Characteristics of M-Sand as a Partial Replacement with Fine Aggregate in Mix Design

Shreyas. K

Asst professor, Dept of Civil engineering, Don Bosco Institute of Technology, Bangalore, India

***Abstract*: There is a great demand of both coarse & fine aggregates for the construction of infrastructural facilities, rather than using a conventional river sand as a fine aggregate in concrete mix as one of the construction material which has led to the scarcity of the material an alternative material such as manufactured sand can be used for the construction purposes. A replacement of finer aggregates by a manufactured sand by varying proportions leads to the increase in both engineering & physical properties of concrete constituents which are to be considered in recent trends. In the present study manufactured sand with varying proportions from 0 to 40 % by its weight are mixed with concrete materials as a partial replacement with fine aggregates & analysed for its physical and engineering properties, with the further analysis an introduction of manufactured sand in a proper proportions will lead to increase in the compressive strength by 15 to 20% for the concrete cubes which are being tested for 7 days, 14 days & 28 days strength.**

***Key words*: Manufactured sand, compressive strength, Mix design, Physical & engineering properties of cement concrete materials.**

I. INTRODUCTION

Advancement of concrete technology can reduce the consumption of natural resources and energy sources which also will lessen the burden of pollutants on environment. The feasibility of using manufactured sand as a partial replacement and in some cases replacing fully with river sand in concrete will lead to further increase in utilisation of alternate materials keeping the environment away from the hazards. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water whereas River Sand is common form of fine aggregate used in the production of concrete but has become very expensive due to rapid depletion of river bed, high transportation cost etc. The sustainable development for construction involves use of non-conventional and innovative materials & also to recycle the waste materials in order to compensate the lack of natural resources and to find alternative ways to conserve the environment. Using alternative materials in place of natural aggregate in concrete production makes concrete a sustainable and environmentally friendly construction material. M-Sand has similar physical & chemical properties as of natural river Sand & can be effectively utilised for the construction activities. These alternate construction materials participate in the hydraulic reactions contributing significantly to the composition and microstructure of hydrated product, with the use of alternate materials as an admixture for the concrete material will offer in cost reduction, energy savings, arguably superior products with minimal hazards to the environment.

II. REVIEW OF LITERATURE

Manufactured sand particles are generally more angular with a rougher surface texture than river sand particles. M- sand can also contain significant quantities of particles smaller than 75 μm and are called as rock micro fines. From the studies on influence of M-sand characteristics such as rock micro fines content, surface roughness, crushing value, the strength and abrasion resistance of pavement cement concrete (PCC) shows that the increment of limestone micro fines amount in M-sand from 4.3% to 20% by its weight will increase the compressive and flexural strength of cement blocks and also improve the abrasive resistance of the Plain Cement Concrete (PCC). The abrasion resistance of PCC is improved with the increment of surface roughness and decease in crushing and Los Angeles abrasion value of sand particles [1].

The natural river sand is one of the cheapest resource of sand material available However the excessive mining of river bed to meet the increasing demand for sand in construction industry has led to the ecological imbalance in the country. Now a days sand available in the river bed is very coarse and contains very high percentage of silt and clay, the silt and clay present in sand will reduce the strength of the concrete blocks and holds dampness.

A few alternatives have come up for the industry to bank on of which manufactured sand or M -sand, as it is called is found to be the most suitable one to replace river sand. M-sand has caught the attention of the construction industry and environmentalists alike for its quality and minimum damages it causes to the environment. Usage of M-Sand can drastically reduce the cost since like river sand, it does not contain impurities and wastages is almost nil since it is made with modern technology and machinery. Once the M-sand becomes more popular in the construction industry, the demand for river sand and illegal sand -mining would come down. The particles are more rounded and granular with minimal sharp edges. Usage of M- Sand can overcome the defects occurring in concrete such as honey combing, segregation, voids, capillary etc [2].

Volume of concrete consumed by the construction industry is very large, in India conventional concrete contains natural sand obtained from river beds and as termed as fine aggregates. In recent times with a boost in construction activities, there is a significant increase in the consumption of concrete causing the depletion of natural sand. This has led to several environmental issues thereby government imposing a ban on the unrestricted use of natural sand and has resulted in the scarcity and significant rise in the cost of natural sand. Therefore, an alternative to river sand has become the need of the hour these days, promotional use of manufactured sand will conserve the natural resources for sustainable development of the concrete in construction industry [3].

Sand is used as a fine aggregate in mortars and concrete in which Natural river sand is the most preferred choice as a fine aggregate material. River sand is a product of natural weathering of rocks over a period of millions of years. It is mined from the river beds and sand mining has disastrous environmental consequences. River sand is becoming a scarce commodity and hence exploring alternatives to it has become imminent. Rock crushed to the required grain size distribution and is termed as manufactured sand (M-sand). In order to arrive at the required grain size distribution the coarser stone aggregates are crushed in a special rock crusher and some of the crushed material is washed to remove fines. This investigation is an attempt to evaluate the characteristics of mortars and concrete using M-sand as fine aggregate. For the purposes of comparison characteristics of mortar and concrete with river sand has also been explored, apart from characterising the properties of M-sand, tests were performed on the mortars and concrete using M-sand & is compared with natural river sand [4].

Slump and air content of fresh concrete and absorption and compressive strength of hardened concrete were also investigated in which the test results show that this industrial bi product is capable of improving hardened concrete performance up to 10% also enhancing fresh concrete behaviour and can be used in architectural concrete mixtures containing white cement. The compressive strength of concrete was measured for 7 and 28 days in order to evaluate the effects of M sand on mechanical behaviour, many different mortar mixes were tested Leaving the waste materials to the environment directly can cause environmental problem. Hence the reuse of waste material has been emphasized and also waste can be reused to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste deposits [5].

Manufactured sand is purposely made of waste quarry fines through further screening and processing. Over years, it is used increasingly as fine aggregate in replacement of natural sand due to the environmental pressure of limited natural source and the interest in optimizing the concrete mix. An admixture was developed particularly to overcome the problems for concrete mix using manufactured sand in replacement of natural sand can be made up to 100%.Test results have shown that concrete mix using manufactured sand up to 100% with the admixture developed is able to be workable as normal concrete mix without compromising properties of fresh and hardened concrete. It is not an unusual sight to see over-growing piles of waste product build up on a quarry site. Huge Stockpiles of this unused or low-value material are an obvious problem in a quarry site, Sometimes it is measured by hundreds of thousands of cubic meters, these mountains occupy valuable quarry space and are an environmental headache. On the other hand, available natural sand resources are becoming less economic or totally out of reach to the concrete producer due to increasing environmental pressure, therefore it is of great significance to use the quarry fractures as fine aggregate in concrete industry[6].

III. MATERIALS & METHODOLOGY

1. Materials

a. Ordinary Portland Cement of 53 Grade.
b. Aggregates of pertaining Sieve size (<20mm) as per IS standards.
c. River Sand of pertaining Sieve size (<4.75mm) as per IS standards.
d. Manufactured Sand of pertaining Sieve size (<4.75mm) as per IS standards

2. Methodology

Preliminary tests were conducted on the concrete materials as per IS standards & specifications for its physical & engineering properties, cubes were casted in the standard metallic moulds & vibrated to obtain the required sample size of specimen. The moulds were cleaned initially and oiled on all the sides before concrete sample is poured in to it. Thoroughly mixed concrete is poured into the moulds in three equal layers and compacted using vibrating table for a small period of 5 minutes. The excess concrete is removed out of the mould using trowel and the top surface is finished with smooth surface. After 24 hours the samples were demoulded and put in curing tank for the respective periods of 7, 14 and 28 days a set of 5 samples were prepared for each stage of curing. The temperature of curing tank was maintained about 25 degree during the analysis of compressive strength were tabulated.

The main aim of the methodology is to-

- To calculate the compressive strength of M25 grade plain concrete by laboratory experiments as per IS specifications.
- To find the percentage of River sand replaced in concrete with manufactured sand as an admixture

that gives maximum characteristic compressive strength.

3. *Tests (physical properties) conducted on Concrete materials*

➢ **Test on cement**

- Fineness of cement.
- Normal Consistency of cement.
- Soundness test.
- Specific gravity.
- Initial setting time of cement.
- Final setting time of cement.

TABLE-1 Test on Cement

Si no	Test	Method of test	Average Result	Permissible value
1	Fineness of cement	IS 269-1976	6%	Max 10%
2	Normal consistency	IS:4031-Pt-4	29%	26 to 33%
3	Soundness	IS:4031-Pt-3	6 mm	< 10mm
4	Specific gravity	IS:2720-Pt-3	3.0	3.12 to 3.19
5	Initial setting time	IS 4031-1968	35 mins	Min 30 mins
6	Final setting time	IS 4031-1968	280 mins	Max 600 mins

➢ **Tests on Coarse aggregates**

- Sieve analysis.
- Specific gravity.
- Water absorption.
- Aggregate shape test.
- Aggregate crushing test.
- Aggregate impact test.
- Los Angeles abrasion test.

TABLE-2 Test on coarse aggregates

Si no	Test	Method of test	Average Result	Permissible value
1	Sieve analysis	IS:2720-Pt-4	Fineness modulus = 3.0	2.3 to 3.1
2	Specific gravity	IS:2386-Pt-3	Bulk specific gravity = 2.6 Apparent specific gravity = 2.5	2.5 to 3.2
3	Water absorption	IS:2386-Pt-3	1.0	<2%
4	Aggregate shape test Flakiness index	IS 2386-1 (1963)	20%	<30%
	Elongation index		21%	
5	Aggregate crushing test	IS:2386-Pt-4	18.44%	<30%
6	Aggregate impact test	IS:2386-Pt-4	15%	<24%
7	Los Angeles abrasion test	IS: 2386-(Part IV) – 1963	20%	<30%

➢ **Test on fine aggregates – River sand (Size <4.75mm)**

- Specific gravity and Water absorption test.

TABLE-3 Test on fine aggregates (River sand)

Si no	Test	Method of test	Average Result	Permissible value
1	Specific gravity	IS:2720-Pt-3	Bulk specific gravity = 2.50 Apparent specific gravity = 2.48	2.53 to 2.67
2	Water absorption	IS:2386-Pt-3	0.8	<2%

➢ **Test on fine aggregates – Manufactured sand (Size <4.75mm)**

- Specific gravity and Water absorption test.

TABLE-4 Test on fine aggregates (Manufactured sand)

Si no	Test	Method of test	Average Result	Permissible value
1	Specific gravity	IS:2720-Pt-3	Bulk specific gravity = 2.60 Apparent specific gravity = 2.5	2.53 to 2.67
2	Water absorption	IS:2386-Pt-3	1%	<2%

4. *Tests (Engineering properties) conducted on Plain Concrete*

➢ **Test on concrete**

- Slump test.
- Compaction factor.
- Vee Bee consistometer.
- Compressive strength of concrete.

TABLE-4 Test on concrete

Si no	Test	Method of test	Average Result	Permissible value
1	Slump test	IS-7320-1974	True slump for 0.6 water cement ratio	--
2	Compaction factor	IS-1199-1959	0.9	--
3	Vee Bee consistometer	IS-10510-1983	20 seconds	--
4	Compressive strength of plain concrete (7 days)	IS 1489-1991	18.44 N/mm^2	Min 17 N/mm^2
5	Compressive strength of plain concrete (14 days)	IS 1489-1991	22.0 N/mm^2	Min 22 N/mm^2
6	Compressive strength of plain concrete (28 days)	IS 1489-1991	25.3 N/mm^2	Min 25 N/mm^2

5. *Tests (Engineering properties) conducted on Concrete with partial replacement of M-sand*

➢ **Test on concrete**

- Slump test.
- Compaction factor.
- Vee Bee consistometer.
- Compressive strength of concrete.

TABLE-5 Test on concrete with partial replacement of M-sand

Si no	Test	Method of test	Average Result
1	Slump test	IS-7320-1974	True slump for 0.6 water cement ratio
2	Compaction factor	IS-1199-1959	0.9
3	Vee Bee consistometer	IS-10510-1983	23 seconds
4	Compressive strength of concrete with M sand (7 days)	IS 1489-1991	31.2 N/mm^2
5	Compressive strength of concrete with M sand (14 days)	IS 1489-1991	40 N/mm^2
6	Compressive strength of concrete with M sand(28 days)	IS 1489-1991	49 $/mm^2$

VI. EXPERIMENTAL DESIGN

MIX DESIGN

Volumetric batching is done for the material mix to analyse the amount of quantity required for casting each cube specimen considering the design mix as M25 grade (cement: fine aggregate: coarse aggregate) is 1: 1: 2 as per IS 383-1970 & IS 456-2000 specifications. The aggregates with cement mix are varied up to 35% of porosity by varying the materials having minimal or zero number of fine aggregates & is mixed with cement for a water cement ratio of 0.6 to cast the moulds for analysing the compressive strength of 7, 14 & 28 days strength for an average of 5 specimens.

The percentage of manufactured sand is varied from 0 % to 40% & is added to the concrete mix as an admixture & is tested for its compressive strength for varying 7, 14 & 28 days strength. The obtained results are tabulated as a comparison of characteristic strength between plain concrete mix & M sand as an admixture for the concrete mix of M25 grade for an average of 5 specimens.

IV. RESULTS & DISCUSSION

Relation between characteristic compressive strength for the plain concrete mix for 7, 14 & 28 days

With the volumetric batching for the plain concrete material mix is done to analyse the amount of quantity required for casting each cube specimen considering the design mix as M25 grade (cement: fine aggregate: coarse aggregate) is 1: 1: 2 as per IS 383-1970 & IS 456-2000 specifications & tested for its strength for 7, 14 & 28 days strength in which the compressive strength by testing under compressive testing machine has given an average values of 18.43 N/mm^2 & 25.34 N/mm^2 which are more than permissible limits as per specifications respectively.

TABLE-5: Comparison of compressive strength in concrete specimens for 7, 14 days & 28 days in N/mm^2

Si no	Average strength at 7 days (N/mm^2)	Average strength at 14 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	18.4	21.1	24.38
2	18.55	21.9	26.98
3	18.54	22.0	25.50
4	18.10	21.6	24.40
5	18.60	23.4	25.45

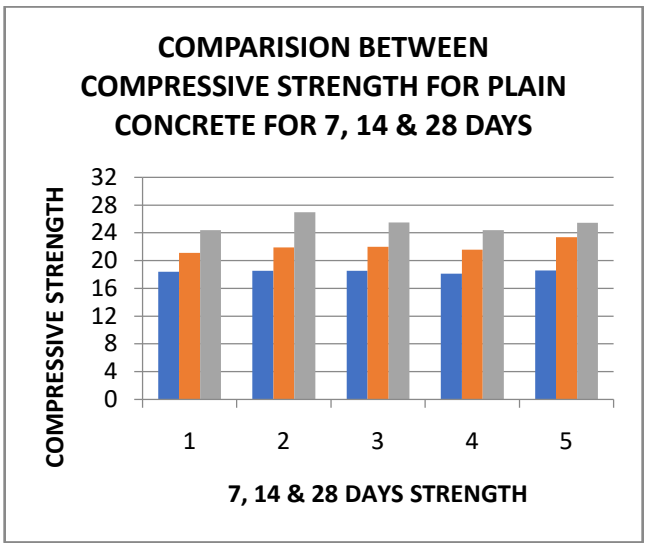

Fig-1: Comparison between compressive strength of plain cement concrete for 7, 14 days & 28 days

Relation between characteristic compressive strength for the concrete mix & manufactured sand as an admixture for 7, 14 & 28 days

With the inclusion of Manufactured sand in varied proportions the strength of concrete gradually increases up to a certain limit but the gradually decreases. By the experimental analysis with the inclusion of Manufactured sand up to 40% by its weight as a filler material will lead to increase in the initial compressive strength of the concrete blocks. There is 10% to 20% increase in initial compressive strength for 7 days & also 10% to 15% increase in initial compressive strength for 28 days where as initial & final characteristic compressive strength gradually decreases from 30% increase in Manufactured sand in the concrete mix.

TABLE-6: Comparison of compressive strength for various specimens with varying % in manufactured sand for 7, 14 & 28 days in N/mm^2

Si no	% OF MANUFACTURED SAND	Average strength at 7 days (N/mm^2)	Average strength at 14 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	0	18.44	22	25.3
2	10	28.59	36.87	47.78
3	20	31.22	40.2	49.0
4	30	32.55	41.52	50.53
5	40	32.73	40.2	47.1

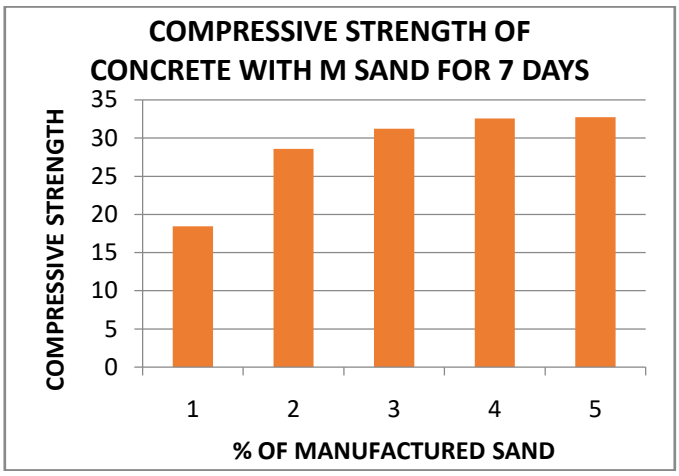

Fig-2: Comparison between compressive strength of plain cement concrete with manufactured sand as admixture for 7 days

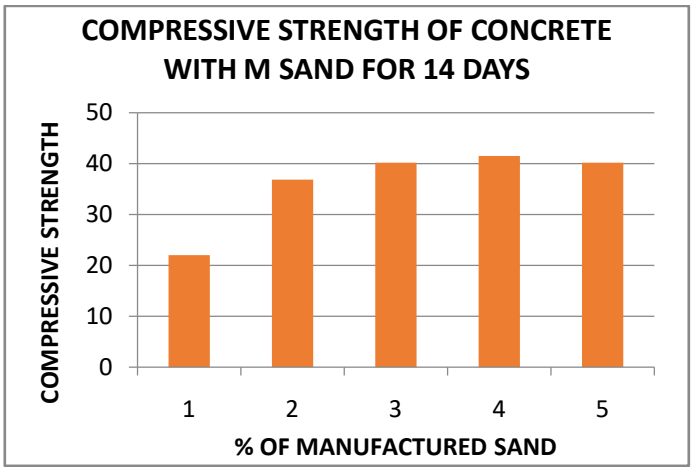

Fig-3: Comparison between compressive strength of plain cement concrete with manufactured sand as admixture for 14 days

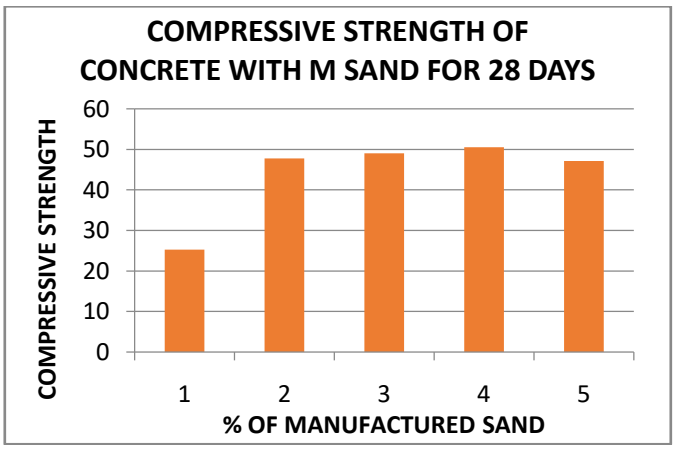

Fig-4: Comparison between compressive strength of plain cement concrete with manufactured sand as admixture for 28 days

V. CONCLUSION

Based on the various laboratory tests as per IS standards for the porous concrete by varying the composition the following conclusions are drawn:

1. Mechanical behavior of concrete cubes prepared without chemical admixtures were studied for compressive strength test with curing time of 7 days, 14 days and 28 days which shows characteristic increase in its strength behavior.
2. It can be noticed that 10% replacement of cement with manufacture sand in mild condition are showing an increase in compressive strength for 28 days & with up to 40%% replacement of cement with manufactured sand in mild condition are showing a variation in its compressive strength.
3. With the presence of manufactured sand as an admixture, it has been concluded that it can be very effective in assuring good cohesiveness between mortar and concrete.
4. From the above study, it can be concluded that the manufactured sand can be used as a replacement material for filler material and up to 40% replacement will give an excellent results both in strength & quality aspects.
5. Also with increase in percentage of M sand up to 40% will lead to the improvement in properties related to durability & workability of concrete.
6. The mix prepared with 20% replacement of fine aggregate by M sand is most economical and gives high compressive strength when compared to conventional mix.

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