Abstract

Building sustainable infrastructure brings forth the idea of using environmentally friendly materials, such as bamboo, for reinforcement in concrete structures. However, a design framework for bamboo reinforced concrete (BRC) is still in its early stages due to the inherent uncertainties in the properties of bamboo, concrete, and the bond between them. The present work focuses on developing a design methodology for BRC beams considering the randomness of the major variables. The scope of this work is limited to developing load and resistance factor design (LRFD) equations for flexural BRC beams subjected to dead and live load combinations.

The properties of bamboo vary inter- and intra-species. A prerequisite to developing a rational design of BRC members, therefore, involves two stages—(i) a statistical characterisation of the mechanical properties of bamboo, and (ii) identifying the variables contributing significantly toward the stress-strain/load-displacement behaviour. The present work first experimentally characterises the longitudinal tensile properties of *Bambusa Balcoa*, a commonly found bamboo species in India. Statistical analysis of the experimental results suggests that most of the mechanical properties follow a lognormal distribution. The elastic modulus is found to have a dominant contribution toward stress-strain behaviour. A high fidelity finite element model, the results of which are validated with experiments, indicates that only the variation of elastic modulus can capture 92% of the variability in the experimental results. Also a low-fidelity finite element model was created by using equivalent tensile modulus, which can capture 82% of the variability in the experimental results.

Bamboo possesses comparatively lower bond strength than steel embedded in concrete. The bond properties significantly impact the behaviour of BRC beams, especially the displacement response. Therefore, it is essential to characterise the bond properties between bamboo and concrete before designing a BRC beam. In this work, the bond properties are experimentally characterised first through a series of pull-out tests. The average bond strength is found to be 2.41 MPa with a standard deviation of 0.4 MPa. Statistical analysis of the experimental findings suggests that the bond strength follows a lognormal distribution. Subsequently, a finite element (FE) model for the pull-out tests is developed by utilising a surface-based cohesive interaction. The numerical results of this study agree with the experimental results. By treating the bond stress as a random quantity in the numerical model, 81% of the experimental results get captured.

Before developing the LRFD-based design framework, the major variables that affect the behaviour of BRC beams are identified – the tensile properties of bamboo, the compressive properties of concrete, the bond strength between them, and the load. Various reinforcement percentages are experimentally investigated in order to capture the variation in the response of the beams. Following this, a FE model is developed, and the results are compared with those obtained from experimentally tested beams. Choosing the longitudinal modulus of bamboo, the compressive strength of concrete and the bond between them as per descriptive statistics provides a good envelope to the experimental results. By assigning the major variables as per their distribution in the numerical model, a synthetic dataset is generated based on which Monte Carlo simulations (MCS) are performed. The beam is assumed to be governed by the limit state of collapse in flexure. From the MCS, the reliability indices of 1.71, 2.18, and 2.25 are obtained for the BRC beams with reinforcement percentages of 1.5%, 2.5%, and 3.7%, respectively. Subsequently, the partial safety factors for bamboo with different dead and live load combinations are calibrated to different target reliabilities. Designers can make use of the proposed partial safety factors for designing BRC flexural members.

Keywords: *Longitudinal tensile characteristics, Bond characteristics, Bamboo reinforced concrete, Finite element modelling, Reliability analysis, Load and resistance factor design.*