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Effect of Rock Fractured Materials Replacement in Concrete-Its Strength and Durability Study

K M GOPALAKRISHNAN[1] AND R MURUGESAN[2]

[1]*Department of Civil Engineering, Erode Sengunthar Engineering College, Thudupathi, Erode – 638 057, Tamil Nadu, India*

[2]*Department of Civil Engineering, Institute of Road and Transport Technology, Erode – 638 316, Tamil Nadu, India*

Email: *gkrishnan004@gmail.com, murugesan_raamin@yahoo.com*

Abstract: Concrete as a construction material has a large potential all over the world. The resources required for manufacturing a good quality of concrete is delpeting year after year on one side. On the other side dumping of waste produced by industries create serious environmental problems in a global point of view. The fast and vast infrastructural developments in construction demand huge quantity of natural sand for concrete manufacturing. Dwindling resources the natural sand pose environmental problem and hence government restrictions on sand quarry resulted in scarcity and significant increase in its cost. This not only increases the cost of construction but also delays the project due to non-availability of natural sand. These problems have led to the search for alternative materials for fine aggregate that are eco-friendly besides being inexpensive. One such material is manufactured sand (M Sand), produced by crushing, normally using a Vertical Shaft Impactor (VSI) to make cubical grains. The spiraling costs of river sand have increased the cost of construction significantly in the past two decades. This research experimentally investigates the effect of M-Sand in M30 grade structural concrete to attain higher compressive strength and better workability with super plastizicer. Compared to the conventional, the results are superior with better quality, uniformity and high resilience. The durability studies indicate that the replacement ratios are moderate in electrolytic analysis, high density, less voids in harden state. Usage of M-Sand can overcome the defects occurring in concrete such as honey combing, segregation, voids, capillary, etc. Manufactured sand obtained after technical process is found suitable to use in structural components.

Keywords: *Manufactured Sand, Natural Fine Aggregate, Compressive strength, Acid attack, Chloride permeability, Sorptivity.*

1. Introduction

With the worldwide decline, the availability of construction sand (river sand) along with the environmental pressure is to reduce the extraction of sand from rivers. With the ban on sand mining implemented by different states and with the increasing demand for river sand for construction works, many civil engineers have expressed the need to promote the use of manufactured sand in the construction industry. As per reports, manufactured sand is widely used all around the world and technicians of major projects around the world insist on the compulsory use of manufactured sand because of its consistent gradation and zero impurity [16]. There is a need for ‘clean sand’ in the construction from the durability point of view. Indiscriminate mining and quarrying is posing threat to the environment [7]. As the demand for natural river sand is surpassing the availability, there is a fast depletion of natural sand sources. [14] Replacement of natural sand to the artificial sand can be used for making good concrete. It helps in conservation of natural sand. [6] Sharp edges of the particles in artificial sand provide better bond with the cement than the rounded part of the natural sand. Manufactured sand is the answer for this problem especially when some states have already banned the use of river sand for construction. This sand has been defined well in IS 383-1987[3]. There is a need to study the shape characteristics of manufactured sand, effect of micro fines on concrete characteristics such as modulus of elasticity, shrinkage, creep etc., Concrete mix proportion by resorting to particle packing approach is the need of the hour when it comes to use of manufactured sand as a replacement to natural river sand. While using the manufacturing sand, the water absorbing tendency is relatively higher when compared to natural sand and this affects the workability and results in formation of honey combs and lesser strength of the structure. To overcome this effect, super plasticizer named Conplast SP430 is used to increase the workability of the concrete [8].

According to Mehta [13], the three fundamental elements for supporting an environment friendly concrete technology for sustainable development are the conservation of primary materials, the enhancement of the durability of concrete structures and a holistic approach to the technology.

When rock is crushed and sized in a quarry the main aim has generally been to produce coarse aggregates and road construction materials meeting certain specifications [16]. Generally, this process has left over a proportion of excess fines of variable properties, generally finer than 5-mm size. The premixed concrete industry has for some time tried to find ways to utilize this material as a controlled replacement of natural sand. In order to do this it has been recognized that provided the material is appropriately processed and selected from suitable materials then a sand replacement can be produced to meet the highest quality concrete specification.

Manufactured sand is defined as a purpose-made crushed fine aggregate produced from a suitable source material. Production generally involves crushing, screening and possibly washing. Separation into discrete fractions, recombining and blending may be necessary. It is recognized from both local and overseas experience, that some quarry sources or some rock types within any particular quarry would not be suitable for use as manufactured sand in concrete.

2. Material Properties

2.1 Cement

Ordinary Portland Cement (43 Grade) with 28 percent normal consistency Conforming to IS: 8112-1989 was used.

2.2 Fine Aggregate

Fine aggregate used in this study is both natural sand and manufactured sand. Manufactured sand obtained from RPP Crushers (P) Ltd., Erode and river sand obtained from kavery river basin are used for construction. The physical properties and chemical composition of fine aggregate are listed in Tables 1 and 2 respectively [10].

Table 1: *Physical Properties of Fine Aggregate [12]*

Property	Manufactured sand	Natural sand
Specific gravity	2.54-2.60	2.60
Bulk relative density (kg/m^3)	1720-1810	1460
Absorption (%)	1.20-1.50	Nil
Moisture content (%)	Nil	1.50
Fine particles less than 0.075mm (%)	12-15	06
Sieve analysis	Zone II	Zone II

Table2: *Chemical Composition of Fine Aggregate[12]*

Chemical Composition	Manufactured sand (%)	Natural sand (%)
SiO_2	62.48	80.78
Al_2O_3	18.72	10.52
Fe_2O_3	06.54	01.75
CaO	04.83	03.21
MgO	02.56	00.77
Na_2O	Nil	01.37
K_2O	03.18	01.23
TiO_2	01.21	Nil
Loss of ignition	0.50	0.35

2.3 Coarse Aggregate

Crushed stone coarse aggregate conforming to IS: 383 -1987 [3] was used. Different properties of coarse aggregate are determined and the results are shown in table 3.

Table 3: *Properties of Coarse Aggregate*

S.no	Coarse aggregate	Values
1	Size	20mm
2	Bulk density	1674kg/m^3
3	Fineness modules	7.16
4	Specific gravity	2.8
5	Water absorption	0.55%

2.4 Superplaticiziser

Conplast SP430 is high performance super plasticizing admixture used to maintain the workability and strength of the concrete. The composition of conplast SP430 is Sulphonated Naphthalene Formaldehyde condensate and some active solids [8]. It provides excellent acceleration of strength at early ages and major increase in strength at all ages by significantly reducing water demand in the concrete mix. It also provides improved durability by increasing ultimate strength and reducing concrete permeability. Table 4 shows the different properties of the superplastiziser used in this study.

Table 4: *Properties of Conplast SP430*

S.no	Properties	Values
1	Active solids	40% by weight
2	Air entrainment	11.63 kg/m^3
3	Specific gravity	1.2
4	Chloride content	Nil

2.5 Concrete Mix Design

Since there is none of the method available for designing the concrete mixes with manufactured sand as fine Aggregate. The mix design method proposed by IS [9] are used to design the Conventional Concrete mixes and finally natural sand was replaced by manufactured sand to obtain the concrete mixes. The mix proportion is arrived for characteristic compressive strength of 30MPa.

3. Experimental Programme

3.1 Workability Test

In the present study, the slump flow test is used for noting the slump value and passing ability of the concrete [8]. To maintain the uniform workability, conplat 430 type superplastiziser is added upto 3.75% for 0% to 100% replacement of manufactured sand.

3.2 Compressive Strength Test

The compressive loading tests on concrete were carried out on a compression testing machine of capacity 2000 kN. For the compressive strength test, a loading rate of 2.5kN/s was applied as per IS: 516–1959[11]. The specimen used was 150 mm cube. The test was performed at 28, 90 and 180 days.

3.3 Splitting Tensile Strength Test

The indirect method of applying tension in the form of splitting was conducted to evaluate the tensile properties of concrete. The split tensile strength is a more reliable technique to evaluate tensile strength of concrete (lower coefficient of variation) compared to other methods. The split tensile strength of 150 mm diameter and 300 mm high cylindrical specimens @ 28 days strength was determined to assess the effect of manufactured sand replacement on the tensile properties of the concrete as per ASTM C496[2].

3.4 Flexural Strength Results

Concrete specimens of 100mm x 500mm are cast to determine the flexural behavior of concrete in accordance with ASTM C78-94 [2] at a loading rate of 0.2kN/s. The bearing surface of the supporting and loading rollers were wiped clean and any other loose fine aggregate or other materials removed from the surface of the specimen where they are to make contact with the rollers. The specimen was then placed in the machine and two point loads was applied. Load was increased until the specimen failed and the load at failure was recorded.

3.5 Acid Attack

The chemical resistance of the concrete was studied through chemical attack. Initial weight of the specimen is noted before acid curing. 3% of H2SO4 solutions were added for every 1 liter of water and the specimens are immersed for 90 days period of curing. The solution was replaced at regular intervals to maintain constant concentration throughout the test period. The specimens were then removed from the curing tank and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. Weight of specimen after acid curing is weighed. Percentage weight loss and compressive strength of the specimen is determined.

3.6 Chloride Permeability Test

The chloride permeability test was conducted to assess the concrete quality as per ASTM C 1202 [1]. For this test 100×50 mm cylindrical specimens were used. A potential difference of 60V DC was maintained across the specimen. One of the surfaces was in contact in a sodium chloride solution (NaCl) and the other with a sodium hydroxide solution (NaOH). The total charge passing through in 6 hrs was measured, indicating the degree of resistance of the specimen to chloride ion penetration. In addition, resistivity or conductivity can also be determined from the initial current reading, since the resistance of the disk can be calculated immediately from Ohm's law: R=V/I where R is resistance, V is voltage, and I is current. The resistivity is determined from: Resistivity =RA/L where A is area of the disk, and L is thickness of the disk.

3.7 Modified Sorptivity

Sorptivity measures the rate of penetration of water into the pores in concrete by capillary suction. Cumulative volume of water that has penetrated per unit surface area of exposure 'q' is plotted against the square root of time of exposure 'SQRT(t), the resulting graph could be approximated be a straight line passing through the origin. The slope of this straight line is considered as a measure of rate of movement of water through the capillary pores. This measurement is called sorptivity.

4. Results And Discussions

4.1 Workability Test

Uniform slump value in the range of 40mm to 60mm is maintained throughout the experiment to ensure the workability of concrete. The value of slump for all the replacement ratios of manufactured sand is shown in figure1.

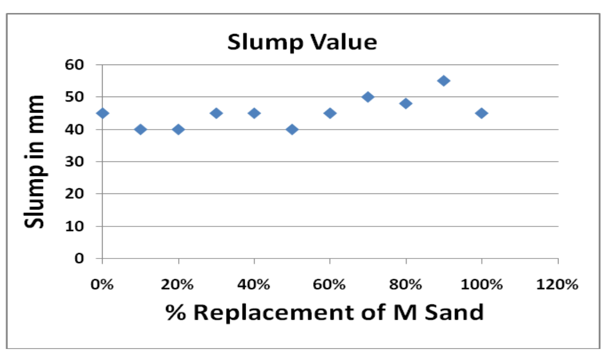

Figure 1: *Slump Cone Test*

4.2 Compressive Strength Test

The results of compressive strength of cubes are obtained and are presented in Figure 2. The variation of compressive strength with respect to type of concrete made by using natural sand and manufactured sand shows that the mixes with the manufactured sand up to 70% as fine aggregate gives consistently higher strength than the mixes with natural sand. The maximum strength is at 50% replacement level. The sharp edges of the particles in manufactured sand provide better bond with the cement than the rounded part of the natural sand. Higher replacement of manufactured sand requires excess quantities of water. In order to maintain the workability and to increase the strength super plasticizers are added to achieve the result.

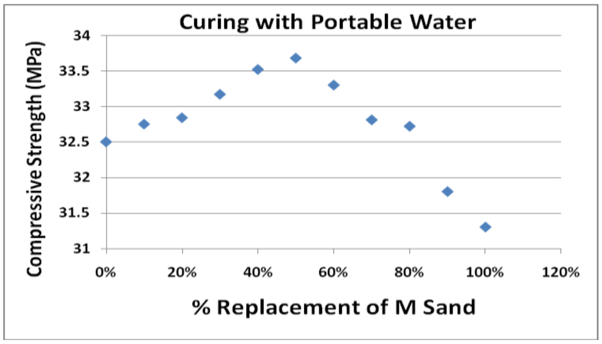

Figure 2: *Compressive Strength Test (Mpa)*

4.3 Splitting Tensile Strength Test

The results of split tensile strength test of cylinders are obtained and are presented in figure 3. From the figure, it can be seen that as the replacement percentage increases, the Split Tensile Strength also increases up to 50% replacement of manufactured sand and then decreases gradually. The Split Tensile Strength is more for the concrete made with manufactured sand than the conventional when added with Latex.

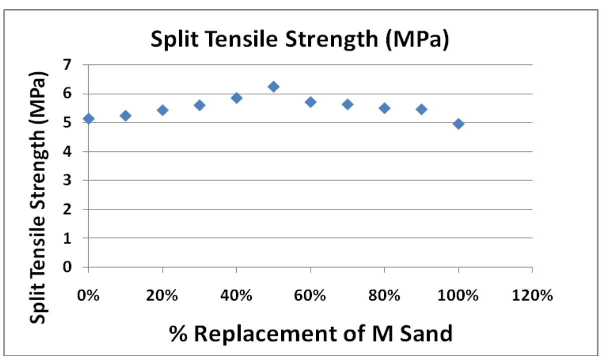

Figure3: *Split Tensile Strength Test (Mpa)*

4.4 Flexural Strength Results

The flexural strength results are presented in figure 4. From the figure, it can be seen that as the replacement percentage increases, the Flexural Strength also increases up to 50%. The Flexural Strength is more for the concrete in addition with binding material compared to conventional concrete. The percentage increase in strength is more for the specimen with 50% replacement and having a super plastiziser dosage of 1.25%.

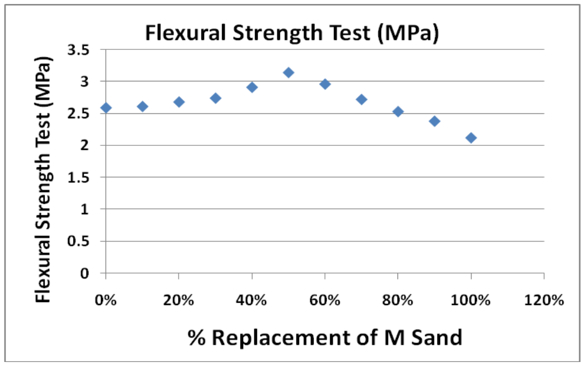

Figure 4: *Flexural Strength Test (Mpa)*

4.5 Acid Attack

Concrete is susceptible to acid attack because of its alkaline nature. The components of the cement paste break down during contact with acids [19]. Most pronounced is the dissolution of calcium hydroxide which occurs according to the reaction, M .T. Bassuoni [4] $2HX+Ca(OH)_2 > CaX_2+2H_2O$. Concrete cubes after normal curing are immersed in 3% H_2SO_4 for 90 days. The solution was replaced at regular intervals to maintain constant concentration throughout the test period. After 90 days period of immersion, the specimen surfaces were cleaned to remove weak reaction products and loose materials. The initial weights and the weight of specimen after 90 days of immersion in acid and the weight losses were determined. The concrete cubes were deterioted mainly at edges and appeared to be of a white color. Fattuhi [5] found that acid attack decreased with decrease in cement content. The results of % weight loss and the compressive strength are shown in Figure 5 and 6.

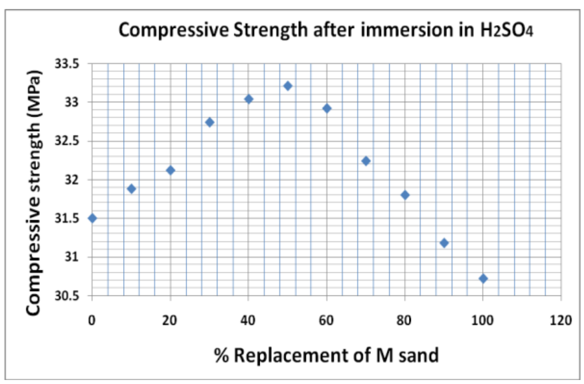

Figure 5 *Compressive Strength after immersion in H_2SO_4*

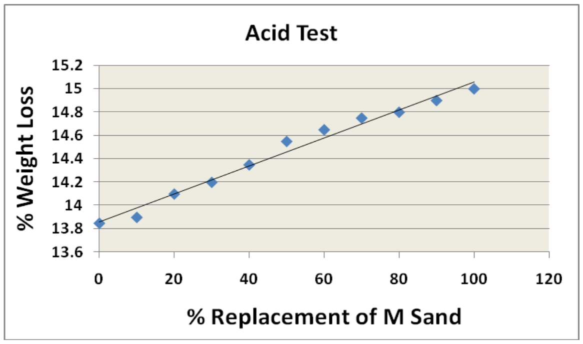

Figure 6 *% weight loss due to H_2SO_4*

4.6 Chloride Permeability Test

The chloride ion penetrability limits suggested by ASTM C1202 were compared with the obtained results [1]. Usually chlorides penetrate in concrete by diffusion along water paths or open pores. Some of these chlorides can react with the cement compounds, mainly tricalcium-aluminates (C_3A), forming stable chloro complexes. The excess of chloride is free and leads to the initiation of the corrosion process. During this test 60 V DC supply is provided and the readings are noted at every 30 minutes up to 6 hours. Total charge passing was found between 2000 to 4000 that means chloride permeability is moderate. Thus both natural sand and manufactured sand are moderate to the chloride permeability. The results of compressive strength and chloride ion permeability are shown in figure 7 and 8.

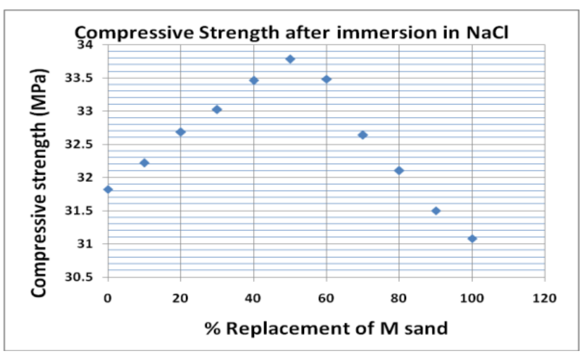

Figure 7 *Compressive Strength after immersion in NaCl*

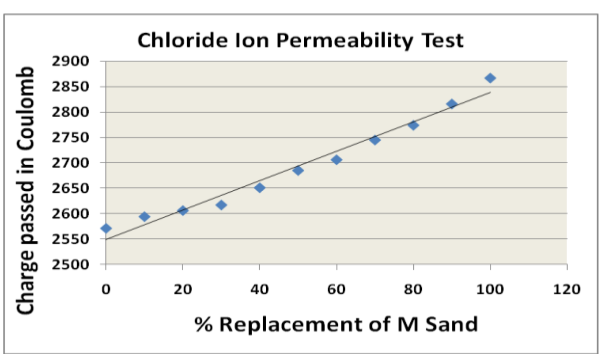

Figure 8 *Charge passed in coulomb*

4.7 Modified Sorptivity Test

In this present study, the test for sorptivity was conducted on 100 mm cube specimens as per ASTM C 642 - 1992 [2] by drying the specimens in an oven at a temperature of 105^{o}C to constant mass and then immersing them in water after cooling the specimens to room temperature and measuring the gain in mass at regular intervals of 30 minutes duration, for a period of two hours. The result is shown in figure 9. The sorptivity was computed by considering the slope of the plot 'p' versus 'SQRT (t)" [12]

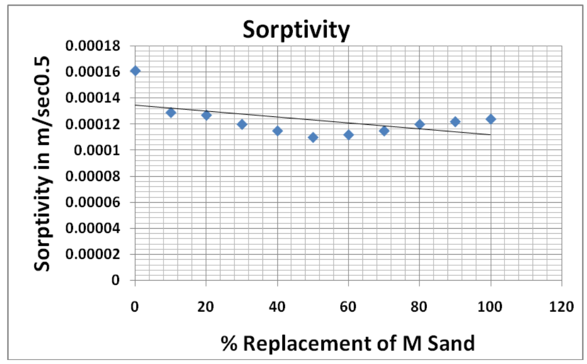

Figure 9 *Modified Sorptivity Test*

5. Conclusion

Based on the experimental investigation, the behavior of manufactured sand in concrete is concluded

- From the result, replacing of manufactured sand as fine aggregate has no detrimental effect on the strength and performance of concrete, when designed correctly.
- The sharp edges of the particles in manufactured sand provide better bond with the cement than the rounded part of the natural sand. It was found that the mixes with the manufactured sand upto 70% as fine aggregate gives consistently higher strength than the mixes with natural sand.
- Weight loss in manufactured sand specimen is almost same with respect to natural fine aggregate when immersed in sulphuric acid solution during the experimental period and the permeability of concrete is moderate and suitable for construction.
- The manufactured sand used in this investigation is economical compared to river sand.
- Use of manufactured sand gives good cohesive, uniform and dense mix and diminishes the segregation and bleeding tendency.
- The strength of the concrete gradually increases up to 50% replacement level of manufactured sand.

From this investigation the replacement of fine aggregate, not only reduces the cost of construction but also minimizes the scarcity of natural fine aggregate and reduces the depletion of natural recourses. Usage of manufactured sand in concrete is ecofriendly, non-hazardous considering the technical, environmental and commercial factor.

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