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Impact of Artificial Sand on the Properties of Concrete and Mortar

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Abstract: *An enormous quantity of concrete is consumed by the construction industry. About 37.5 % volume of concrete is comprised of sand. A good class concrete is produced by cautious mixing of cement, fine and coarse aggregates, water and admixtures as required to obtain an optimum quality and economy. Generally, cement and coarse aggregates are factory made products and their quality and standards can be easily controlled and maintained. Water used for mixing of concrete is usually tap water. The fine aggregates or sand used is usually obtained from natural sources particularly river beds or river banks. Nowadays due to constant sand mining, the natural sand is reducing at an alarming rate. Sand dragging from river beds has led to several environmental issues. Due to various environmental issues Government has expelled the dragging of sand from rivers. This has led to a scarcity and substantial increase in the cost of natural sand. There is a vital need to find an alternative to Natural Sand. The only long term replacement for sand is Artificial sand. In the present study, an attempt has been made to experimentally study the properties of concrete and mortar by replacing the 100% natural sand with artificial sand. The results have shown that the natural sand can be replaced with the artificial sand to produce concrete and mortar of satisfactory strength and durability.*
Key words: *Artificial Sand, Concrete, Natural Sand, Strength.*

I. Introduction

Sand is a vigorous element in making two most used construction materials viz. cement concrete and mortar. Usually, Natural Sand, which is made by natural enduring of rocks over many years, is preferred as fine aggregate. The economic growth 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 an environment such as destruction 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 controlled or banned by the authorities. Regulatory 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 (Priyanka A. Jadhav and Dilip K. Kulkarni, 2013). This sand removed from fields, in addition to depleting the fertile top soil, impairs the quality of concrete/mortar. Artificial sand, which is obtained by crushing the rock, is emerging as a viable alternative to Natural Sand. This material is in use for quite some time in developed countries. The use of this sand (also called artificial sand, Artificial sand, Robo Sand etc.,) is picking up in India in major cities. Use of methodically produced Artificial Sand as an alternative to Natural Sand is the requirement of the hour and will provide a long term solution to Indian Construction Industry.

Indiscriminate mining of sand from riverbeds is posing a serious threat to an environment such as destruction 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 controlled or banned by the authorities. Regulatory 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 (Priyanka A. Jadhav and Dilip K. Kulkarni, 2013). This sand removed from fields, in addition to depleting the fertile top soil, impairs the quality of concrete/mortar. Artificial sand, which is obtained by crushing the rock, is emerging as a viable alternative to Natural Sand. This material is in use for quite some time in developed countries. The use of this sand (also called artificial sand, Artificial sand, Robo Sand etc.,) is picking up in India in major cities. Use of methodically produced Artificial Sand as an alternative to Natural Sand is the requirement of the hour and will provide a long term solution to Indian Construction Industry.

Artificial sand is crushed fine aggregate formed 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 (Amnon K., and Hadassa B,2006) . Production generally involves crushing, screening and possibly washing. Separation into discrete fractions, recombining and blending may be essential.

Artificial Sand is produced by nurturing hard stones of changing sizes to primary and secondary crushers, for size saving and these crushed stones are extra 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 (Nagraj T.S,2000) . The procedure of attrition also enables the reduction of surface roughness of the fine aggregate elements 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 uncontrolled. This is not suitable for construction, as they result in the higher water demand leading to lack of control on workability/retention of workability as well as strength issues (Jadhav P., and Kulkarni D ,2012)

With the built-in process of unlike stages of screening, Artificial Sand plants confirm proper grading for better particle size distribution. By washing, the percentage of micro fines (passing 75 microns) is controlled below 15% by weight. The washing facility also provides keeps the Artificial Sand in wet or partially wet condition. This will help to decrease the water absorption rate by Artificial Sand during concrete manufacturing and hence better workability and workability retention. Table 1 shows the properties of natural sand and artificial sand (Hudson B.P, 1997).

Table 1 Properties of sand

Properties	**Natural Sand**	**Artificial Sand**
Shape	Spherical	Cubical
Gradation	Cannot be controlled	Can be controlled
Impurities	Present	Absent
Particle passing 75 micron	Up to 3%	Up to 15%
Grading zone	Conforms to zone II and III	Conforms to zone II

II. Procuring Ingredients

2.1. Cement

Portland Cement, the most widely used cementitious ingredients in present day concrete comprises of phases that consist of compounds of calcium, silicon, aluminum, iron, and oxygen.

43 grade Ordinary Portland Cement (OPC) with a specific gravity of 3.15, initial setting time 100 minutes, final setting time 300 minutes, complying with I.S 8112 was used.

2.2. Aggregate

These are primarily, naturally occurring, inert granular materials such as sand, gravel, or crushed stone. However, technology is broadening to include the use of recycled materials and synthetic products.

The locally available sand of zone II had the specific gravity of 2.62 and water absorption as 1%. The specific gravity of the locally available coarse aggregate was 2.93 and water absorption as 0.5%. The coarse aggregate (All-in-aggregate) used was about 20 mm maximum size and 4.75 mm minimum size. An aggregate, used for experimental investigation, confirmed to the provisions of the I.S 383 specification.

2.3. Water

Water used for mixing and cleaning was free from an injurious amount of oils, acids, alkalis, salts, sugar, organic materials, or other substances that can be deleterious to concrete, complying with I.S. 456.The Ph value of water was found to be 6.5.

III. Fixing The Desired Mix Proportion

The mix design carried out to form the M20 and M30 grade of concrete by using I.S. 10262 with a water-to-binder (W/B) ratio of 0.45.

3.1. Batching and Mixing

The concrete ingredients viz. Cement, sand, and coarse aggregate were weighted according to mix proportions and are dry mixed on a platform. The required quantity of water was added to the dry mix and homogeneously mixed.

3.2. Casting of Specimens

The homogeneous concrete mix was placed layer by layer in moulds and kept on the vibrating table. The specimens are giving the required compaction, both manually, and through a table vibrator. After through compaction, the specimens were finished smooth.

IV. Results

4.1. Workability of Concrete

Figure 1 shows the results of workability of concrete. This was measured by showing slump test. Keeping the water-cement ratio at 0.45 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 Natural Sand and Artificial Sand as fine aggregate. Concrete with Natural Sand gave higher slump value. IS 456 code stipulates a minimum slump of 50 mm for medium workability. Both the concrete mixes met this requirement irrespective of the type of sand.

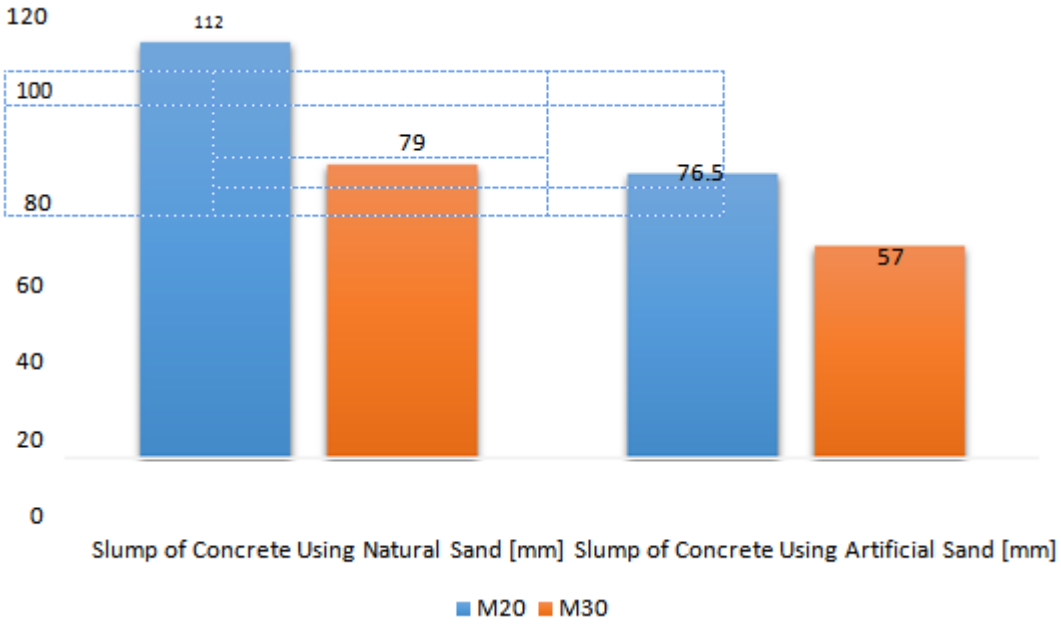

Figure 1 Workability of concrete

4.2. Compressive Strength of Concrete

Compressive strength was resolute by testing the 28 days cured cube specimens. The mean compressive strength values of cube specimens are reported in Figure 2. The compressive strength of M20 and M30 grade concrete with Artificial Sand as a fine aggregate is 6.5 – 9% higher when compared to the results using Natural Sand as fine aggregate.

4.3. Flexural Strength of Concrete

Flexure strength of concrete was determined using prisms (size: 100 x 100 x 500 mm) as per IS 516 guidelines. Three specimens were tested in each category and the mean values are reported in Figure 3. The results show that use of Artificial Sand as fine aggregate exhibits 12

– 15% higher flexure strength in comparison to the results of concrete with Natural Sand

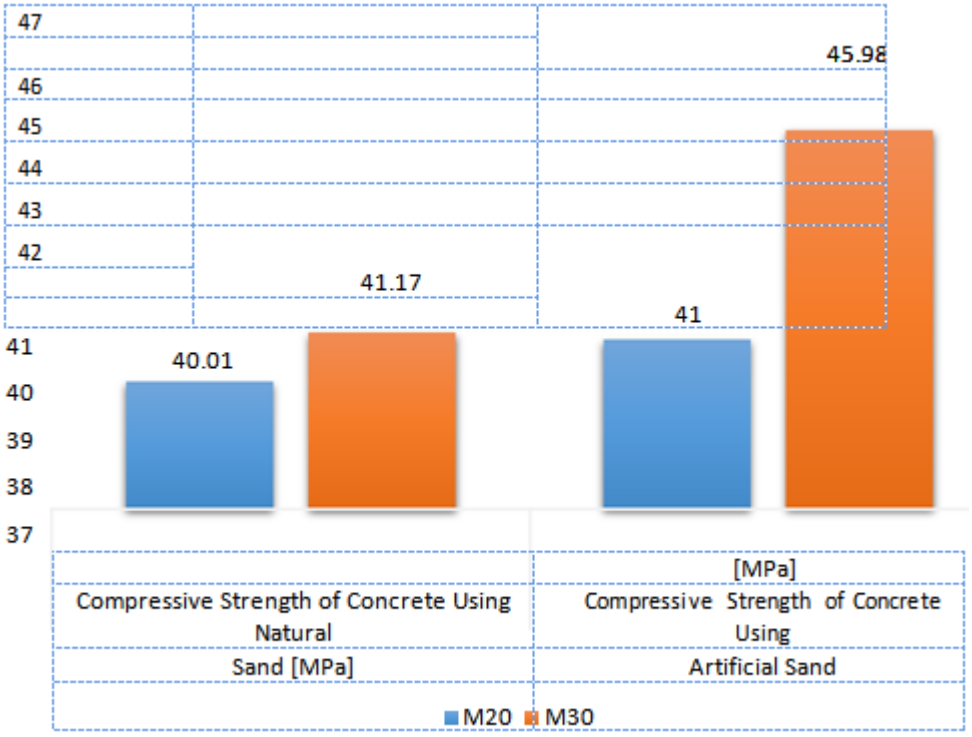

Figure 2 Compressive strength of concrete

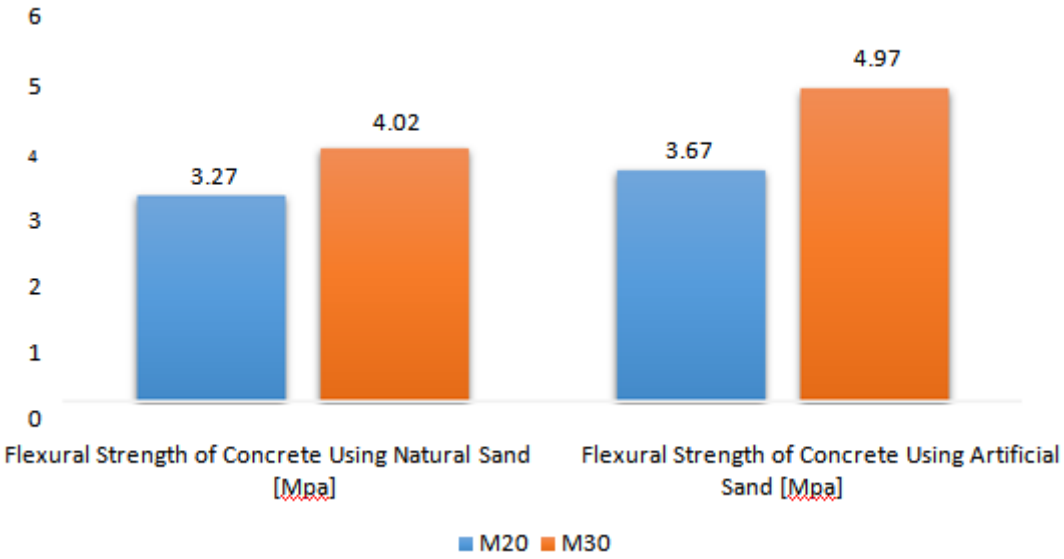

Figure 3 Flexural strength of concrete

4.4. Bond Strength of Concrete

The bond between rebar and the concrete was inspected by directing pull out test. The pullout test was achieved using 12 mm HYSD bar for M20 concrete. The bond strength at failure (mean of 3 specimens) with Natural Sand and Artificial Sand as fine aggregates is 13.4 MPa and 14.7 MPa respectively. The bond strength is found to be slightly advanced in case of concrete with Artificial Sand.

4.5. Permeability of Concrete

Concrete cubes of 150mmx150mm were casted and cured for a period of 28 days. A sample of diameter 100mm and thickness 50mm are subjected to a direct current of 60 volts across two faces. The specimens are placed in between two chambers one with NaOH (0.3N) and other with sodium chloride (3%)

solutions. The current passing through the specimen, the specimen is monitored regularly over six hours. The total charge that has passed through the specimen is calculated and is the value of product of time in seconds and current in amperes and unit is "Coulomb" shown in table 2.

Table 2 Permeability of concrete

Grade of Concrete	Water Cement Ratio	Concrete Using Natural Sand		Concrete Using Artificial Sand	
		Coulombs	Permeability	Coulombs	Permeability
M20	0.45	5024	High	798	Very low
M30		4050		585	Very low

4.6. Compressive Strength of Mortar

The compressive strength of the mortars at 28 day 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 artificial Sand is twice that of mortars made with natural sand.

Table 3 Compressive strength of mortar

Mix Proportion	Flow %	Compressive Strength of Mortar Using Natural Sand [Mpa]	Compressive Strength of Mortar Using Artificial Sand [Mpa]
1:6	85	4.05	8.52
	100	3.87	8.02
1:4	85	6.89	15.01
	100	6.12	15.40

4.7. Water Retentivity of Mortar

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 natural sand and artificial Sand were 26.1% and 27.5% respectively. For 1:4 cement mortar it was 24.8% and 36.7% for natural 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.

V. Discussion On Results

Artificial sand has balanced physical and chemical properties that can withstand any aggressive environmental and climatic conditions as it has enhanced strength and overall economy. Usage of Artificial sand can overcome the defects occurring in concrete such as honey combing, segregation, voids, capillary etc.

The superior shape, proper gradation of fines, smooth surface texture and consistency in production parameter of chemically stable sands provides higher strength to concrete Manufactured sands are made by crushing aggregate to sizes appropriate for use as a fine aggregate. During the crushing process the manufactured sand have irregular shapes. Due to irregular shape of the aggregates there is a better packing among the particles thereby reducing the voids in concrete. This may be due to the fact that replacement of natural sand by artificial sand may show the optimum reaction with optimum filler capacity. Artificial sand is free from elongated and flaky particle since it is perfect grading and cubical shaping using VSI shaping machine. Hence concrete using artificial sand has given higher strength. Artificial sand has minus 150 micron less than 10% and minus 45 micron less than 2% only. This helps the concrete to maintain water absorption rate of concrete less than 2% which helps to produce concrete of consistent quality.

The crusher dust is flaky and angular in shape which is troublesome in working. There is no plasticity in the mortar which makes it even difficult for the mason to work, whereas the cubical shape with grounded edge and superior gradation gives good plasticity to mortar providing excellent workability.

Artificial sand is graded with precession by removing the micro fines correctly and thus it has higher 'Finess Modules Index' compared to natural sand and crusher dust. Therefore concrete with artificial sand has given good workability for concrete.

Usage of Artificial sand can drastically reduce the cost since like natural sand, it does not contain impurities and wastage is NIL. In International Construction Scenario, no natural sand is used at all, only sand is manufactured and used, which gives superior strength and its cubical shape ensures significant reduction in the cement used in the concrete

Artificial sand is the only alternative to natural sand. Dredging of river beds to get natural sand will lead to environmental disaster like ground water depletion, water scarcity, threat to the safety of bridges, dams etc.

Beside with the Government contemplating ban on dredging of River beds to quarry natural sand, as part of the growing concern for environment protection, Artificial sand will be the only available option.

The mining of sand from riverbeds is being planned by the legal authorities, as uncritical mining is producing damage to the atmosphere. This has resulted in the deficiency of sand obstructing the construction activity. Understanding the severity of the problem, the Governments of various States have proficient the use of Artificial Sand (not Crusher dust), as an alternative to Natural Sand after starting the presentation of Concrete and Mortar containing Artificial Sand as fine aggregates. A case study started by Karnataka Government at IISc reveals that the features of mortars and concrete using Artificial Sand as a fine aggregate are superior when linked to mortars and concretes using natural Sand as fine aggregate. Artificial Sand dwindling within the grading Zone II as specified by IS 383 Artificial from the hard rock is appropriate as fine aggregate in concrete and masonry mortars. Also, IS-2116 and IS 383 codes license the use of crushed stone fine aggregate in masonry mortars and concrete. In view of this, Artificial Sand is endorsed to be used as an alternative to Natural Sand. This would simply take care of handling the insufficiency of Natural Sand and information to lessening the control of construction motion on the surroundings.

VI. Conclusions

Based on above study following conclusions are drawn

- Compressive strength of concretes with Artificial Sand is 6.5 – 9% higher when compared to the results using natural sand.
- Use of Artificial Sand exhibits 12 – 15% higher flexure strength in comparison to the results of concrete with natural sand.
- The bond strength is found to be slightly more in case of concrete with artificial sand.
- Water retentivity of mortar by using artificial sand was found to improved up to 11.9%.
- Resistance to penetration of water as proved by rapid chloride penetration test , is increased with artificial sand in concrete.
- Concrete with Natural Sand gave higher slump value
- Usage of artificial sand reduced the cost of concrete.

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