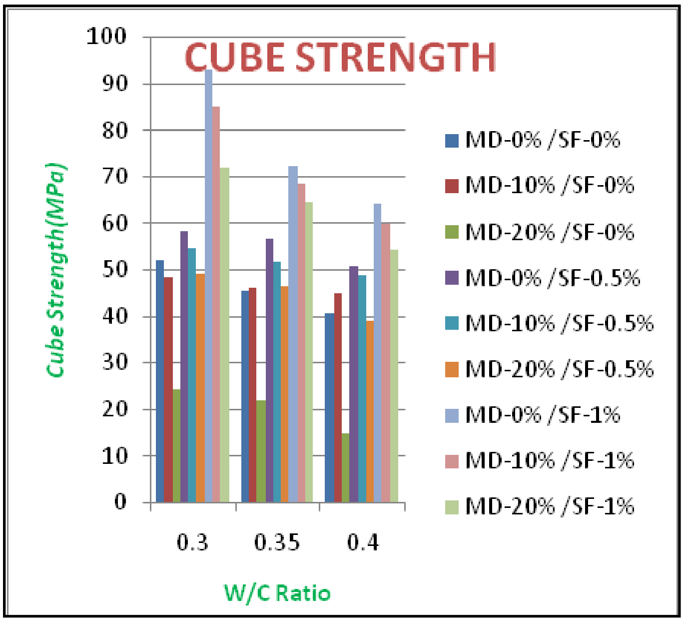

Fig. showing Variation of compressive strength of concrete Vs W/C with different percentages of S.F(Steel fibre) and different percentage of M.D(Marble Dust).

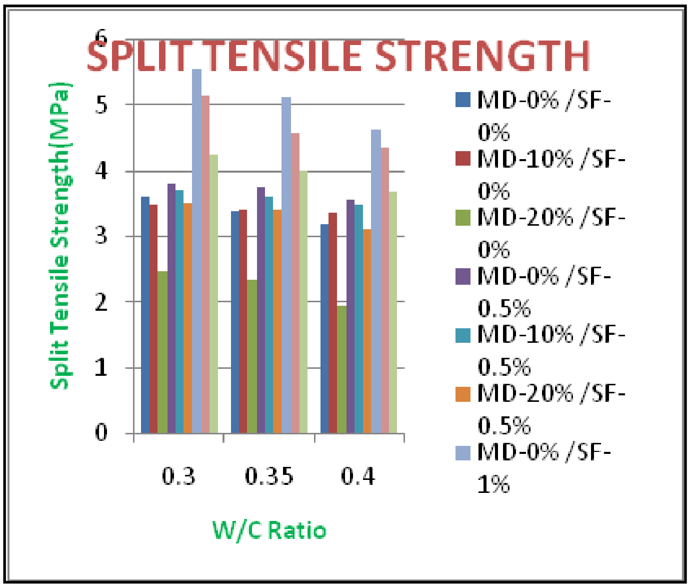

Fig. showing Variation of split strength of concrete Vs W/C with different percentage of S.F and different percentage of M.D.

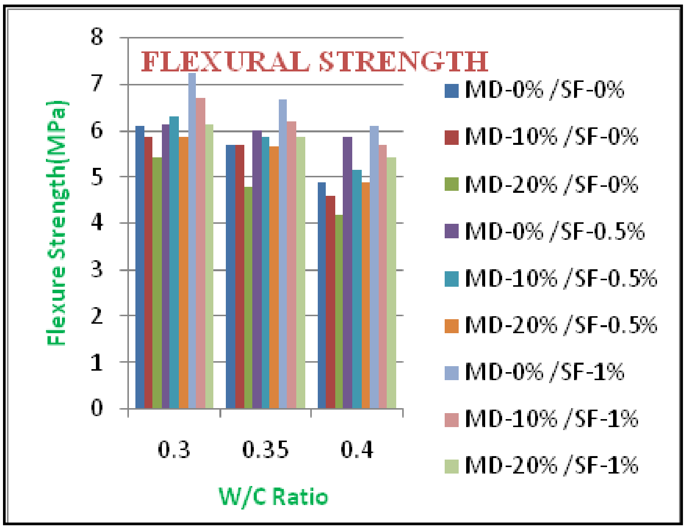

Fig. showing Variation of flexure strength of concrete Vs W/C with different percentage of S.F and different percentage of M.D.

VI. Conclusions

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

- 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 fibre show an increased compressive strength as compared to nominal mix.
- The split tensile strength also tends to increase with increase percentages of steel fibres 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 fibres, 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.
- A considerable saving in cement is achieved on replacing marble dust with cement, which hence is a saving for future as well.
- Maximum strength (flexure, compressive as well as split

tensile) of pavement quality concrete incorporating marble dust and steel fibres, both, is achieved for 10% marble dust replacement and 1% steel fibres. However, if the marble dust content is increased to 20%, even with 1% steel fibre, the increase is not very significant.

VII. Scope For Future Study

- Further study can be made by increasing the percentage of fibre content.
- Different types of fibres like synthetic fibre, carbon fibres, or glass fibres may be used for future investigation.
- In durability properties, concrete mixes containing fibres exposed to freezing and thawing cycles, can be investigated.
- Further study can be done on concrete mixes containing fibres subjected to elevated temperature.

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