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Influence of incorporation of rice husk ash and coarse recycled concrete aggregates on properties of concrete

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HIGHLIGHTS

- Influence of rice husk ash in normal and recycled aggregate concrete was studied.
- No substantial effect on properties of concrete was detected up to 10% RHA.
- Use of 10–15% RHA and 100% RCA in concrete was recommended.

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ABSTRACT

The present research work has been carried out for accessing the effect of utilisation of 100% coarse recycled concrete aggregates and 0–35% rice husk ask (RHA) in designing concrete mixes. For this, 5%, 10%, 15%, 20%, 25%, 30% and 35% of rice husk ash has been introduced in natural aggregate concrete (NAC) and recycled aggregate concrete (containing 100% coarse recycled concrete aggregates) as replacement of cement. Different properties of aforementioned designed concrete mixes such as workability, 7, 28 and 90 days compressive strength, spilt tensile and flexural strength, modulus of elasticity, non-destructive parameters (rebound number and ultrasonic pulse velocity), water absorption, density, volume of voids has been determined. The analysis of experimental results depicts that the behaviour of concrete substantially is influenced by the incorporation of coarse recycled concrete aggregates and rice husk ash in concrete. However, concrete mixes containing 100% coarse recycled concrete aggregates and 10–15% rice husk ash satisfies the design requirements for application in construction industry.

1. Introduction

Currently, the usage of recycled concrete aggregates manufactured from the waste concrete brought from the site of construction and demolition, has been promoted for mitigation of scarcity of natural aggregates in various parts of world. Moreover, the problems associated with the disposal of huge quantity of waste concrete produced from construction and demolition activity could be solved to certain extend by the recycling of waste concrete elements [1]. These pieces of waste concrete brought from demolition site were crushed and then sieved for preparation of recycled concrete aggregates. These recycled concrete aggregates can be classified into coarse and fine aggregates based upon their particle size. The investigation based upon the utilisation of fine fraction of recycled concrete aggregates in concrete demonstrated that its use had significant adverse effects on properties of concrete [2]. Therefore, use of coarse fraction of recycled concrete aggregates (also termed as recycled coarse aggregates) were more viable option than fine fraction in making concrete. Lower specific gravity and higher water absorption was observed for recycled coarse aggregates (RCA) as compared to natural coarse aggregates (NCA) [3]. These inferior properties of RCA could be due to the presence of less dense and porous mortar adhered to it [4]. The moisture states of RCA and curing conditions of concrete had substantial influence on workability and strength of concrete [5,6]. Moreover, the properties of RCA was influenced by the nature of the source concrete from which these RCA were manufactured [7,8]. Therefore, it was

Abbreviations: CS, compressive strength; NCA, natural coarse aggregates; NFA, natural fine aggregates; NAC, Natural aggregate concrete; RAC, recycled aggregate concrete; RCA, recycled coarse aggregates; RHA, rice husk ash; RN, rebound number.

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recommended for determination of composition and physical properties of recycled aggregates prior to its application in concrete mixes [9]. The workability of concrete incorporating RCA decreased with the enhancement in the RCA(%) as the water absorption of RCA was very high as compared to corresponding values of natural ones [10,11]. The CS of concrete remained unaltered up to 30% replacement level of RCA and increase in RCA(%) in concrete beyond 30% mark reduced the strength significantly [12]. The CS of concrete incorporating 100% RCA was found to be deceased up to 25% than the corresponding mix made with NCA owing to the inferior characteristics of RCA as compared to that of natural ones [11,13–15]. Around 10–15% reduction in tensile strength was detected when 100% NCA were replaced by RCA [10,15–17]. Similarly, reduction in modulus of elasticity was around 45% for the concrete containing 100% RCA as modulus of elasticity was primarily influenced by characteristics of coarse aggregates [18–22]. Furthermore, the relationship between CS and modulus of elasticity was established based upon the experimental results available in existing studies [22]. The degradation in the properties of concrete with the incorporation of RCA was due to the more porous nature of the interfacial zone (ITZ) as compared to NAC [23,24]. The characteristics and dosage of superplasticizers had substantial influence on properties of recycled aggregate concrete [25]. Previous studies reported that durability characteristics and non-destructive parameters were influenced by the introduction of RCA in concrete mixes [16,26–30].

Improvement of aggregate characteristics by reducing the adhered mortar content, bringing modifications in mixing methods and incorporation of pozzolanic materials are the various methods proposed by previous researchers for enhancing the properties of recycled aggregate concrete [31–33]. Ultrasonic cleaning of aggregates, pre-soaking of aggregates with various types of acids and increasing the stages of crushing improved the properties of RCA owing to removal of adhered mortar present in it. Two stage mixing approach with silica fume and cement, and tripe mixing method were employed in designing recycled aggregate concrete mixes [33–37]. Significant improvement in the ITZ characteristics was achieved through these mixing techniques which enhanced the properties of recycled aggregate concrete. Various industrial and agricultural end products having pozzolanic activity such as fly ash, ground granulated blast furnace slag, silica fume, pulverised fly ash, ground bagasse ash were incorporated in recycled aggregate concrete mixes as partial replacement or addition to cement [38–42].

Rice husk ash (RHA), obtained by the combustion of rice husk (outer cover of rice grain) in a temperature range of 300 °C to 450 °C, has been utilised as substitution of cement for designing concrete mixes. Workability of concrete was found to be dependent upon the fineness of RHA and incorporation of ultrafine RHA enhanced the workability of concrete [43]. However, reduction in the slump value of concrete was observed with the increase in RHA(%) in concrete [44–46]. The concrete mixes containing RHA up to 20% had attained similar CS to that of control mix without RHA. Enhancement in the incorporation level of RHA beyond this strength reduced significantly [46]. Similarly, use 20% RHA did not have any substantial effect on durability behaviour of concrete [47]. The relation between CS and split tensile strength was found to be similar to that of normal concrete [48]. Tangchirapat et al. [49] incorporated 20%, 35% and 50% rice husk bark ash as partial substitute to cement in concrete mixes containing 100% RCA. Rice husk bark ash was produced by incinerating rice husk and eucalyptus bark in biomass power plant. Improvement in strength of concrete and slight reduction (around 4%) in modulus of elasticity was detected with the incorporation of 20% rice husk bark ash.

Several studies have been conducted to investigate the effect of various types of pozzolanic materials on fresh, hardened, durability characteristics and microstructure of concrete incorporating recycled coarse aggregates. However, the studies intended for accessing the influence of use of rice RHA as substitute to cement on behaviour of concrete made with recycled aggregates are scarce in existing literature. Therefore, the present investigation has been conducted to investigate the effect of utilisation of 100% RCA and varying percentages of RHA on workability, compressive and tensile strength, modulus of elasticity, non-destructive parameters, water absorption, density and volume of voids of concrete mixes.

2. Experimental programme

2.1. Materials

The cement used to carry out the experiment was Ordinary Portland Cement (OPC) of 43 Grade confirming to the Bureau of Indian Standard Specifications [50]. The whole experimental programme was designed in such a way that it was finished within 30 days from the date of procurement of cement in order to reduce the adverse effects on properties of cement because of storage of cement. To characterize the cement properties, standard test has been conducted and the values of the test are illustrated in the Table 1. The sand collected from the bed of nearby river was utilised as natural fine aggregate (NFA) in different concrete mixes, which was confirming to Zone III as per the IS 383 [51] specification. The crushed dolerite utilised as NCA was of 20 mm nominal size. The RCA was prepared from the waste concrete collected from the demolished railway ballast sleepers from Angul (A city of Eastern India) and the RHA was procured from Radhakrishna rice mill Sambalpur (A city of Eastern India). The rice husk is burned up to a temperature of 500° to 600 °C and grinded in the ball mill. The backscatter scanning electron microscopic image (BSEM) of RHA is presented in Fig. 1. The chemical composition of cement and rice husk ash is presented in Table 2. The standard tests were performed over both types of aggregates and these results are illustrated in Table 3.

2.2. Concrete mixture

The detailed concrete mix proportion is illustrated in Table 4. The water/cement (W/C) ratio was fixed at 0.45 throughout the experimental programme. The full substitution of NCA was carried out by RCA and partial replacement of cement was done by 5%, 10%, 15%, 20%, 25%, 30%, and 35% of RHA. The mix design was carried out as per the standard procedures of IS 10262 [52]. The water available of the concrete laboratory which can be utilised for the human consumption was employed for the preaprtaion of concrete mixes. Trial slump test was performed and slump value of 100% RCA incorporated concrete nearer to control mix (50–70 mm) was detected with the usage of pre-soaked recycled coarse aggregates. Additional 10% extra material by weight was taken to mitigate the loss of material during mixing, casting, and placing of concrete. A commercially available polycarboxylic ether based superplasticizer (Fosroc-Auramix 300) was used to make the workable concrete for casting, placing and curing.

2.3. Specimen casting and curing

An electric operated manual laboratory mixer of capacity 0.06 m^3 was used for the concrete mixing. Initially, recycled coarse aggregates and half of the mixing water were mixed in the mixer for two min. After that, cement sand and remaining portion of mixing water was poured into the mixer and mixed for another two minutes. The workability of concrete for each batch was measured and it was expressed in terms of slump. After completion of mixing