Study on the Influence of Manufactured Sand on Deflection Characteristics of Coconut Shell Concrete Slab

R. Ramasubramani and K. Gunasekaran

1 Introduction

Concrete is the most commonly used material, due to its strong and versatile nature. It is a composite material, made of cement, aggregates and water. Sometimes admixtures and many other ingredients are added to improve its properties. Hence concrete is considered as the major base material for construction. Coarse aggregates are used in the concrete, which provides strength to the material. Generally, crushed stones, gravel and recycled aggregates are used as a coarse aggregate. The use of these aggregates reduces the natural resources, thereby damaging the environment, which in turn leads to ecological imbalance. Therefore, many alternate approaches have been put forward, like using industrial wastes, domestic wastes, and recycled materials. Likewise, agricultural wastes can also be used as an alternate material. In countries like India, where agriculture is the major work, a large amount of solid wastes is discharged from agriculture. One such agricultural waste is coconut shell (CS). This shall be used as a replacement material for conventional coarse aggregate [1–7], since it is one of the most propitious agro wastes.

Fine aggregates are used in the concrete, which provides workability to the material. Natural river sand (R-sand) was used initially, but in recent times due to the continuous extraction of R-sand, manufactured sand (M-sand) is used as an alternate material [8–12]. This M-sand is manufactured by pulverizing the granite stone and it is graded well in the desired proportion. It is also found to be cost-effective, has lesser impurities and good working properties than R-sand. The utilization of M-sand

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Fig. 1 **a** Coconut shell crusher, **b** Crushed coconut shells

is said to be eco-friendly since it prevents the dredging of riverbeds. Hence, in this study, it is proposed to use M-sand as fine aggregate and CS as coarse aggregate in the production of concrete.

1.1 Coconut Shell Aggregate

Coconut shell (CS) is very durable, possesses high resistance to abrasion, and does not degenerate easily. Traditionally, it has been used to make ornaments, fancy items, and household utensils and also made into activated carbon. Large percentages of CS are discarded daily as solid waste. Therefore, it is an effective means of disposing of this abundant waste and to keep a cleaner environment. CS is used as coarse aggregate in the production of lightweight concrete (LWC) because of the lower density compared to the density of conventional crushed stone aggregate (CSA) [1, 2]. For this study, raw CS was collected and crushed using a crusher. The size of the CS is confined to a maximum size of 12.5 mm because of its low strength and stiffness compared to CSA. The appearance of the CS is impartially smoothened on one side and rugged on the other side [5]. The pounded boundaries are uneven and sharp. The crusher used to crush the CS is shown in Fig. 1a and the crushed CS is shown in Fig. 1b.

1.2 Manufacture Sand (M-Sand)

Manufactured sand (M-sand) was obtained by the crushing rock deposition to produce a fine aggregate of superior quality that conforms to IS standard. It also develops high concrete strength compared to R-sand used concrete [8–12].

Table 1 Details of mix ratios adopted

Mix	R-sand (%) & M-sand (%)	Mix ratio Cement: River sand: M-Sand: CSA: w/c
Conventional concrete (CC)—Cement content used: 320 kg/m^3		
CCM1	100 & 00	1: 2.22: 0.00: 3.66: 0.55
CCM2	75 & 25	1: 1.66: 0.60: 3.66: 0.56
CCM3	50 & 50	1: 1.11: 1.21: 3.66: 0.58
CCM4	25 & 75	1: 0.55: 1.81: 3.66: 0.59
CCM5	00 & 100	1: 0.00: 2.42: 3.66: 0.60
Coconut shell concrete (CSC)—Cement content used: 510 kg/m^3		
CSCM1	100 & 00	1: 1.47: 0.00: 0.65: 0.42
CSCM2	75 & 25	1: 1.10: 0.40: 0.65: 0.42
CSCM3	50 & 50	1: 0.73: 0. 80: 0.65: 0.42
CSCM4	25 & 75	1: 0.37: 1.21: 0.65: 0.42
CSCM5	00 & 100	1: 0.00: 1.61: 0.65: 0.42

2 Materials and Mix Proportions

In this experimental work, the binder used was 53 grade ordinary Portland cement (OPC) conforming to IS 12269: 2013 [13]. CSA and CS as coarse aggregates and R-sand and M-sand as fine aggregates in concrete production. Potable water that is free from contamination was utilized for the whole process of producing concrete. The mix proportions for CC and CSC with varying proportions of R-sand and M-sand in which 100% R-sand used mixes (ref Table 1) were selected from the earlier studies [1, 2].

In each mix, the M-sand and R-sand are increased and decreased, respectively, in the percentage of 0, 25, 50, 75 and 100%. Since many studies have been carried with R-sand, holding it as a reference, M-sand was added partially as per the percentage given above to the mix proportions. Whereas the CSA was completely substituted by CS in the concrete. Different water-cement (w/c) ratios were adopted for varying proportions accordingly.

3 Experimental Study

In this experimental study, concrete cubes and slabs were cast and examined to find the compressive strength, density and deflection characteristics. The specimens were made in both the types of CCM and CSCM concretes. These two sets of concretes were made with varying percentages of R-sand and M-sand and a comparative study was made. A total of ninety cubes 100 × 100 × 100 mm size were cast as per IS

516: 2018 [14], and ten slabs 533 × 838 × 40 mm (selected from the literature) [15, 16] were cast and examined to find the compressive strength, density, and deflection of the both CC and CSC.

3.1 Specimen Test

The concrete constituents were mixed with respect to the mixed proportions in a concrete mixture machine and then put in frames in three layers, tamping each layer using a tamping rod, till the frame is filled completely. The purpose of tamping is to remove the excess air and lower the void content. Aluminum handheld floating was done to ensure that the holes were completely filled. This process was adopted over the top surface of the slabs after following the evaporation of excess water. To produce a smooth and dense surface of the slabs, troweling was done using a steel trowel after the aluminum handheld floating. After casting, the specimen was kept in an undisturbed manner for 24 h, then the specimen was taken out from the frame and placed in a curing tank, where the water level was maintained at a minimum of 50 mm above the top surface of the slab specimen. The curing period was 28 days to attain the targeted strength.

After 28 days, slabs were left for surface drying and whitewashed before testing. Also, before testing, required markings were plotted on the specimen and then placed in the loading frame of capacity 40 T. The edges of the slab were provided as simply supported. Alignment of the slab was tested and leveling was checked using the plumb bob for making concurrent of both slab center and loading from the center [15, 16]. A steel ball was exactly placed at the middle of the slab using plaster of Paris. The digital dial gauge was fixed at the bottom of the slab and was set to zero before loading. Then the load was persistently applied on the steel ball using a hydraulic jack and the slab was gradually subjected to an increase in loading till the slab fails. The readings from the dial gauge were also noted. The samples of cast cube and slab specimens are shown in Fig. 2. The cast slabs before testing are indicated in Fig. 3, the schematic diagram of deflection testing is shown in Fig. 4, and the slab testing arrangement for the deflection study is shown in Fig. 5. All tested specimens are shown in Fig. 6.

4 Results and Discussion

The CC and CSC with various proportions of R-sand and M-sand fine aggregates were compared. The use of M-sand in its place of R-sand exhibited better results in both CC and CSC. Since this study focused mainly on deflection characteristics slabs, it is found that the CS plays an important role in this property. In this study,

Fig. 2 Sample of cast specimens **a** cube **b** slab

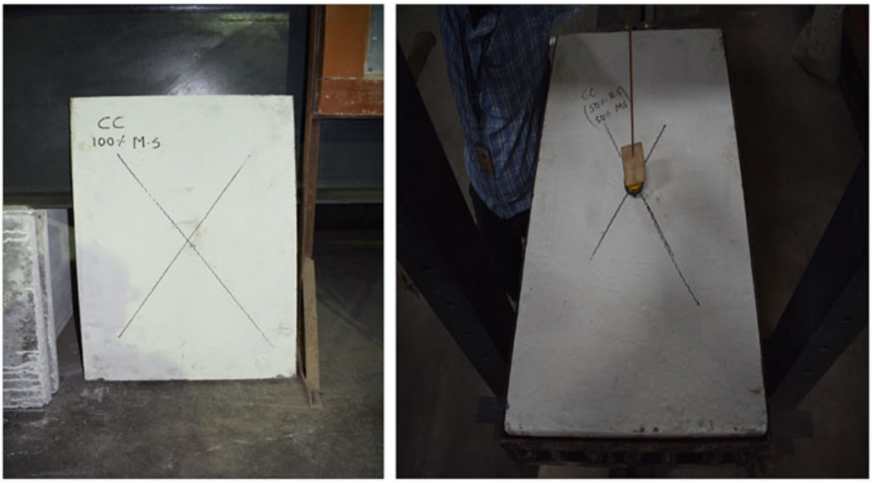

Fig. 3 Cast slabs before test

no reinforcements were used in order to avoid its effects in the concrete, since this experimental study mainly focuses on the cracking and deflection behavior of the plain concrete slabs. Test results are discussed in this section.

4.1 Compressive Strength

For all the mixes CCM1 to CCM5 and CSCM1 to CSCM5, compressive strength and density were found at 3, 7 and 28 days as per IS 516: 2018 [14]. Fresh and hardened concrete properties of both CC and CSC in different mixes are presented in Table 2.

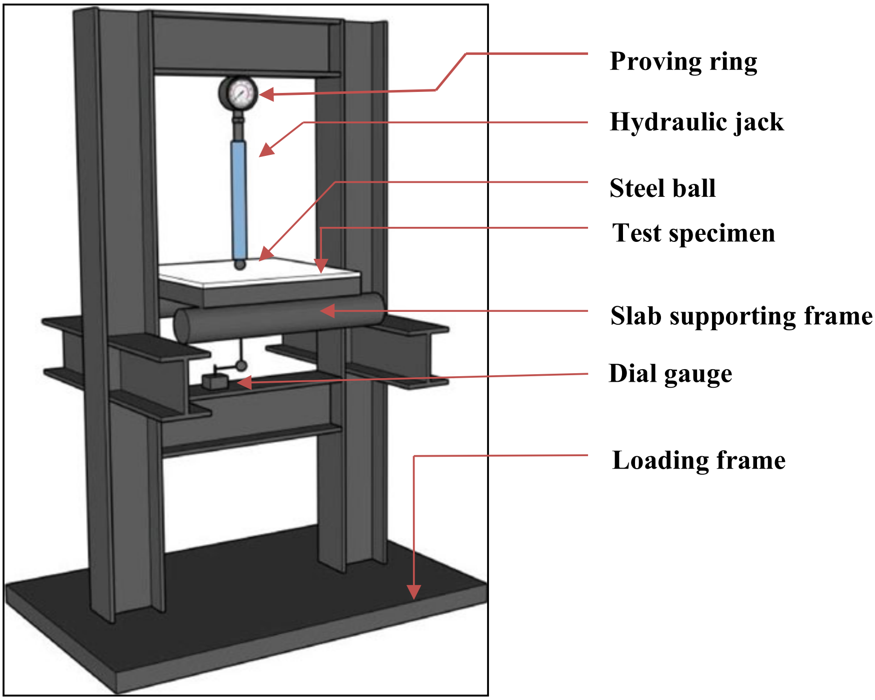

Fig. 4 Schematic diagram of deflection test

Fig. 5 Slabs under deflection load

4.2 Slabs Deflection

Load versus deflection curve is plotted as a graphical representation for CCM1-CCM5 as shown in Fig. 7 and CSCM1-CSCM5 is shown in Fig. 8. From the graph, it could be noticed that the CSC shows more deflection than the CC. But as a whole, the CSCM took less load than the CCM. Load taken by CCM5 is greater than CCM1

Fig. 6 Tested slab specimens

Table 2 Fresh and hardened concrete properties

Mix types	Fresh concrete density (kg/m^3)	3 days		7 days		28 days	
		Density (kg/m^3)	Strength (N/mm^2)	Density (kg/m^3)	Strength (N/mm^2)	Density (kg/m^3)	Strength (N/mm^2)
Conventional concrete (CC)							
CCM1	2480	2450	17.30	2460	22.70	2465	29.00
CCM2	2515	2485	18.60	2495	23.68	2505	29.98
CCM3	2545	2520	20.50	2535	24.65	2545	30.97
CCM4	2580	2550	22.60	2560	25.62	2570	31.96
CCM5	2605	2585	23.10	2600	26.60	2610	32.95
Coconut shell concrete (CSC)							
CSCM1	2035	1935	16.80	1950	19.20	1980	26.85
CSCM2	2065	1970	17.10	1980	19.70	2025	27.20
CSCM3	2100	2010	17.85	2025	20.40	2065	27.85
CSCM4	2135	2045	18.90	2065	22.10	2110	28.30
CSCM5	2165	2080	20.80	2100	23.30	2150	29.10

and CSCM5 is greater than CSCM1. Hence, it can be stated that when the percentage of M-sand is increased the strength in both CC and CSC increases. The same trend was reported in the literature on deflection characteristic study on CSC with QD [16] also stated that the use of QD in CSC also contributed to reducing the deflection characteristics on the slab in addition to CS role [15, 16]. Also, CSC warns against failure as compared with CC. This suggests that CS plays a crucial role in the concrete ductility property. The load versus deflection of CCM and CSCM mixes used slabs are shown in Tables 3 and 4.

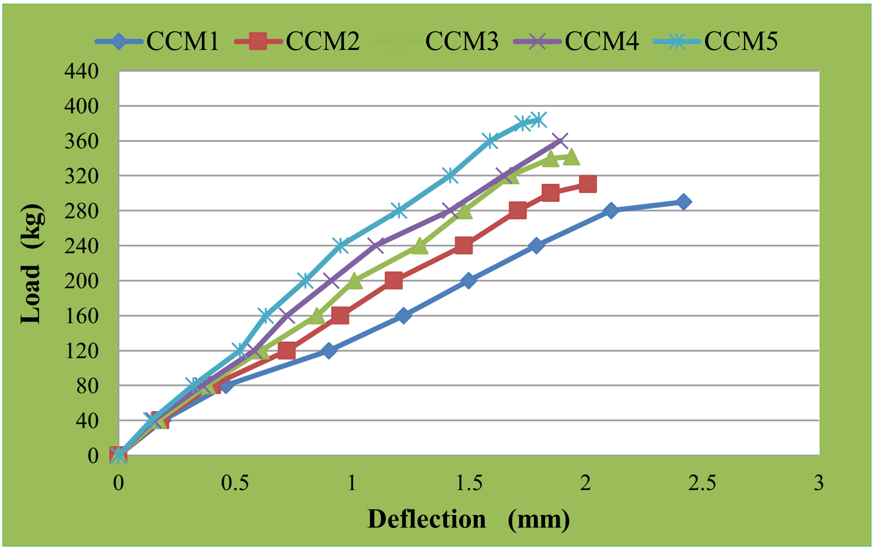

Fig. 7 Load versus deflection for CCM1 to CCM5

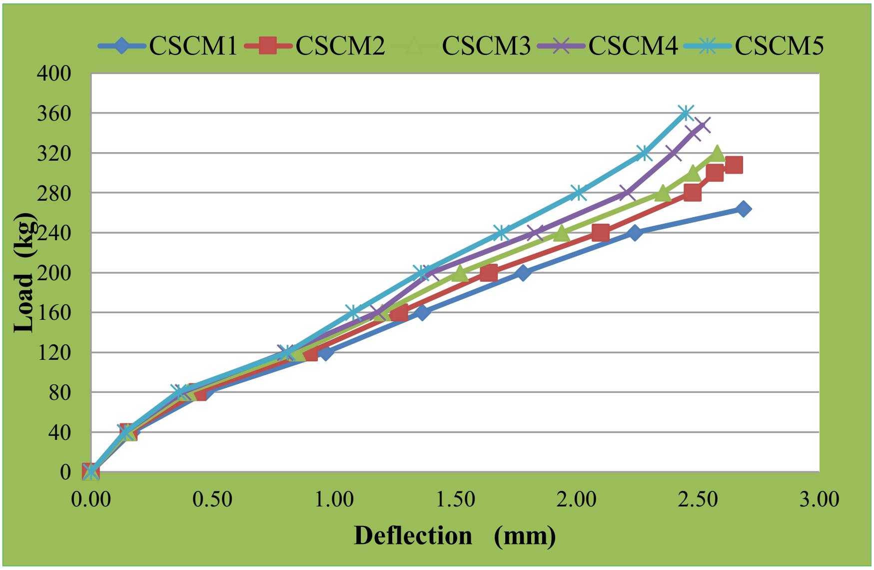

Fig. 8 Load versus deflection for CSCM1 to CSCM5

Table 3 Load versus deflection on CCM mixes slabs

Load in kg	Deflection in (mm)				
	CCM1	CCM2	CCM3	CCM4	CCM5
0	0	0	0	0	0
40	0.19	0.18	0.17	0.15	0.14
80	0.46	0.4	0.38	0.36	0.32
120	0.9	0.72	0.61	0.58	0.52
160	1.22	0.95	0.85	0.72	0.63
200	1.5	1.18	1.01	0.91	0.8
240	1.79	1.48	1.29	1.1	0.95
280	2.11	1.71	1.48	1.42	1.2
290	**2.42**	–	–	–	–
310	–	**2.01**	–	–	–
320	–	–	1.68	1.65	1.42
342	–	–	**1.94**	–	–
360	–	–	–	**1.89**	1.59
384	–	–	–	–	**1.80**

Table 4 Load versus deflection on CSCM mixes slabs

Load in kg	Deflection in (mm)				
	CSCM1	CSCM2	CSCM3	CSCM4	CSCM5
0	0	0	0	0	0
40	0.17	0.16	0.15	0.14	0.14
80	0.47	0.44	0.40	0.38	0.36
120	0.97	0.90	0.85	0.8	0.81
160	1.37	1.27	1.20	1.18	1.08
200	1.78	1.64	1.52	1.4	1.36
240	2.24	2.10	1.94	1.83	1.69
264	**2.69**	–	–	–	–
280	–	2.48	2.36	2.21	2.01
308	–	**2.65**	–	–	–
320	–	–	**2.58**	2.40	2.28
348	–	–	**–**	**2.52**	–
360	–	–	**–**	**–**	**2.45**

4.3 Comparison with IS Code

Span to effective depth ratio of the tested slabs is 13.34 (L/d = 533/40) [17]. Maximum deflection from the results of the deflection test for different percentages of substitutes of M-sand used CC is 1.80 mm and CSC is 2.45 mm which is less than the 13.34 mm.

5 Conclusion

The characteristics of CC and CSC were compared with varying proportions of R-sand and M-sand. From the observations, it was noted that the concrete with 100% M-sand gives better results. The compressive strength of CC is higher and deflection is lower than CSC. When the percentage of M-sand increases, concrete density and compressive strength increase and vice versa. Results of the deflection show that if percentages of M-sand increase the central deflection of the slab decreases. It was found that CSCM mixes exhibit greater deflection compared to CCM mixes. Also, CSCM warns against failure compared with CCM. This indicates that CS plays an important role in concrete ductility property. CSC is also suitable in accordance with IS 456: 2000 code criteria of span to effective depth ratio. It should, however, further works are to be carried out before it can be used along with reinforcement.

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