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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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