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SK Jain
Professor and Head, Department of Farm Structures, College of Agricultural Engineering and Technology, Dapoli, Maharashtra, India

Corresponding Author:
SK Jain
Professor and Head, Department of Farm Structures, College of Agricultural Engineering and Technology, Dapoli, Maharashtra, India

Investigations on physical properties and bulking of natural sand and artificial sand

SK Jain

Abstract
The specific gravity of natural sand was found to be 2.50 and that of artificial sand was 2.65. The average loose bulk density of natural sand was found to be 1.640 g/cc and that of artificial sand was found to be 1.780 g/cc. The average compacted bulk density of natural sand was found to be 1.715 g/cc and that of artificial sand was found to be 1.856 g/cc. The average void ratio of natural sand and artificial sand was found to be 0.344 and 0.288 respectively. Bulking of artificial sand was higher than natural sand for same percentage of water added. At 8 per cent water content in natural sand and artificial sand, maximum bulking was occurred.

Keywords: Investigations, physical, properties, bulking, artificial

Introduction
Currently, India has taken a major initiative on developing the infrastructures such as express highways, power projects and industrial structures etc., to meet the requirements of globalization. In recent years, concrete technology has made significant advances which have resulted in economical improvements in strength of concrete. This economic development depends upon the intelligent use of locally available materials. One of the important ingredients of conventional concrete is natural sand or river sand, which is one of the constituents used in the production of conventional concrete. Sand has become highly expensive and also scarce. However, due to the increased use of concrete in almost all types of Construction works, the demand of natural or river sand has been increased. To meet this demand of construction industry excessive quarrying of sand from river beds is taking place causing the depletion of sand resources. Natural sand is excavated from river bed impacts on environment in many ways. Due to digging of the sand from river bed reduces the water head, so less percolation of rain water in ground, which result in lower ground water level. There is erosion of nearby land due to excess sand lifting as well as it destroys the flora and fauna in surrounding areas.

Concrete is widely Use in making architecture structure, foundation, highway construction, runway, parking structure, pools/reservoir, pipes etc. Concrete consist of mainly sand which is about 35 per cent, It may be natural sand made from river or artificial sand. There are many kinds of rocks could be used to make artificial sand *viz*. granite, pebbles, basalt etc. In construction industry natural sand is used as an important building material and world consumption of sand in concrete alone is around 1000 million tons per year making it scarce and limited.

The construction industry has identified some waste material like fly ash, slag, lime stone powder, siliceous stone powder and crush sand for use in traditional concrete. And due to high rising of cost of natural sand there must be need to replace natural sand with artificial sand.

Use of crush sand in construction is nothing new in western world. It is being used there since few decades. Crush sand is a kind of waste material that is generated from the stone crushing industry which is abundantly available to extent of 200 million tons per annum which has land fill disposal problem and health and environment hazard. The present study was to determine the physical properties of natural sand and artificial sand and to test bulking of sand.

Sakthivel *et al*. (2013) [6] found that the partial replacement of sand with 10per cent of artificial sand has given the optimum results and concluded that if partial replacement of sand with artificial sand up to 10per cent in M20 grade of concrete is done, the replacement of natural sand with crush sand is economical and use of crush sand is possible without affecting the strength of structure.

Sahu and Sachan (2003) [5] found that crushed stone dust waste can be used effectively to replace natural sand in concrete. If 40per cent sand is replaced by stone dust in concrete, it will not only reduce the cost of concrete but at same time will save large quantity of natural sand and will also reduce the pollution created due to the disposal of this stone dust on valuable fertile land. Ilangovana *et al*. (2000) [3] investigated the possibility of using crushed rock as 100per cent replacement for sand, with varying compacting factors. It was found that the compressive, flexural strength and durability studies of concrete made of quarry rock dust are nearly 10per cent more than the conventional concrete. Verma and Pajgade (2015) [8] studied the effect of partial replacement of natural sand (NS) by crushed sand (CS) and partial replacement of cement by supplementary cementing material. Supplementary Cementing materials (SCM) Fly Ash and GGBS have been used and cement has been replaced by three combination of Fly ash (15per cent, 20per cent, and 25per cent) and two combinations of GGBS (40per cent & 50per cent). In both the cases, 50per cent natural sand was replaced by crushed sand. Both the materials have shown good compatible results when used and it was found that use of Supplementary Cementing materials shown better results in terms of compressive strength and workability due to reduction in water/ cement (w/c) ratio. Jadhav *et al*. (2013) [4] studied the effect of replacement of natural sand by manufactured sand on the properties of cement mortar in which the Results are compared with reference mix of 0per cent replacement of natural sand by manufactured sand. The compressive strength of cement mortar with 50per cent replacement of natural sand by manufactured sand revealed higher strength as compared to reference mix. The overall strength of mortar linearly increases for 0per cent, 50per cent replacement of natural sand by manufactured sand as compared with reference mix. Angelin *et al*. (2015) [1] predicted that replacement of natural sand with manufactured sand in order of 60per cent will produce concrete of satisfactory workability and compressive strength. Tapkire *et al*. (2014) [7] found that the physical properties of crushed sand satisfied the Indian Standard requirement. But in workability test it is less workable as compare to river sand concrete and it is also practically found that at the time of concreting in site by using concrete pump the blockage of concrete pump is found and was not working properly. Also, the compressive strength was found to be 8 per cent less than the river sand concrete. Thus, it was suggested that at the time of concrete used in crushed sand always used admixture for workability and strength improvement of concrete. Awasare *et al*. (2014) [2] concluded that the 7 and 28 days compressive strength of concrete by using wash, foundry and crush sand is less than that of natural sand. It was also reported that the 7 and 28 days split tensile strength of concrete wash, foundry and crush sand was less than that of natural sand.

Material and Methodology

The locally available river sand and manufactured artificial sand was used for the study. Artificial sand used was process controlled crushed fine aggregate produced from quarried stone by crushing or grinding and classification to obtain a controlled gradation product that completely passes the 4.75mm sieve. The instruments used were weighing balance, pycnometer, cylindrical metal jar, tamping rod of 16 mm diameter and measuring scale. Natural sand samples were procured from the riverbanks of Man-ganga River and the artificial sand was purchased from the sand crusher.

Specific gravity

The weight of empty pycnometer was noted, and then a considerable amount of sand was filled in the pycnometer and again noted the current weight. Then, fill the pycnometer with water having sand already in it, then again note down the current weight. Finally, take out all the sand and note down the final weight of water filled in pycnometer. The following formula was used to calculate specific gravity of the sand.

$$\text{Specific gravity} = (W_2 - W_1) / [(W_4 - W_1) - (W_3 - W_2)]$$

Where

W_1 = weight of pycnometer, g
W_2 = weight of pycnometer and sand, g
W_3 = weight of pycnometer, sand and water, g
W_4 = weight of pycnometer and water, g

Bulk density

Loose Bulk Density

The container was fill with sand sample loosely. Then by using a weighing balance, The weight of the filled container was noted. Loose bulk density was calculated by,

$$\text{Loose bulk density} = W / V$$

Where

W = Weight of loose filled sand, g
V = Volume of container, cc

Compact Bulk Density

The container was filled one-third with sand sample and tamped with 25 strokes of the rounded end of the tamping rod. Further, sand was added in two layers and tamped by 25 strokes on each layer. The container was finally filled to overflowing stage, and the surplus aggregate struck off, by using the tamping rod as a straight edge. The net weight of the sand in the measure shall be determined and the compacted bulk density calculated by,

$$\text{Compact bulk density} = W' / V'$$

Where

W' = weight of compacted sand, g
V' = volume of container, cc

Void Ratio

The void ratio of sand is defined as the ratio of volume of voids to volume of solids. It is a dimensionless quantity and is closely related to porosity. Void ratio is calculated as,

$$\text{Void ratio} = 1 - \frac{\text{Bulk density}}{\text{Specific gravity on saturated surface dry basis}}$$

Bulking of sand

The sufficient quantity of the moist sand was filled loosely into cylinder. The height of moist sand column was measured. Let it be H_1 cm. The moist sand is taken out without loss on paper. The cylinder is half filled with water. The moist sand is poured back into the cylinder slowly and simultaneously stirred with a 6 mm diameter steel rod, so that its' volume is reduced to a minimum. Level the top surface of the inundated sand and measure its depth at the middle with the steel rule.

Let the height of submerged sand column be H_2 cm. The percentage of bulking of the sand due to moisture was calculated from the formula:

Bulking of Sand, % = $(H_1 - H_2) / H_2 \times 100$

Where
H1 = Height of moist sand and water in container, cm
H2 = Height of submerged sand in water, cm

Results and Discussion
The results obtained for specific gravity, loose bulk density, compacted density, void ratio, test for bulking for natural and artificial sand are discussed.

Specific gravity
Table 1 revealed the observations for specific gravity of natural and artificial sand. The specific gravity of natural sand was found to be 2.50 and that of artificial sand was 2.65. The artificial sand Posses higher specific gravity than the natural sand. Thus, it was found that the higher the specific gravity the higher the proportions of concrete. However, the higher cement-water ratio leads to the less density and weight of concrete.

Table 1: Specific Gravity observations

S.N.	Particulars	Natural sand			Artificial Sand		
		Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	Weight of container (g) W_1	594.2	594.2	594.2	594.2	594.2	594.2
2	Weight of container + sand (g) W_2	794.2	794.2	794.2	794.2	794.2	794.2
3	Weight of container + sand + water (g) W_3	1780.7	1776.2	1778.3	1783	1782.5	1782.2
4	Weight of container + Weight of water (g) W_4	1658.0	1658.0	1658.0	1658.0	1658.0	1658.0
6	Specific Gravity	2.58	2.44	2.50	2.67	2.65	2.64
	Average	2.50			2.65		

Bulk density
Loose bulk density: Table 2 revealed the observations of loose bulk density for natural sand and artificial sand. The average loose bulk density of natural sand was found to be 1.640 g/cc and that of artificial sand was found to be 1.780 g/cc. It is due to the reason that basalt rocks are heavier than quartz.

Table 2: Loose bulk density

S. N.	Sample	Natural sand			Artificial sand		
		Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	Volume of container (lit)	15	15	15	15	15	15
2	Weight of sand (Kg)	24.86	24.58	24.4	26.7	26.75	26.69
3	Bulk density, g/cc	1.657	1.638	1.626	1.780	1.783	1.779
	Average	1.640			1.780		

Compacted bulk density
Table 3 revealed the observations of compacted bulk density of natural sand and artificial sand. The average compacted bulk density of natural sand was found to be 1.715 g/cc and that of artificial sand was found to be 1.856 g/cc.

Table 3: Compacted Bulk density observations

S. N.	Sample	Natural sand			Artificial sand		
		Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	Volume of container (lit.)	15	15	15	15	15	15
2	Weight of sand (Kg)	25.7	25.75	25.77	27.74	27.94	27.85
3	Bulk density, g/cc	1.713	1.716	1.718	1.849	1.862	1.856
	Average	1.715			1.856		

Void ratio: The void ratio of natural sand as revealed in Table 4 comes to the tune of 0.344 and that of artificial sand comes to 0.2876. It revealed that packing of artificial sand was higher than natural sand.

Table 4: Void ratio observations

S.N.	Sample	Natural sand			Artificial sand		
		Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	Bulk density, g/cc	1.713	1.716	1.718	1.849	1.862	1.856
2	Void ratio	0.337	0.345	0.35	0.288	0.287	0.288
	Average	0.344			0.2876		

Bulking of sand
It was revealed from Table 5, Table 6 and Fig. 1 that with the addition of 8 per cent of water in natural sand bulking of sand obtained was 16.95 per cent. The bulking of natural sand increases in the range of 6.17 per cent to 16.95 per cent with respect to increase in water content from 2 per cent to 14 per cent in sand. Whereas, the bulking of artificial sand increased in the range of 4.53 per cent to 20.00 per cent for the addition of water content from 2 per cent to 14 per cent in artificial sand. Bulking of artificial sand was higher than natural sand for same percentage of water added. At 8 per cent water content in natural sand and artificial sand, maximum bulking was occurred. It was also found that further increase in water content decreases the bulking of sands.

Table 5: Observation of percentage bulking of natural sand

Water content in moist sand, %	Initial height, cm (H_1)	Final height of natural sand, cm (H_2)			Bulking of natural sand, %
		Trial 1	Trial 2	Trial 3	Average
2	200	187	184	185	6.17
4	200	185	183	180	8.51
6	200	179	175	177	12.99
8	200	170	172	171	16.95
10	200	174	176	173	14.72
12	200	180	179	180	11.32
14	200	185	184	186	8.10

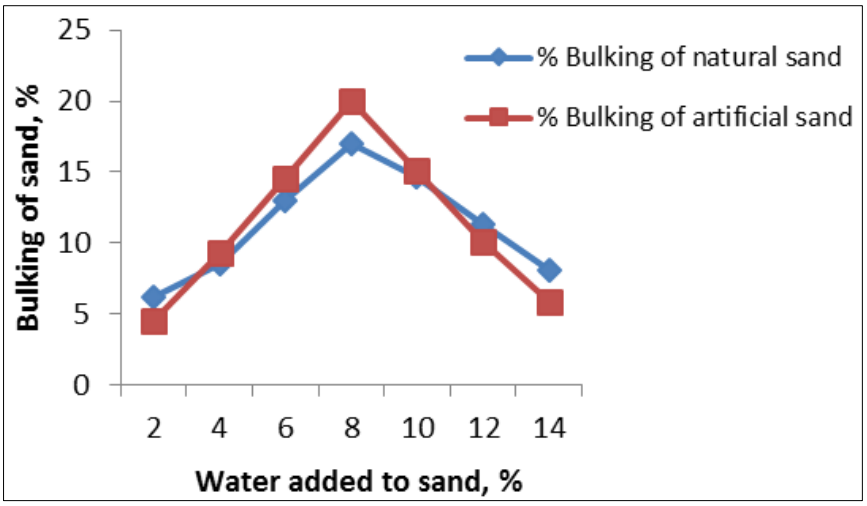

Fig 1: Bulking test results of sands

Table 6: Observation of % bulking of artificial sand

Water content in moist sand, %	Initial height, cm (H_1)	Final height of artificial sand, cm (H_2)			Bulking of artificial sand, %
		Trial 1	Trial 2	Trial 3	Average
2	200	193	191	190	4.53
4	200	185	182	182	9.28
6	200	176	175	173	14.50
8	200	168	165	167	20.00
10	200	176	172	173	15.16
12	200	180	181	181	10.07
14	200	189	190	188	5.82

Conclusions

It was found that specific gravity of artificial sand was higher than natural sand. The loose and compacted bulk density of artificial sand was found higher than natural sand. The void ratio of artificial sand was found lower than natural sand. It was also found that bulking of natural sand was lower as compare to artificial sand. It was found that bulking of artificial sand decreases rapidly in comparison to natural sand with increase in moisture. The artificial sand is cheaper than natural sand and artificial sand is waste by product of stone crushers thus, artificial sand found to be economic and could be used as substitute for natural sand.

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