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Eco Friendly – Manufactured Sand: An Alternative Construction Material for Concrete

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ABSTRACT

The depletion of natural sand creates scarcity of river sand near to the worksite and also increased its cost of conveyance many folds. The non-availability of natural sand creating the major environmental issues such as depletion of natural water table, drought of water, etc. Hence to substitute for natural river sand for the construction industry needs an alternative material to be found out. Hence an attempt has been made in this present work to use the eco-friendly machine made Granite rock sand from vertical shaft impact crushers called manufactured sand (M-sand) as fine aggregates. This paper presents an experimental investigation on strength and durability properties of the concrete made of eco-friendly sand replaced by natural sand and the results were compared with the conventional said concrete. Concrete mix design was carried out as per Indian standard specification. From the current investigation, strength properties shows that the compressive strength, modulus of rupture and split strength is increases nearly 20% more than the conventional concrete. Concrete with manufactured sand possess superior durability performance than the conventional sand concrete.

KEY WORDS: Durability Properties, Manufactured sand, Mechanical Properties, Super plasticizer.

1. INTRODUCTION

In developing countries like India, the development of infrastructural facilities such as construction of major expressways, bridges, elevated corridors, metro Rail systems, tunnelling works, developing major ports, power projects and industrial structures etc., are inevitable. To meet the above requirements, concrete plays a vital role to develop infrastructural facilities for a specified life span. It is essential to make the good quality of concrete to meet the specified life span duration of the structure under various exposure conditions. On other hand the cost component of natural river sand in concrete is increasing due its non-availability. Hence it is very vital to search an alternative material for concrete constructions. M-sand is used in this present experimental work for medium grade concrete and this M-sand is manufactured with hard granite stone boulders crushed in vertical shaft impact crushers. A lot of research works were done with crushed stone, manufactured sand Ilangovan (2008) reported that the replacement of natural sand in quarry rock dust as full replacements is possible. Babu (1992), Nagaraj and Zahda Banu (1996) and Narashiman (1998), reported that the consumption of cement, cost of concrete made with quarry rock dust, compression strength of concrete were studied and reported. Sahu (2003), Ilangovan and Nagamani (2006), studied and reported that the significant increase is compressive strength, split tensile strength with 40% replacements of sand by quarry rock dust in concrete and full replacements is also possible in concrete with proper treatments of quarry rock dust before use in concrete construction. Wakchaure (2012) reported that the compressive strength, indirect split tensile strength and modulus of rupture of concrete with artificial sand as fine aggregates was increases from 2.81% to 10%. Chitlange (2008) studied and reported that the use of admixture is necessary in all grades of concrete to restrict water cement ratio to 0.50. Guptha (2006) studied and reported that the manufactured sand is satisfying the requirements of fine aggregates such as strength, shape, gradation, and angularity. Jayaraman and Senthil Kumar (2013) studied and reported that by optimization of fully replacements of natural sand by manufactured sand with nano silica in high performance concrete had increased compressive strength, tensile strength and modulus of rupture of concrete proportionate to increase in percentage of nano silica. The main objectives of current study is to investigate the mechanical and durability properties of hardened concrete with manufactured sand as fine aggregates and compared the results with conventional sand concrete, and to find out the optimum percentage of manufacture sand replaced as fine aggregates.

2. MATERIAL AND METHODS

Materials:

Cement: Ordinary port land cement 53 Grade (Penna Super) is used for the present work confirming to IS: 12269-1987.

Fine Aggregates:

Natural River sand: Natural river sand obtained from the river Cauvery near Karur, which is sand hub for Tamil Nadu is used. The physical properties are reported in Table.1.

Manufactured Sand: The Manufactured sand obtained from vertical shaft Impact Crusher at Salem (SRC M-Sand), Tamil Nadu was used. Fine aggregates are confirming to zone II of 383-1970 as per the details of Sieve analysis. The physical properties are presented in Table.1.

Coarse Aggregates: Crushed natural granite stone aggregate of size 20mm and 12.50mm were used by blending the aggregates by trial and error method to give good gradation as per standards. The physical properties of course aggregates are presented in Table.1.

Water: Fresh potable water having the p^Hvalue of 7 is used for making up the concrete specimen and also for curing the concrete samples.

Super Plasticizer: Super Plasticizer is used work is CERACEM 300 RS(G) Grade Confirming to the Standards.

Mix proportions: There is no specific method of design concrete mixes with manufactured sand as fine aggregates available. Hence the Design of mix is done using IS: IS : 456-2000 and 10262-2009. Then Natural sand was replaced by Manufactured sand with 10% incremental increase up to 100% replacements. The mix Propertions for M30 Grade of concrete for vaying replacements of fine aggregates with M-sand is presented in Table.2.

Specimen and Test Details:

Mechanical Properties: Concrete cubes of size 150mm x 150mm x 150mm used for compressive strength, Concrete cylinders of size 150mm x 300mm used for indirect tensile strength of concrete and concrete prism of size 100mm x 100mm x 500mm used for modulus of rupture study. The concrete specimens are cast for M30 grade Concrete with 20mm graded aggregates and natural sand as fine aggregates, and this concrete is said to be the controlled concrete and is denoted as M1.It is replaced by manufactred sand with 10% incremental increase and the mix are denoted as M2, M3, M4, M5, M6, M7, M8, M9, M10, and M11 respectively. The workability of fresh concrete is measured interms of slump in accordance with IS:1199-1959. The ingredients of concrete such as coarse aggregates, fine aggregates, water and admixtures are properly mixed in the concrete mixer machine till the unifrom consistency is achieved. For each mix specimens are casted and tested after 7, 14 & 28 days. The concrete cube specimens are properly compacted on a Table vibrator, and the cylinders are casted and compacted with needle vibrator. Similarly the concrete prisms are also compacted with needle vibrator. The mechanical properties such as compressive strength, split tensile strength and modulus of rupture are calculated as per standards IS: 516-1959.

Table.1. Physical Properties of the Aggregates

S.No	Property	Coarse Aggregate	Fine Aggregate	
			M-sand	Natural Sand
1	Specific gravity	2.70	2.45	2.60
2	Bulk Density kg/m^3	1510	1556	1460
3	Fineness modulus	6.67	3.54	3.44
4	Water absorption (%)	0.85	1.10	1.00
5	Moisture Content (%)	0.85	1.15	1.10
6	Fineness particles less than 150 microns	-	6.80	2.60
7	Sieve analysis	-	Zone II	Zone II
8	Aggregate Impact value	12.50	-	-

Table.2. Mix Proportions details

S.No	Mix Details	Cement (Kg/cum)	Natural sand (Kg/cum)	M-sand (Kg/cum)	Coarse Aggregates (Kg/cum)	Water/ Cement	SP
1	M1	390	544	0	1277	0.40	0.60%
2	M2	390	490	540	1277	0.40	0.60%
3	M3	390	435	109	1277	0.40	0.60%
4	M4	390	381	163	1277	0.40	0.60%
5	M5	390	326	218	1277	0.40	0.60%
6	M6	390	272	272	1277	0.40	0.60%
7	M7	390	218	326	1277	0.40	0.60%
8	M8	390	163	381	1277	0.40	0.60%
9	M9	390	109	435	1277	0.40	0.60%
10	M10	390	54	490	1277	0.40	0.60%
11	M11	390	0	544	1277	0.40	0.60%

Durability Properties: Durablity properties of the concrete in the present study is to test the concrete with M-sand for water absorption, acid attack, alkaline attack, rapid chloride permeability test, and sorptivity with conventional sand and manufactured sand. Concrete cube specimen of size 150mm x 150mm x 150mm are cast for properly evaluate the water absorption, acid and alkaline resistence test.The 100mm diameter and 50mm thick cylinders are cast to find out the rapid chloride permeability and sorptivity test. The concrete specimens are properly casted and cured for the required number of days before the sample is taken for the durability tests.The durability tests are carried out as per the standards and specifications.

3. RESULTS AND DISCUSSIONS

Workability Properties: The workability of concrete is measured using slump cone. Results for the different mixes are measured and presented in table.3 with using super plasticizer. The slump value increases for all mixes with super plasticizer.

Table.3. Slump cone test

S.No	Mix	Slump (mm)
1	M1	82
2	M2	86
3	M3	89
4	M4	89
5	M5	90
6	M6	92
7	M7	94
8	M8	96
9	M9	96
10	M10	98
11	M11	100

Mechanical Properties:

Compressive Strength: Figure.1 shows the 7 days, 14 days and 28 days compressive strength of casted concrete specimen. Conventional concrete exhibits the target mean strength. Test results revealed that the M-sand replaced concrete displays good results than the conventional one.

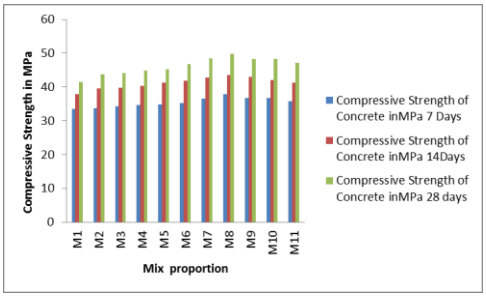

Figure.1. Compressive Strength of concrete after 7, 14 and 28 days

Split Tensile Strength: The M-sand replaced concrete displays better split tensile strength than the conventional one. Figure 2 demonstrates the 7 days, 14 days and 28 days split tensile strength of casted concrete specimen. Concrete with 70% M-sand replacement shows the better result than the other mixes.

Figure.2. Split Tensile Strength of concrete after 7, 14 and 28 days

Modulus of rupture: Figure 3 shows the 7 days, 14 days and 28 days Modulus of rupture of casted concrete specimen. As demonstrated in split tensile, concrete with 70% of M-sand replacement shows the better Modulus of rupture value than other mixes.

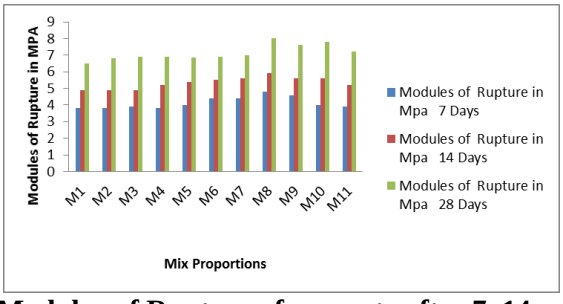

Figure.3. Modulus of Rupture of concrete after 7, 14 and 28 days

Durability Properties:

Water Absorption: Figure 4 shows the results obtained from water absorption test. Result revealed that the presence of M-sand in the concrete reduces the water absorption capability.

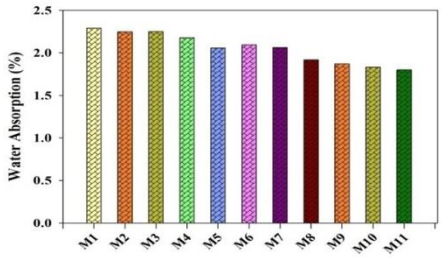

Figure.4. Water Absorption test

Acid and Akaline Attack: To observe the behavior of M-sand replaced concrete under severe environment, acid attack and alkaline attack test are carried out on the test specimen. Figure.5 and Figure.6 shows the weight loss results of acid attack and alkaline attack on specimen after 30 days, 56 days and 90days acid and alkaline curing. The result shows that the acid resistance and alkaline resistance of the manufactured sand is more than the conventional sand concrete.

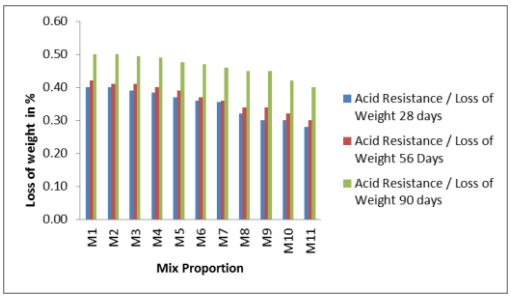

Figure.5. Acid Attack test

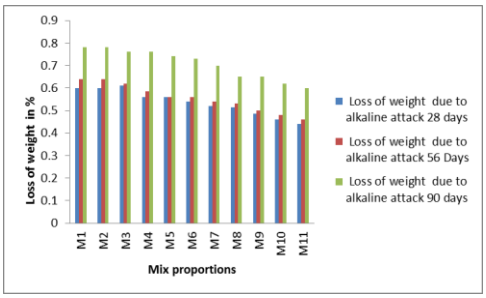

Figure.6. Alkaline Attack test

Figure.7. RCPT Setup

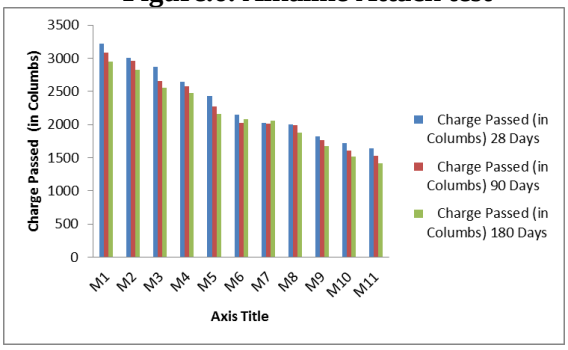

Figure.8. RCPT Results for M30 Grade Concrete

Figure.9. Sorptivity Test on M-sand Specimen

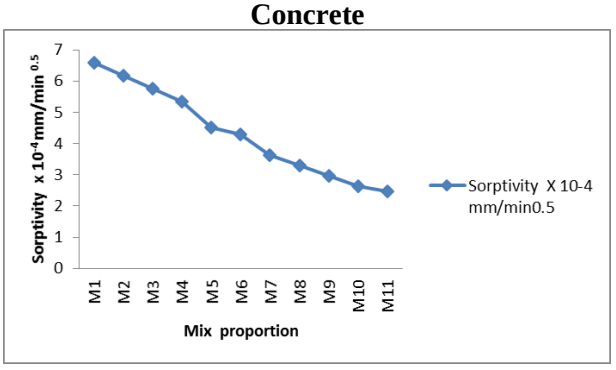

Figure.10. Sorptivity Test Results for M30 Grade Concrete

Rapid Chloride Penetration Test: RCPT test was made as per ASTM C 1202, on all the different mixes. Figure.7 shows the Rapid Chloride Penetration Test (RCPT) setup. RCPT test is carried out on all the different mixes and the results are shown in the Figure.8. It is observed that charge passed in conventional mix is higher than the concrete with manufactured sand mixes. Up to 60 % replacement of M-sand comes within the moderate permeability zone and beyond 60% replacement gives low permeability. Hence forth the penetration of chloride ion in the conventional sand concrete is more than the M Sand concrete, in otherwise the Manufactured sand concrete is less chloride ion penetration values than the natural sand concrete.

Sorptivity: Figure.9 and Figure. 10 shows the sorptivity test specimen setup, and the sorptivity test results for M30 grade Concrete respectively. The results demonstrated that all the mixes are performed better. Results revealed that the sorptivity in concrete with M sand shows lesser than the conventional sand concrete due to the fines and microfines present in the manufactured sand.

4. CONCLUSIONS

The following are the conclusions drawn from the present investigation.

- The Physical properties of manufactured sand satisfies the requirement of the specifications for natural sand as per IS 383-1970.
- Workability of the concrete increases with increase in M-sand replacement which can be kept control by varying the chemical admixtures dosage.
- The compressive strength of M30 grade concrete with M sand increases by 12.80% at 7days, 15.03% at 14 days and 19.78%at 28 days compared to conventional concrete at 70% replacement level.
- The split tensile strength of M30 grade concrete with M sand increases by 16.19% at 7days, 17.39% at 14days and 19.79% at 28days than the conventional sand concrete at 70% replacement level.
- The modules of rupture of concrete with M sand increases by 21.05% at 7 days, 20.41% at 14 days and 23.08% at 28 days than the conventional sand concrete at 70% replacement level.
- Natural sand if replaces by 100% with manufactured sand in M30 grade concrete also gives the increase in strengths than the conventional sand concrete and the Flexural strength obtained as per the test is more than the value as specified in IS:456-2000.
- The Durability of the concrete with M-sand was assessed and the result shows the healthier performances.
- The Durability of the concrete for water absorption test results shows that the percentage water absorption is lesser in manufactured sand than the conventional sand concrete.
- The acid attack test and sulphate resistance of the M sand shows lower at all replacement level for M30 Grade concrete than the natural sand concrete. This clearly states that the durability of M sand concrete in acid resistance and sulphate resistance is higher than the conventional concrete.
- The RCPT Values of the M-sand concrete up to 60% replacement exhibit moderate chloride ion penetration and beyond which exhibits low chloride ion penetration
- The sorptivity or the surface water absorption of concrete with manufactured sand shows good performance up to 100% replacement level.
- Aforesaid analysis clearly reveals that the manufactured sand could be used as an innovative replacement material for fine aggregate in concrete even up to 100%.

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