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Sustainable Utilization of Marble Dust and Rice Husk Ash as a Partial Substitute for Fine Aggregate in Concrete

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Abstract: A sustainable method for partially substituting fine aggregate in concrete with marble dust and rice husk ash is described. This approach focuses on the utilization of these materials to minimize environmental impact while maintaining the integrity of the concrete structure. In this study, the fine aggregate was partially substituted with marble dust and rice husk ash. Additionally, sisal fiber was incorporated as secondary reinforcement for concrete at percentages of cement by weight. Concrete has good compressive strength but is weak in tension and bending. Thus, sisal fibers were added to enhance the mechanical properties. Sisal fibers were included at 0.1% and 0.2% of cement weight for varying percentages of mineral admixture substitution. 30% of cement was replaced with mineral admixtures, with replacement levels of 0%, 10%, 15%, 20%, and 30% of marble dust and rice husk ash. The slump cone and compaction factor tests were performed on fresh concrete mixes to determine workability. Standard cubes, cylinders, and prisms were cast to evaluate the compressive, split tensile, and flexural strengths of the hardened concrete. The results show that the replacement of cement with marble dust and rice husk ash with sisal fiber as an additional reinforcing material shows considerable improvement in tensile and flexural strength. The material properties and test results are presented graphically.

Keywords: Marble Dust, Rice Husk Ash, Sisal Fiber, Partial Replacement

1. Introduction

The construction industry involves a lot of evaluation along with the development of human civilization. Right from ancient times human sheltering styles have evolved into further and further modern forms according to our requirements. Today we lead a sophisticated life when compared to ancient life. The modern abstract construction idea brings all our requirements into one building. The modern sophisticated life is possible with the help of concrete material. Presently, major construction systems use concrete to construct structures.

Technology has made a huge impact on a sophisticated life; it reduces mortal physical involvement and is more customized to our requirements. Technology simplifies every human exertion, indeed though we're using conventional concrete material. Because concrete constituents are fluently available materials like cement, sand, aggregate, and water. These materials are directly uprooted from natural resources. Due to rapid-fire modernization, construction activities lead to the reduction of natural resources. We need to consider by-product waste emissions from various industries, manufacturing units, agricultural conditioning, thermal power plants, mining, etc. The environment is rapidly degrading due to construction materials consumption and waste generation by human activities. There are several by-products, dumped into the ground, here marble dust powder, and rice husk ash is considered for partial replacement for cement. Manufacturing of cement emits a further quantum of carbon dioxide and heat energy, which isn't a healthy condition for the terrain. Concrete has good compressive strength but is weak in split tensile and flexural strength. Sisal fiber was added to improve split tensile and flexural strength. The vast cost of concrete is reduced by the partial replacement of cement with waste by-products.

2. Scope of Experimental Work

The experiment aims to minimize manufacturing quantities and concrete production costs by partially replacing cement with marble dust powder and rice husk ash. This will cut CO2 emissions and natural resource extraction in cement production. To increase mechanical qualities of concrete, such as split tension and flexural strength, and to delay early cracking owing to loading. To attain this mechanical strength, a small amount of sisal fibers is added to the cement weight.

3. Overview of Literature

Here is an overview of other author's experimental work results done on the partial replacement of cement by marble dust powder, rice husk ash, and sisal fiber in concrete. The combination of replacement is the individual by-product or combined form. The marble dust and fly ash were partially replaced for cement at 0%, 5%, 10%, and 20% by weight of cement. The mechanical property of concrete compressive and split tensile strength increases for M25 grade at 15%. Marble dust 10% of partial replacement for cement can increase the bond strength between concrete and steel [1]. Very fine powder of rice husk ash 10% partial replacement for cement gives good compressive strength, less permeability, and normal workability of concrete. Sisal fiber 1.5%, which is a short discrete 4cm length along with superplasticizers 0.2%, and water–cement ratio 0.45 for M20 and M25 grade concrete. Fresh concrete shows good slump value and an effective compaction factor. The mechanical properties of compressive strength and tensile strength increase up to 50% in the control mix [2]. The compressive strength on the 28th day confirms that the optimum replacement of 10%

of marble dust powder for cement expresses high compressive strength. 10% of rice husk ash replacement for cement has good strength without any ill effects for M30 and M60 grade concrete [3, 4]. OPC cement partially replaced a range of 0 to 20% increases strength, but anything beyond this limit reduces the compaction factor and density of concrete. Marble dust at 10% replacement for cement gives compressive strength with 0.4 w/c ratio and 7.5% gives tensile strength with 0.5 w/c ratio. Cement and sand are replaced with 5%, 10%, 15% fly ash, and 20%, 40%, and 60% marble dust, optimum percentage is 10% for fly ash and 40 to 50% for marble dust [5]. The durability study on OPC mortar conducted, in this OPC replaced range with rice husk ash 0 to 30%. 20% replacement shows more durability than OPC mortar [6]. The thermal-conditioned woven sisal fiber gives better results than untreated fiber, and the tensile and flexural strength increases. Rice husk with and without superplasticizers, by adding super plasticizers gives a higher percentage of rice husk ash up to 30% and reduces water requirement [7]. Waste marble dust 12.5% replacement increases both compressive and tensile strength on concrete, excess then 12.5% strength decrease [8]

4. Materials

4.1. Cement

Cement is a key binding element in concrete; it reacts with water and functions as a binder. This experiment employed ordinary Portland Cement (OPC 53 grade) to evaluate the specimens on the 7th, 14th, and 28th days. This type of cement does not have partial replacement like PPC. To attain good strength, OPC is utilized in place of any mineral admixture-based cement. The quality check specification followed as per OPC 53 grade code, IS 12269-1987.

4.2. Fine aggregate

M-sand is used as a fine aggregate to fill gaps between coarse aggregates. M-sand that has been rinsed from the quarry and is free of fine dust for use in concrete. Currently, M-sand is employed in construction; testing on M-sand will help future construction. The quality of M-sand followed as per IS 383-1970 code for concrete M-sand.

4.3. Coarse aggregate

Coarse aggregate makes up 60 to 70% of the overall volume of concrete and should be free of undesirable stones. Well-graded aggregate is utilized in concrete because it can bear the load applied to it. Normally, 20mm size aggregate is utilized to prepare structural concrete work; the size and other properties are followed according to the given specification for coarse aggregate in IS 383-1970 for concrete. Moreover, the test procedure was followed and conducted as per IS 2386-3(1963).

4.4. Water

Water should be free of pollutants, salt, chemicals, and other contaminants. Because contaminants in water erode steel and induce permeability in concrete. According to IS 456:2000, the pH value of water should not be lower than 6. The water-cement ratio of 0.50 remains consistent throughout all mixtures

4.5. Marble dust

Marble dust is a byproduct of the marble cutting and grinding processes in industry. Marble is a naturally extracted substance from the earth that requires cutting, dressing, and surface grinding. These activities produce fine marble dust and slurry as byproducts. This finely fragmented marble dust circulates easily in the air, polluting it. Marble dust is treated with water during cutting and other procedures to produce a slurry. Marble dust is created by pouring the powder and drying it in the sun. Tons of marble dust deposited on the earth will harm the ecosystem. So, marble dust has been subjected to some experimental studies as a replacement for cement and fine aggregate. In this experiment, marble dust powder residue is used to partially substitute cement in concrete.

4.6. Rice husk ash

Rice husk ash is derived from agricultural rice farming byproducts. The outer coat of rice was removed during the rice manufacturing process by heating it at a high temperature, and the rice husk was then burnt into ash. It is a very finely divided particle, ideal for partial replacement of cement. It is better suited to cement replacement than fine aggregate in concrete and mortar. The finer the ash, the better the compaction of the concrete. There were no minute voids in mass concrete.

4.7. Sisal fiber

Sisal fiber is a cultivated plant that provides additional material for various object production needs. It is utilized as secondary reinforcement in concrete to enhance mechanical qualities such as compressive, split tension, and flexural strength. It minimizes the significant breaking chance of concrete after applying load to hardened concrete. Many elements determine the strength of sisal fiber in concrete. Examples include aspect ratio, length, diameter, orientation, chemically treated versus untreated form, and so on. The short discrete form of fiber is better suited to improving the strength-gaining elements of the long size. To improve the mechanical qualities of concrete, 0.1 to 0.2% of the cement weight was added with sisal fiber.

5. Mix Design Proportion

For experimental purposes, an M20-grade concrete mix was designed. M20 grade of concrete mix design calculated as per IS 10262-2009[2009], by using this code concrete mix proportion designed as given table 1 and 2.

Table 1. Design Mix Proportion

w/c ratio (lit/m³)	Cement (kg/m³)	Fine aggregate (kg/m³)	Coarse aggregate (kg/m³)
198	395	719	1051
0.50	1	1.82	2.61

Table 2. Percentage of Varying Replacement

S.no	Mix	Fine aggregate replacement percentage		
		Marble dust (%)	Rice husk ash (%)	Sisal fiber (%)
1.	NC	0	0	0
2.	M1	0	30	0.1
3.	M2	10	20	0.1
4.	M3	15	15	0.1
5.	M4	20	10	0.1
6.	M5	30	0	0.1
7.	M6	0	30	0.2
8.	M7	10	20	0.2
9.	M8	15	15	0.2
10.	M9	20	10	0.2
11.	M10	30	0	0.2

6. Experiments

The fresh and hardened concrete was made with varying mix quantities. The fresh concrete tests described in IS 1199-1959, as well as the slump cone test and compaction test, were used to determine the workability qualities of concrete at various mineral admixture and sisal fiber percentages. In the hardened concrete tests described in IS 519-1959, compressive split tension and flexural strength tests were performed to know the load-carrying capacity of varied percentage mixes with the normal mix.

Cubes, cylinders, and prisms were cast for compression, split tension, and flexural strength tests. M20 grade concrete mixed according to the designed mix proportion ratio, using manual mixing. Marble dust powder and rice husk ash are replaced as 0%, 10%, 15%, 20%, and 30% for cement weight, respectively. Furthermore, sisal fiber accounts for 0.1% to 0.2% of the total weight of cement. The range of partial replacement of marble dust powder and rice husk ash varies, but the combination of total contributes 30%, together with sisal fiber. The fresh concrete mix test slump cone test and compaction factor test were done to obtain the workability of concrete at different mix ratios. Cubes size 150x150x150 mm, Cylinder size 150mm diameter and 300mm height, Prism size 500x100x100 mm all are standard sizes used to cast concrete. To obtain compressive strength, split tensional strength and flexural strength hardened concrete tests were conducted at curing age on the 7^{th}, 14^{th}, and 28^{th} day.

7. Results and Discussion

7. 1. Physical properties tests

The various physical properties of cement are enumerated in table 3, table 4 compares the fine and coarse aggregates and Table 5 compares Properties of Marble Dust and Rice Husk Ash. Table 6 enumerates the various physical properties of sisal fiber.

Table 3. Properties of Cement

S.no	Physical properties	Value
1.	Type of cement	OPC 53 (JSW)
2.	Specific gravity	3.10
3.	Fineness modulus	2.90

Table 4. Properties of Fine Aggregate and coarse aggregate

S.no	Physical properties	Fine Aggregate	Coarse Aggregate
1.	Specific gravity	2.63	2.70
2.	Water absorption	2.20%	2.8%
3.	Fineness modulus	2.70	7.35
4.	Silt content	1.0%	17%

Table 5. Properties of Marble Dust and Rice Husk Ash

S.no	Physical properties	Marble Dust	Rice Husk Ash
1.	Specific gravity	2.50	2.40
2.	Water absorption	2%	6%
3.	Fineness modulus	2.80	2.10

Table 6. Properties of Marble Dust

S.no	Physical properties	Test result
1.	Specific gravity	2.50
2.	Water absorption	2%
3.	Fineness modulus	2.80

Table 7. Properties of Rice Husk Ash

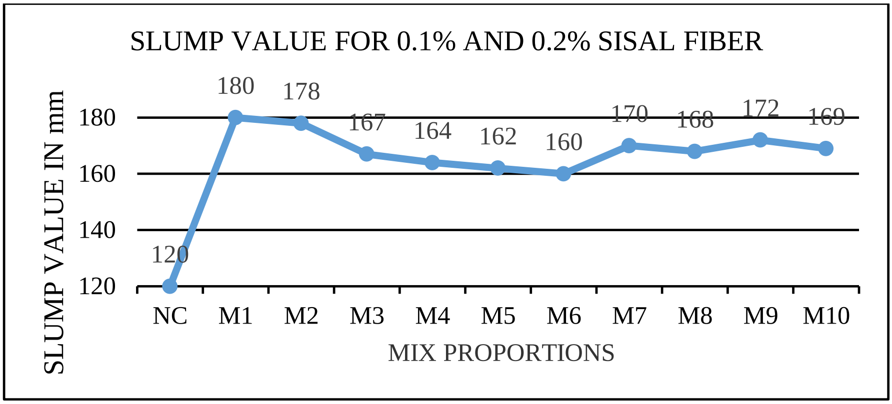
S.no	Physical properties	Test result
1.	Specific gravity	2.40
2.	Water absorption	6%
3.	Fineness modulus	2.10

Table 8. Properties of Sisal Fiber

S.no	Physical properties	Test result
1.	Aspect ratio	2.63
2.	Thickness	2.10
3.	Length	2.75
4.	cellulose	55-65 %
5.	Water soluble material	1-4%

7.2. Fresh concrete tests

7.2.1. Slump cone test



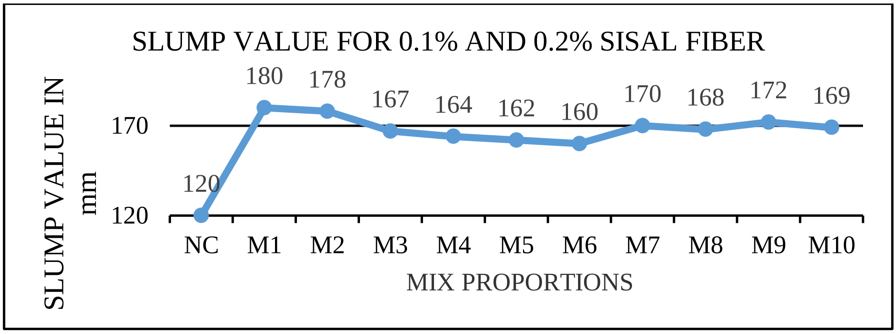


Figure 1. Slump Cone Test

Figure 1 compares compares the slump cone results for 0.1% and 0.2% sisal fiber, with an additional 30% cement replacement using rice husk ash. The comparative results demonstrate that mix 1 achieves the highest slump value with 30% RHA as a whole replacement of cement. When compared to the standard mix of all the fiber-reinforced and marble dust powder, rice husk ash concrete has poorer workability.

7.2.2. Compaction factor test

Figure 2 compares compares the effects of concrete mixes with 30% cement substitution in addition to sisal fiber at amounts of 0.1% and 0.2% by weight of cement. When compared to all mixes, mix 10 and mix 8 have a high compaction factor at 0.2% sisal fiber. The graph demonstrates that as the percentage of sisal fiber grows, so does the compaction factor. Equal to mix 10, mix 8 has the second highest+ compaction factor value. However, when mineral additive concrete is compared to nominal concrete, it has a lower value. This comparative graph illustrates that the value of mix 5 with 0.1% fiber decreases before increasing again after mix 5.

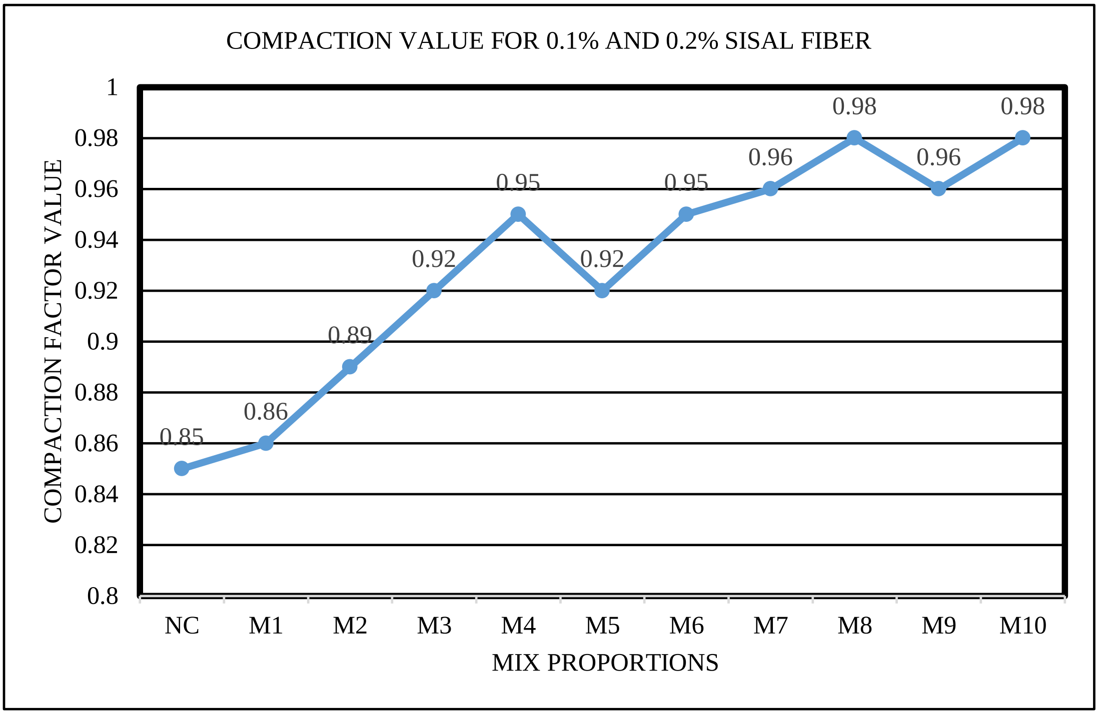


Figure 2. Compaction factor Test

7.3. Harden concrete tests

7.3.1. Compressive strength test

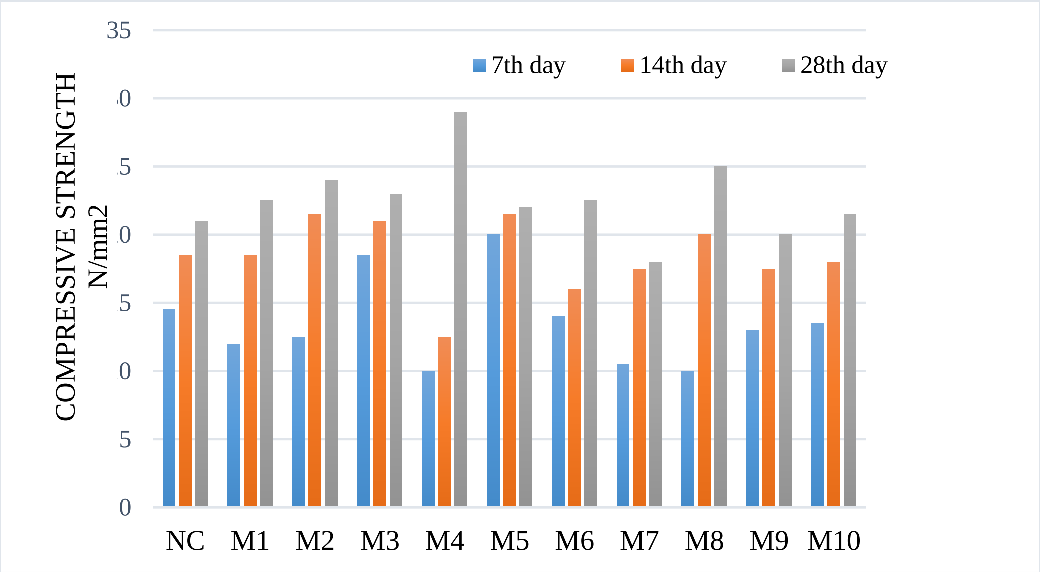


Figure 3. Compressive Strength

Figure 3 the above graph shows the comparative results of compressive strength of concrete for mixes with 0.1% sisal fiber and 0.2% sisal fiber. All the results of the mineral admixture concrete were verified with the values of conventional concrete. The concrete is cast and cured for a total period of 28 days, and they were tested in the recommended days such as 7 days, 14 days, and 28 days. Among all the proportional mixes, mix 4 attains the maximum compressive strength with 20% marble dust and rice husk ash in 28 days for 0.1% sisal fiber. Following mix 4, mix 8 achieves the second-highest strength with 15% marble dust and 15% RHA. When compared to the earlier strength of concrete, mix 5 achieves maximum strength and along with mix 3 attains the second highest strength at 7 days. The addition of 0.1% sisal fiber with 20% marble dust and 10% RHA in 30% replacement of cement achieves the maximum strength in all the mixes. From the graphical representation, there is a gradual increase in the compressive strength of concrete from 7 days results to that of 28 days results.

7.3.2. Split tensile strength test

Figure 4 shows the comparative results of split tensile strength for the concrete with the addition of 0.1% and 0.2% sisal fiber respectively—the split tensile strength of concrete in 7 days, 14 days, and 28 days obtained in N/mm2. As of the above graph, mix 8 achieves the maximum split tensile strength among all the mixes, and after mix 8 with 0.2% sisal fiber, mix 4 with 20% marble dust and 10% RHA with the addition of 0.1% sisal fiber attains the maximum split tensile strength. When the earlier strength of concrete is verified, mix 9 with 20% marble dust and 10% RHA with 0.2% sisal fiber and mix 3 with an equal quantity of both marble dust and RHA with 0.1% sisal fiber to attain the maximum tensile strength at 7 days test. By adding sisal fiber in increasing quantity by the weight of cement, the tensile and flexural properties of the concrete increased.

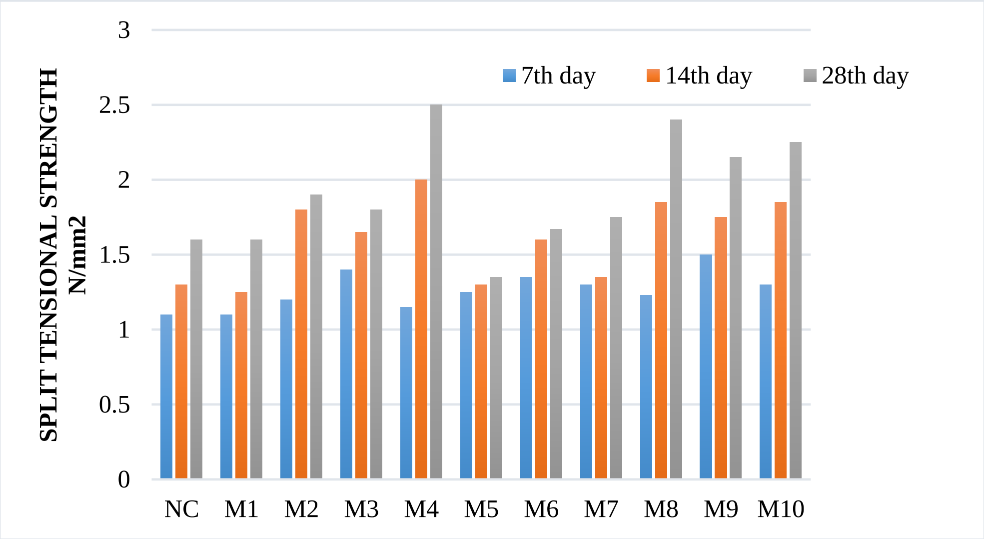


Figure 4. Split Tensile Strength

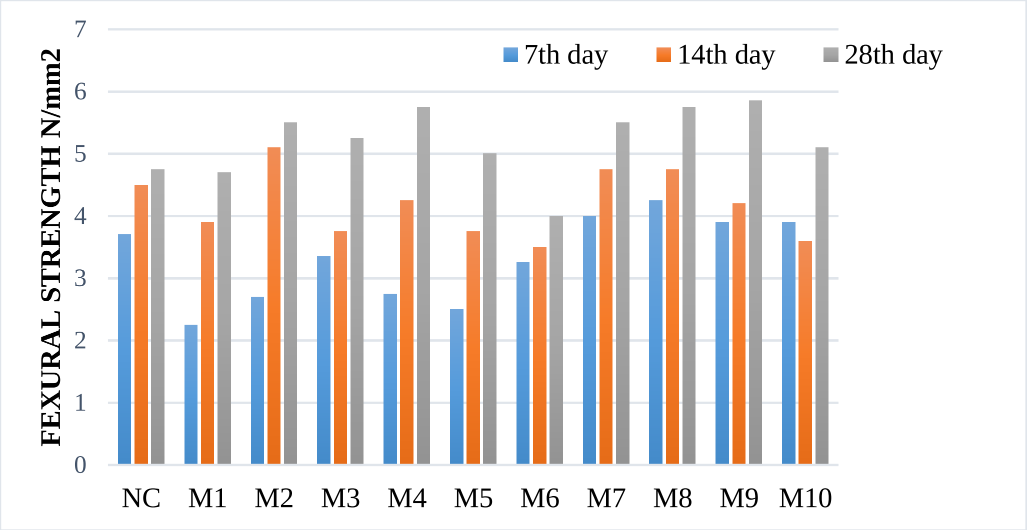


Figure 5. Flexural Strength

7.3.3. Flexural strength test

Figure 5 shows shows the comparative results of flexural strength for the concrete with the addition of 0.1% and 0.2% sisal fiber respectively. The flexural strength of concrete in 7 days, 14 days, and 28 days is obtained in N/mm2. As of the above graph, mix 4 achieves the maximum flexural strength among all the mixes, and after mix 4 with 0.1% sisal fiber, mix 8 with 15% marble dust and 15% RHA with the addition of 0.2% sisal fiber attains the maximum flexural strength. When the earlier strength of concrete is verified, mix 8 with 15% marble dust and 15% RHA with 0.2% sisal fiber and mix 7 with 10% marble dust and 20% RHA with 0.2% sisal fiber to attain the maximum tensile strength at 7 days test. By adding sisal fiber in increasing quantity by the weight of cement, the tensile and flexural properties of the concrete increased.

8. Conclusion

The study here suggests use of marble dust and rice husk ash as a replacement for cement to reduce the cement content in the concrete. Up to 30% of cement replacement with a combination of these two mineral admixtures is possible. Along with the mineral admixtures, sisal fiber is used as a reinforcing element with an aspect ratio of 100 to achieve a high tensile and flexural property. The first five mixes with 0.1% sisal fiber added along the mineral admixture concrete, mix 4 (M4) attains the maximum compressive strength and with 0.2% of sisal fiber, M8 attains high strength in compression. When the compressive strength of both 0.1% and 0.2% sisal fiber is compared, mixing with 0.1% attains a higher strength. When the earlier strength of concrete is examined, mix 5 (M5) attains the highest strength. In the split tensile strength test among all the mixes, mix 8 (M8) with 15% marble dust and 15% RHA with the addition of 0.2% sisal fiber acquired the higher strength parameters. This shows that to addition of a higher volume of sisal fiber increases the split tensile strength accordingly. In the case of flexural strength results, mix 4 (M4) and mix 8 (M8) attain more or less the same strength at 28 days results. This shows that an increase in the volume of marble dust increases the flexural strength of concrete. Thus, we conclude that marble dust, rice husk ash being a large amount of waste material used as a cement replacement along with sisal fiber as a reinforcing element in varying proportions of 0.1% and 0.2%, the flexural and tensile property of the concrete is improved.

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