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Study for the relevance of coconut shell aggregate concrete non-pressure pipe

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Abstract The general behaviour of coconut shell aggregate concrete pipe is comparable to that of conventional concrete pipe. Three-edge bearing test results show that, both coconut shell aggregate concrete and conventional concrete pipes abide more load than load specified as per IS 458: 2003. The application of hydro static pressure not resulted in the formation of beads of water on the pipe surface during the application of the test pressure of 0.07 N/mm^2 as per IS 458: 2003. Absorption properties of both coconut shell aggregate concrete and conventional concrete pipes are well within the allowable limits as per IS 458:1988 on the conditions specified. Test results and performance of coconut shell aggregate concrete pipes encourage the use of coconut shell as an aggregate for the replacement of conventional coarse aggregate in reinforced concrete pipes production.

1. Introduction

Concrete is a friend of the environment in all stages of its lifespan, from raw material production to demolition, making it a natural choice for sustainable building construction. Because of ease availability of concrete constituents, less production time, to produce any size and shape at any moment compared to other construction material, concrete is the most widely used man-made material in the world today. Concrete is the only material which can be easily compatible for the replacement of normal constituents compared to all other construction materials. Therefore concrete researchers are continuing their research to replace concrete constituents from various wastes deliver from industries, domestic, agricultural, etc. [1–10].

Recently, authors are involved and established a concrete making use of an agricultural waste such as coconut shell (CS) as coarse aggregate in the production of coconut shell aggregate concrete (CSAC). It was studied about mechanical and bond properties of CSAC [11], long term study on compressive and bond strength of CSAC [12], reinforced lightweight CSAC beam behaviour under flexure [13], reinforced lightweight CSAC beam behaviour under shear [14], plastic shrinkage and deflection characteristics of CSAC slab [15], reinforced lightweight CSAC beam behaviour under torsion [16] and also some durability properties of CSAC [17].

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From these studies, it can be understood that the CSAC properties and behaviours were similar to those of conventional concrete (CC) and also its durability properties were within the range of CC. Therefore, authors initiated an attempt for the application of CSAC into some of the field element. Hence, this study focuses on the relevance of CSAC into an element like concrete pipe.

2. Coconut shell aggregate

Adequate debate on the subject of the yield of coconut in global and local availability of CS and its diverse uses in different field were already made in the past publications [11–17]. Also the method of making of CS as aggregate, physical and mechanical properties of CS, and the style to be followed in using CS as aggregate for making of concrete were also discussed and published in Elsevier. Nevertheless, for the reader's benefit of this manuscript, few of the significant properties of CS such as water absorption and specific gravity are invigorated once again that the average moisture content and water absorption of the CS were 4.20% and 24.00% respectively. The average specific gravity and the apparent specific gravity were found as 1.05–1.20 and 1.40–1.50 respectively, and these values are comparatively less than the specific gravity of conventional aggregates. These entail that, when CS is used in concrete it falls in the group of lightweight concrete (LWC) [11].

3. Precast concrete pipe

3.1. Classification of precast concrete pipe

As per the Indian specification for precast concrete pipe IS 458: 2003 [18], concrete pipes are classified mainly as non-pressure pipe (NP) and pressure pipe (P) respectively. Further NP pipes are sub classified into four classes such as unreinforced concrete non-pressure pipes (NP1) normally used for drainage and irrigation use, above ground or in shallow trenches, reinforced concrete, light-duty, non-pressure pipes (NP2) normally used for drainage and irrigation use, for cross drains/culverts carrying light traffic, reinforced and also unreinforced (in case of pipes manufactured by vibrated casting process) concrete, medium-duty, non-pressure pipes (NP3) normally used for drainage and irrigation use, for cross drains/culverts carrying medium traffic and reinforced and also unreinforced (in case of pipes manufactured by vibrated casting process) concrete, heavy-duty, non-pressure pipes (NP4) normally used for drainage and irrigation use, and for cross drains/culvert carrying heavy traffic, respectively. All, unreinforced and reinforced concrete NP pipes shall be capable of withstanding a test pressure of 0.07 N/mm^2 (7 m head).

Similarly, pressure pipe (P) is sub classified into three classes such as reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.2 N/mm^2 (20 m head) (P1), normally used for on gravity mains, the site test pressure not exceeding two-thirds of the hydrostatic test pressure, reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.4 N/mm^2 (40 m head) (P2) and reinforced concrete pressure pipes tested to a hydrostatic pressure of 0.6 N/mm^2 (60 m head) (P3), both are normally used for on pumping mains, the site test pressure not exceeding half of the hydrostatic test pressure, respectively.

3.2. Materials and methodology

Ordinary Portland cement, river sand, CS, and the potable water are the constituents used for the production of CSAC. Crushed granite stones (CGS) of 12.50 mm sizes were employed to prepare CC elements for comparison. CSs were collected from the local oil mill and transported to SRM University premises. CS was used in saturated surface dry (SSD) condition at the time of producing CSAC. Fig. 1 shows the crushed CS under in SSD state.

3.2.1. Selection and design of pipe

In this study, reinforced concrete pipes of 150 mm internal diameter and the barrel wall thickness of 25 mm of NP3 pipes are selected. The length of pipe selected is 2 m, 6 numbers of 6 mm diameter mild steel are used as minimum longitudinal reinforcement and 3 mm diameter wire is used as circumferential reinforcement with the pitch of 50 mm. The prepared reinforcement cages for making concrete pipes are shown in Fig. 2. These design requirements of this pipe are provided in accordance with the IS 458: 2003 [18].

3.2.2. Pipe production

As per IS 458: 2003 [18], both for CSAC and CC, minimum compressive strength of 35 N/mm^2 at 28-days was fixed as target strength. For the production of pipe, moulding machine which is shown in Fig. 3 is used for this work. The mixing of concrete constituents and the procedure for making pipe as followed by the pipe manufacturer is adopted for this work. The volume batching of concrete constituent materials is used for the mixing and the same is converted into weigh batch. Mix proportions used in this work are given in Table 1. From the quantity of cement required for producing one pipe, it was calculated the cement content required is approximately equal to 815 kg/m^3, which satisfies the minimum cement content to be used for non-pressure pipe is 450 kg/m^3 as per IS 458: 2003 [18].

Pipes were cast using both CC and CSAC for the comparison study. The reinforcement cages were prepared as per the sizes and the spacings suggested in IS 458-2003 [18] as shown in Fig. 2. As per the mix propositions selected, the concrete constituents were mixed through the mechanical mixer machine. Mixing was continued for not less than 2 min until there was a uniform distribution of the materials and the mass was uniform in colour and consistency. Slump cone test was performed on fresh concrete mix for its consistency and 9 companion cubes of 100 × 100 × 100 mm were prepared for its

Figure 1 Crushed coconut shell in SSD state.

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Figure 2 Reinforcement cages for making concrete pipes.

Figure 4 Pipe manufacturing process.

Figure 3 Pipe moulding machine.

compressive strength tests in which 3 cubes were tested at an age of 3 days, 7 days and 28 days respectively. Both slump cone test and compressive strength tests were performed as per IS 516: 1959 [19].

Pipe moulds were placed in the manufacturing plant and the fresh concrete was placed before setting has commenced. Concretes were poured in the moulds continuously and this process took 10–15 min for the completion pipe cast every time. This process was continued and the concrete was consolidated by spinning action of the machine. Fig. 4 shows process of concrete consolidation by spinning action of the machine. The pipes cast were kept undisturbed for about a day. The pipes were left for curing in the site itself for 28 days.

4. Experimental programme

The specimens of pipes were subjected to the following tests in accordance with IS 3597: 1998 [20] such as hydrostatic test, three-edge bearing test, and absorption test as well.

4.1. Three-edge bearing test

Three-edge bearing test was done by the method given in accordance with IS 3597: 1998 [20]. The pipe was allowed to surface dry before testing. The specimen was placed on the two bottom bearing strips in such a way that the pipe tests firmly and with the most uniform possible bearing on each strip for the full length of the pipe. Each end of the pipe at a point mid-way between the lower bearing strips was marked and then diametrically opposite points thereof were established. The top bearing block was placed in such a way that it contacts the two ends of the pipe at these marks. After placing the specimen in the machine on the bottom strips, the top bearing was symmetrically aligned in the testing machine. Load was applied at a uniform rate as specified in IS 3597: 1988 [20] until the formation of a 0.25 mm wide crack and then up to the ultimate strength load has been reached. Fig. 5 shows the schematic diagram of three-edge bearing method in which 1 indicates the complete machine, 2 indicates the test specimen, 3 indicates the top bearing block, 4 indicates the pressure gauge and 5 indicates the hydraulic jack respectively. Fig. 6 shows the pipe specimen under three-edge bearing test.

Table 1 Mix proportions.

Description	Cement	Sand	12.50 mm CGS	Water
Mix proportions – for conventional concrete for one pipe (0.027 m^3)				
Conventional mix by volume	0.42 cft	1.1 cft	0.75 cft	11 l = 0.385 cft
Ratio by volume	1	2.67	1.78	0.91
By weight	22 kg	80 kg	34 kg	11 kg
Ratio by weight	1	3.64	1.55	0.50
Mix proportions – for coconut shell concrete for one pipe (0.027 m^3)				
By weight	22 kg	80 kg	14 kg	11 kg
Ratio by weight	1	3.64	0.64	0.50

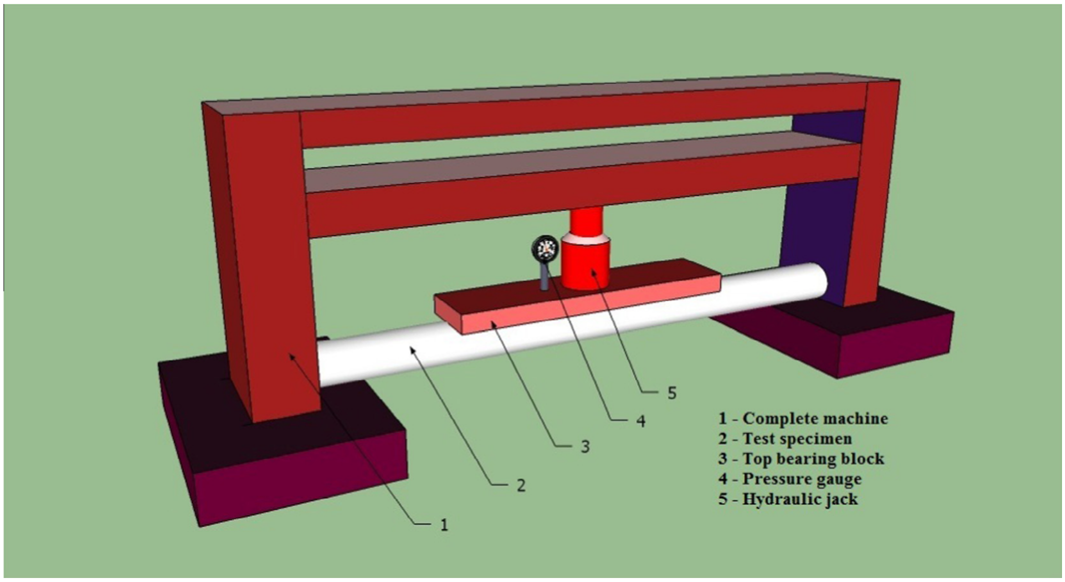

Figure 5 Schematic diagram of three edge bearing method.

4.2. Hydrostatic test

The specimen for determination of leakage under internal hydrostatic pressure should be sound and hence pipes are tested for this purpose. Pipes are pre-soaked by submerging in water for a period not less than 6 h before testing and excess water removed in accordance with IS 3597: 1998 [20]. The pipe was supported in such a way that the longitudinal axis is approximately horizontal and the exterior surface excepting the supports was examined readily before test starts. The equipment for making the test was made in such way that the specimen under test was filled with water to the exclusion of air and subjected to the required hydrostatic pressure. Hydrostatic pressure was applied to the whole pipe subjected to pressure in the 'as laid' condition. Pressure was applied at a gradual rate until the test pressure of 0.07 N/mm^2 is reached as per IS 458: 2003 [18]. Pressure was maintained for 2 min. Fig. 7 shows the schematic diagram of hydrostatic test method in which 1 indicates the loading machine, 2 indicates the test specimen and 3 indicates the water filling and pressure application respectively. Fig. 8 shows the pipe specimen under hydrostatic test.

4.3. Absorption test

Pipe specimens for absorption test were prepared by cutting across the pipes for the length of 300 mm using diamond blade and the test was conducted in accordance with IS 3597: 1998 [20]. Prepared pipe specimens were dried in an oven at a temperature of 110 °C for a period of 36 h. Fig. 9 shows that the pipe specimens were placed in an oven. After this specified duration, the dry mass of the specimens was determined at ambient temperature. After drying and weighing, the specimens were immersed in clean water at room temperature for the period of 10 min and also up to 24 h as specified in accordance with IS 458: 1988 [21]. Specimens were removed from the water after the specified period and allowed to drain for not more than one minute. The superficial water was then

Figure 6 Specimen under three-edge bearing test.

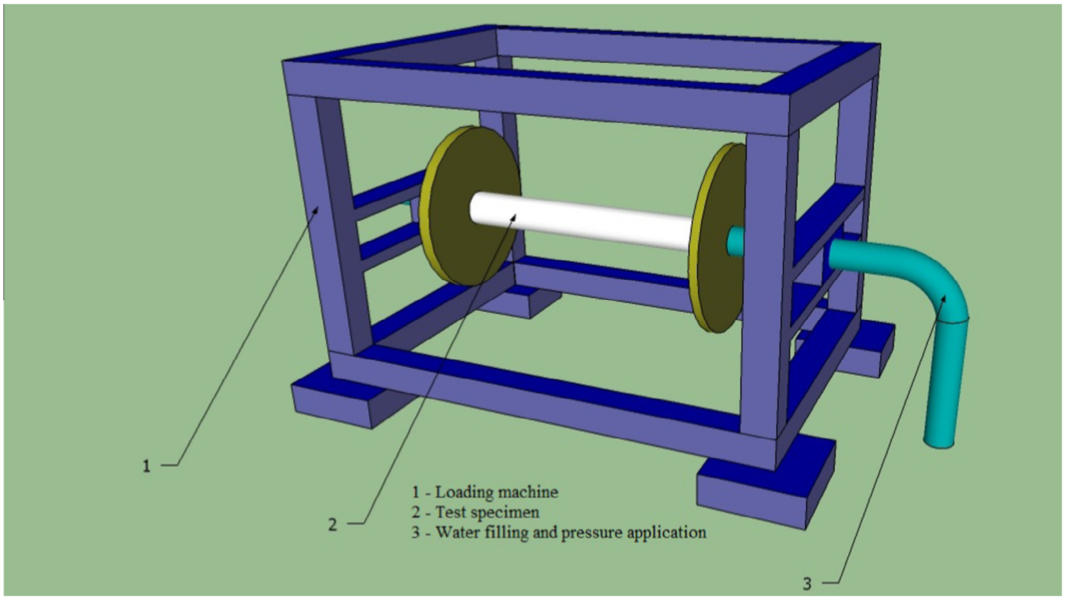

Figure 7 Schematic diagram of hydrostatic test method.

Figure 8 Specimen under hydrostatic test method.

Figure 9 Pipe specimens placed in an oven.

removed by absorbent cloth and the specimens were weighed immediately. The increase in mass of the specimens over its dry mass has been taken as the absorption of the specimen and expressed as a percentage of the dry mass.

5. Results and discussion

From the tests conducted on both CSAC and CC, fresh concrete consistency, hardened concrete compressive strength, experimental tests on pipe specimens such as three edge bearing, hydrostatic pressure and absorption tests results are presented and discussed in this section. The fresh and hardened concrete properties of both CSAC and CC are given in Table 2.

5.1. Consistency and compressive strength

Slump test results show that the mixes were given medium degree of workability. Since the process of making concrete

Table 2 Properties of concrete used.

Parameters	Coconut shell Aggregate concrete (CSAC)	Control concrete (CC)
Minimum targeted strength (N/mm^2)	35	35
Slump (mm)	48	45
Fresh state density (kg/m^3)	1910	2140
3-day hardened density (kg/m^3)	1940	2165
3-day compressive strength (N/mm^2)	19.74	22.06
7-day hardened density (kg/m^3)	1965	2200
7-day compressive strength (N/mm^2)	25.26	28.18
28-day hardened density (kg/m^3)	2025	2245
28-day compressive strength (N/mm^2)	36.90	42.24

Table 3 Three-edge bearing test results.

Strength requirement of NP3 pipe for three edge bearing test as per IS 458:2003 [18]	CSAC pipes (kN/m)	CC pipes (kN/m)
Load to produce 0.25 mm crack, 13.70 kN/m	15.20	18.45
Ultimate load, 20.55 kN/m	22.20	26.66

pipes was adopted using spinning actions, it is good enough to have this consistency of mixes. Compressive strengths of CSAC and CC mixes obtained were 36.90 N/mm^2 and 42.24 N/mm^2 at 28-days respectively, which satisfy the minimum requirements of 35 N/mm^2 for the selected NP3 pipe as per IS 458:2003 [18].

5.2. Three-edge bearing test

As per IS 3597: 1998 [20], the 0.25 mm crack load is the maximum load applied to the pipe before a crack having a width of 0.25 mm measured at close intervals, occurs throughout a length of 300 mm or more. The crushing strength in Newton per linear metre of pipe was calculated by dividing the total load on the specimen by the nominal laying length of pipe as per IS 3597: 1998 [20]. Three-edge bearing test results are given in Table 3. In this study, 0.25 mm crack width was occurred at 15.20 kN/m on CSAC pipe and 18.45 kN/m on CC pipe respectively, that are greater than the load 13.70 kN/m to produce 0.25 mm crack as per IS 458: 2003 [18]. Similarly, the ultimate load was reached at 22.20 kN/m on CSAC pipe and 26.66 kN/m on CC pipe respectively, that are greater than the ultimate load 20.55 kN/m required as per IS 458:2003 [18].

Table 4 Absorption test results.

Description	CC pipe	CSAC pipe
Length of pipe (mm)	300	300
Weight of pipe before placed in oven (kg)	10.720	9.950
Weight of oven dried pipe at 110 °C up to 36 h (kg)	10.460	9.780
Weight of pipe after 10 min water absorption (kg)	10.652	9.985
% water absorption after 10 min	1.83	2.09
Weight of pipe after 24 h water absorption (kg)	10.944	10.267
% water absorption after 24 h	4.63	4.98

5.3. Hydrostatic test

The specimen for determination of leakage under internal hydrostatic pressure should be sound and full-size pipe. Hydrostatic pressure was applied to the whole pipe at a gradual rate until the test pressure of 0.07 N/mm^2 is reached as per IS 458: 2003 [18]. Pressure was maintained for 2 min. The application of pressure not resulted in the formation of beads of water on the both CSAC and CC pipe surfaces. Since the test pressure has been reached without the beads of water growing or running, the test pressure was maintained constant for 1 min + 30 s for each 10 mm of wall thickness as per IS 3597: 1998 [20]. This shows that both the CSAC and CC pipes are performing well under hydrostatic pressure. At the end of the holding period the pressure was released immediately and the test pipes were drained completely.

5.4. Absorption test

Absorption test results on both the CSAC and CC pipes are presented in Table 4. As per IS 458: 1988 [21], absorption test results should satisfy that in the first 10 min, absorption should not exceed 2.5% of the dry mass and the total absorption at the end of 24 h should not exceed 6.5% of the dry mass. In this study, in the first 10 min, CC and CSAC pipes absorptions are 1.83% and 2.09% respectively and both pipes satisfy the condition specified by IS 458:1988 [21]. Similarly, in total absorption at the end of 24 h, CC and CSAC pipes absorptions are 4.63% and 4.98% respectively and both pipes also satisfy the condition specified by IS 458:1988 [21]. Therefore, absorption properties of CSAC pipes are comparable with CC pipes and the reason for this is because of use of CS in SSD condition during the production of CSAC.

6. Conclusions

Non-pressure pipes (NP3) normally used for drainage and irrigation use, for cross drains/culverts carrying medium traffic and reinforced CSAC pipes were selected for this study and CC pipes were also considered for comparison. Both CSAC and CC pipes were tested for their capacity on three-edge bearing test, hydrostatic test, and absorption test in accordance with IS 3597: 1998. Based on the results obtained, the following conclusions were made.

Mix ratio used conventionally for the production of CC pipes by the manufacturer can also be used for the CSAC pipes

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production. In general, CSAC pipes behave similar to CC pipes when subjected to three-edge bearing test and hydrostatic test. Three-edge bearing test results show that the 0.25 mm crack width was occurred at 15.20 kN/m on CSAC pipe and 18.45 kN/m on CC pipe respectively, that are greater than the load 13.70 kN/m to produce 0.25 mm crack as per IS 458: 2003. Similarly, the ultimate load was reached at 22.20 kN/m on CSAC pipe and 26.66 kN/m on CC pipe respectively, that are greater than the ultimate load 20.55 kN/m required as per IS 458:2003.

The application of hydrostatic pressure not resulted in the formation of beads of water on both CSAC and CC pipe surfaces during the application of the test pressure of 0.07 N/mm^2 as per IS 458: 2003. This shows that both the CSAC and CC pipes are performing well under hydrostatic pressure. In this study, in the first 10 min, CC and CSAC pipes absorptions are 1.83% and 2.09% respectively during the first 10 min and both pipes satisfy the condition that the absorption should not exceed 2.5% of the dry mass as per IS 458:1988. Similarly, in total absorption at the end of 24 h, CC and CSAC pipes absorptions are 4.63% and 4.98% respectively and both pipes also satisfy the condition that the absorption should not exceed 6.5% of the dry mass as per IS 458:1988. Therefore, absorption properties of CSAC pipes are comparable with CC pipes.

This research study, test results and performance of CSAC pipes encourage the use of coconut shell as an aggregate for the replacement of conventional coarse aggregate in reinforced concrete pipes production and can be used for drainage and irrigation use, for cross drains/culverts carrying medium traffic. However, further studies are to be studied on other types of non-pressure and pressure pipes before its implementation in practice respectively.

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