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ACCELERATED PROPERTIES OF STEEL FIBRE REINFORCED CONCRETE CONTAINING FINER SAND

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ABSTRACT

The present study focuses on the influence of finer sand for producing the accelerated rate of hardening at early ages in steel fibre reinforced concrete. Experimental tests were conducted on the concrete mixtures containing different percentage of finer sand (0, 10, 20 and 30%) and the performances were compared with normal concrete obtained from the source directly. The test results indicated that with higher replacement level upto 20% finer sand showed an increased cube and cylinder compressive strength (44.2 and 33.1 MPa) respectively at 7 days compared to reference concrete mixes containing river sand at 28 days. It can also be noted that the concrete mixes containing finer sand particles showed a consistent strength increase compared to conventional controlled concrete. From the experimental test results it is suggested that, finer sand can be effectively utilized for producing high early strength concrete without affecting the durability properties. However, the replacement level of finer sand can be restricted upto 30%, since it will affect the hardened and durability properties of concrete.

Keywords: accelerator, steel fibre concrete, finer sand, durability properties, strength.

1. INTRODUCTION

Ferrous and non ferrous foundries use silica sand to create cores and metal casting to produce the higher amount of solid wastes generated by foundries and dumped huge tons per annum, molds can be exposed to higher temperatures upto 1600^0C depending upon the usage. The reuse of finer sand is high quality silica sand that is by product of metal casting industries has become an increasing concern in recent years due to increasing landfill costs and current interest towards sustainable development. A good amount of work has been carried out in recent years for the large scale utilization of finer sand in concrete. The beneficial properties of finer sand can be realized in terms of the improved mechanical properties in concrete after longer curing period. However, the early age setting properties of cement concrete is greatly affected when finer sand is partially replaced with normal sand. This leads to positive effects on the use of finer sand for fast track concreting such as concrete pavement applications. The present study is aimed at to accelerate the setting properties without affecting the durability properties; it has been provided a major thrust towards the large scale utilization of finer sand in pavement construction since the replacement levels of finer sand upto 30%. There is an increasing demand to study the engineering properties of finer sand concrete and make it a more versatile construction material on earth. In addition to this, the effect of cost can be reduced appreciably by replacing large quantities of cement with finer sand. Several research works had been investigated to use of finer sand for several kinds of civil engineering applications (Merve Basar H *et al*., 2012) in his research studies concluded that the finer sand when partially replaced upto 20% exhibited almost same strength results with that of controlled concrete. However, to increase the partial replacement of sand showed the reduction in strength performance, density and also increased the water absorption ratio of the concrete mixtures, it has been plotted the relationship between ultrasonic pulse velocity and compressive strength was reported at different curing days. (Gurdeep Kaur *et al*., 2012) observed from ferrous and non-ferrous foundries waste molding sands characterized and investigates the effects of incorporating fungal treated finer sand 20% from that test results showed that higher compressive strength upto 15.6% increased after 28 days was achieved and also suggested that is capable to form good C-S-H gel increase the ability of cement to react properly with finer sand containing concrete. (Konstantin Kovler and Nicolas Roussel, 2011) this paper deals with consolidated more number of literatures work for fresh and hardened concrete properties is a relatively new type of concrete with high flow ability and cohesiveness, when compared to conventional concrete more than 70 research paper studies on the hardened mechanical properties of self compacted concrete had been analyzed and correlated to produce comparisons with the properties of equivalent strength normally vibrated concrete, relationship were obtained between cylinder and cube compressive strength, tensile and elastic modulus. (Rafat Siddique and Albert Noumowe, 2008) reported that compressive strength of stabilized finer sands decreased with the increase in finer sand content in the mixtures. Finer sand contributes to the increased bleeding due to increased voids of the mixture created by the coarser particles of finer sand compared to the flyash particles, it exhibits lower unit weight, higher water absorption, and higher percent void compared to regular concrete sand at the age of 28 days, splitting tensile strength increased by 12 to 20% when compared to ordinary mix without finer sand, whereas increased upto 20% at the age of 56 days and modulus of elasticity of finer sand flyash concretes with 0 to 30% fine aggregate that is sand replacement was higher than the control mix at all ages. (Rafat Siddique *et al.*, 2011) reported that the

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effect of using finer sand as partial replacement of fine aggregates, the test results indicate that industrial by products can produce concrete with sufficient strength and durability of the concrete regarding resistance to rapid chloride penetration test values as per (ASTM C1202-97) was recorded less than 750 coulombs at 90 days and 500 coulombs at 365 days, which comes under very low category thereby, indicating effective use of finer sand as an alternate fine aggregate material. (Rafat Siddique, Geert de Schutter *et al.*, 2009) investigated the different percentage of finer sand and concluded the tests result were performed for the properties of fresh, mechanical, flexural strength and modulus of elasticity were observed at different curing days, the increase in compressive strength with the inclusion of finer sand resulted in the denser concrete matrix and also due to higher percentage of silica content present in the finer sand. (Gurpreet singh and Rafat Siddique, 2012) concluded that concrete mixes containing finer sand taken on weight basis (0, 5, 10, 15 and 20%) were adopted for five different concrete mix proportions it was observed from test result that the mechanical properties and modulus of elasticity of concrete was found to be enhanced for concrete containing 15% finer sand at 28 days testing; as well as there was an increase in the ultrasonic pulse velocity values and decreased chloride ion penetration in concrete, which indicates that good quality of concrete can be produced for a structural grade concrete.

1.1. Research significance

The present study is aimed at the potential reuse of finer sand obtained from the byproduct of ferrous and nonferrous metal casting industry as partial replacement of fine aggregates in various percentages (0-30%), to determine the various mechanical and durability characterizes of concrete. Application of finer sand in concrete will lead to diversion of large amount of finer used for land filling and manufacture of cost effective prefabricated structural elements.

2. EXPERIMENTAL METHODOLOGY

2.1. Material used

Ordinary Portland cement was of 53 grade conforming to IS 12269-1987 was used and the properties are given in Table-1. Plain concrete is a mixture comprised of cement, coarse and natural river sand and water by volume. Finer sand can be used as a fine aggregate substitute in OPC concrete. Fine aggregates was river sand as conforming to Zone II as per IS 383 1970 with a specific gravity of 2.64 and fineness modulus of 2.90 and the sieve analysis of fine aggregate is given in Table-2 and shown in Figure-1. Crushed angular granite coarse aggregates, less than 12.5 mm was used. The properties of coarse aggregates are: Specific gravity = 2.80, Dry rodded unit weight = 15560 Kg/m^3, Good portable water was used for all the mix proportions during concreting. Finer sand used in this study was obtained from the nearby metal finer industry located in the Vellore Region of Tamil Nadu, India which produces metal components for the automobile industry. Physical properties of finer sand was determined as per codal provisions and found to be having a specific gravity value of 2.19, fineness modulus value of 2.16, bulk density 2275 Kg/m^3 and water absorption of 6.5%. An accelerating chemical admixture consisting of calcium nitrate was used in the concrete mixtures to obtain the early age strength of concrete.

Table-1. Physical properties of cement (53 grade OPC).

S. No.	Description	Values
1	Consistency	31%
2	Initial setting time	160 minutes
3	Final setting time	265 minutes
4	Specific gravity	3.29
5	Fineness of cement	5%
6	Cement mortar compressive strength at the	
	Age of 3 days	25.37 N/mm^2
	Age of 7 days	27.58 N/mm^2

Table-2. Sieve Analysis of Natural River sand and finer sand.

S. No.	Sieve size (mm)	Cumulative percentage of passing river sand	Cumulative percentage of passing finer sand
1	4.75	97.8	-
2	2.36	95.3	-
3	1.18	69	99.7
4	0.6	20.7	98.1
5	0.3	5.3	15.55
6	0.15	1.3	2.15
7	0.075	0.1	-
8	Pan	-	-

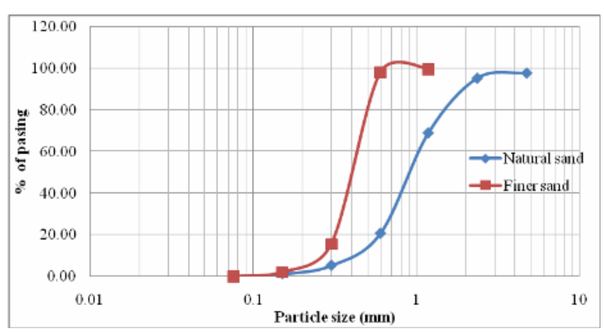

Figure-1. Sieve analysis for Natural River sand and finer sand.

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2.2. Concrete mix preparations

In this study a total of 10 different concrete mixtures were prepared using 0%, 10%, 20% and 30% using finer sand as replacement of regular sand (fine aggregate) and the composition of concrete mixtures are presented in Table-3. The conceptual mix design was adopted for arriving different with a target slump of 80 mm and a w/c ratio of 0.3. The water content for reference mix and various mix proportions was found to be 142 Kg/m^3 were established by keeping the fine aggregate to coarse aggregate ratio of 0.6 and w/c ratio of 0.3.

2.3. Casting of specimen

The ingredients were mixed in a rotating mixer of capacity 50 Kg for a period of 3 minutes. The Accelerator was then mixed thoroughly with the mixing water and added to the mixer and casted in a steel cube mould of standard size 100 x 100 x 100 mm and cylinders consisting of 100 mm diameter x 200 mm height and the concrete mixtures were compacted on a table vibrator. The surface finishing was done very carefully to obtain a uniform smooth surface. All the specimens were cured in the same curing tank to maintain the uniformity of the specimens and were tested for the mechanical properties i.e., compressive strength. Tests were performed at 7, 28 and 56 days of curing period.

2.3. Fresh concrete properties

Fresh concrete properties are slightly affected with the addition of finer sand in preparing concrete mixtures. The properties of fresh concrete slightly decrease due to fineness of finer sand and observed to increase the water demand compared to river sand replacement. Also, it is likely that the consistency of fresh concrete is affected by the presence of impurities, silt and very fine materials in finer sand.

2.4. Ultrasonic pulse velocity

Ultrasonic pulse velocity test method consists of measuring the time of travel of an ultrasonic pulse, passing through the concrete to be tested. The UPV test equipment consists of transmitting transducers for generating electromagnetic pulse and a receiving transducer for receiving these electronic pulses travelling inside the concrete. The electro magnetic pulse frequencies range from 45 to 54 KHz and the pulse can be recorded manually or electronically. The path length between transducer divided by time of travel gives the average UPV (km/sec) of wave propagation and compared the values as per BIS 1311 part 1 1978.

2.5. Rapid chloride penetration test

The size of the cylinders (100 mm diameter and 5 mm height of the cylinder) were cast for rapid chloride penetration resistance test (according to ASTM C 1202-97) covered the determination of the electrical conductance of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. The test method consisted of monitoring the amount of electrical current passed through cylinders for a 6-hours period that is log time and recorded time also maintained at every 30 minutes intervals. A potential difference of 60 voltage dc was maintained across the ends of the specimen, one of which was immersed in a sodium chloride solution (+ve charge), the other in a sodium hydroxide (-ve charge) solution. The total charge passed, in coulombs, was related to the resistance of the specimen to chloride ion penetration (as shown in Figure-2). Each of the presented test results is the average of three measurements.

Table-3. Mixture proportions of various concretes.

Mix ID	Finer sand (%)	Steel fibre (volume fraction %)					Cement	Fine Aggregate	Coarse Aggregate	Water	Accelerator (%)	F/C Ratio	W/C Ratio	Cement to total aggregate ratio
							Kg/m^3							
M	-	-	-	-	-	-	473	672	1113	142	1	0.6	0.3	0.26
M1A1		-	0.5	-	-		425	605	1113	142	1	0.6	0.3	0.26
M1A2	10	-	-	1	-		425	605	1113	142	1	0.6	0.3	0.26
M1A3		-	-	-	1.5		425	605	1113	142	1	0.6	0.3	0.26
M2B1		-	0.5	-	-		378	538	1113	142	1	0.6	0.3	0.26
M2B2	20	-	-	1	-		378	538	1113	142	1	0.6	0.3	0.26
M2B3		-	-	-	1.5		378	538	1113	142	1	0.6	0.3	0.26
M3C1		-	0.5	-	-		331	471	1113	142	1	0.6	0.3	0.26
M3C2	30	-	-	1	-		331	471	1113	142	1	0.6	0.3	0.26
M3C3		-	-	-	1.5		331	471	1113	142	1	0.6	0.3	0.26

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Figure-2. Rapid chloride permeability test apparatus.

3. TEST RESULTS AND DISCUSSIONS

3.1. Mechanical properties

Compressive strength of cubes, cylinder and splitting tensile strength results of various mix proportions of the concrete are presented in Table-4 and plotted in Figures 3 to 8. It could be observed that concrete mixtures made with finer sand exhibited the higher strength than plain concrete. The test results on the compressive strength of concrete using finer sand was found to increase with replacement level upto 20% and further increase at 30% had shown a negative trend. There is improvement of highest compressive strength for the mix id of M2B3 (44.2 and 33.1 MPa) i.e., 5% and 19% increase in compressive strength of cubes and cylinders, respectively at 20% replacement of finer sand after 7 days as compared to that of plain concrete with F/C ratio of 0.6 and 1% accelerator. Similar increase in compressive strength at 10% replacement of finer sand in concrete cubes and cylinders is observed. It can be noted from the test results that an optimal addition of finer sand (20%) showed a remarkable improvement in the compressive strength with improved mechanical properties. This can be evidently seen from the rate of hardening which increased with the increase in the fineness of finer sand.

3.2. Split tensile strength

A similar test results can be observed from the split tensile strength test as that of compressive strength where the optimal addition of finer sand showed better strength results. A highest average split tensile strength of 4.10 MPa (M2B3) was obtained for 20% of finer sand at 28 days, which is found to be higher than the split tensile strength (3.60 MPa) of plain concrete.

2.3. Ultrasonic pulse velocity

The test results were recorded for different curing days 7, 28 and 56 days as shown in Table-5. The ultrasonic pulse values were found to be showing good increase (USPV) for the concrete mixtures and found that more than plain concrete mixture and also values according to BIS 13311(part1): 1992 it comes under the zone of good quality of concrete in term of density and homogeneity, for all the values plotted with different mix id as shown in Figure-9. This essentially shows that the good quality concrete was obtained at much exhibited period of curing with the addition of accelerator and fibres.

3.3. Rapid chloride penetration resistance

The durability of concrete to resist the penetration of chloride ions is a critical parameter in determining the permeation properties of concrete which reflects the refined microstructure of concrete. The RCPT value of different percentage of finer sand at the age of 28 and 90 days is shown in Figure-10. It can be seen that the RCPT values decreases with increase in age 90 days. The RCPT value for normal concrete without finer sand was found to be less (600 and 310 coulombs) than that of 10% finer sand (710 and 400 coulombs) at 28 and 90 days except for 20 and 30% of finer sand. It is observed that cement type, w/c ratio, curing condition and testing method have effect on chloride permeability of concrete. The replacement level of 20% finer sand in the present study showed very less rapid chloride penetration resistance value thereby indicating good permeability on addition of finer sand in concrete.

3.4. Water absorption

It is evident from the experimental test result as shown in Figure-11 that the plain concrete showed that less water absorption (5.5%) and addition of finer sand in concrete mixtures led to increase the water absorption. However, the addition of 20% finer sand was observed to be 6.3% and 30% finer sand showed a water absorption of 6.8% thereby satisfies the codal provision and a 20% replacement of finer sand can be recommended could be considered acceptable.

Table-4. Compressive strength results of different mixture proportion of concretes.

Mix Id	W/C ratio	F/C ratio	Fibres %	Accelerator %	Avg. compressive strength for cubes (MPa)			Avg. compressive strength for cylinder (MPa)			Ratio of strength for 7 days of cylinder/cube	Split Tensile strength at 28 days (MPa)
					7 days	28 days	56 days	7 days	28 days	56 days		
M	0.3	0.6	0	1	42.1	43.6	44.1	27.8	29.2	32.1	0.66	3.60
M1A1	0.3	0.6	0.5	1	39.3	40.2	42.7	25.9	27.8	28.9	0.66	3.20
M1A2	0.3	0.6	1	1	41.8	42.5	43.4	26.4	28.1	29.7	0.63	3.15
M1A3	0.3	0.6	1.5	1	42.5	43.3	44.8	28.3	29.6	30.3	0.67	3.40
M2B1	0.3	0.6	0.5	1	39.9	42.1	43.6	29.7	30.9	32.4	0.74	3.85
M2B2	0.3	0.6	1	1	42.1	43.9	47.5	30.4	31.5	33.3	0.72	3.70
M2B3	0.3	0.6	1.5	1	44.2	45.6	50.8	33.1	34.7	39.5	0.75	4.10
M3C1	0.4	0.6	0.5	1	37.4	39.2	40.7	28.9	29.5	31.7	0.77	3.35
M3C2	0.4	0.6	1	1	38.5	40.3	41.9	29.4	30.3	32.4	0.76	3.10
M3C3	0.4	0.6	1.5	1	37.8	39.4	42.2	30.9	31.8	33.9	0.82	2.90

Table-5. Ultrasonic pulse velocity of concrete for different curing days.

Mix Id	Ultrasonic pulse velocity (Km/sec)		
	7 days	28 days	56 days
M1	3.30	3.49	3.71
M1A1	3.30	3.50	3.67
M2A2	3.43	3.61	3.78
M1A3	3.52	3.69	3.82
M2B1	3.40	3.60	3.79
M2B2	3.51	3.61	3.83
M2B3	3.40	3.52	3.91
M3C1	3.32	3.56	3.64
M3C2	3.37	3.51	3.76
M3C3	3.40	3.52	3.68

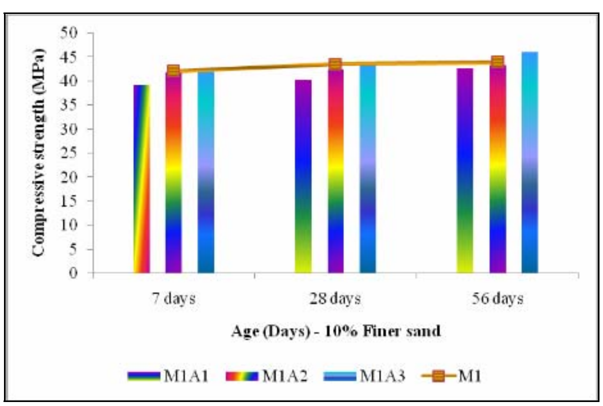

Figure-3. Compressive strength of concrete cube with 10% finer sand for various mixture proportions.

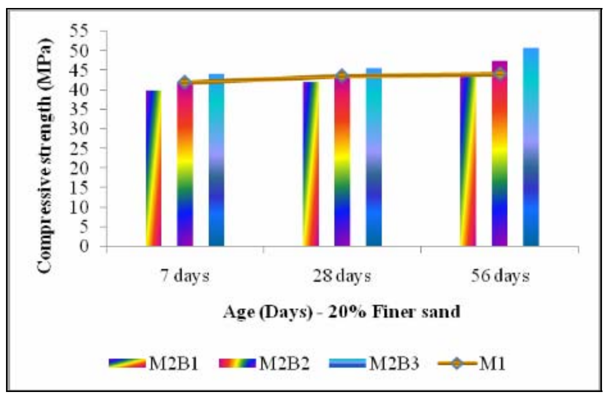

Figure-4. Compressive strength of concrete cube specimens with 20% finer sand for various mixture proportions.

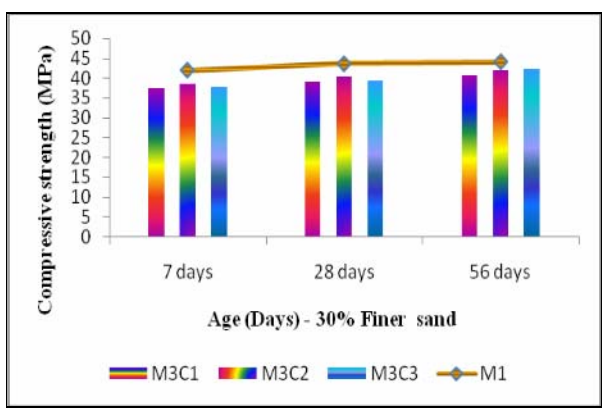

Figure-5. Compressive strength of concrete cube test with 30% finer sand for various mixture proportions

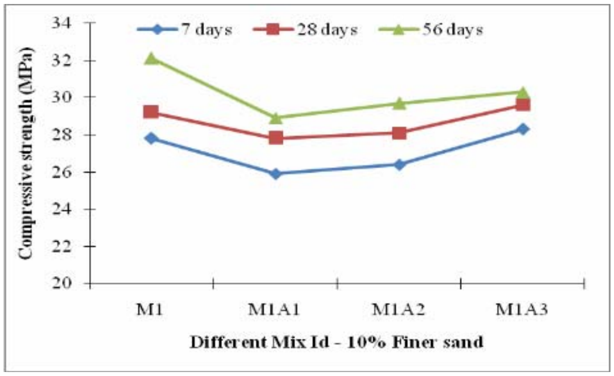

Figure-6. Compressive strength of concrete cylinder with 10% finer sand for various mixture proportions.

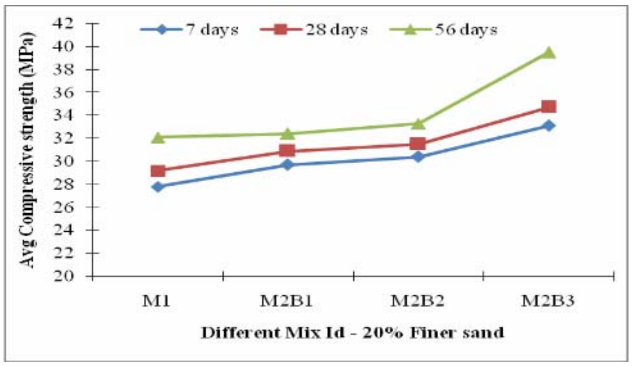

Figure-7. Compressive strength of concrete cylinder with 20% finer sand for various mixture proportions.

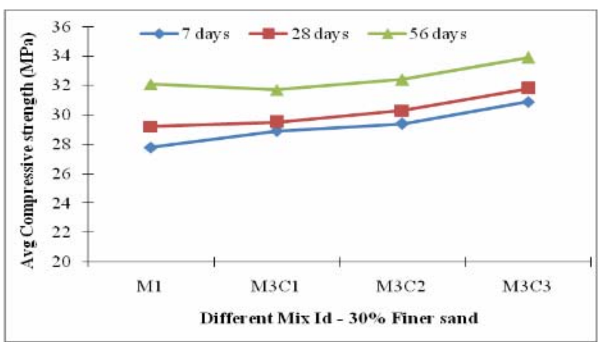

Figure-8. Cube compressive strength of concrete cylinder with 30% finer sand for various mixture proportions.

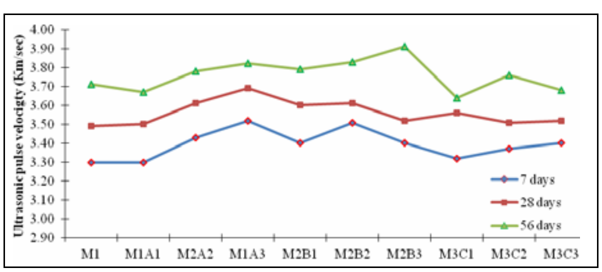

Figure-9. Ultrasonic pulse velocity test for various mix id.

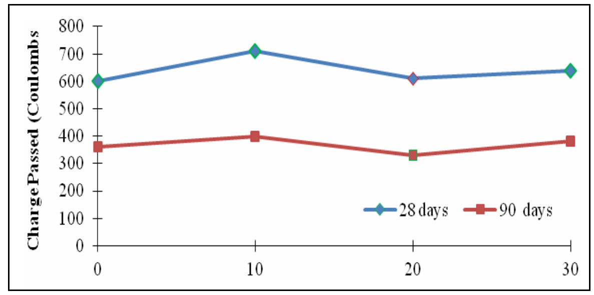

Figure-10. Variation of charge passed for different percentage of finer sand.

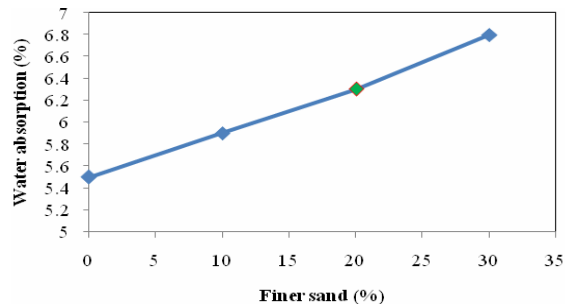

Figure-11. Effect of finer sand on water absorption ratio at 28 days.

4. CONCLUSIONS

The following conclusions are drawn from this experimental test results:

- Compared to natural sand, finer sand was found to have superior concreting properties since it consists of fine grained particles.
- Partial replacement level of finer sand upto 20% showed an increase in strength properties of all concrete mixtures at 7 days and 28 days.
- The improvements in the strength properties of concrete at both fresh and hardened stages were found to be good when finer sand was replaced instead of river sand.
- The effect of fine aggregate to coarse aggregate ratio (F/C) of 0.6 and water to cement ratio (W/C) of 0.3 was observed to be showing good improvement in the strength gain.
- The effect of accelerator was found to improve the setting properties of all the concrete mixes used in the study.
- Addition of finer sand (20%) increased the ultrasonic pulse velocity values at various curing ages and showed a reduction in the chloride ion penetration in concrete, which shows that concrete have developed a refined microstructure.
- However, the higher replacement of 30% of finer sand caused a significant reduction in compressive strength compare to normal concrete and can be restricted upto 20%. The effective utilization of finer sand can be recommended wherein the large depletion of river

sand is anticipated and also where high fineness of sand is required for producing self leveling concrete.

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