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Impact of Marble Dust and Hooked End Steel Fibers on the Properties of Concrete

Priyanka Ramkripal Singh[1] and Rommy Sharma[2]

[1,2]*Galgotias University*
E-mail: [1]priyanka24978@gmail.com, [2]rommysharma011@gmail.com

Abstract—"*Green Concrete" comprising of waste marble dust is an innovative product in the construction field whose results made a big positive impact on the sustainability of environment as well as beneficial for construction industries in terms of economy. Along with waste marble dust, hooked steel fibres in the form of reinforcement are also provided to improve its tensile strength to resist cracking. In this experimental study, cement was replaced with marble dust at 10%, 20% and 30% by weight. It was observed that 10% replacement of Cement with marble Dust increases the compressive strength of concrete. With further addition of Steel fibers at 1%, 2% and 3% by weight of cement, it was observed that at 10% replacement and 3% addition of steel fibers provides optimum strength. This experimental study adds valuable contribution and positive impact in minimizing the environmental pollution caused by marble dust up to some extent and thereby helps in creating a sustainable and clean environment. The materials are proportioned by their weight. The results were comparable with that of conventional mix.*

Keywords*: WMD (Waste Marble Dust), Hooked Steel Fibre, Compressive Strength, Split Tensile Strength, Flexure Strength.*

1. INTRODUCTION

Marble ranks the largest produced natural stone in the world and it accounts for 50% of the world's natural stone production. This is now being produced in voluminous amount in India to determine and ensure the effects on the physical and mechanical properties of fresh and hardened concrete. By product or mostly called waste materials left during generation of any particular chemical entity can cause environmental problems. Hence the reuse by products such as stone slurry and solid waste being produced in marble stone industry is considered essential and vital. Solid waste results from the rejects at the mine sites or at the processing units, while the stone slurry is a semi solid liquid substance consisting of particles originating from the sawing and polishing machines. It is pertinent to mention that the stone industry presents an annual of 68 million tons of processed products.

To make it more effective, it is also important to improve the tensile strength of concrete along with the compressive strength of concrete by adding reinforcement in concrete. As we know that concrete can be formulated with high compressive strength but always has lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension (often steel bars). Generally hooked steel fibres are preferred because of its better bonding strength along the concrete. This project describes the feasibility and impact of marble dust on the behaviour of concrete with addition of reinforcement in the form of hooked steel fibres. Standard cubes, beam and cylinders were tested to examine the behaviour of marble powder and hooked steel fibre mixed concrete.

There are two types of by-product of marble processing. During marble processing, 30% of stone (in case of unprocessed stone) goes to scrap because of being smaller size and irregular shape. This is then sold to chip manufacturers. In case of semi-processed slab, the scrap level reduces to 2-5%. The other waste material is slurry. It is basically the water containing marble powder. The water is reused till it gets thick enough (70% water and 30% marble powder) to be reused. It can be safely estimated that 1 ton marble stone processed in gang-saw or a vertical/horizontal cutter produces almost 1 ton of slurry (70% water).

2. RESEARCH SIGNIFICANCE

The main objectives of the experimental study are as follows:

i. To study the influence of percentage replacement of cement by marble waste powder on the physical and chemical properties of Ordinary Portland Cement Concrete.

ii. To study the effects of percentage replacement of cement by marble waste powder on different properties of hardened concrete.

iii. To study the effect of hooked steel fibres on the tensile and flexural strength of concrete comprising of marble waste powder.

3. EXPERIMENTAL PROGRAM

The fibres used for this project was Hooked End Steel Fibres. This shape is probably the most popular and successful in the history of SFRC. Hooked End (HE) fibres can be used in almost any known application for SFRC. For example HE 55/35 and HE 75/35 are primarily used in shotcrete applications. They provide excellent workability when using fibres with up to an aspect ratio of 60. Aspect ratios up to and including 80 provide satisfactory workability. Load transfer in the crack is very good with this fibre shape. Thus after the appearance of the first crack the loss of load-bearing capacity occurs quickly, but then stabilizes and in some cases even begins to increase again after large cracks have developed. HE fibres have lengths in the range of 35 to 60 mm, diameters range from 0.55 to 1 mm and tensile wire strengths range from 1100 to 1900 MPa.

4. MATERIALS AND METHODS OF TESTING

The samples were prepared in order of increasing WMD replacement content as 0%, 10%, 20% and 30%. Also, after the investigation of concrete by replacing cement with waste Marble dust, addition of Hooked shape steel fibres are also added to check whether there is any improvement in the tensile strength of concrete or not. These steel fibre are added along with waste marble dust in 1%, 2% and 3% proportion. The concrete mix of 1:1.5:2.6 was kept constant throughout the research.

Fig. 1: Waste marble Dust

Fig. 2: Hooked Steel Fibers

4.1 Specimen Specifications

The specimens were of 150mm x 150mm x 150mm cube moulds, 150mm x 300mm cylindrical moulds and 100mm x 500mm beam moulds. After 24 hours, all specimens were demoulded and water cured at room temperature (16°C ± 2) for 7 days, 14 days and 28 days. After curing period was over, the specimens were tested for properties under investigation.

4.1.1 Compression Strength Test

Compression strength test of the specimen were identified as per (IS: 516-1959-Methods of tests for strength of concrete).Out of many test applied to the concrete, this is the one of the most important test which gives an idea about all the characteristics of concrete. By this single test one can judge whether concreting has been done properly or not. For cube test, specimens of size 100mm x 100mm x 100mm are used in this study. For most of the works cubical moulds of size 150mm x 150mm x 150mm are commonly used.

The concrete comprising of marble dust and hooked steel fibre was poured in the mould and tampered properly so as not to have any voids. After 24 hours the specimens were demoulded and were kept in water for curing. The top surface of these specimens was made even and smooth. These specimens were tested by compression testing machine after 7 days curing, 14 days curing, 21 days curing, 28 days curing. Load should be applied gradually at the rate of 140 kg/cm² per minute till the specimens fails. Load at the failure divided area of the specimen gives the compressive strength of concrete.

4.1.2 Tensile Test

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. However, tensile strength of concrete is very low in comparison to its compressive strength.

Apart from the flexural test the other methods to determine the tensile strength of concrete can be broadly classified as (a) Direct methods and (b) Indirect methods. The direct method suffers from a number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration and to the application of uniaxial tensile load which is free from eccentricity of load will induce combined bending and axial force condition and the concrete fails at the apparent tensile stresses other than the tensile strength.

As there are many difficulties associated with the direct tension test, a number of indirect methods have been developed to determine the tensile strength. In these tests, in general a compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses developed in the specimen. The tensile stress at which the failure occurs is termed the tensile strength of concrete.

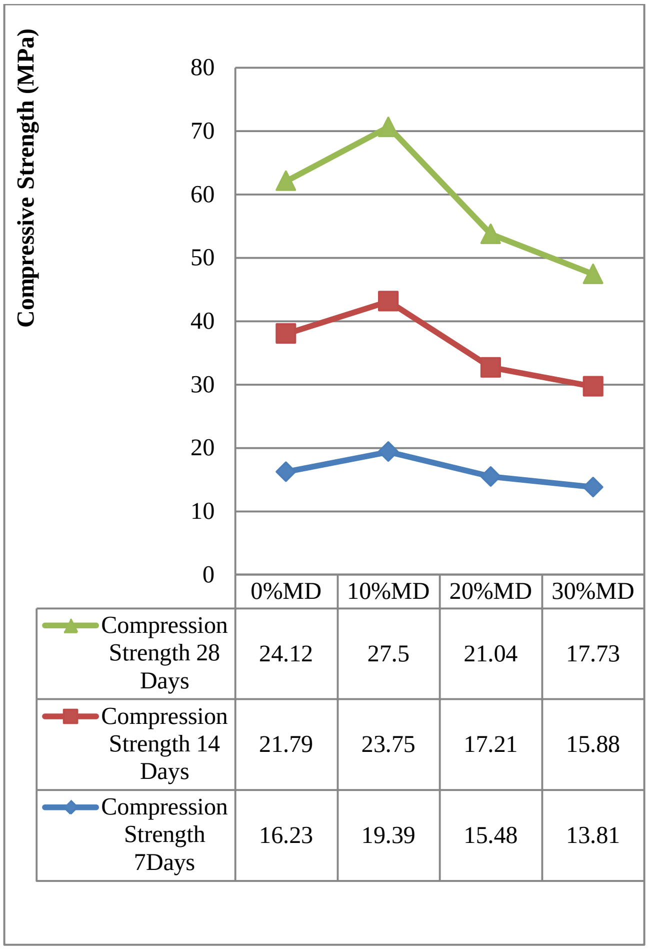
4.1.3 SPLIT-CYLINDER TEST

It is the standard test, to determine the tensile strength of concrete in an indirect way. This test could be performed in accordance with IS: 5816-1970.

A standard test cylinder of concrete specimen (300mm x 150mm diameter) is used in this research which is placed horizontally between the loading surfaces of compression testing machine. The compression load is applied diametrically and uniformly along the length of cylinder until the failure of the cylinder along the vertical diameter.

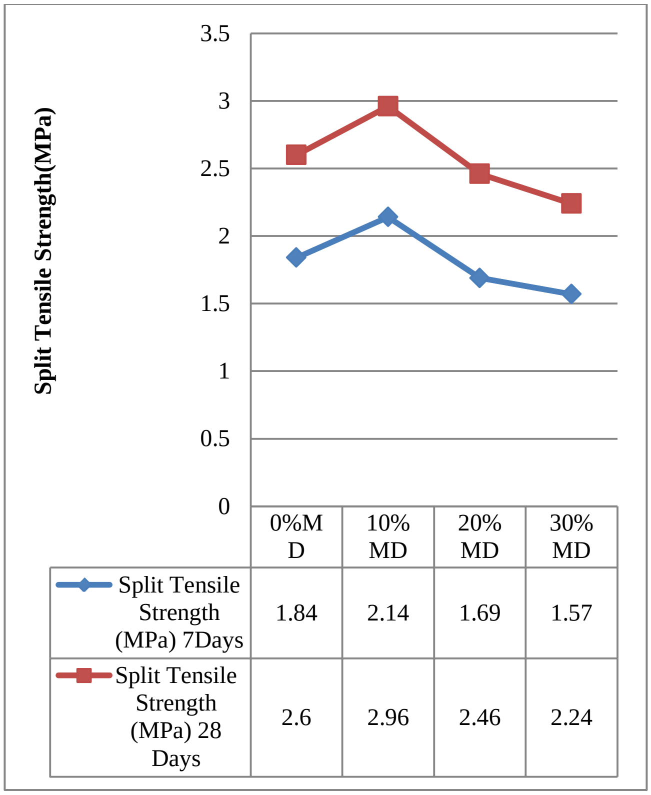
5. TESTS AND RESULTS

All the test results of Control Mix, with replacement of cement by WMD and with addition of Steel fibers are as follows:



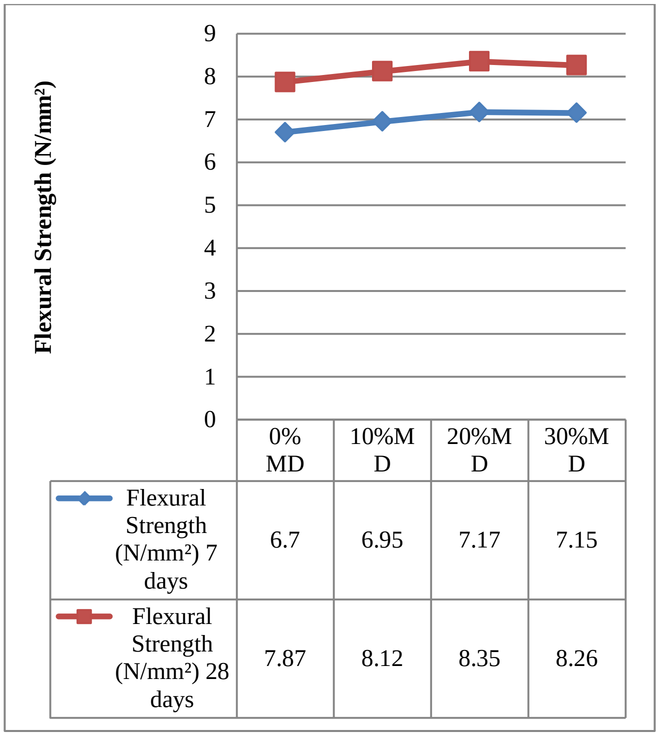
	0%MD	10%MD	20%MD	30%MD
Compression Strength 28 Days	24.12	27.5	21.04	17.73
Compression Strength 14 Days	21.79	23.75	17.21	15.88
Compression Strength 7Days	16.23	19.39	15.48	13.81

Fig 3 Compressive strength of concrete with different replacement of cement with waste marble dust



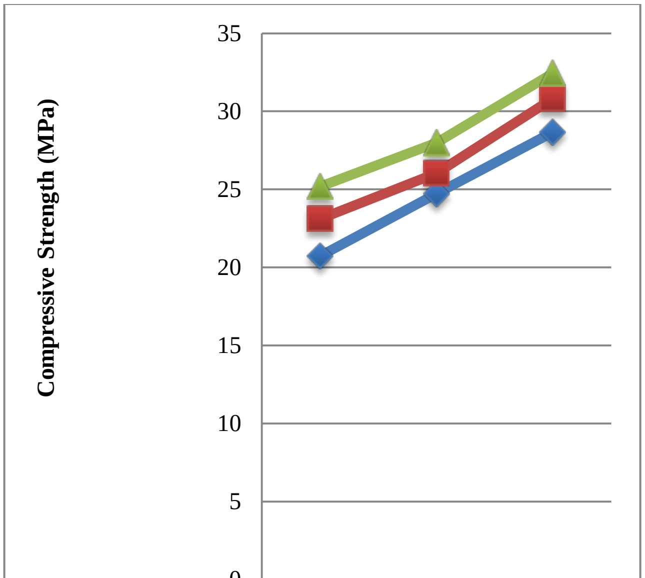
	0%MD	10% MD	20% MD	30% MD
Split Tensile Strength (MPa) 7Days	1.84	2.14	1.69	1.57
Split Tensile Strength (MPa) 28 Days	2.6	2.96	2.46	2.24

Fig. 4: Tensile strength of concrete with different replacement of cement by waste marble dust



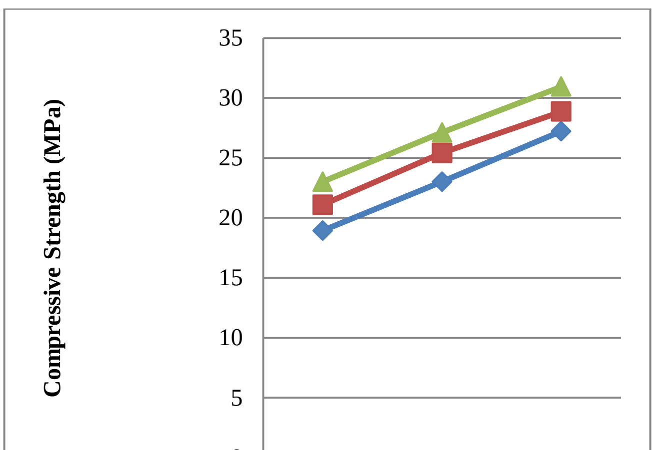
	0% MD	10%MD	20%MD	30%MD
Flexural Strength (N/mm^2) 7 days	6.7	6.95	7.17	7.15
Flexural Strength (N/mm^2) 28 days	7.87	8.12	8.35	8.26

Fig. 5: Flexure strength of Concrete at different percentage replacement by marble dust



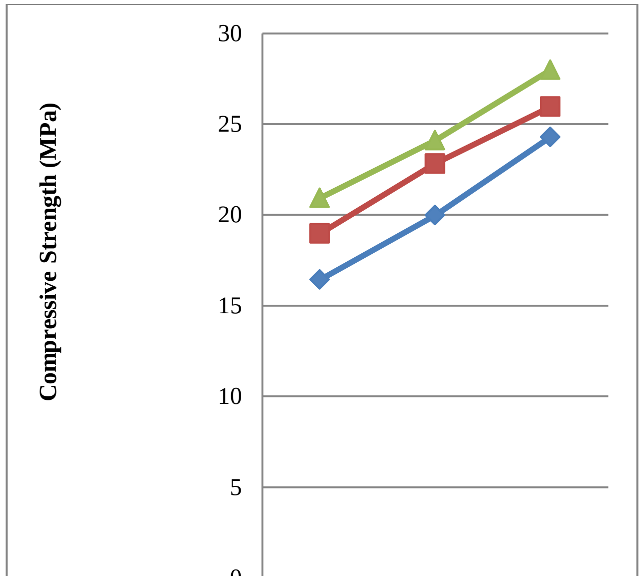
	7days	14 days	28 days
10%MD+1%SF	20.73	24.72	28.67
10%MD+2%SF	23.1	26.04	30.82
10%MD+3%SF	25.18	28	32.45

Fig. 6: Compressive Strength of concrete with 10% replacement of marble dust with addition of hooked steel fibre at different percentages



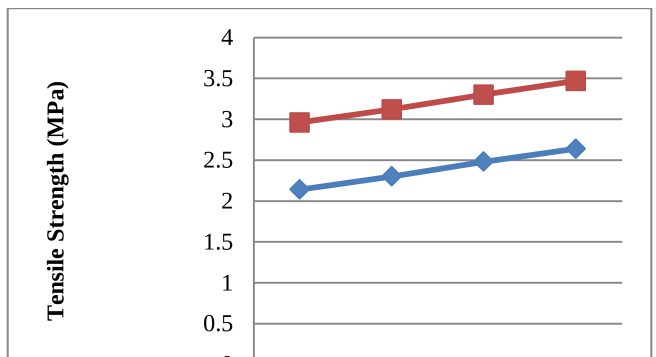
	7days	14 days	28 days
20%MD+1%SF	18.94	23.01	27.23
20%MD+2%SF	21.09	25.41	28.86
20%MD+3%SF	23.02	27.12	30.94

Fig. 7: Compressive Strength of concrete 20% replacement of marble dust with addition of hooked steel fibre at different percentages



	7days	14 days	28 days
30%MD+1%SF	16.43	19.98	24.29
30%MD+2%SF	18.97	22.83	25.96
30%MD+3%SF	20.93	24.11	27.99

Fig. 8: Compressive Strength of Concrete with 30% replacement of marble dust with addition of hooked steel fibre at different percentages



	10%MD+0% SF	10%MD+1% SF	10%MD+2% SF	10%MD+3% SF
Split Tensile Strength (MPa) 7Days	2.14	2.3	2.48	2.64
Split Tensile Strength (MPa) 28 Days	2.96	3.12	3.3	3.47

Fig. 9: Tensile strength of concrete 10% replacement of marble dust with addition of hooked steel

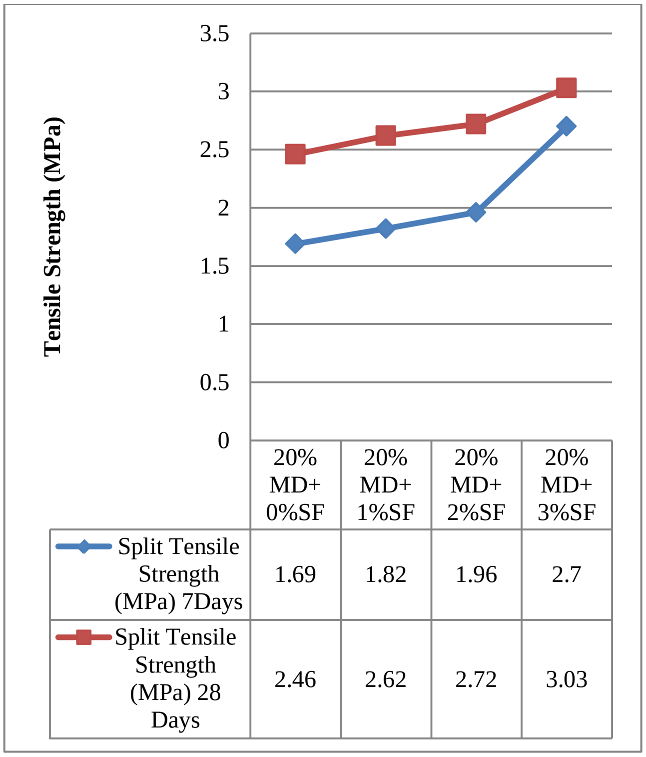


Fig. 10: Tensile strength of concrete 20% replacement of marble dust with addition of hooked steel fibre at different percentage

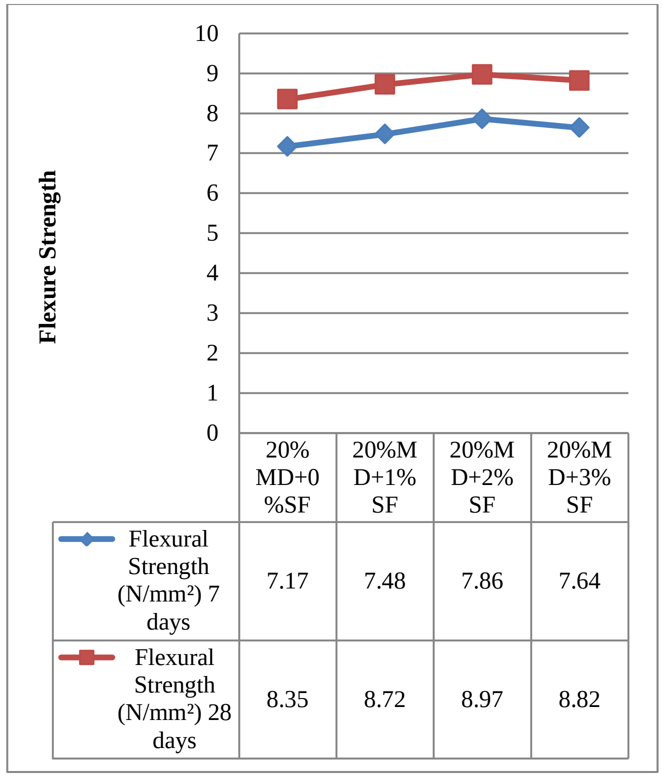


Fig. 12: Flexural strength of concrete comprising of 20% replacement of marble dust with addition of Steel Fibers.

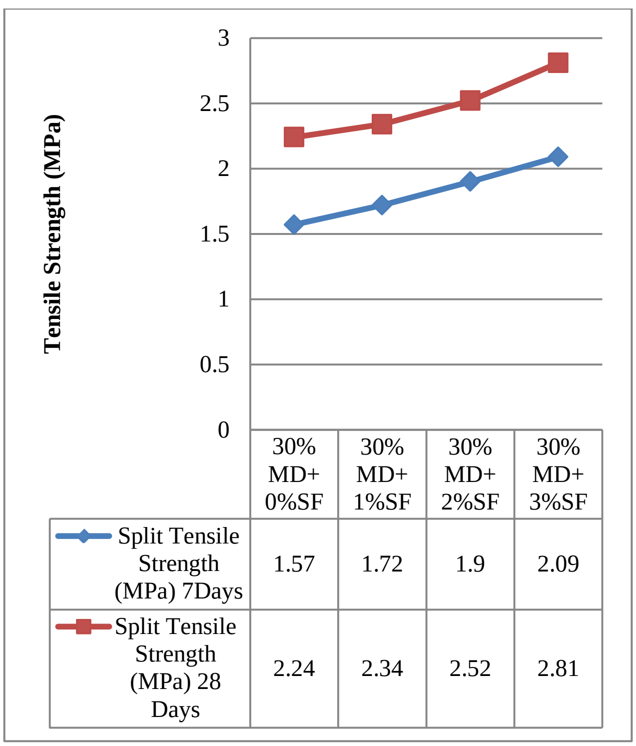


Fig. 11: Tensile strength of concrete 30% replacement of marble dust with addition of hooked steel fibre at different percentage

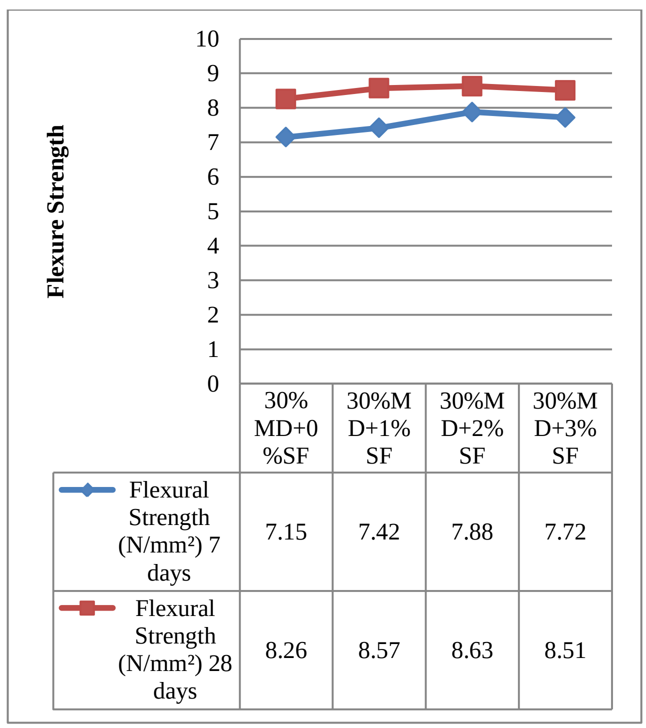


Fig. 13: Flexural strength of concrete comprising 30% replacement of marble dust with addition of different values of steel fibre

6. CONCLUSIONS

In this research, recycling of industrial marble dust for the production of green concrete with addition of hooked steel fibre had been studied and the following conclusions were drawn:

1. The compressive strength, split tensile strength and flexure strength of concrete specimens reduces with percentage increase in Marble dust.
2. The replacement of Ordinary Portland Cement specimens by 10%MD gives more compressive strength than that of Conventional Concrete sample. While replacing cement by WMD at 20% and 30%, results in reduction of strength as compared to control sample.
3. Blending WMD with cement gives quite satisfactory results. The optimum values of compressive strength, split tensile strength and flexural strength are achieved at 10% marble dust replacement.
4. From the results, it is cleared that the compressive strength, split tensile strength and flexural strength are on the higher side for (10%MD+3%SF) i.e. replacement of marble dust by 10% and addition of 3% hooked steel fibre as compared to that produced by replacing cement by different percentage of marble dust with addition steel fibre at different percentage.
5. It was observed from the results that the addition of 3% steel fibre gain more compressive strength, split tensile strength and flexure strength of concrete comprising of waste marble dust as compared to 1% and 2% addition of steel fibre.

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