Indian Journal of Science and Technology, *Vol 9(2), DOI: 10.17485/ijst/2016/v9i2/86352, January 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Size Effect Studies on Concrete made of Natural and Artificial Sand

D. Sivakumar[1*], T. Hemalatha[2], R. Rajeshwaran[1], N. Murugan[1] and M. Kotteeswaran[1]

[1]Department of Civil Engineering, Vel Tech High Tech Dr. Rangarajan Dr. Sakunthala Engineering College, Chennai - 600062, Tamil Nadu, India;
shri.sivakumar1974@gmail.com, rajeshwaran442@gmail.com, vasanth6130@gmail.com, koteezrockz@gmail.com
[2]Structural Engineering Research Centre (CSIR - SERC), Chennai - 600113, Tamil Nadu, India;
hemalatha@serc.res.in

Abstract

Objective: An experimental investigation was carried out to study the size effect on concrete specimens. **Methods:** In order to study the size effect compressive and split tensile test were conducted on standard and high strength concrete (M30 and M60) specimens of two different sizes of cubes (150 x 150 x 150 mm and 100 x 100 x 100 mm) and cylinders (150 x 300 mm and 100 x 200 mm) made of natural and artificial sand. In addition to this, the flexural strength test was also conducted for beam (500 x 100 x 100 mm) to compare the flexural strength of the beams made of natural and artificial sand. **Findings:** The result showed that the larger size concrete specimen fails at a lower stress than a smaller one and it was also observed that there was no significant variation in the strength with two sizes considered. The mechanical properties obtained with natural sand and artificial sand indicates that strength obtained for artificial sand was higher than that of natural sand for both M30 and M60 grade of concrete. **Applications/Improvements:** From this study, it was concluded that the standard cube of 150 x 150 x 150 mm and 100 x 100 x 100 mm can be used interchangeably for the test purpose. Similarly, for split tensile strength, standard cylinder of 150 x 300 mm and 100 x 200 mm can be used interchangeably.

Keywords: Artificial Sand, Mechanical Properties, Size Effect, Strength Characteristics

1. Introduction

The size of a concrete specimen under static loading may influences its behavior. This is known as a "size effect" and can be defined as the dependence of concrete nominal strength on concrete specimen. Size effect can be explained by a combination of fracture mechanics and plasticity because the fracture in a concrete structure is driven by the stored elastic energy that is released globally from the entire structure and it is highly related to the energy balance at the time of fracture process. Response of the structure and damage evolution is expected to depend upon the size; however it is not that much clear how the strength of material affect this size effect phenomenon.

The size effect is mainly due to the strength of the material and its randomness behavior and also due to release of energy when a large crack occurs or a large fracture process zone containing damaged material gets developed before the maximum load is reached[1]. The compressive strength is generally used to check the quality of concrete and is simply calculated as the stress at the time of failure based on the transverse cross-sectional area of concrete specimen. The 28-days compressive strength is universally accepted as a general index of concrete strength. The compressive strength of concrete is the basic and important material property in the design of reinforced concrete structures. It has become a problem to use this value as the control specimen sizes and shapes are different from country to country.

In India, the characteristic compressive strength is usually measured based on 150 x 150 x 150 mm for cubes, 150 x 300 mm for cylinders and 100 x 100 x 500 mm for

** Author for correspondence*

beam. But, the ACI code of practices, the use of lesser sizes gained more acceptance as the need to test high strength concrete increases. In this context the size effect becomes an important parameter for the compressive strength. Experiments on concrete structure members under local pressure indicated that the compressive strength of concrete at the bearing area is increased by the confinement effect provided by the enveloping concrete. Although design codes propose specific criteria to prevent bearing failure, they do not consider size effect which is an important phenomenon in the fracture mechanics of concrete/reinforced concrete[1].

Experimental and theoretical studies carried out in the recent past showed that structural concrete behavior (subjected to tension, compression, shear or torsion) is largely influenced by the size of the specimen. The size effect was studied by behavioral comparisons of geometrically similar test specimens. Experimental and numerical studies are in plenty and those studies show that larger compression specimens had steeper softening paths and larger beams were weaker in bending, shear and torsion[2].

In addition to that, this study also investigated the effect of 100% replacement of natural sand by artificial sand where cement, fine and coarse aggregate are basic needs for any construction industry. Sand is a prime material used for preparation of mortar and concrete and which plays a major role in mix design. Now a day's erosion of naturals and considering environmental issues, there is a scarcity of natural sand. The non-availability or shortage of natural sand will affect the construction industry; hence there is a need to find the new alternative material to replace the natural sand, such that excess natural erosion and harm to environment is prevented[2].

1.1 Research Significance

- This size effect of structural component needs more focus and hence in this study it is proposed to carry out a compression and split tensile test on concrete made of natural and artificial.
- Two different geometrically similar specimens of standard and high strength concrete are cast and tested to study the size effect behavior.
- In strength of materials concept, whatever the size of specimen either it may be larger or smaller both fails at same stress but in conventional method the smaller specimen fails at high stress whereas the larger specimen fails at lower stress[3].

1.2 Objectives

- To determine the influence of size effect on concrete.
- To use M sand as a fine aggregate in concrete.
- To compare the strength characteristics using M sand and natural sand in concrete.
- To find out workability, compressive strength, split tensile strength of concrete specimens.

2. Materials and Methods

There is scarcity of natural sand due to heavy demand in growing construction activities which forces to find the suitable substitute. The cheapest and the easiest way of getting substitute for natural sand is by crushing natural stone to get artificial sand of desired size and grade which would be free from all impurities[4]. For the purpose of experimentation concrete mixes are designed for M_{30} and M_{60} grade by 100% replacement of natural sand by artificial sand[5].

2.1 Artificial Sand (M–Sand)

Artificial sand is manufactured sand (Figure 1) produced from crushing of granite stones in required grading to be used for construction purposes as a replacement for natural sand. As per reports, artificial 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.

- The artificial sand (M–sand) has required gradation of fines, physical properties such as shape, smooth, surface textures and consistency.
- These physical properties of sand provides greater strength to the concrete by reducing segregation, bleeding, honeycombing, voids and capillary[6].
- Since M–sand is processed from quality of granite, it has the balanced physical and chemical properties
- This property of M–sand helps the concrete structures withstand extreme environmental conditions and prevents the corrosion of reinforcement steel.
- The M–sand makes the concrete require less amount of water and provide higher workable concrete and increases the strength of concrete.
- The M–sand has optimum initial setting and final setting time as well as excellent fineness.
- The usage of M–sand is more ecofriendly.

Figure 1. Manufacture sand.

2.2 Comparison of Natural Sand and Artificial Sand

The Table 1 represents the properties of natural and artificial sand. It is noted that artificial sand is more advantageous since there is no clay and organic impurities which affects setting and compressive strength and the particles below 75 micron are nearer to the limit of 15%. It is advisable to make suitable adjustment of w/c ratio and ensure early curing to avoid plastic shrinkage cracking[7].

Table 1. Comparison of natural and artificial sand

Properties	Natural Sand	Artificial Sand
Shape	Spherical Particle	Cubical Particle
Gradation	Cannot be controlled	Can be controlled
Particle passing 75 micron	Up to 3%(IS:383-1970)	Up to 15% (IS:383-1970)
Clay and Organic impurities	Likely to be present	Absent
Grading Zone	Mostly conforms to Zone II and III	Manufactured to conform to Zone II

2.3 Basic Tests and Mix Design

The process of selecting correct ingredients of concrete and to determine their proportions to make the concrete good in strength, workability and durability, is termed as concrete mix design[8]. The proper mix design has been arrived by conducting a basic tests of aggregate and the tests to be conducted arespecific gravityand water absorption test as per (IS 2386-3) and bulk density test and sieve analysis as per (IS 2386-1). The basic test results of aggregates and results of mix design calculations are presented in Table 2 and Table 3 respectively.

Table 2. Basic test results of aggregates

Properties of Coarse and Fine Aggregate	20mm Coarse Aggregate	12.5mm Coarse Aggregate	R – Sand	M – Sand
Loose density	1412.03kg/m^3	1421.77 kg/m^3	Nil	Nil
Rodded density	1600.68 kg/m^3	1578.23 kg/m^3	Nil	Nil
Fineness modulus	5.13	4.49	2.63	2.92
Specific gravity	2.68	2.71	2.57	2.65
Water absorption	0.54	0.70	1.35	1.87

Table 3. Mix design results

Grade and Type of Mix Material	R Sand Mix/M$_{30}$ Design (Kg/m^3)	M Sand Mix/M$_{30}$ Design (Kg/m^3)	R Sand Mix/ M$_{60}$ Design (Kg/m^3)	M Sand Mix/M$_{60}$ Design (Kg/m^3)
Cement	350	350	450	450
Fly Ash	-	-	60	60
Coarse Aggregate – 20mm	500	500	514	514
Coarse Aggregate – 12.5mm	500	500	425	425
Fine Aggregate	850	877	779	788
Water	170	170	173	173
Superplasticiser	PCE 4450	PCE 4450	Vararplast PC 432	Vararplast PC 432
SP Dosage	0.4%	0.5%	0.45%	0.5%
Total	**2370**	**2397**	**2401**	**2410**

2.4 Test Specimens

The cube specimens[9] of size 15 x 15 x 15 cm and 10 x 10 x 10 cm and the cylindrical specimens of size 15 cm in diameter and 30 cm long and 10 cm in diameter and 20 cm long[10] and beam specimen of size 50 x 10 x 10 cm are selected for moulding and these concrete specimens are cured for testing. Tests were conducted after 28 days of curing. Three specimens from each batch shall be made for testing and the average values are taken. The tests conducted are compressive strength test on cube specimens and flexural strength test on beam as per IS 516 and split tensile strength on cylinder specimens as per IS 5816.

3. Results and Discussions

3.1 M_{30} Concrete

The Table 4 indicates the results of M_{30} grade concrete. From Table 4, it may be observed that the compressive strength of cube specimens of size 150 x 150 x 150 mm is less than the compressive strength of cube specimens of size 100 x 100 x 100 mm in both natural and artificial sand. Similarly the split tensile strength of cylinder specimens of size 150 x 300 mm is less than the split tensile strength of cylinder specimens of size 100 x 200 mm in both natural and artificial sand. The flexural strength of beam size 500 x 100 x 100 mm is more for artificial sand compared to natural sand.

Table 4. Results for M_{30} grade of concrete

Name of the test	Size of the Specimen	Natural Sand (N/mm²)	M – Sand (N/mm²)
Compressive Strength Test	150 x 150 x 150 mm	40.5	42.1
	100 x 100 x 100 mm	44.0	46.6
Split Tensile Strength Test	150 x 300 mm	3.09	3.47
	100 x 200 mm	3.22	3.79
Flexural Strength Test	500 x 100 x 100mm	4.03	4.94

Figure 2 represents the plot between the size of concrete specimens (X-axis) and the compressive strength (Y-axis) for M_{30} grade of concrete. It is seen from Figure 2 that the compressive strength decreases with the increase in size of concrete specimens for both natural and artificial sand.

Figure 3 indicates the plotted between the size of concrete specimens (X-axis) and the split tensile strength (Y-axis) for M_{30} grade of concrete. It is seen from Figure 3 that the split tensile strength decreases with the increase in size of concrete specimens for both natural and artificial sand.

Figure 4 describes the plot for M_{30} grade concrete. From Figure 4, it was observed that the flexural strength of beam made of artificial sand is more compared to the beam made of natural sand.

The results found in the Figures 2, 3, 4 are similar to the results observed by the previous researchers[11].

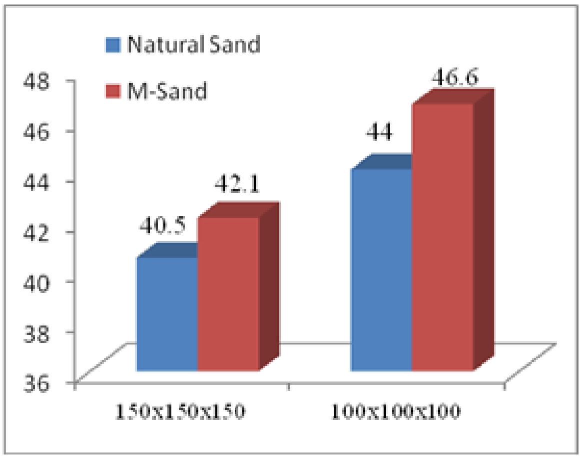

Figure 2. Compressive strength for M_{30} grade of concrete.

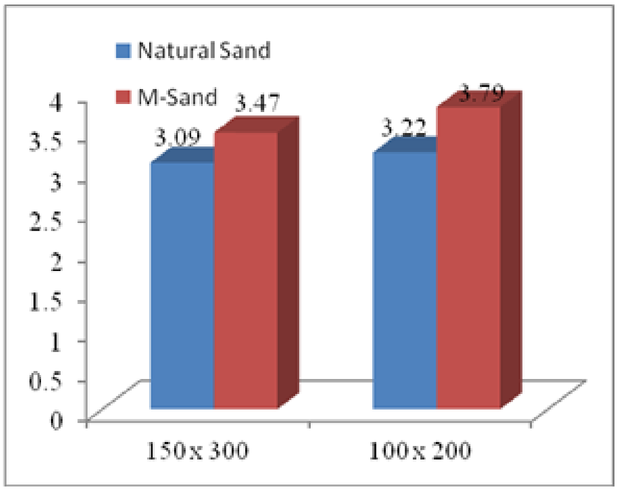

Figure 3. Split tensile strength for M_{30} grade of concrete.

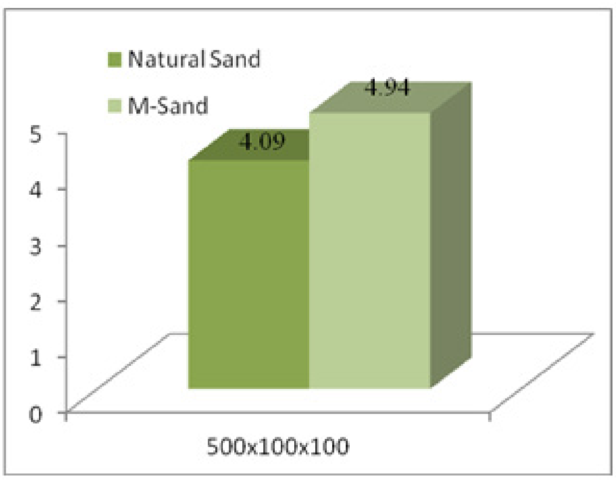

Figure 4. Flexural strength for M_{30} grade of concrete.

3.2 M_{60} Concrete

The Table 5 indicates the results for M_{60} grade of concrete. It may be observed from Table 5 that the compressive strength of cube specimens of size 150 x 150 x 150 mm is less than the compressive strength of cube specimens of size 100 x 100 x 100 mm in both natural and artificial sand. Similarly the split tensile strength of cylinder specimens of size 150 x 300 mm is less than the split tensile strength of cylinder specimens of size 100 x 200 mm in both natural and artificial sand. The flexural strength of beam size 500 x 100 x 100 mm is more for artificial sand compared to natural sand.

Table 5. Results for M_{60} grade of concrete

Name of the Test	Size of the Specimen	Natural Sand (N/mm^2)	M – Sand (N/mm^2)
Compressive Strength Test	150 x 150 x 150 mm	69.5	71.6
	100 x 100 x 100 mm	75.2	76.2
Split Tensile Strength Test	150 x 300 mm	3.14	3.99
	100 x 200 mm	3.65	4.12
Flexural Strength Test	500 x 100 x 100 mm	7.23	7.89

Figure 5 represents the plot between the size of concrete specimens (X-axis) and the compressive strength (Y-axis) for M60 grade of concrete. It is seen from Figure 5 that the compressive strength decreaseswith the increase in size of concrete specimens for both natural and artificial sand.

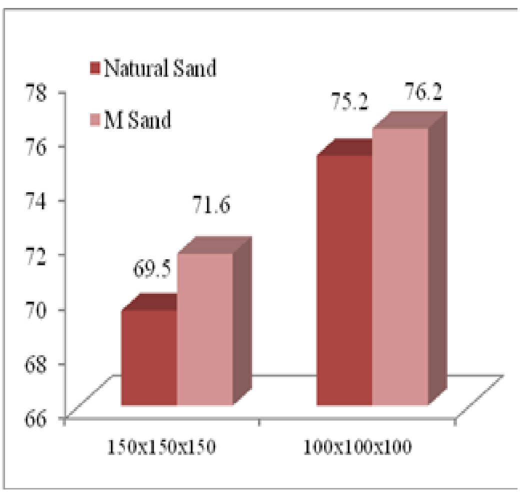

Figure 5. Compressive strength for M_{60} grade of concrete.

Figure 6 indicates the plot between the size of concrete specimens (X-axis) and the split tensile strength (Y-axis) for M_{60} grade of concrete. It is seen from the Figure 6 that the split tensile strength decreases with the increase in size of concrete specimens for both natural and artificial sand.

Figure 7 describes the plot for M_{60} grade of concrete. From Figure 7, it was found that the flexural strength of beam made of artificial sand is more compared to the beam made of natural sand.

As similar to Figures 2, 3, 4, results found in the Figures 5, 6, 7 are similar to the results observed by the previous researchers[11].

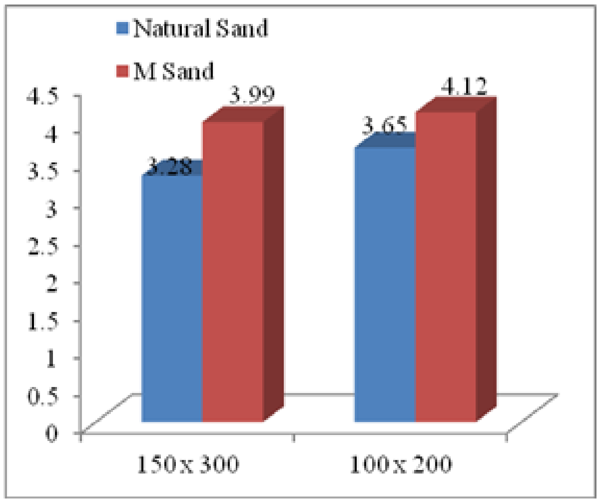

Figure 6. Split tensile strength for M_{60} grade of concrete.

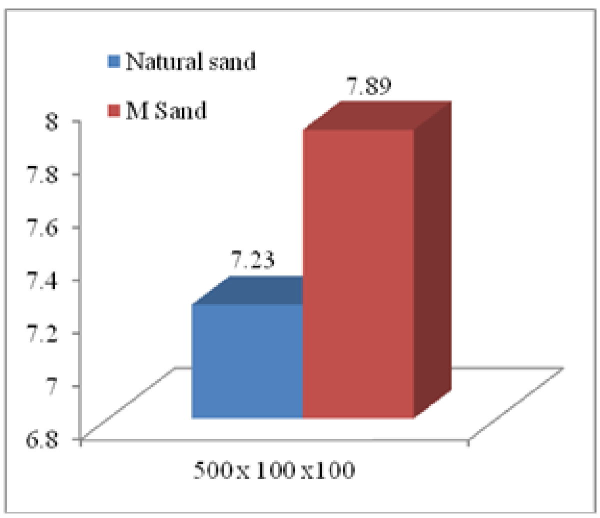

Figure 7. Flexural strength for M_{60} grade of concrete.

4. Conclusion

The compressive strength, split tensile strength were determined for two sizes and two grades of concrete to evaluate the effect of size with respect to grade of concrete. The flexural strength for standard beam size made of natural and artificial sand is also determined. Further, the influence of 100% replacement of natural sand with M sand is also studied. The following conclusions are derived:

- The mechanical properties obtained with natural sand and M–sand indicates that strength obtained for artificial is higher than that of natural sand for both M_{30} and M_{60} grade of concrete.
- In general, the size of the specimen affects the load carrying capacity or stiffness of the concrete. From the size effect study conducted, it is observed that there is no significant variation in the strength with two sizes considered. Size effect is not dominant for the two sizes considered in this study. Moreover, the size effect is not influenced by the type of fine aggregate used. The mechanical properties obtained from both artificial and natural sand were almost the same.

Hence, from this study, it can be concluded that the standard cube of 150 x 150 x 150 mm and 100 x 100 x 100 mm can be used interchangeably for the test purpose. Similarly, for split tensile strength, standard cylinder of 150 x 300 mm and 100 x 200 mm can be used interchangeably.

5. References

1. Bazant ZP, Pfeiffer PA. Determination of fracture energy properties from size effect. ACI Materials Journal. 1987 Nov-Dec; 84(6):463–80.
2. Elavenil S, Vijaya B. Manufactured sand, a solution and an alternative to natural sand and in concrete manufacturing. Journal of Engineering, Blue Ocean Research Journals. 2013; 2(2):20–4.
3. Krishna Rao MV, Rathish Kumar P, Srinivas B. Effect of size and shape of specimen on compressive strength of Glass Fiber Reinforced Concrete (GFRC). Architecture and Civil Engineering. 2011; 9(1):1– 9.
4. Vinayak RS, Popat DK. Properties of concrete by replacement of natural sand with artificial sand. International Journal of Engineering Research and Technology. 2012 Sep; 1(7): 1–7.
5. Shaikh MG, Daimi SA. Durability studies of concrete made by using artificial sand with dust and natural sand. International Journal of Earth Sciences and Engineering. 2011; 4(6):823–5.
6. Hudson BP. Manufactured sand for concrete. The Indian Concrete Journal. 1997. p. 237–40.
7. Venkatarama Reddy BV. Suitability of manufactured sand (M-sand) as fine aggregates in mortars and concrete. CSIC project report; 2011.
8. Vanitha S, Natarajan V, Praba M. Utilisation of waste plastics as a partial replacement of coarse aggregate in concrete blocks. Indian Journal of Science and Technology. 2015 Jun; 8(12):1–6.
9. Aïtcin PC, Miao B, Cook WD, Mitchell D. Effects of size and curing on cylinder compressive strength of normal and high-strength concretes. ACI Materials Journal. 1994 Jan; 91(4):349–55.
10. Malaikah S. Effect of specimen size and shape on the compressive strength of high strength concrete. Pertanika J Sci Technol. 2005; 13(1):87–96.
11. Kim JK, Yi ST. Application of size effect to compressive strength of concrete members, Sadhana. 2002 Aug; 27(4):467–84.