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Flexural behaviour of bamboo based ferrocement slab panels with flyash

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HIGHLIGHTS

- Enhanced first crack load with the addition of flyash.
- Improved crack resistance behavior of ferrocement slab panels.
- Development of ferrocement slab panel system using bamboo reinforcement.
- Effective use of flyash and bamboo in ferrocement slab panel system.

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ABSTRACT

There is a need to develop low cost building elements with the help of locally available materials to fulfil the demand of low cost houses. In rural areas the bamboo, available in abundance, may be utilized as replacement of common M.S. or HYSD bars (a costly building material). Flyash, a by-product from thermal power plants can replace cement in normal mortar or concrete. The flexural behaviour of bamboo based ferrocement slab panels reinforced with chicken wire mesh layers has been studied to improve the serviceability limit. Experimental investigations on simply supported ferrocement slab panels subjected to monotonically increasing uniformly distributed load have been investigated. The experimental programme consists of testing 12 ferrocement slab panels of size 470 mm × 940 mm with the thickness of 40 mm and 50 mm each having 6 slabs. Out of these slabs, 6 numbers with conventional mortar 1:3 and 6 after 15% cement replacement by fly ash, with adopting grids of bamboo strips as skeletal reinforcement, were cast, cured under wet gunny bags for 28 days and then tested under uniformly distributed loading and the test results obtained were compared with the theoretical results. Test results show that the first crack load and the experimental failure load have been found almost same for both types of slabs. The ultimate load has been found to be about doubled the first crack loads. All slabs exhibited large ductility before final failure in flexure.

1. Introduction

In most developing countries, the technology for construction of houses depends on imported building materials to a large extent. With the rapid increase in the demand for housing, the existing stock of conventional building materials like cement, steel etc. would fall short of the demand, if it is consumed indiscriminately. In order to provide basic infrastructure facilities as proper dwelling units to the millions of homeless people, low cost building materials has become an important issue. Researchers suggest that ferrocement can be an alternative material for roofing as it is economical [1,2]. American Concrete Institute ACI 549 developed a report on ferrocement in 1988 [3] and consecutively a guide for the design, construction and repair in 1989 [4]. There is a need to achieve the alternative building materials like flyash as partial replacement of cement, and bamboo for steel bars, a costly building material. This gives considerable savings in consumption of cement and steel. If bamboo can be cured to not absorb water, preserved, and then be coated to adhere to cement well, bamboo would be better than steel in concrete for poor countries lacking a cheap source of steel. In this context, this research work has been undertaken in the laboratory to develop cheap building elements using locally available bamboo as the main structural element.

Ferrocement is a composite produced from cement, sand, wire mesh, skeletal steel and certain mineral admixtures like flyash. Studies on the use of ferrocement done by Al-Kubaisy [5], suggest that the cracking behavior of slabs made of ferrocement improved considerably well. The use of ferrocement proves to be worthy with respect to the small crack space and width. This is due to

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the high specific surface of the ferrocement meshes. Also, it is said to have a greater cracking performance along with a high tensile strength and modulus of rupture. Studies by Chee Ban Cheah et. al. [6] suggest that there is a high tendancy for thin ferrocement panels to fail in the pure bending mode when subjected to a flexural load. The long term effects and the durability of bamboo reinforcement is of real concern. Studies by Cordero [7] and Lopez [8] conclude that bamboo is widely used as reinforcement material in the load bearing walls in Brazil with durability of more than 10 decades. They also concluded that when the correct practices and procedures for using bamboo as reinforcement in the construction industry were not followed, bamboo degradation is possibly observed. Many researchers [9–16] have reported use of bamboo as reinforcement in the construction of bamboo based ferrocement slab panels. Mansur et al. [9] studied the cement mortar reinforced with bamboo mesh in a manner similar to ferrocement. The main parameter of the study was the volume fraction of bamboo and its surface treatment. Test results indicate that inclusion of bamboo mesh imparts considerable ductility and toughness to the mortar, and increases significantly its tensile, flexural and impact strengths. Use of some waterproofing coating has been found to be effective to overcome high water absorption of bamboo and to improve its seemingly poor bond strength. Wu You and Zongjin Li [10] reported the flexural behavior of bamboo-fibre-reinforced mortar laminates. The laminate considered in this study is a sandwich plate and extruded fibre-reinforced mortar sheet. Due to its high strength to weight ratio, the reinforced bamboo can remarkably strengthen the mortar and reduce the total weight of the laminate. Test results show that, for the laminates with reformed bamboo plate on the bottom as tensile layer and fibre-reinforced mortar sheet on the top as compressive layer, the flexural strength values can be improved to greater than 90 MPa. Vijay Raj [11] investigated the potential of bamboo for utilization as reinforcement in ferrocement skeletal grid. He concluded that bamboo is a cheap and replenishable agricultural resource; the availability of which can be regulated as per the demand. The utilization of bamboo reinforcements in ferrocement can thus turn out to be a cheap and ideal alternative for the present and future time, where most other resources like steel etc are rapidly getting depleted. He has also recommended that to popularize their use it is necessary to develop standard designs so that these are available to the common man. Lee, Teang Shui [12] investigated the properties of bamboo material that can be utilized for the skeletal framework in ferrocement structures and tests were performed to establish the properties of bamboo and bamboo reinforced mortar. Bond, swelling-shrinkage behavior of bamboo culm and impact are some of the tests conducted. It was found that structurally sound and lighter structures made from bamboo as the skeletal framework can be constructed. Prasad, J. et al. [13] studied the use of bamboo for making low cost housing in hilly regions. However, wall and roof elements made of simple bamboo mat do not last due to their poor strength against static as well as impact loads and durability. It is recommended to use bamboo based cement-sand mortar panels as wall and roofing elements in dwelling units made in hilly regions. As suggested by P.K. Imbulan et al. [14], based on the available literature on physical and mechanical properties of bamboo, bamboo is no longer the "poor man's timber" and it can be used confidentally in structural applications.

It has been established that bamboo based ferrocement slabs up to an effective span of 1.5 m can be easily constructed for use in residential public buildings [15]. Based on the studies by Kumar Sanjay et. al., it is reported that the cost of bamboo reinforced ferrocement slab with conventional mortar and flyash was found to be about 50% less than the conventional reinforced ferrocement elements [16]. The span/deflection ratio as 200 for ribbed ferrocement element was suggested by Trikha et. al. [17]. Arif M et. al. suggested that a replacement of 20% cement by flyash has shown marginal loss in the strength and the structural performance of ferrocement panels with woven and hexagonal wire mesh under flexure [18]. Based on the studies done by T. Ahmed et. al. [19], it is suggested that the suitability of using roof slab system comprising of ferrocement panels with 0% and 20% flyash resting over reinforced concrete beams for low cost housing as it is said to have lower crack width. They also suggest that the aforesaid system using flyash is ductile and environmentally viable. To reduce its cost, the use of flyash as partial replacement of cement in the mortar matrix would further lead to an eco-friendly low cost construction without any loss of structural integrity. The thickness of ferrocement slab panels generally ranges from 25mmto 50 mm. Flexural tests were conducted on ferrocement panels of size 470 mm × 940 mm (40 mm and 50 mm thickness) with hexagonal wire meshes in 2 layers using 15% flyash as partial replacement of cement. The main objective of this investigation was to examine the suitability of using flyash in the mortar matrix. Test on mortar control specimens and the wire meshes were also carried out. The structural units using the ferrocement panels can be used with confidence as roofing elements.

2. Experimental programme

In order to study the effect of flyash on the flexural behaviour of ferrocement slabs, test panels of 40 mm and 50 mm thick were considered. The bamboo strips in the skeletal grid with two layers of chicken wire mesh were placed as reinforcement in the test panels. A minimum of three identical specimens were tested for each group.

2.1. Materials

The materials required for casting test panels are cement, flyash, sand, water, bamboo strips and wire meshes, which are discussed below.

2.1.1. Cement and flyash

Ordinary Portland Cement 43-grade satisfying the requirements of IS specifications [20] having specific gravity – 3.1, fineness-3.25% on IS 90 micron sieve was used. The class F-Type flyash obtained from Jojobera power plant (Jamshedpur) confirming to IS specifications [21] with its physical properties: grey in colour, fine spherical particulates ranging in diameter from 100 to 0.5 μm, 1.5% fineness retained on IS 90 micron sieve and specific gravity – 2.04 was used. The chemical properties of class F-type flyash were found to be Fe (T) = 2.1–3.5, MgO = 0.20–0.60, CaO = 0.85–1.2, Alkali = 1.45–1.55, Al_2O_3 = 21.9–24.3, SiO_2 = 44.9–47.6, TiO_2 = 1.49, C = 12–20, P_2O_5 = 0.309–0.663, percents.

2.1.2. Sand and water

Locally available sand from river, Kharkai, Jamshedpur, India passing through the IS 4.75 mm sieve, and free from impurities having specific gravity – 2.59, fineness modulus-2.61 and confirming to zone-II as per IS specifications [22] was used. Tap water was used for both mixing of mortar and curing of test specimens.

2.1.3. Bamboo strip and wire mesh

Locally available bamboo strip of size 12 mm × 12 mm thick coated with anti-termite and then protective coating (TOP COAT) to preserve it against the action of insects, fungus and water, was used as specified by IS: 8242-1976 [23]. The specimen tested was having an ultimate tensile strength (max.) = 72.54 N/mm^2, modulus of elasticity (max.) = 45.2 kN/mm^2, moisture content = 18.18% and specific gravity = 0.811. Fig. 1 indicates a typical