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Partial Used of Foundry sand as Replacement of Sand in Concrete Production

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Abstract

This article discusses experimental results performed to appraise the use of foundry sand (FS) in concrete production as a replacement source for fine aggregates. Six different substitutions rates (10, 20,30,40,50 and 60 %), FS originating from the metal casting industry has been used as a replacement for fine aggregate. Different tests slump cone, compressive strength, split tensile strength, UPV, Rebound hammer, flexural strength tests were conducted to understand FS's effects on concrete performance. Foundry sand study of grain size distribution showed that 8% of FS was less than 75 µm, and foundry sand water absorption was about 2.15 %. The test results showed that concrete mixtures containing up to 30 percent of the foundry sand had their strength properties were relatively close to the strength of the control mixture. The decline in intensity is due to the FS fineness and the FS involvement of dust and mud. The test results showed that the substitution rate for good concrete output up to 30 percent can be used effectively without affecting the specific standards and that a replacement rate exceeding 30 % is not favorable.

Keywords*—Foundry sand, Concrete, Workability, Compressive strength, Flexural strength.*

I.INTRODUCTION

Most generally, in the construction industry, concrete is used as a building material and offers various benefits such as good mechanical toughness, low cost, and high rigidity. In recent decades, demand for concrete has gradually increased due to the construction of infrastructure. River sand is one of the main constituents of concrete production and is used as a fine aggregate. The high demand for concrete has resulted in unsustainable mining of river sand at the bottom of the river, causing numerous adverse effects such as river bed widening, water level decrease, and salt penetration into the river. The ban on sand extraction from rivers has raised the sand prices, severely affecting the construction industry's stability. Hence it is important to find alternative content for river sand. Over the last few decades, there has been much work on the use of industrial waste as a substitute/exchange source for fine aggregates. Research shows that replacing concrete with alternative materials improves both mechanical and durable properties and, in practice, leads to more sustainable concrete development [6-11].

The Foundry Sand (FS) is a mixture of high metal alloys in a high silica content mainly used in foundry. Silica sand shall be mixed with clay or chemical substances and used during casting. For days, foundries gather sand and dump it when sand cannot be recycled. It is considered by the foundries to be waste[1]. In the process, nearly 15% of the casting sand is

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discarded, which equals millions of tonnes. In India this waste has been accumulated by many foundries in surrounding empty areas, causing environmental problems.

Despite expanded landfill limits in surrounding cities, companies are being forced to consider new methods to recover waste. Foundry sand has been used for road applications in recent decades, but the volume of waste recovered in this manner is still small. Of this cause, the need to use FS is becoming quite urgent in many ways. Recently work on the usage of FS in unique and concrete based items has been carried out. The mechanical properties of concrete including FS are tested by Siddique et al[1]. In three separate ratios, the fine aggregate was substituted by foundry sand (10 percent, 20 percent, and 30 percent). With the replacement of FS, a small improvement in the strength properties was found and it was proposed that FS could be used successfully in concrete manufacturing. Bakis et al.[2] results have shown that fine aggregate substituted with 10 percent FS is ideal for asphalt concrete mixtures. Kraus et al.[3] performed a study to determine the effectiveness of utilizing FS in SelfConsolidating Concrete (SCC). However, it was concluded that it is feasible to manufacture economical SCC using FS, although more work is required to decide the optimum proportion of FS. Siddique et al.[4] attempted to research the structural, toughness, and microstructural properties of made concrete. The tests revealed that concrete mixtures with foundry sand displayed strong carbonation tolerance and fast penetration of the chloride. The concrete's mechanical properties increased with FS replacement, and it was proposed that FS be used in concrete manufacturing without compromising the properties of mechanism and longevity. In another research, Singh and Siddique[5] examined the abrasion tolerance and strength properties of the waste foundry sand (WFS) comprising concrete. Basar et al.[6] were investigating the feasibility of re-use of FS in ready-mixed concrete (RMC) production. The test findings showed that partial replacement of FS reduced concrete strength and increasing the concrete mixture's water demand. Although much work on the re-use of FS in civil engineering applications has been carried out, minimal work has been carried out on the usage of FS in concrete production; more work is required to evaluate the optimum FS replacement in concrete manufacturing. Furthermore, environmental pollution induced by FS dumping should be reduced in the Nashik district, in Maharashtra, India. To address the two issues, experimental research was performed on the re-use of FS obtained from a metal casting factory, Nashik, in Maharashtra, India, at various replacement levels as a substitute for fine aggregate in concrete processing. The optimal proportion of FS in concrete manufacturing was determined based on the test results obtained. The outcomes of the experiments collected were checked using the phrases specified in concept specifications.

II.EXPERIMENTAL PROGRAM

A.MATERIALS

Standard/commercial Portland cement has been used as a binder in this article. The properties of the cement were determined following IS 2720 (Part 3): 1963[12] are shown in Table I. The river's natural sand, which traversed 4.75 mm, was used as a fine aggregate. A local blue metal jelly was used as a rough, 20 mm thick aggregate. Sieving experiments were conducted on both fine and coarse aggregates according to IS 2386 (1): 1963[14] results are shown in Table II. Foundry sand (FS) collected Mohiniraj Enterprises, Ambad MIDC, Nashik, Maharashtra (India). The physical and chemical properties of FS have been checked to Indian specifications. The typical gravity and density of FS are about 2.1 and 1620 kg / m^3, respectively. The water absorption of FS was about 0.42%, which is higher than normal air absorption due to the inclusion of ash and wood particles. A sieve analysis revealed the FS particle size distribution and found that 8% of the FS was less than 75 µm. This suggests that

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FS is a good thing. The chemical properties of the FS were checked in compliance with IS 4032:1985[16], and the findings revealed that FS comprises approximately 88.85% silica (SiO_2) and 4.5% alumina (Al_2O_3). The findings of a chemical study showed that the FS is a substance that is very appropriate for concrete construction.

TABLE I. PROPERTIES OF CEMENT

Properties	**Average value**	**IS 81121989.**
Specific gravity	3.15 (standard)	3.15
Fineness (%)	4	<10%
Consistency (%)	32	-
Initial setting time (min)	78	>30
Final setting time (min)	380	>600

TABLE II.PROPERTIES OF RIVER SAND AND CA

Properties	**River sand**	**CA 20 mm size**
Specific Gravity	2.72	2.12
Water Absorption (%)	4.25	1.54
Fineness modulus	2.5	7.01
Moisture Content	-	1.90
Unit weight (kg/m3)	1850	1630

B.Concrete

According to IS 10262[17], the concrete mix proportions were designed to achieve the strength of M20. Concrete mixes were 1:1.65:3.63 percent. A constant water-cement ratio (W / C) was observed of both mixtures, and the value was around 0.40. For the seven compounds, six compounds were combined by 10%, 20%, 30%, 40%, 50%, and 60% river sand with FS, the remaining one being without FS control mixture (CM). The detailed formulas of the seven proportions are outlined in Table 3.

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TABLE III.MIXTURE PROPORTION

Items	Control Mix	10% FS	20% FS	30% FS	40% FS	50 % FS	60% FS
Water	191. 6	191.6	191.6	191.6	191.6	191.6	191.6
Cement	354.8 1	354.81	354.81	354.81	354.81	354.81	354.81
Sand	588.1 8	529.36	470.54	411.72	352.90	294.09	235.27
Coarsed aggregate	1289. 45	1289.45	1289.45	1289.45	1289.45	1289.45	1289.45
Foundry sand	0	58.82	117.64	176.46	235.28	293.28	352.91

C.Specimen Preparation

Concrete blends with and without FS exchange. The rate of substitution for FS was 10%, varying from 10% to 60%. In this study, at least three times the FS was washed off with fresh water to remove ash and clay. The FS was then dried for two days in the sun and used in concrete combinations. Aggregates such as asphalt, natural sand, coarse aggressive, and FS were weighed and dried for all mixtures. These aggregates were then mixed into the laboratory lot mixer to avoid further loss of material and water retention. The slump cone test was used to test fresh physical properties like concrete workability. The weight of the concrete unit was also measured. The test was designed to test 150x150x150 mm, 150x300 mm cement, cube, and cylinders in pressure and tensile strength. Only beams on a scale of 100 x 100 x 500 mm were used to assess concrete flexural strength.

All samples, such as cylinder cubes and beams, were filled in three layers of concrete, and each concrete layer was effectively compressed using a table vibrator. Upon casting all pieces, the experiments were filled with a plastic sheet to prevent a lack of moisture. Afterward, specimens have been stored at room temperature for 24 hours, then removed and placed into the healing tank until the study date. The cubes were measured in a compression testing machine (CTM) with a capacity of 3000 kN at age 7, 28, and 91 days after the necessary healing days. The cylinders and beams were evaluated in the CTM and Flexural Testing Machines at age 7, 28, and 91 days of age, respectively, to determine the tensile strength and flexural quality of the concrete. All specimens were examined in compliance with Indian standards. To ease the description of mixtures, names have been given for mixtures such as CM, 10FS%, 20% FS, 30% FS, 40 FS%, 50FS% and 60FS %. The term 30 %FS, for example, suggested that the concrete combination produced 30 percent of the foundry sand.

III.RESULT AND DISCUSSION

A.Workability

The slump cone check was used to assess the concrete's operability. The FS's effect on the workability is shown in Table IV. It can be noted that the replacement of FS in concrete increases the practicality of the concrete; however, the rise in the substitution rate also affects the practicality of concrete. Nevertheless, with the replacement rate up to 10 percent, the impact of FS on workability is not important, and the mixture slump value was relatively equal to the CM. Nevertheless, a decrease in the concrete's workability was found beyond the

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10 percent replacement limit. We recognize the concrete workability is directly proportional to the fineness of the concrete content used. The fineness of the FS raises the concrete's water pressure through water absorption, resulting in a decrease in the concrete's workability. The other possible factor because of the existence of ash and clay particles is the high water absorption properties of the FS. The mixture's workability was reduced by the time elapsed. Usually, slump depletion happens when the hydration phase extracts the water from the concrete.

TABLE IV.SLUME CONE VALUE

Sr. No.	% Replacement of foundry sand	Slump (mm)
1	0	100
2	10	95
3	20	95
4	30	80
5	40	40
6	50	35
7	60	28

B.Compressive strength

Table V indicates the compressive strength of all mixtures at the age of 7, 28 and 91 days. This investigation aims to reuse the FS in concrete production without compromising the limitations set out in the specific standards. The test results revealed that FS can be used successfully in concrete manufacturing as a replacement ingredient for the fine aggregate. Although there was no significant strength increase, the compressive strength of the concrete mixtures comprising up to 30FS % was relatively close to the performance of the CM. Relative to 20%FS and 30%FS mixtures, CM mixtures displayed an improved compressive strength of 3.11% and 7.97%, respectively, at 28 days of age, which is not significantly different from CM's strength rating. However, 40%FS,50%FS and 60%FS mixtures displayed weaker intensity compared to CM, and the mixtures reported a decline of 20.11%, 21.52% and 23.41% percent compressive strength compared to CM at 28 days of age. The rise in the FS substitution rate reduces the intensity of the concrete in all ages (28 and 91 days) and the impact was important at a substitution rate of over 30 percent. The inclusion of more silica in the FS was expected to increase the hydration cycle and increase the production of C_3S significantly. Nonetheless, the fineness of the FS reduces concrete workability and as a
result, lowers the concrete's compressive strength.

The FS's fineness induces water demand in the concrete resulting in poor workability and this water demand is directly proportional to the FS substitution intensity. The low concrete workability reduces concrete compaction and raises concrete porosity. The change in porosity reduces the concrete density and results in a reduction in the compressive strength. The existence of mud, sawdust and wood starch is another possible factor. Also, concrete density is related to the physical properties of the concrete components used. Most foundries still use clay, sawdust, and wood flour to shape the molds as a binding medium.

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These particles' existence increases the material's basic density and also lowers the concrete's density by producing air voids in the concrete. The following calculation was proposed by ACI 209 (ASTM Type 1)[18] to determine the compressive strength of concrete over time.

$$f_{cm}(t) = f_{c28}\,\frac{t}{4+0.85t} \qquad (1)$$

where$f_{cm}(t)$ is the mean compressive strength at the age of t days, f_{c28} is mean compressive strength at 28 days and t is the age of the concrete in days. The calculated compressive strength values of the concrete are listed in Table V. The relationship between the compressive strength calculated and computed is shown in the Fig. 1. To govern the relationship, the linear regression line was used to demonstrates clearly that the calculated compressive strength of the concrete, wellconforming with the computed strength, was very high (R^2 = 0.9457).

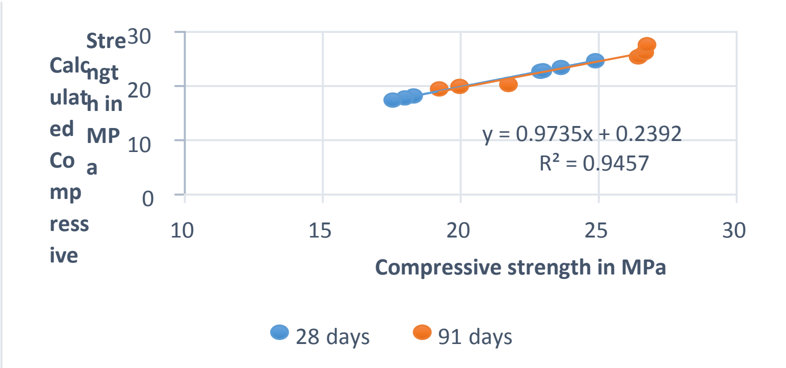

Fig. 1.Relation between measured and computed compressive strength of concrete.

TABLE V.COMPRESSIVE STRENGTH

Mix designation	Compressive Strength (N/mm²)			Calculated Compressive Strength as per (ACI 209(Type 1)) (N/mm²)	
	7 days	28 days	91 days	28 days	91 days
CM	17.86	22.72	26.43	22.88	25.40
10%FS	18.26	22.81	26.46	22.97	25.50
20%FS	18.31	23.45	26.66	23.62	26.22
30%FS	18.54	24.69	26.74	24.87	27.60
40%FS	17.72	18.15	21.72	18.29	20.30
50%FS	17.35	17.83	19.96	17.96	19.94
60%FS	16.48	17.40	19.21	17.53	19.46

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C.Ultra Sonic Pulse Velocity

The Ultra Sonic Pulse Velocity (UPV) values of all concrete mixtures were calculated at the ages of 28 and 91 days according to IS 13311(1):1992[19]. The results showed that the calculated UPV values of the concrete mixture up to 30% replacement were nearly equal to the UPV values of the CM relative to CM and that the measured values of all the mixtures were higher than 3500 m / s;

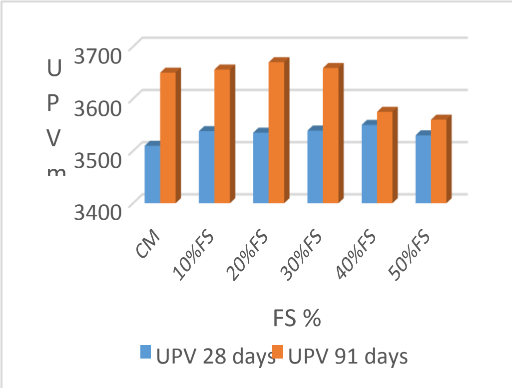

Fig. 2.Ultrasonic pulse velocity test.

D.Flexural strength

The average flexural strength of all concrete mixtures for the 7, 28 and 91 days is described in Table VI. The concrete mix flexural strength was equivalent to the control mix flexural strength at a replacement rate of up to 30 %. However, the concrete's flexural strength began to decline significantly when the replacement rate was higher than 30%. The control mixture's flexural strength was 3.70 N / mm^2 at the age of 28 days, whereas the mixtures FS 10%FS, FS 20%FS, and FS 30% FS reached capacities of 9.75%, 12.70%, and 14.05%, respectively, greater than CM strength. After aging, the flexural strength of all concrete mixtures was increased; nevertheless, the quality gain was low beyond the replacement limit of 40%, 50% and 60%. The equation is indicated by IS 456:2000[20] to measure the flexural strength of the concrete from the compressive stress, where the flexural f_{ft} is flexural strength of the concrete and the $f_{ck}$is the compressive strength of the material.

$$fft = 0.7X\sqrt{fck} \quad (2)$$

A regression analysis shows the relationship between the calculated and the simulated flexural strength in figure 4. It can be observed that the association between the measured and estimated intensity was quite high, and the mean R^2 value was for 28 days is 0.9428 and for 91 days is 0.9002. According to the standards, FS is essential to be used in the concrete output as a fine aggregate at a maximum substitution rate of 30 %.

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TABLE VI.FLEXURAL STRENGTH

Mixtures designation	Measured flexural strength (N/mm^2)			Calculated flexural strength (IS 456:2000) (N/mm^2)	
	7 days	28 days	91 days	28 days	91 days
CM	2.08	3.70	4.10	3.33	3.63
10%FS	2.22	4.10	4.50	3.34	3.60
20%FS	2.27	4.17	4.57	3.38	3.61
30%FS	2.29	4.22	4.62	3.47	3.61
40%FS	2.01	3.05	3.46	2.9	3.26
50%FS	1.90	2.95	3.37	2.96	3.12
60%FS	1.79	2.83	2.77	2.91	3.06

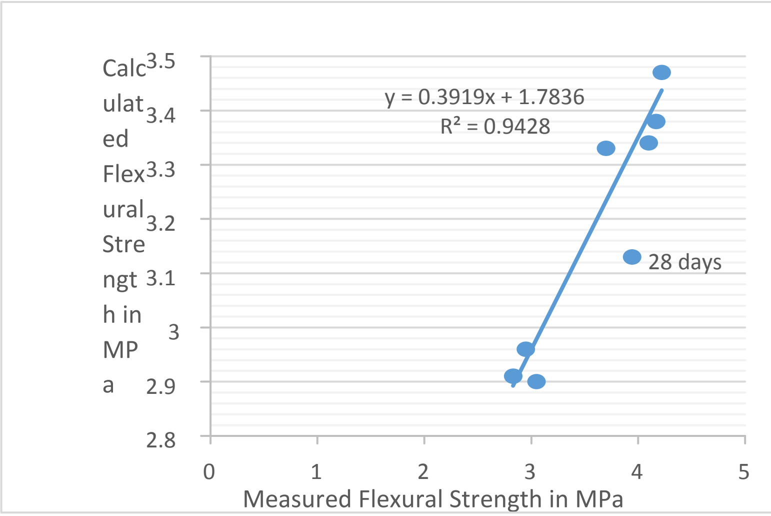

Fig. 3.The relation between measured and calculated flexural strength of concrete.

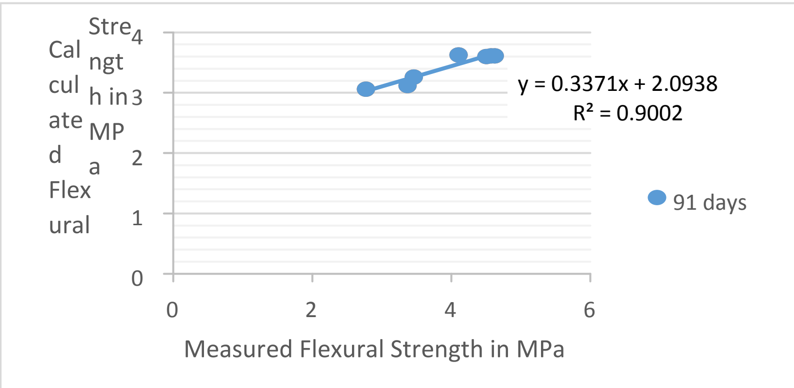

Fig. 4.The relation between measured and calculated flexural strength of concrete.

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E.Splitting tensile strength

The splitting tensile strength of the concrete was determined at 7,28, 91 days of age and the findings are summarized in Table VII. The results show that the concrete's tensile strength has declined as the FS replacement rate has increased; however, the mixture's tensile strength with a 30 % replacement rate is greater to the CM value. At 28 days the tensile strength decrease of the cement mixes FS 10%, FS 20% and FS 30% was 2.35%, 5.20% and 10.38%, respectively, and this gap in strength is not relatively high. In the CEB-FIP Model Code: 1990(21) a relation equation (3) between tensile strength (f_{st}) and bending resistance f_{ft} of concrete is recommended, while h is the depth of the beam in mm and h_0 of 100 mm. The forces obtained are shown in N / mm^2.

$$f_{st}= f_{ft}x\ 1+^{2(}2^{h}(^{'}h^{h/o}h^{)}o^{0})_{0}^{7}{}_{.7} \qquad (3)$$

The compressive strength of the concrete alone was generally measured to estimate the consistency of the concrete and the tensile force of the concrete was generally determined by empirical correlation. The relationship between the compressive force and the tensile strength was calculated and expressed in equation (3) based on the resulting test results. On the basics of equation (4), the concrete's division tensile stress has been established, the results shown in Table VII. The correlation between the tensile strength measured and calculated was strong as shown in fig 5.

$$f_{st}= 0.85\ (f_{ck})^{0.315} \qquad (4)$$

TABLE VII.SPLIT TENSILE STRENGTH

Mixtures designation	**Measured split tensile strength (N/mm^2)**			**Computed split tensile strength (CEB-FIP (1990)) (N/mm^2)**		**Computed split tensile strength (by Eq. (4)) (N/mm^2)**	
	7 days	28 days	91 days	28 days	91 days	28 days	91 days
CM	2.58	3.66	3.51	2.47	2.73	2.27	2.38
10%FS	1.95	3.60	3.45	2.73	3.00	2.28	2.39
20%FS	2.02	3.85	3.52	2.78	3.05	2.30	2.40
30%FS	2.63	4.04	4.23	2.81	3.08	2.33	2.40
40%FS	2.43	3.81	3.84	2.03	2.31	2.12	2.24
50%FS	2.12	3.62	3.96	1.97	2.25	2.10	2.18
60%FS	1.98	3.64	3.79	1.89	1.85	2.09	2.15

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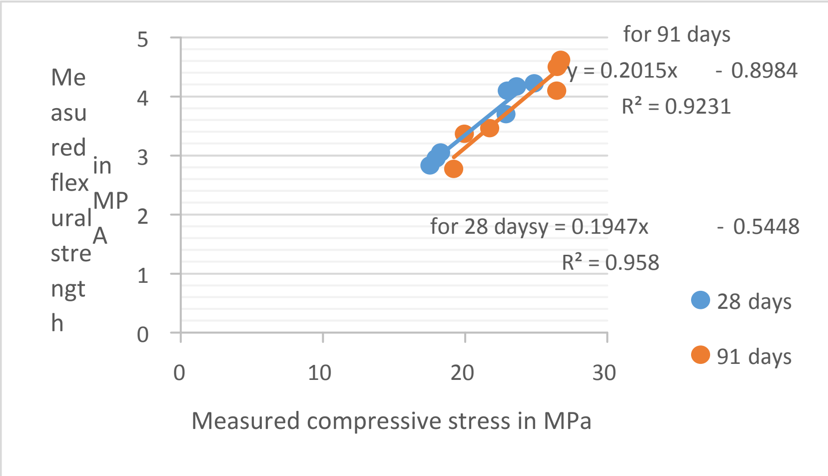

Fig. 5.Relation between measured compressive stress and measured flexural strength of concrete.

F.Elasticity Modulus

Based on equation (5) and (6), recommended by the IS 456:2000 [20] and IS 13311(1):1992 [19], respectively, the dynamic concrete elastic modulus from compressive strength and UPV values at the age of 28 and 91 days is measured and summarized in Table VIII. The discrepancy between the values of the elastic modulus obtained and measured using IS 452:2000 and IS 13311(1):1992[19] indicates no big difference, and the values were relatively close.

TABLE VIII.MODULUS OF ELASTICITY

Mixtures designation	Measured Modulus of elasticity (kN/mm²)		modulus of elasticity (IS13311(1):1992) (kN/mm²)		modulus of elasticity(IS456: 2000) (kN/mm²)	
	28 days	91 days	28 days	91 days	28 days	91 days
CM	23970.16	25698.45	24746.51	26760.80	23832.75	25705.05
10%FS	26165.48	26489.56	25143.68	26848.85	23879.90	25719.64
20%FS	25254.15	26758.41	25101.67	27054.87	24212.60	25816.66
30%FS	25348.62	25245.56	25157.90	26892.93	24844.51	25855.36
40%FS	25896.45	24975.23	25314.54	25672.43	21301.40	23302.36
50%FS	25587.26	24568.17	25030.11	25457.35	21112.79	22338.30

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IV.CONCLUSION

The following result was derived from the study carried out on five mixtures:

The fineness and strong absorption properties of FS lessen the workability of the concrete and also reduces the operability of that concrete with an improvement of the replacement rate FS. The strength properties of the FS-containing concrete mixtures of up to 30% relatively close to the CM performance in all concrete ages.

The 20%FS and 30%FS mixtures, CM mixtures displayed an improved compressive strength of 3.11% and 7.97%,

respectively, at 28 days of age,

The FS 20% and the FS 30% concrete mixtures reported a decline of only 3.11% and 5.7% respectively compressive strength at age 28 relative to the CM. The control mixture's flexural strength was 3.70 N / mm^2 at the age of 28 days, whereas the mixtures FS 10%FS, FS 20%FS, and FS 30% FS reached capacities of 9.75%, 12.70%, and 14.05%, respectively, greater than CM strength. Because of FS fineness and the inclusion of mud, sap and wood flour in the FS the concrete mixtures exhibited an under-behavior over and above the substitute level of 30 percent compared with the CM.

From the findings obtained, it is proposed that FS can be successfully used as a fine aggregate in strong concrete manufacturing without impacting concrete quality, with a replacement rate of up to 30 percent.

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