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Evaluating the Behavior of Concrete After Addition of Stone Dust to Steel Fiber Reinforced Concrete

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Abstract

In contemporary construction practices, the utilization of concrete has become indispensable for various civil engineering projects worldwide. Concrete, augmented with both natural and artificial fibers, plays a crucial role in bearing compressive loads and efficiently transferring structural loads to the reinforcement and foundation. The current research delves into exploring the transformative effects of different mix designs, incorporating varying percentages of steel fibers, on the behavior of concrete. The study encompasses a comprehensive analysis of key performance indicators, including compressive strength, flexural strength, split tensile test, wet and dry density, and slump test to assess concrete workability. The findings of the investigation reveal a notable enhancement in the strength characteristics of steel fiber-reinforced concrete compared to conventional concrete. This improvement is indicative of the positive influence exerted by the incorporation of steel fibers within the concrete matrix. It underscores the potential of steel fiber reinforcement as a viable strategy for achieving superior concrete performance. The results affirm that, with judicious consideration and proper implementation, introducing steel fibers to concrete within specific limits can significantly elevate its strength and overall structural integrity. In conclusion, the study advocates for the strategic integration of steel fibers in concrete mix designs to optimize strength characteristics. This approach holds promise for advancing the effectiveness and durability of concrete structures, contributing to the evolution of more resilient and sustainable construction practices on a global scale.

Keywords: Concrete, Steel fiber reinforcement, Mix design, Compressive strength, Flexural strength.

INTRODUCTION

Concerns regarding the overuse of natural sand have prompted researchers to explore alternatives, particularly in regions like India where its scarcity is impacting environmental stability, causing soil erosion, water level depletion, and sediment supply reduction [1]. Fine aggregates, including natural sand, are pivotal in the composition of concrete, and their substitution with materials like stone dust is being investigated to maintain concrete's integrity while addressing environmental concerns [2],[3]. Studies have demonstrated that replacing natural sand with stone dust not only enhances concrete's compressive strength but also contributes to sustainability efforts by utilizing waste materials [1],[4]. Researchers are exploring various waste materials, including marble dust, tile dust, and stone dust, to improve concrete properties without compromising sustainability [5],[6],[7],[8]. Stone dust, as a byproduct with limited utility, offers a readily available alternative to natural sand, enhancing concrete's workability and cost-effectiveness [9],[10][11],[12]. Additionally, Stone Dust Steel Fiber Reinforced Concrete (SDSFRC) research suggests its potential as a sustainable solution to minimize waste material impact, showing improvements in compressive strength and

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cost-effectiveness [10],[11][12],[13]. Moreover, researchers are considering the potential toxicological properties of concrete materials to develop sustainable solutions and mitigate environmental impact for future generations [6],[14],[16]. These efforts aim to balance the demands of construction with environmental conservation, offering promising avenues for sustainable development in the concrete industry.

Methodology

Conducting a comprehensive analysis of reinforced concrete involves a series of essential tests to determine the strength of diverse concrete compositions. This study adheres to the Indian standard code, ensuring that all tests are performed in accordance with the specified guidelines. For analysis Compressive strength, flexural strength, split tensile and workability test are performed along with wet and dry density of concrete.

Compressive Strength

Higher compressive strength concrete has a higher resistance to pressure, which makes it more durable and able to withstand heavier loads. There are several factors that can affect the compressive strength of concrete, including the water-cement ratio, the amount and type of aggregate, the age of the concrete, and the curing conditions. Enhanced compressive strength in concrete signifies heightened resistance to pressure, rendering it more robust and capable of bearing heavier loads. Numerous factors contribute to the compressive strength of concrete, including the water-cement ratio, aggregate quantity and type, concrete age, and curing conditions. Of these, the water-cement ratio holds paramount importance; an excess of water can diminish strength. In instances of an overly high water-cement ratio, the concrete becomes weaker and incapable of supporting substantial loads. The choice of aggregate also plays a crucial role, where coarse aggregates like gravel and crushed stone contribute to strength, while finer aggregates like sand diminish it. Additionally, the age of the concrete is a determinant, with the compressive strength increasing as the concrete matures due to the gradual hardening of the cement. Ensuring the proper curing of concrete is essential for maximizing its strength potential. For applications in residential and commercial settings, we target a compressive strength ranging from 2500 to 5000 pounds per square inch (psi). To enhance concrete strength, special mixes with increased cement content are employed, coupled with meticulous curing practices, maintaining moisture at around 70°F for a minimum of 28 days.

Flexural strength pertains to the material's ability to withstand bending forces. While concrete is robust, its inherent limitations in bending can be addressed by incorporating additional support such as rebar or mesh. The extent of reinforcement varies based on the structure's size and environmental conditions.

Split tensile strength evaluates how well concrete withstands splitting forces, typically registering lower than compressive and flexural strength. The evaluation involves subjecting a concrete sample to increasing splitting forces until failure, with the required force serving as an indicator of tensile strength. This testing method aids in determining the necessary additional support for structures. A higher split tensile strength correlates with superior concrete quality, indicating better performance in scenarios involving bending forces.

Dry and Wet Density

Density serves as a critical parameter in assessing the strength and durability of concrete, encompassing both dry and wet density measurements. Dry density, determined when the concrete is completely dry, is pivotal for gauging the material's strength and resilience. It depends on the composition, including water, aggregate, cement, and admixtures. Typically, dry density surpasses wet density since water constitutes a significant portion of the concrete's weight. Conversely, wet density, measured when the concrete is still moist, is crucial for determining the necessary water content to achieve desired properties. Both dry and wet density are vital metrics influencing the strength and

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durability of concrete, necessitating accurate measurement of both aspects.

Workability is a key attribute of concrete that profoundly impacts its utility. It gauges how easily concrete can be shaped and manipulated, primarily influenced by its consistency and moisture content. Achieving the right balance is crucial, as overly wet or dry concrete, or one that is too stiff or weak, poses challenges in construction. Effective workability is paramount for precision and durability in structures. Poorly mixed or worked concrete can result in structural issues such as cracking and uneven surfaces. Thorough testing, including the slump test, helps assess workability by measuring the concrete's consistency. Proper water management is crucial, as excess water weakens concrete, while insufficient water makes it challenging to work with. Adequate mixing ensures uniform distribution of materials. Weather conditions also play a role; hot, dry weather accelerates water evaporation, and cold, wet weather hampers workability. In summary, concrete workability is pivotal for successful construction. Optimal ingredient mixing, careful water management, and weather considerations are essential for achieving the desired consistency and moisture content, ensuring effective and reliable concrete.

RESULTS AND DISCUSSION

Compressive Strength of Concrete

To determine the compressive strength of concrete 11 mix design is performed with varying fiber content, total 99 cubes were casted which are tested for 7 days, 14 days and 28 days. The results are given in Table 1.

The result shows that after addition of 3% fiber to concrete maximum strength for compression is achieved that is 35 MPA for 7 days, 36.80 MPA for 14 days and 46 MPA for 28 days, after increasing the percent of fiber for M7 mix the declination in compressive strength is shown in Figure 1.

Flexural Strength

For flexural strength analysis 99 samples are prepared 3 for 7 days,14 days and 28 days. Each sample were tested for flexural strength analysis and average value of flexural is considered from three test result on every 7 days. The values from flexural analysis are tabulated in Table 2.

Flexural Strength shows improved strength till addition of fiber for M8 concrete which is 4% of fiber after further addition declination in flexural strength is noted.

Split Tensile Strength

For experimental analysis 99 samples are made which are tested for 7, 14 and 28 days. The values of tests are given in Table 3. The variation of strength is shown using graph in Figure 3. From the results it is found that up to 3% fiber percentage the strength increases and after that the values decreases which shows the ratio of fiber which can be used for better strength in concrete for enhancing split tensile.

Table 1. Compressive strength of concrete with varying fiber content for 7, 14 and 28 days.

S.N.	Mix. Design.	Fibre Content V_f (%)	Compressive Strength f_{cu}, MPa			% Variation in Compressive Strength of conventional concrete		
			7 days	*14 days*	*28 days*	*7 days*	*14 days*	*28 days*
1	M0	0.0	29.00	34.67	43.33	-	-	-
2	M1	0.5	31.60	33.87	42.34	8.97	-1.83	-2.29
3	M2	1.0	32.34	34.93	43.67	11.52	0.62	0.77
4	M3	1.5	33.34	35.60	44.50	14.97	2.15	2.69
5	M4	2.0	34.34	35.73	44.67	18.41	2.46	3.08
6	M5	2.5	34.50	36.27	45.33	18.97	3.70	4.62
7	M6	3.0	35.00	36.80	46.00	20.69	4.92	6.15
8	M7	3.5	33.00	36.00	45.00	13.79	3.08	3.85
9	M8	4.0	32.33	35.73	44.67	11.48	2.46	3.08
10	M9	4.5	31.33	35.47	44.33	8.04	1.85	2.31

11	M10	5.0	30.00	35.20	44.00	3.45	1.23	1.54

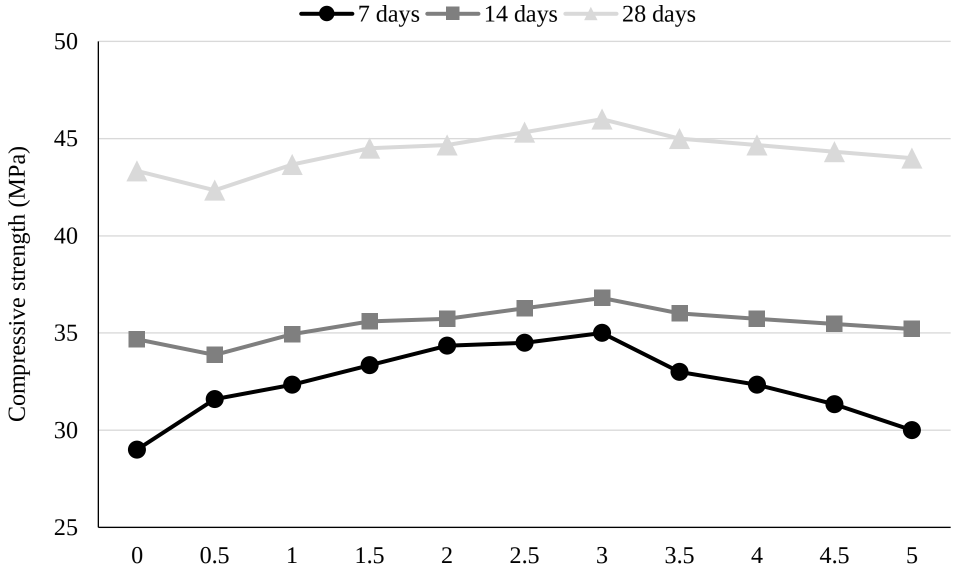

Figure 1. Variation of Compressive strength for 7, 14, 28 days with fiber percentage.

Table 2. Flexural Strength determination after 7, 14, and 28 days curing time.

S.N.	Mix. Designation.	Fibre Volume fraction V_f (%)	Flexural strength (MPA)			% Variation in Flexural Strength		
			7 days	*14 days*	*28 days*	*7 days*	*14 days*	*28 days*
1	MO	0.0	5.12	4.84	6.05	-	-	-
2	M1	0.5	5.22	4.82	6.03	2.03	-0.44	-0.44
3	M2	1.0	5.33	4.81	6.01	4.14	-0.66	-0.66
4	M3	1.5	5.57	4.76	5.95	8.85	-1.76	-1.76
5	M4	2.0	5.69	4.89	6.11	11.20	0.88	0.88
6	M5	2.5	5.73	5.03	6.29	11.98	3.96	3.96
7	M6	3.0	5.75	4.97	6.21	12.34	2.64	2.64
8	M7	3.5	5.76	5.23	6.53	12.50	7.94	7.94
9	M8	4.0	5.83	5.61	7.01	13.80	15.86	15.86
10	M9	4.5	5.49	5.55	6.93	7.29	14.54	14.54
11	M10	5.0	5.39	5.53	6.91	5.20	14.10	14.10

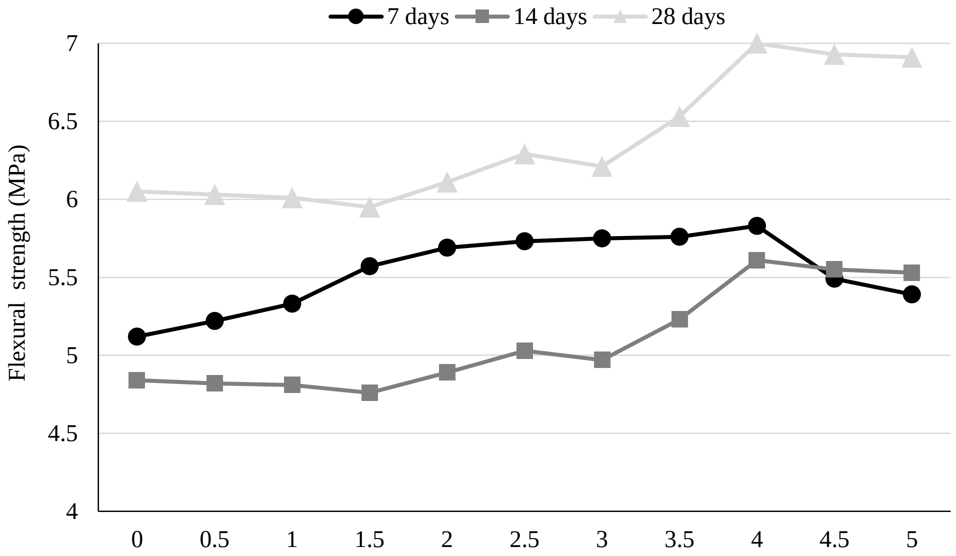

Figure 2. Flexural strength with variation of fiber percentage for 7, 14, 28 days curing.

Table 3. Split tensile strength with varied fiber percentage tested at 7 days, 14 days and 28 days.

S.N.	Fiber Content %	Split Tensile Strength (MPA)			% Variation in split tensile strength over control concrete		
		7 Days	***14 Days***	***28 Days***	***7 Days***	***14 Days***	***28 Days***
1	0	2.21	2.21	2.76	0	0.00	0
2	0.5	2.23	2.53	3.16	0.98	11.69	14.62
3	1	2.42	2.62	3.27	9.62	14.77	18.46
4	1.5	2.65	2.87	3.59	20.19	24.00	30.00
5	2	2.68	3.04	3.80	21.15	30.15	37.69
6	2.5	2.76	3.13	3.91	25.00	33.23	41.54
7	3	3.00	3.16	3.95	36.06	34.46	43.08
8	3.5	2.98	3.14	3.93	34.98	33.85	42.31
9	4	2.87	3.06	3.82	29.81	30.77	38.46
10	4.5	2.34	2.63	3.29	5.77	15.38	19.23
11	5	2.23	2.55	3.18	0.96	12.31	15.38

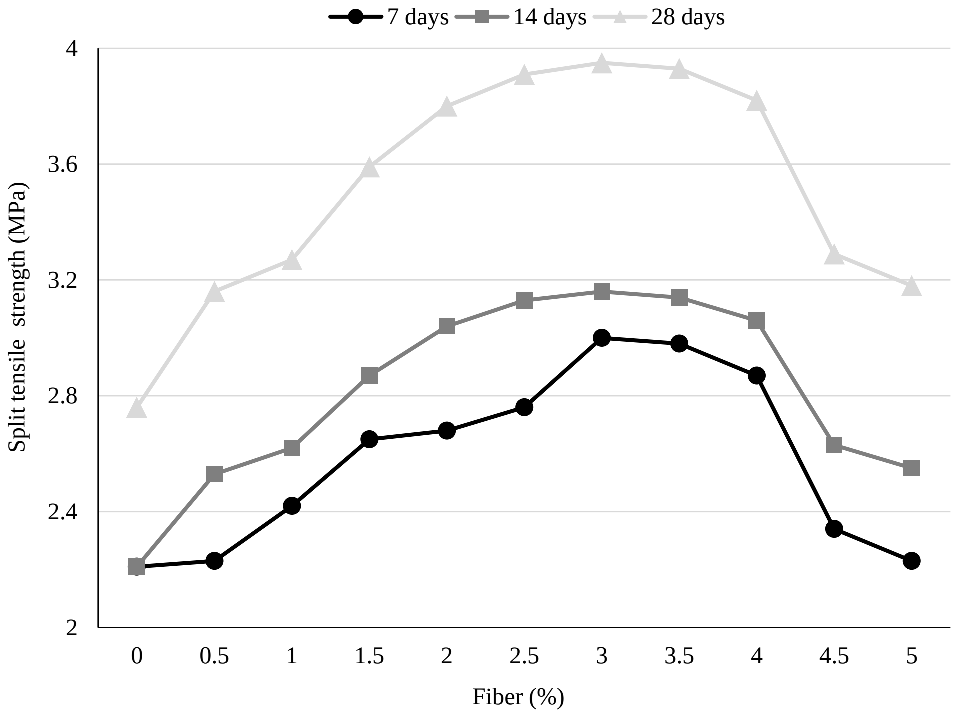

Figure 3. Split tensile strength with fiber percentage variation for 7, 14 and 28 days.

Dry and Wet Density

The dry and wet density of concrete cube are determined

The densities are tabulated in Table 4, and graph shows variation in Figure 4.

Workability of Concrete

In the current study the workability is calculated with different fiber ratio in mix. The result is tabulated in Table 5. The regression analysis was performed for fiber factor and slump loss which shows good

The results show that after increasing the percentage of fiber more than 3% the slum height decreases which shows low workability.

Table 4. Wet and Dry Densities of concrete with varying fiber percentage

S.N.	Mix. Design.	Fibre Volume fraction V_f (%)	Water cement ratio	Wet. Density (Kg/m^3)	Dry Density (Kg/m^3) at 7 days	Dry Density (Kg/m^3) at 14 days	Dry Density (Kg/m^3) at 28 days	Wt. of Cube (Kg)In Wet Condition	Wt. of Cube (Kg) In Dry Condition	Wt. of Cube (Kg) In Dry Condition@ 28 days
1	M0	0	0.4	2760	2680	2675	2690	2.76	2.68	2.69
2	M1	0.5	0.4	2750	2670	2665	2680	2.75	2.67	2.68
3	M2	1	0.4	2720	2660	2655	2670	2.72	2.62	2.67
4	M3	1.5	0.4	2700	2650	2645	2660	2.7	2.6	2.66
5	M4	2	0.4	2690	2640	2635	2650	2.69	2.59	2.65
6	M5	2.5	0.4	2660	2638	2605	2620	2.66	2.57	2.62
7	M6	3	0.4	2650	2630	2585	2600	2.65	2.55	2.6
8	M7	3.5	0.4	2620	2615	2565	2580	2.62	2.54	2.58
9	M8	4	0.4	2600	2600	2526	2540	2.6	2.52	2.54
10	M9	4.5	0.4	2590	2590	2506	2520	2.59	2.51	2.52

11	M10	5	0.4	2550	2582	2501	2515	2.55	2.5	2.51

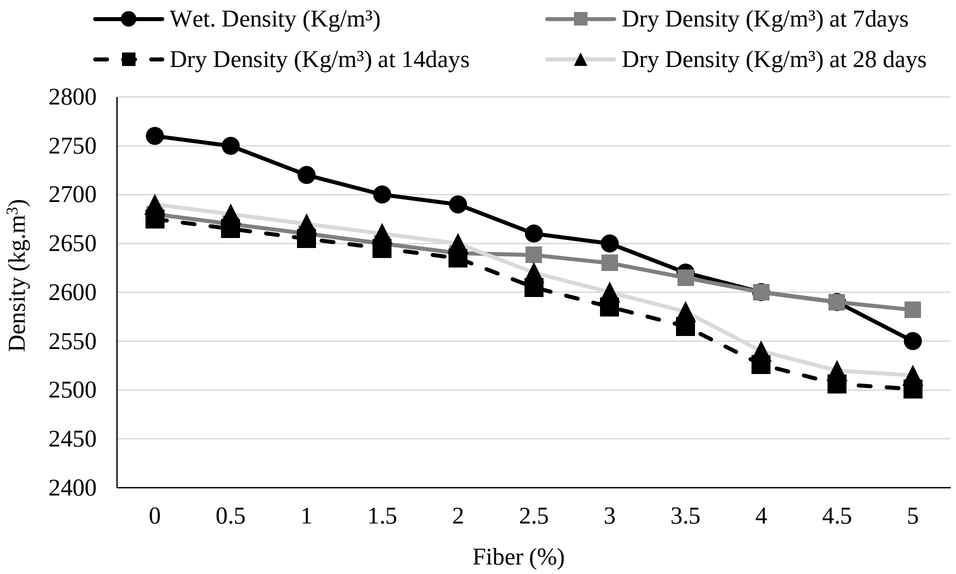

Figure 4. Wet and Dry density.

Table 5. Workability by slump cone test.

S.N.	Fibre Volume fraction V_f (%)	Fibre factor V_f.(l/d)	Slump (mm)	Slump loss (%)	Dry Density in Kg/m^3 at 28 days	Density loss (%)
1	0	0	60	0.00	2690	0.00
2	0.5	0.4	52	13.33	2680	0.37
3	1	0.8	50	16.67	2670	0.74
4	1.5	1.2	48	20.00	2660	1.12
5	2	1.6	45	25.00	2650	1.49
6	2.5	2	42	30.00	2620	2.60
7	3	2.4	40	33.33	2600	3.35
8	3.5	2.8	35	41.67	2580	4.09
9	4	3.2	30	50.00	2540	5.58
10	4.5	3.6	28	53.33	2520	6.32
11	5	4	25	58.33	2515	6.51

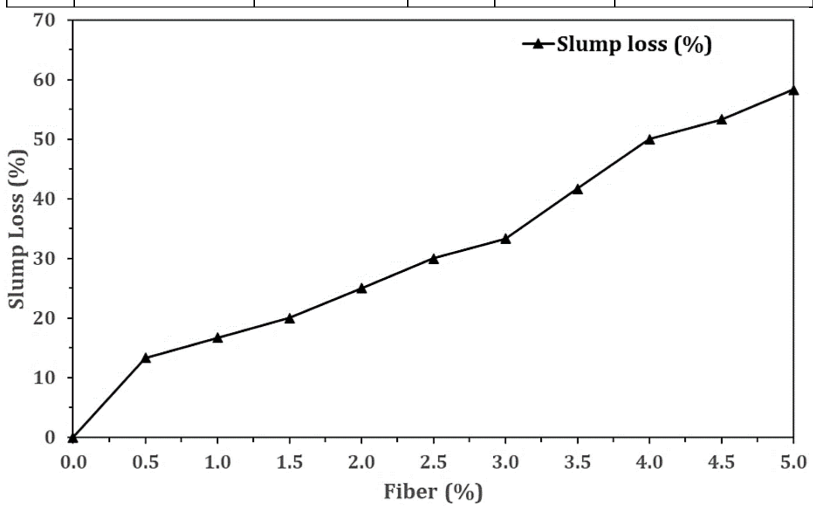

Figure 5. Fiber Factor and slump loss (%).

CONCLUSION

The result drawn from different experimental analysis of the study shows that inclusion of fibers in concrete increases the strength up to certain limit for all the test after certain limit the strength and quality starts to deplete. The result from the study concludes that:

1. The workability of concrete increases with increase in fiber up to 3% fiber volume fraction after which the results show decrease in slump, Shown in Figure 5.
2. The flexural strength of concrete shows that adding 4% of fiber in concrete gives maximum strength, after which further addition of fiber shows decrease in strength for 7,14 and 28 days of curing, shown in Figure 2.
3. The wet and dry density of concrete is calculated for concrete cubes the maximum wet density was determined at 3% fiber, Maximum wet density was 2650 kg/m^3 and Maximum dry density for 7, 24 and 28 days was 2630 kg/m^3, 2585 kg/m^3, 2600 kg/m^3.
4. The workability of concrete was examined and the slump for 4% fiber was found to be 25 mm.
5. The compressive strength of concrete was tested and found that at 3% fiber addition the maximum compressive strength is achieved after further addition of fibers the decreased compressive strength is found.

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