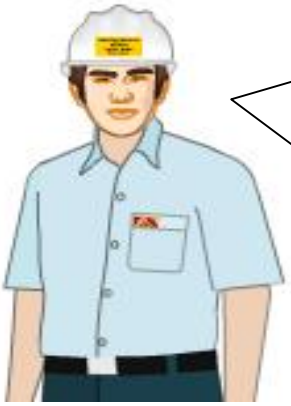
Vol. 02 No. 02
July 2013

Tech Mailer



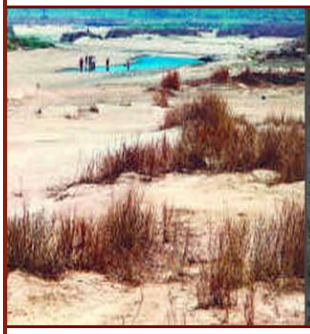
Dear Reader,

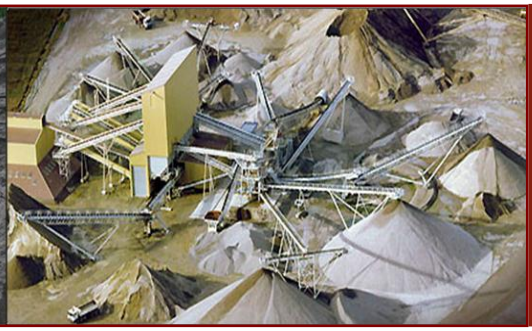
Mankind has been blessed with fairly abundant natural resources. Society has to face the fury of nature, if they are over exploited. Sometimes it may be catastrophic. One such disaster was witnessed in Uttarkhand. Indiscriminate mining of Sand also amounts to overexploitation of the natural resources, adversely impacting the environment in several ways.

It is also imperative to keep pace with the growth in construction and sand is one of the vital construction materials. One of the attractive alternatives to Sand is Manufactured Sand. It possesses properties similar to that of river sand and is a more sustainable construction material.

This issue focuses on **"Manufactured Sand – *the need of the hour*".**

We hope you find the mailer informative and useful. Happy Reading!!





Issue Highlights

- *About Manufactured Sand*
- *Comparison of Manufactured Sand with River Sand*
- *Suitability as fine aggregates in Concrete*
- *Suitability as fine aggregates in Mortars*

Introduction

Sand is a vital ingredient in making two most used construction materials viz. cement concrete and mortar. Traditionally River sand, which is formed by natural weathering of rocks over many years, is preferred as fine aggregate. The economic development fuelling the growth of infrastructure and housing generates huge demand for building materials like sand. The indiscriminate mining of sand from riverbeds is posing a serious threat to environment such as erosion of riverbed and banks, triggering landslides, loss of vegetation on the bank of rivers, lowering the underground water table etc. Hence, sand mining from riverbeds is being restricted or banned by the authorities. Controlling extraction along rivers has caused the illegal activities to spread into hillside and farmlands, creating public hazards such as landslide, deep ponds, and hanging cliffs. This sand extracted from fields (popularly known as filter sand), in addition to depleting the fertile top soil, impairs the quality of concrete / mortar. Manufactured sand, which is obtained by crushing the rock, is emerging as a viable alternative to river sand. This material is in use for quite some time in developed countries. The use of this sand (also called artificial sand, M-Sand, Robo Sand etc.,) is picking up in India in major cities. ***Use of scientifically produced Manufactured Sand as an alternative to river sand is the need of the hour and will provide a long term solution to Indian Construction Industry***.

Manufactured Sand

Manufactured sand is crushed fine aggregate produced from a source material and designed for use in concrete or for other specific products. Only source materials with suitable strength, durability and shape characteristics should be used. Production generally involves crushing, screening and possibly washing. Separation into discrete fractions, recombining and blending may be necessary.

Crushing

Vertical Shaft Impact Crusher

Manufactured Sand is produced by feeding hard stones of varying sizes to primary and secondary crushers (Jaw crusher and Cone crusher), for size reduction and these crushed stones are further crushed in Vertical Shaft Impact (VSI) crusher to reduce the particle size to that of sand. The VSI crusher by its unique design and action of attrition produces well-shaped fine aggregate particles that are cubical and angular. The process of attrition also enables the reduction of surface roughness of the fine aggregate particles to some extent.

During the production processes, it is ensured that sand stockpiles are not contaminated with weathered/highly altered rock or with clay and other contaminants. Crushing of multiple source rocks into a single sand stockpile is also not be permitted unless it can be demonstrated that such a process is under blending control and produces a consistent product.

The fine particles obtained, as a by-product during crushing of rocks to produce coarse aggregates (by jaw crusher and/or cone crusher) is known as Crusher Dust/Quarry Dust. This often contains higher percentage of dusty, flaky particles and particle sizes are un-controlled. This is not suitable for construction, as they result in higher water demand leading to lack of control on workability / retention of workability as well as strength issues.

Screening and Washing

With built-in process of different stages of screening, Manufactured Sand plants ensure proper grading for better particle size distribution.

By washing, the percentage of micro fines (passing 75 micron) is controlled below 15% by weight. The washing facility also provides keeps the Manufactured Sand in wet or partially wet condition. This will help to reduce the water absorption rate by Manufactured Sand during concrete manufacturing and hence better workability and workability retention.

Comparison of River Sand and Manufactured Sand

Table 1: Comparison of Properties of River Sand and Manufactured Sand

Properties	River Sand	Manufactured Sand	Advantages of Manufactured. Sand
Shape	Spherical particle	Cubical particle	Higher Cohesion and Compressive Strength
Gradation	Cannot be controlled	Can be controlled	Reduction in Voids and Higher strength
Particle passing 75micron	Up to 3%(IS:383-1970)	Up to 15% (IS:383-1970)	Refer Note below
Clay and Organic impurities	Likely to be present (retard the setting &comp. strength)	Absent	Better Concrete Quality
Grading zone (IS-383)	Mostly conforms to Zone II and III	Manufactured to conform to Zone II	Zone II ideal for Concrete

Note: When particles below 75µ are nearer to the limit of 15%, it is advisable to make suitable adjustment of water to cement ratio and ensure early curing to avoid problems of plastic shrinkage cracking

Suitability of Manufactured Sand as fine aggregates for Concrete& Mortars – *A Case Study*

A study was conducted at Indian Institute of Science, Bangalore, to ascertain the suitability of Manufactured Sand as fine aggregate in Concrete (grades of M20, M30) and Cement mortars (ratio 1:4 and 1:6).Tests were conducted to study fresh and hardened properties of the Concrete and Mortars made with river and Manufactured Sand.

It was found that:

1. *Grading limits of Manufactured Sand fell within the grading Zone-II of fine aggregates as specified in IS 383.*
2. *Shape of the Manufactured Sand particles resembled the shape of river sand particles.*
3. *Bulk density and specific gravity of Manufactured Sand were comparable to those of river sand.*

Concrete

The details of the tests on concrete, comparison of results tabulated in Table 2 and inferences drawn are given below.

Consistency of concrete:

This was measured by conducting slump test. Keeping the water-cement ratio at 0.50 and using super plasticizer (at 15 ml per kg of cement as specified by the manufacturer), the slump values were determined for both M20 and M30 mixes using river sand and Manufactured Sand as fine aggregate. Concrete with river sand gave higher slump value. IS 456 code specifies a minimum slump of 50 mm for medium workability. *Both the concrete mixes met this requirement* irrespective of the type of sand.

Compressive and flexure strength of concrete:

Compressive strength was determined by testing the 28 days cured cube specimens. The mean compressive strength values of 5 cube specimens are reported in Table 2.*Compressive strength* of M20 and M30 grade concretes with Manufactured Sand as fine aggregate is *6 – 9% higher* when compared to the results using river sand as fine aggregate.

Flexure strength of concrete was determined using prisms (size: 100 x 100 x 500 mm) as per IS 516 code guidelines. Three specimens were tested in each category and the mean values are reported in Table 2. The results show that use of Manufactured Sand as fine aggregate exhibits *12 – 15% higher flexure strength* in comparison to the results of concrete with river sand.

Table 2: Characteristics of concrete using Manufactured Sand and River sand

Concrete Grade	Water-Cement ratio	River Sand			Manufactured Sand		
		Slump (mm)	Compressive Strength (MPa)	Flexural Strength (MPa)	Slump (mm)	Compressive Strength (MPa)	Flexural Strength (MPa)
M30	0.50	80	42.20	3.90	55	44.78	4.54
M20	0.50	110	37.68	3.29	76	41.03	3.86

Bond strength:

The bond between rebar and the concrete was examined by conducting pull out test. The pull out test was performed using 12 mm HYSD bar for M20 concrete as per IS 2770 code guidelines. The bond strength at failure (mean of 3 specimens) with river sand and Manufactured Sand as fine aggregates is 13.9MPa and 14.1MPa respectively. The *bond strength* is found to be *marginally higher* in case of concrete with Manufactured Sand.

The *stress-strain behaviour* of M-sand and river sand concretes were found to be *similar*.

Cement Mortar

The details of the tests on Mortar, comparison of results tabulated in Table 3 and inferences drawn are given below.

1:6 Mfd. Sand mortar at 85%flow

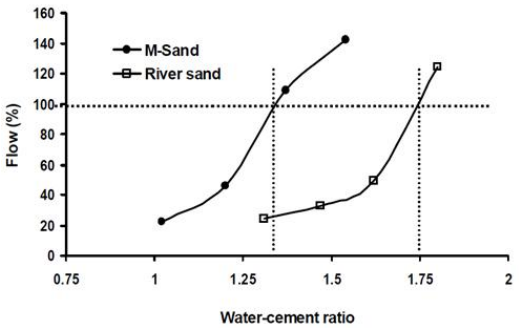
Flow/workability:

Workability of the mortar should be such that it allows the mason to spread the mortar easily and mortar adheres well to the masonry units. It is affected by mortar composition as well as water-cement ratio. Workability of the fresh mortar can be measured by conducting a flow table test as per code guidelines (BS – 4551).

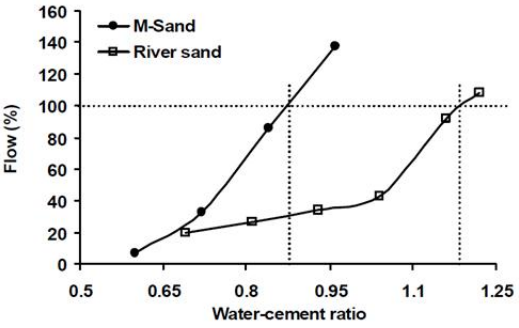
Workability of fresh mortar is expressed as flow value.

Flow tests were performed on the two types of mortars in order to establish relationships between flow and water-cement ratio. The graphs given below show the flow versus water-cement ratio relationships for the 1:6 and 1:4 cement mortars respectively.

Mortars with Manufactured Sand exhibited better flow characteristics. The ideal flow values as collected from different construction sites by IISc are in the range of 85 to 100%. *To achieve a given flow value, mortar with Manufactured Sand requires lower water-cement ratio* as can be seen in the graphs. *Lower water-cement ratio results in better characteristics for the mortars in hardened state*.



Flow vs. w/c for 1:6 CM



Flow vs. w/c for 1:4 CM

Compressive strength of Mortar:

The compressive strength of the mortars was examined for two flow values of 85 and 100% as per IS 2250. The details are given in Table 3. It has been observed that the *compressive strength of the mortar made with Manufactured Sand is twice that of mortars made with river sand*.

Table3: Compressive Strength of Mortars

Mortar Proportion	Flow (%)	Water-cement ratio		Compressive Strength (MPa)			
		River Sand	Manufactured Sand	River Sand		Manufactured Sand	
				7 Days	28 Days	7 Days	28 Days
1 : 6	85	1.72	1.30	2.10	4.03	5.15	8.53
	100	1.75	1.34	1.96	3.82	4.88	8.19
1 : 4	85	1.13	0.84	2.84	7.35	12.89	15.96
	100	1.18	0.88	2.77	6.04	11.89	15.50

Water Retentivity:

Water Retentivity can be defined as the ability of the mortar to retain water against the suction action of the brick or block. Certain amount of water is required for hydration of Cement in the mortar and simultaneous development of strength. If mortar allows more water absorption by the brick/block, it leads to low water-cement ratio in mortar and consequent incomplete hydration of the cement in the mortar, thereby affecting the mortar characteristics and the bond between the mortar and brick/block.

Water retentivity values for 1:6 cement mortar using river sand and Manufactured Sand were 27.3% and 28.5% respectively. For 1:4 cement mortar it was 25.6% and 35.6% for river sand and Manufactured Sand respectively. Thus, *water retentivity of mortar was found to improve with the use of Manufactured Sand*. Better water retentivity results in better strength and bond development.

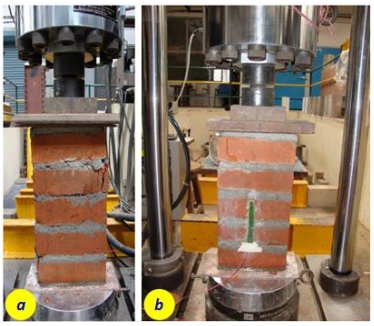
Brick-mortar bond strength:

There should be good bond between the mortar and the brick for the masonry to perform satisfactorily. Bond strength becomes significantly important when the masonry has to resist tensile and shear stresses. Large number of parameters pertaining to bricks/blocks, mortars and construction practices influence the masonry bond strength. Surface characteristics of the masonry unit (pore size distribution, porosity, etc.), moisture content of the unit at the time of construction, absorption characteristics of the unit and mortar composition are some of the important characteristics influencing brick-mortar bond development. Brick-mortar bond strength of the Masonry Prism was tested using Bond – Wrench test as per ASTM C1072.

Flexure bond strength of masonry prisms using local burnt clay bricks and the 1:6 cement mortar with Manufactured Sand and river sand was determined. Six prisms were tested in each category to get the mean value of flexure bond strength. The flexure bond strength of masonry using 1:6 cement mortar (with 85% flow) was 0.06 MPa and 0.15 MPa for river sand and Manufactured Sand mortars respectively. *The flexure bond strength of masonry prism improved by 150% when Manufactured Sand was used* instead of river sand in the 1:6 cement mortar.

Compressive strength of masonry:

Compressive strength of masonry was examined by testing five brick high stack bonded masonry prisms. Prisms (size: 105 x 225 x 445 mm, having height to width ratio of 4.23) were prepared using burnt clay bricks having compressive strength of 10.1 MPa (mean value) and using 1:6 cement mortar with river sand and Manufactured Sand. Compressive strength of the masonry prisms was 3.35 MPa and 4.38 MPa for mortar with river sand and Manufactured Sand respectively. *Nearly 30% increase in masonry strength was observed in mortar made with Manufactured Sand*.



Stack bonded masonry prism under compression test
Fig (a) Typical failure pattern, Fig (b) Prism with strain gauge

Concluding Remarks:

The mining of sand from riverbeds is being regulated by the statutory authorities, as indiscriminate mining is causing damage to the environment. This has resulted in shortage of sand hampering the construction activity. Realizing the severity of the problem, the Governments of various States have allowed the use of Manufactured Sand (not Crusher dust), as an alternative to River Sand after establishing the performance of Concrete and Mortar containing Manufactured Sandas fine aggregates. A case study initiated by Karnataka Government at IISc reveals that the characteristics of mortars and concrete using Manufactured Sand as fine aggregate are superior when compared to mortars and concretes using natural river sand as fine aggregate. Manufactured Sand falling within the grading Zone II as specified by IS 383 manufactured from the hard rock is suitable as fine aggregate in concrete and masonry mortars. Also, IS-2116 and IS 383 codes permit the use of crushed stone fine aggregate in masonry mortars and concrete. In view of this, Manufactured Sand is recommended to be used as an alternative to River sand. This would easily take care of handling the scarcity of river sand and lead to lessening the impact of construction activity on the environment.

References

1. *"Suitability of Manufactured Sand (M-Sand) as fine aggregates in mortars and concrete" – By Prof. B.V. Venkatarama Reddy, Department of Civil Engineering, Indian Institute of Science, Bangalore – 560012. (CSIC project: CP 6597/0505/11-330 dated 5.07.2011)*
2. *ICOMAT – Concrete Initiatives and Innovations.*
3. *Cement Concrete and Aggregates Australia –"Guide to the Specification and use of Manufactured Sand in Concrete"*
4. *http://www.msand.in/poabsmsand.php*

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