SSRG International Journal of Civil Engineering
ISSN: 2348 – 8352 / https://doi.org/10.14445/23488352/IJCE-V9I4P103

Volume 9 Issue 4, 15-19, April 2022
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Original Article

Effect of M Sand and Demolished Concrete Aggregates as a Replacement of Natural Fine Aggregates in Mix Design

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Received:01March 2022 Revised: 08 April 2022 Accepted: 26 April 2022 Published: 30 April 2022

Abstract - *In the present work, the mechanical properties of concrete are investigated using Demolished Concrete Aggregate (DCA) and M-sand to replace natural sand. A total of thirty samples of M20 grade concrete cast with 0%, 20%, 40%, 60%, and 100% replacement with M-sand and DCA, respectively. The mix of M20 grade concrete is derived, confirming IS codes. The results show that DCA reduces the compressive strength, tensile strength, and flexural strength of concrete, whereas all strengths increase with M-sand. In the case of DCA, a nominal 40% replacement of DCA with fine natural aggregate is permissible. This document gives formatting instructions.*

Keywords - *M-sand, Demolished Concrete Aggregate (DCA), Compressive strength, Splitting tensile strength, Flexural strength.*

1. Introduction

Concrete is the main material used extensively worldwide in all types of civil construction. The river sand/fine aggregate is one of the essential ingredients in a concrete mix. Due to insufficient sources of river sand, the cost of concrete production has increased rapidly. Thus, suitable alternative materials must be applied in the concrete production industry. Researchers are continuously studying alternatives for natural/river sand and using M-sand and DCA to replace natural sand for concrete design mix. The compressive strength of partially replaced natural sand by M sand cement mortar of proportions 1:2, 1:3, and 1:6 have been studied with 0.5 and 0.55 w/c ratios (Priyanka A. et al., 2013). The effect on M20 grade concrete-like workability, compressive, split tensile properties. Flexure strength have been studied with 0.4, 0.45, 0.5, 0.55 water-cement ratios and 0%, 20%, 40%, 60%, 80% and 100% percentage replacement of manufactured sand in place of natural sand (Priyanka A, et al., 2012). Unwanted concrete and brickwork can be reprocessed by arranging, crushing, and separating into recycled aggregate. Aggregates normally make up around 55% to 70% of the volume of a concrete mixture.

The management of construction and demolition (C&D) waste is difficult due to the growing considerable amount of demolition rubble, lack of dumping spots, and rise in shipping and clearance costs. But most industries and construction companies are still not aware of these environmentally dangerous wastages and their recycling. As a replacement for river/natural sand, DCA and Manufactured sand (M-sand) are alternate fine aggregates and may be used to produce concrete. Manufactured sand (M-sand) is a by-product while converting quarried stone to coarse aggregates or can be manufactured at stone crushing plants with crushers. Demolished Concrete Aggregates are the wastes collected from a regional building that has been demolished. DCA was manually sieved to remove the natural fine aggregate size, i.e., below 4.75mm. This sieved material thus was treated and tested under normal conditions. Several experimental results show that the quality of M-sand is composed of the river sand in several phases. Investigational outcomes show that the sharp ends of the particles in non-natural sand offer a healthier connection with the cement (Adams Joe et al., 2013). The main objective of the present work is to study the properties of the M20 grade of concrete systematically. With the replacement of natural sand with manufactured sand and Demolished Concrete Aggregates at 0%, 20%, 40%, 60%, and 100%.

2. Materials

The Ordinary Pozzolana Cement (OPC) 43 Grade complying with IS: IS:8112-2013 was used to design the M20 grade of concrete. The properties of 43 grade OPC cement were obtained according to IS:4031-1988 and verified by IS:8112-2013 and presented in Table 1.

Table 1. Physical properties of OPC 43 grade

S.No.	Property	Value
1	Specific Gravity	3.15
2	The fineness of cement by sieving	10%
3	Standard Consistency	32%
4	Initial Setting time (min)	95
5	Final Setting time (min)	234
6	Compressive strength in 3 days (N/mm^2)	23.00
7	Compressive strength in 7 days (N/mm^2)	34.10
8	Compressive strength in 28 days (N/mm^2)	48.00

Coarse aggregates of nominal size 20 mm were chosen. All the properties of coarse aggregates were tested by following IS:2386-(1-4) and according to IS: 383-2016. Table 2 shows the tested physical properties of coarse aggregates used in the concrete design mix.

Table 2. Physical properties of coarse aggregates.

S.No.	Property	Value
1	Specific Gravity	2.74
2	Fineness Modulus	6.8
3	Particle shape	Angular
4	Impact value	9.4%
5	Crushing value	16.2

Fine aggregates below 4.75mm are very important as they help fill the voids between coarse aggregates and mix with Cementous material to form a standard mortar. In the present study, three different fine aggregates were used. Namely, natural sand, manufactured sand, and Demolished Concrete Aggregates. To study the characteristics of the M20 grade of concrete systematically, natural sand is replaced with manufactured sand and Demolished Concrete Aggregates by weight of 0%, 20%, 40%, 60%, and 100%.

Natural/River sand is widely used for all construction works and the production of construction units. River sand is acquired by dredging from river beds. The natural/river sand used in the present work was sieved with the particle sizes grading as per IS:2386 and was in grading zone II (Table 3) as per IS: 383-2016 specifications.

M-sand was used as fine material. Since M-sand is produced at stone crushing plants in a controlled way by keeping the size and shape of particles identical to fine natural materials. During the processing of sand, filtering is done employing a water jet, and satisfactory parting has done by screw classifiers. Thus, manufactured sand can be manufactured according to our requirements, satisfying the natural sand zones. Experimental results show that M-Sand used in the present study as fine aggregate also falls in grading Zone II (Table 3).

Demolished Concrete Aggregates (DCA) were collected from a local Construction and Demolition site in Pantnagar, and collected DCAs were manually sieved to the natural fine aggregate size (i.e., below 4.75 mm). This sieved material thus was treated and tested under normal conditions. All three types of fine aggregate are tested with the procedures given in IS:2386-(1-4) and about IS: 383-2016 specifications. The tested results are given in Table 3.

Table 3. Properties of fine aggregates (natural sand, M-sand, and DCA)

S.No.	Property	Fine Aggregate		
		Natural sand	M-sand	DCA
1	Specific gravity	2.54	2.51	2.83
2	Water absorption	1.6%	2.89%	5%
3	Fineness modulus	3.54	3.28	3.75
4	Grading Zone	II	II	II

All the materials used were locally available in and around Pantnagar, Uttarakhand (India). Table 1 shows the physical properties of Ordinary Portland Cement 43 grade, which are within the allowable limits. The coarse aggregate properties which satisfy the IS standards are given in Table 2. The properties of river sand, M-sand, and DCA has given in Table 3 are within the same grading zone but with different fineness modulus values. The water absorption of manufactured sand and DCA is higher than river sand due to more fine particles.

3. Concrete Mix design M20 with M-SAND and DCA

The mix design has been done according to IS:10262-2009. The obtained mix design proportioning ingredients for M20 grade is 1:1.6:2.9 with a water to cement ratio of 0.5 and cement of 394.30kg. A total of five mixes viz., M0, M1, M2, M3, and M4 are designed with 0%, 20%, 40%, 60%, and 100% replacement with M-sand and DCA, respectively. All the mix proportions with M-sand and DCA are given in Table 4 and Table 5, respectively.

Table 4. Mix proportions for M-sand

Mix No.	Percentage Replacement	Mix proportions (C: FA: CA) {FA= natural sand + % (M-Sand)}
M0	0%	1:1.6:2.9
M1	20%	1:1.5:2.9
M2	40%	1:1.4:2.9
M3	60%	1:1.3:2.9
M4	100%	1:1.2:2.9

Table 5. Mix proportion for DCA

Mix No.	Percentage Replacement	Mix proportions (C: FA: CA) {FA = natural sand + %(DCA)}
M0	0%	1:1.6:2.9
M1	20%	1:1.5:2.9
M2	40%	1:1.3:2.9
M3	60%	1:1.2:2.9
M4	100%	1:1.1:2.9

4. Experimental Detail

The compressive, flexural, and split tensile strengths were examined on an M20 Design mix by replacing natural sand with M-sand and DCA. All tests were carried out at normal room temperature. To obtain a homogeneous design mix, all components, i.e., cement, coarse aggregate, fine aggregate (natural sand, %M-sand and % DCA), and a calculated amount of water, were mixed thoroughly in a dry mixing tray. The required workability of the design concrete mix has been checked using slump and compaction factor test according to Indian standards and has been found within permissible limits. The standard size of cube 150mm×150mm×150mm has been used to study the compressive strengths of concrete. All samples were cured in normal water and were tested on the 7th and 28th days according to IS:516-1959. The splitting tensile and Flexural strengths of concrete were calculated using various relationships with compressive strength as given in ACI building codes (U.Sridhar, 2015), IS codes, and research papers. The relationship between Compressive, Splitting tensile, and Flexure strengths of concrete are given below in Equation (1) to Equation (5). Equations 3 and 4 are provided by the ACI Building Code (ACI Committee 318,1999) and Neville (Neville, A.M,1995), respectively;

$$f_t=0.465(f_c)^{0.5} \text{ ; for M-sand} \quad (1)$$

$$f_t = 0.378(f_c)^{0.5} \text{ ; for DCA} \quad (2)$$

$$f_t = 0.56\,(f_{cc})^{0.5} \quad (3)$$

$$f_t = 0.23\,(f_{cc})^{0.67} \quad (4)$$

$$f_{fs} = 0.62\,(f_{cc})^{0.5} \quad (5)$$

Where ft is the Splitting tensile strength, ffs is the Flexural strength, fc is the Compression Strength of concrete cubes, and fcc is the Cylindrical Compressive Strength. All strengths are in MPa. Equations give the relations (4) and (5) require cylindrical compressive strength to determine concrete's splitting tensile and Flexural strengths. The relation given in Equation (6) has been used to calculate the cylindrical compressive strength of concrete in the present study.

Cylindrical Compressive Strength (fcc) = 0.8 x Cube Compressive strength (fc) …………..(6)

The experimental compressive strength of concrete (with M-sand and DCA) at 7 days and 28 days, given in Table 6 and Table 7, is the average of three cubes specimens cast for each mix proportion. The calculated splitting tensile and the Flexural strengths are also given in Table 6 and Table 7 for each mix proportion.

Table 6. Strengths of M20 grade concrete of M-sand

Mix No.	Percentage Replacement	Avg. Compressive Strength (N/mm^2)		Split tensile Strength (N/mm^2)		Flexural Strength (N/mm^2)	
		7 days	28 days	7 days	28 days	7 days	28 days
M0	0%	34.10	48.00	2.08	2.86	4.56	5.72
M1	20%	36.47	49.74	2.35	3.31	4.73	5.81
M2	40%	38.53	50.62	2.49	3.27	4.88	5.94
M3	60%	41.35	52.40	2.68	3.54	5.19	6.63
M4	100%	42.80	54.90	2.48	3.69	5.06	6.70

Table 7. Strengths of M20 grade concrete of DCA

Mix No.	Percentage Replacement	Avg. Compressive Strength (N/mm^2)		Split Tensile Strength (N/mm^2)		Flexural Strength (N/mm^2)	
		7 days	28 days	7 days	28 days	7 days	28 days
M0	0%	34.10	48.00	2.08	2.86	4.56	5.27
M1	20%	30.63	45.29	1.81	2.53	4.05	5.13
M2	40%	29.37	43.77	1.76	2.46	3.81	4.88
M3	60%	26.88	42.04	1.63	2.31	3.24	4.28
M4	100%	21.30	36.51	1.16	1.37	2.06	2.63

5. Results and Discussion

The obtained strength results (compressive strength, splitting tensile strength, and flexural strength in Tables 6 and 7) at 28 days are plotted to percentage replacement M-sand and DCA sand and are shown in Fig. 1 and Fig. 2, respectively. Figure 1 reveals that with the inclusion of M-sand in varying percentages, i.e., 0%, 20%, 40%, 60%, and 100%, the compressive strength of concrete gradually increased. Since the splitting tensile strength and flexural strength depend on the compressive strength, thus follow the same pattern. Figure 2 exhibits the strengths pattern with different percentage replacements of natural sand by DCA. The compressive strength of concrete decreases gradually to 60% replacement of DCA. But it decreases sharply when natural sand is fully replaced, i.e.%, 100 by DCA sand.

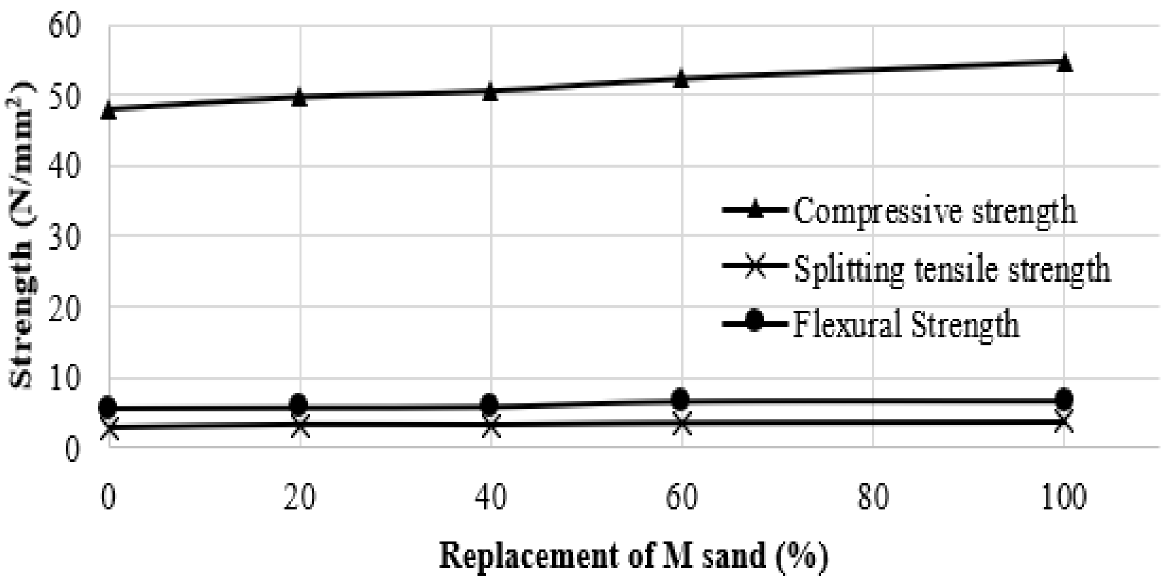

Fig. 1 Strengths of M20 grade concrete with percentage replacements of M-sand

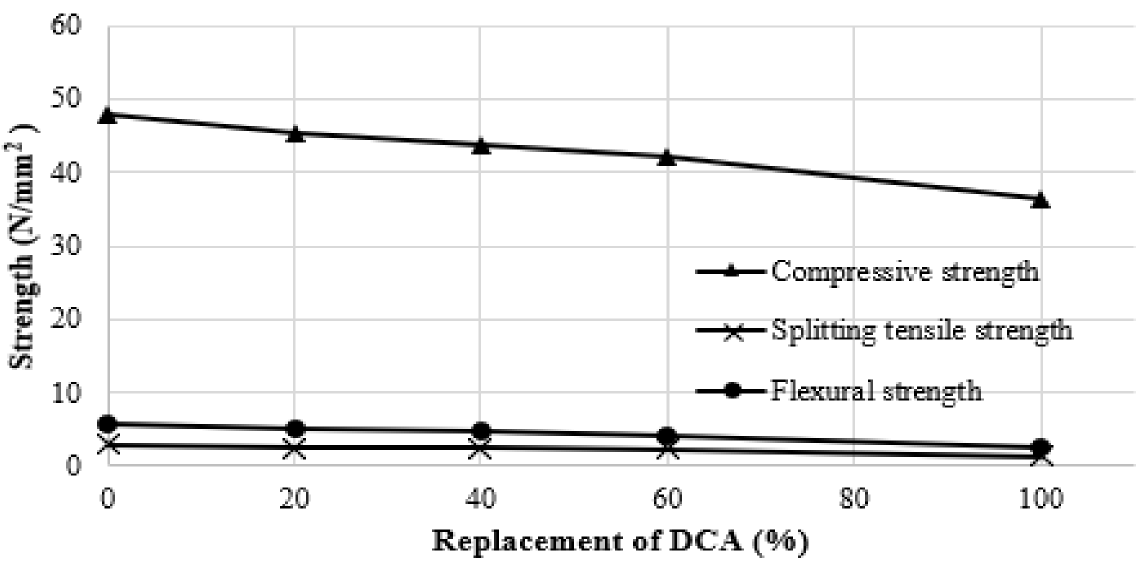

Fig 2. Strengths of M20 grade concrete with percentage replacements of DCA

6. Conclusion

The following conclusions may be drawn based on the experimental investigation.

The physical properties like fineness modulus, grading zone, and specific gravity of natural sand and M-sand are comparable.

The water absorption of DCA sand is very high compared to natural sand and M-sand due to more fine particles.

The experimental results showed that M-sand has similar physical properties as natural/river sand. Thus, it can be used as a substitute for fine aggregates material for concrete production.

It was examined that 100% substitution of natural sand with M-sand results in a higher strength than can be achieved with river sand mixed with concrete. Whereas, in the case of DCA, the strength values decreased with an increase in percentage replacement. There is a significant decrement in strength values while using high percentage replacement with fine aggregate. However, a nominal 40% replacement of DCA with fine aggregate is permissible.

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