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Effect of Steel Fibers on the Performance of Concrete Made with Recycled Concrete Aggregates and Dune Sand

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Abstract: ***This paper aims to develop and evaluate the performance of concrete made with recycled concrete aggregates (RCA) and dune sand (DS) in addition with steel fibers (SF). This work is mainly intended to find the effective ways to reutilize the recycled concrete aggregates as coarse aggregate and due to sand demand dune sand were used as a fine aggregate. Different mechanical and durability properties of recycled concrete aggregates (RCA) and dune sand (DS) concrete mixtures were evaluated. To ensure the properties of cement, fine aggregate, coarse aggregate, recycled concrete aggregate and dune sand preliminary test were determined. Mix design is formulated based on its properties and requirements. Experimentation has been done by using M25 grade concrete. Ordinary Portland cement is used. Fine aggregate and coarse aggregate were partially replaced by recycled concrete aggregates and dune sand at different proportions (25%, 50%, 75%) in addition with 0.25% of steel fibers. Various strengths such as tensile strength, compressive strength, flexure strength and modulus of elasticity are determined. In particular for cube different tests such as non-destructive test (NDT), sorptivity, permeability and acid test has been done. It has been observed that the M2 mix (50% of recycled concrete aggregates and dune sand) has produced better results comparatively.***

Keywords: Steel fibers, Dune sand, recycled concrete aggregates, hardened properties and durability properties.

I. INTRODUCTION

Concrete is probably the most common construction material in the world. Concrete is made up of cement, fine aggregate, coarse aggregate and water. In this study, major attention has been devoted to use recycled concrete aggregates as partial replacement of coarse aggregates and dune sand as partial replacement of fine aggregate by various percentages in addition with steel fibers. Consequently, the increasing demand for aggregates raises concerns of the depletion of their current sources and the availability of new sources. At the end of its service life, a concrete structure is demolished, creating massive amounts of construction and demolition waste (CDW). Recycled concrete aggregates (RCA) were obtained from crushed concrete structures with an unknown strength. Sand is a major component in concrete mixes. Sand from natural gravel deposits or crushed rocks is a suitable material used as a fine aggregate in concrete production. Locally-abundant dune sand was employed as fine aggregates to emphasize the contribution towards sustainable construction. Steel Fibers (SF) were added in the order of 0.25% by volume, to RCA-based concrete mixes in an effort to improve various hardened properties. The addition of SF is used to increase the strength characteristics in concrete.

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II. MATERIALS

A. Cement

Cement is the most important constituent of concrete, it forms the binding medium for the discrete ingredients made out of naturally occurring raw materials. Cement comes in various types and chemical compositions. "Ordinary Portland Cement" 43 Mega Pascal grade of cement is used for concrete.

B. Fine aggregate

Fine aggregate passing through IS 4.75mm sieves conforming to zone II as per IS: 383-1970.

C. Coarse aggregate

Crushed stone and natural gravel are the common materials used as coarse aggregate for concrete. For coarse aggregate crushed 20mm normal size graded aggregate was used. The grading of aggregates should be conformed to the requirements as per IS: 383-1970.

D. Dune sand

The dune sand used in the work was taken from the site of uveri in kanyakumari. Dune sand is a mount, hill or ridge of sand that lies behind the part of the beach affected by tides. Although the particle size of Dune Sand (DS) is different depending on the region, it is very fine, mostly in the range of 0.15–0.6 mm.

Fig.1. Dune sand

E. Recycled concrete aggregate

One of the alternative sources of coarse aggregates is recycled concrete aggregate (RCA) which are obtained from the processed construction and demolition (CDW) wastes.

Fig.2. Recycled concrete aggregate

F. Steel fibers

Steel fiber for concrete is defined as short, discrete lengths of steel fibers with an aspect ratio (ratio of length to diameter) from about 20 to 100, with different cross-sections. A certain amount of steel fiber in concrete can cause qualitative changes in concrete physical property, greatly increasing resistance to cracking, impact, fatigue, and bending, tenacity, durability, and other properties.

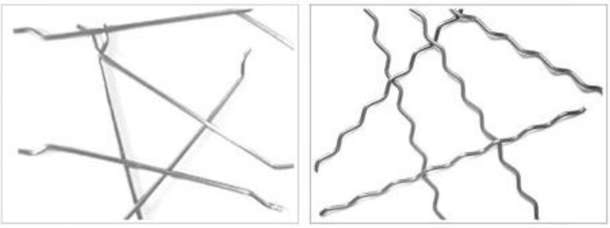

Fig.3. Steel fibers

G. Chemical admixture

The super plasticizer is a chemical admixture which helps in increasing workability of high strength concrete. The super plasticizer used in the casting will be Fosroc Conplast SP430 is a chloride free super plasticizer admixture based on selected sulphonate naphthalene polymers.

Fig.4. Super plasticiser

Table I: Properties of chemical admixture

S.No	Properties	Results
1	Colour	Brown liquid
2	Specific gravity	1.18
3	Chloride content	Nil to BS5075/BS:EN934
4	Air entrainment	Less than 2% additional air entrained at normal dosages
5	Compatibility	Conplast SP430 suitable for Portland cements
6	Health and safety	Conplast SP430does not fall in to hazard classification
7	Fire	Conplast SP430 is water based and non-flammable

Table II: Physical properties of materials

S.No	Materials	Physical Properties	Result
1	Cement	Specific gravity	3.15
		Consistency	32%
		Initial setting time	45mins
		Final setting time	7 hours
2	Fine aggregate	Specific gravity	2.60
		Fineness modulus	3.43
		Water absorption	0.6%
3	Coarse aggregate	Specific gravity	2.80
		Fineness modulus	6.76
		Bulk density	1900Kg/m^3
		Water absorption	0.5%
4	Dune sand	Specific gravity	2.77
		Fineness modulus	3.73
		Water absorption	0.3%
5	Recycled concrete aggregates	Specific gravity	2.70
		Fineness modulus	6.63
		Bulk density	1400Kg/m^3
		Water absorption	2.6%

III. MIX DESIGNATION

In this investigation concrete mix design was designed as per the guidelines specified in **IS 10262-2019**. In this research work, Ordinary Portland Cement, fine aggregate, coarse aggregate, recycled concrete aggregates and dune sand are to be used to make concrete (M_{25}).

Table III: Mix ratio

Cement	Fine Aggregate	Coarse Aggregate
398	782	1118
1	1.96	2.85

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Table IV: Mix percentage

Mix Ratio	Cement (%)	Coarse Aggregate (%)		Fine Aggregate (%)	
		Normal Sand (NS)	Dune Sand (DS)	Coarse Aggregate (CS)	Recycled Concrete Aggregate (RCA)
M	100	100	0	100	0
M1	100	75	25	75	25
M2	100	50	50	50	50
M3	100	25	75	25	75

Table V: Mix proportion

Mix Ratio	Cement (Kg/m^3)	Coarse Aggregate(Kg/m^3)		Fine Aggregate(Kg/m^3)	
		Normal Sand (NS)	Dune Sand (DS)	Coarse Aggregate (CS)	Recycled Concrete Aggregate (RCA)
M	398	782	0	1118	0
M1	398	586.5	195.5	838.5	279.5
M2	398	391	391	559	229
M3	398	195.5	586.5	279.5	838.5

IV. EXPERIMENTAL TEST RESULTS

A. Compression Test

The compressive strength test was conducted in cubes. The size of cube is 150mm × 150mm × 150mm. The casted cube should be cured for 28 days and 56 days. Compression tests are used to determine the material which can sustain over a period under a load.

Table VI: Compression strength

S.No	Mix	Average Compressive Strength (N/mm^2)	
		28 days	56 days
1	M	25.03	26.15
2	M1	26.31	27.27
3	M2	29.65	30.94
4	M3	24.15	25.01

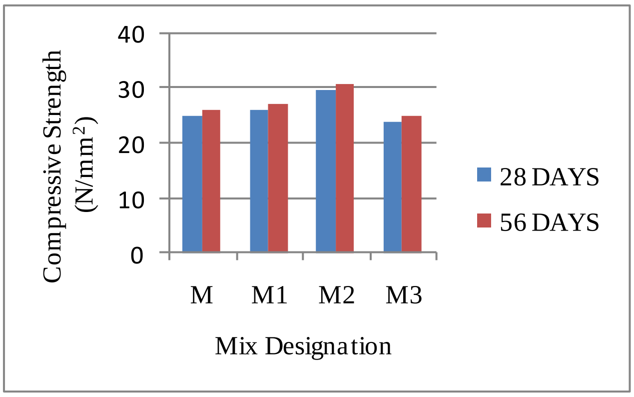

Fig.5. Compression strength

B. Split Tensile Strength Test

The split tensile test was completed according to ASTM C496-90. The size of cylinder is 150 mm diameter and 300 mm height. After casted the cylinder specimen, the moulds were compacted utilizing table vibrator. The casted cylinders should be cured for 28 days and 56 days. A method of determine the tensile strength of concrete using a cylinder which splits across the vertical diameter.

Table VII: Split tensile strength

S.No	Mix	Average Split Tensile Strength (N/mm^2)	
		28 days	56 days
1	M	3.05	3.24
2	M1	3.11	3.37
3	M2	3.22	3.95
4	M3	2.94	3.08

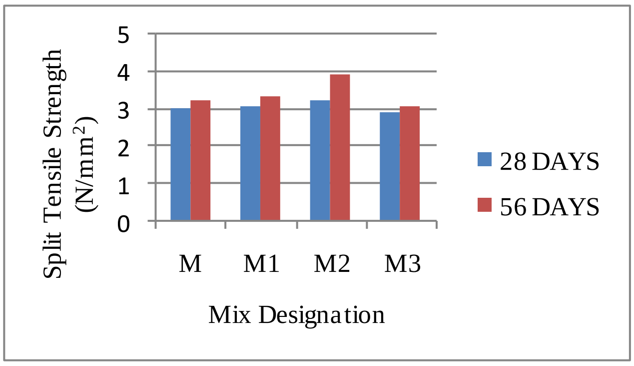

Fig.6. Split tensile strength

C. Flexural Strength

The flexural test was executed according to ASTM C348-14. The size of prism 500 mm × 100mm × 100 mm. The specimen should be casted and it is cured for 28 days and 56 days. The specimens were exposed to flexural test by applying central point load in a universal testing machine.

Table VIII: Flexural strength

S.No	Mix	Average Flexure strength (N/mm^2)	
		28 days	56 days
1	M	4.20	4.95
2	M1	4.49	5.20
3	M2	5.22	5.94
4	M3	4.12	4.82

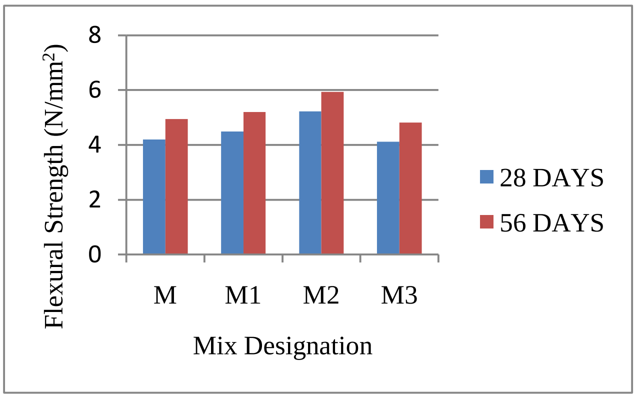

Fig.7. Flexural strength

D. Modulus of elasticity

The cylinder can withstand higher stress, but the concrete will become brittle and sooner cracks will appear. It will indicate the higher elastic modulus. Low elastic modulus indicates that it will bend and deform very easily. High elastic modulus at early ages will result in a higher potential for cracking. Strain can arise from causes other than applied stress like shrinkage.

Table IX: Modulus of elasticity

S.No	Mix	Experimental result (N/mm^2)	Predicted as per IS 456-2000 (N/mm^2)
1	M	26102.8	25220.7
2	M1	27908.14	28470
3	M2	30587.1	28900
4	M3	25533.9	24604.9

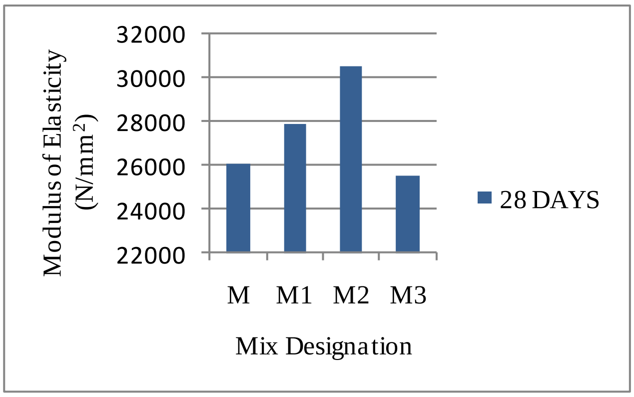

Fig.8. Modulus of elasticity

E. Non Destructive Test

REBOUND HAMMER TEST

Rebound hammer test is used to assess the quality of concrete and to determine the in-situ strength of concrete. Rebound hammer test is conducted on 150mm size cube specimen.

Table X: Rebound hammer

S.No	Mix	Average Compressive Strength (N/mm^2)	Remarks (As Per Is 13311-1992)
1	M	31	Good layer
2	M1	32	Good layer
3	M2	34	Good layer
4	M3	25	Fair

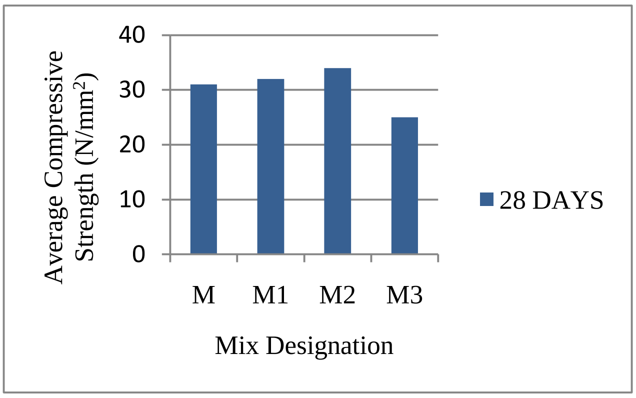

Fig.9. Rebound hammer

ULTRASONIC PULSE VELOCITY

UPV test is used to assess the quality of concrete. UPV test is conducted on 150mm size cube as per IS 13311-1992 and grade of the concrete as excellent, good, medium, doubtful. The results of different concrete were found out at 28 days.

Table XI: Ultrasonic pulse velocity

Mix	Travel Time (μs)	Length Travelled (mm)	Pulse Velocity (mm/μs)
M	Direct	150	3.75
M1	Direct	150	3.33
M2	Direct	150	3.84
M3	Direct	150	3.26

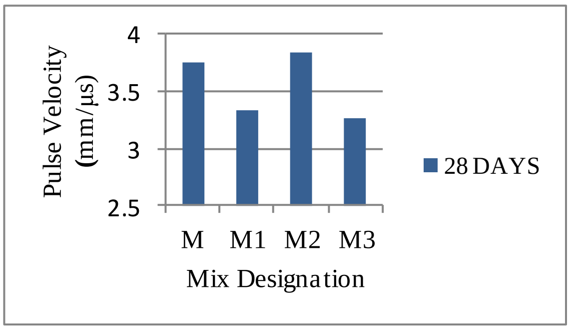

Fig.10. Ultrasonic pulse velocity

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F. Sorptivity Test

Sorptivity is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The sorptivity test is conducted on 150mm size cube at 28 days.

Table XII: Sorptivity

S.No	Mix	Sorptivity ($mm/min^{0.5}$)
1	M	0.001010
2	M1	0.001392
3	M2	0.00039
4	M3	0.00879

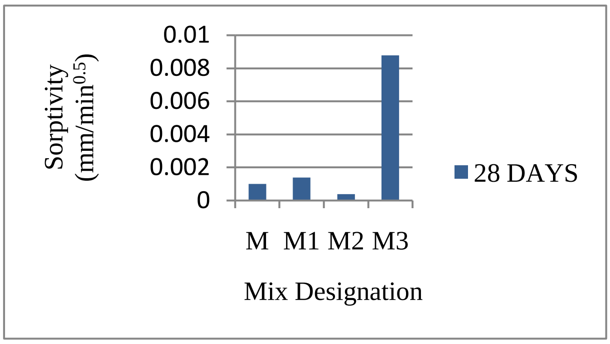

Fig.11.Sorptivity

G. Acid Resistance Test

In H_2SO_4, the maximum percentage weight loss and compressive strength is observed for the 150mm size cube specimen at 28 days.

Table XIII: Percentage weight loss

S.No	Mix	5% of H_2SO_4 solution
1	M	7
2	M1	6.5
3	M2	8.54
4	M3	5.3

Table XIV: Percentage strength loss

S.No	Mix	5% of H_2SO_4 solution
1	M	28
2	M1	32.5
3	M2	26.3
4	M3	35.6

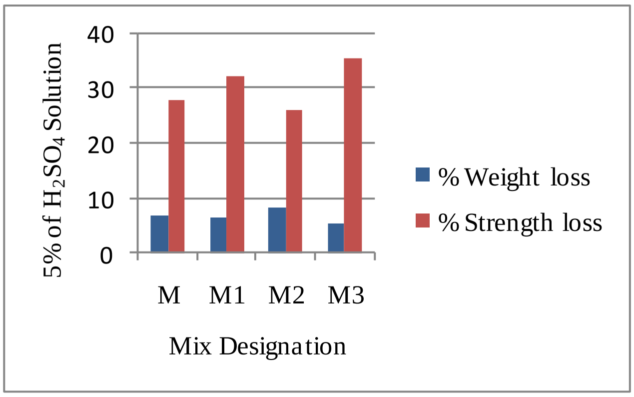

Fig.12. Acid resistance

H. Voids Permeability Test

As per ASTM C-642-06, the permeable voids are determined at 28 days in 150mm size cube specimen.

Table XV: Voids Permeability

S.No	Mix	Volume of permeable voids (%)
1	M	3.0
2	M1	2.8
3	M2	2.5
4	M3	3.2

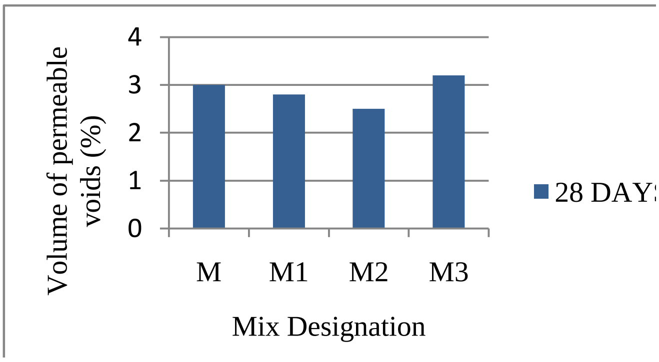

Fig.13. Voids permeability

V. CONCLUSION

Different hardened and durability properties of plain and steel fiber concrete made of recycled concrete aggregate and dune sand were examined in this paper.

1. The compressive strength of cubes shows that, the M2 mix gives more strength when compared with conventional concrete at the age of 28 and 56 days.
2. The split tensile strength of cylinder attains maximum at mix M2 compared with other specimens at 28 and 56 days of curing.
3. The flexural strength of concrete also increases in M2 mix when compared with conventional concrete.
4. The M2 mix attained higher strength in the modulus of elasticity at the early age of 28 days.
5. It has been observed that the mix M2 (50% of recycled concrete aggregates and dune sand) with 0.25% of steel fibers has produced better results comparatively.
6. The recycled concrete aggregate (RCA) replacement increased the water absorption and sorptivity but decreased the ultrasonic pulse velocity.
7. The addition of Steel fibers (SF) improved the hardened properties of recycled concrete aggregates (RCA) than the normal coarse aggregates.

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