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Experimental investigation on strengthening of glulam timber beams using cold-formed steel sections

Misba Gul [a,b,*], Shakeel Ahmad Waseem [c], Javed Ahmad Bhat [d]

[a] Department of Civil Engineering, National Institute of Technology Srinagar, Hazratbal 190006, Jammu and Kashmir, India
[b] Department of Civil Engineering, Islamic University of Science and Technology, Awantipora, 192122 Jammu and Kashmir, India
[c] Department of Civil Engineering, National Institute of Technology Srinagar, Hazratbal 190006 Jammu and Kashmir, India
[d] Department of Civil Engineering, National Institute of Technology Srinagar, Hazratbal 190006 Jammu and Kashmir, India

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ABSTRACT

This study investigates the potential of cold-formed steel (CFS) sections, specifically flat and channel-shaped, to reinforce glued-laminated timber (glulam) beams for improved flexural performance. Both unreinforced and CFS-reinforced glulam beams were tested. The connections used for the reinforcement included epoxy resin alone, a combination of screws and epoxy resin, and an integration of steel with epoxy resin. Through three-point bending tests, various parameters were assessed, including load capacity, moment capacity, flexural rigidity, energy absorption, and Modulus of rupture. Results revealed that CFS sections significantly enhance glulam beam performance, notably preventing brittle failure. Channel-shaped CFS sections emerged as superior for reinforcement, with steel straps and epoxy resin recognized as the most reliable connection method for Steel Timber Composite (STC) beams. In addition to experimental testing, analytical studies were conducted to complement the findings of this research. These included linear elastic-plastic models, and Finite Element Analysis (FEA). While the linear elastic-plastic models did not consider various connection schemes, FEA accounted for these factors, demonstrating the smallest error margin compared to experimental results.

1. Introduction

Timber has historically held prominence in India's architectural framework, symbolizing sustainability and resilience [1]. With India's climatic conditions favoring timber use [1], it is unsurprising that it has been a core construction material. However, the 1996 Supreme Court-imposed timber ban [2] prompted a shift towards alternative materials like concrete, steel, and aluminum [3]. These materials, although durable, considerably elevate carbon emissions [3,4]. In 2020, the Ministry of Environment, Forest, and Climate Change (MoEFCC) took a significant step by revoking the timber ban [5,6]. This decision emphasized the eco-friendly attributes of timber and underlined the socio-economic implications of promoting indigenous wood industries.

Among the timber varieties in India, the abundant Poplar timber from the Kashmir valley has been underutilized owing to its perceived weaknesses [7]. Material science innovations have brought engineered wood products such as glulam to the forefront. By bonding wood laminations parallelly, glulam addresses issues related to natural wood imperfections [8] and endorses sustainable forestry practices by minimizing the reliance on old-growth forests [9]. Despite the benefits of glulam, certain situations may demand heavy cross-sections, which can lead to height limitations. Glulam can be reinforced with materials such as steel plates and fiber-reinforced polymers (FRPs) to address this [10].

In the domain of glulam beam reinforcement, extensive research over recent decades has explored the use a variety of materials ranging from conventional steel [11,12] to advanced fiber-reinforced polymers (FRPs) like carbon fiber-reinforced polymers (CFRP) [13–17] glass fiber-reinforced polymers (GFRP) [18,19], aramid fiber-reinforced polymers (AFRP) [20], and basalt fiber-reinforced polymers (BFRP) [21]. Reinforcement implementation strategies exhibit diversity (Fig. 1 (a)); some research focuses on reinforcing the tension side alone, whereas others incorporate both tension and compression sides, employing methodologies like Near-Surface Mounted (NSM) and Externally Bonded Reinforcement (EBR). The physical form of reinforcement alternates between bar and plate configurations, with orientations set either vertically or horizontally to tailor to the structural requirements.

* Corresponding author at: Department of Civil Engineering, National Institute of Technology Srinagar, Hazratbal, 190006 Jammu and Kashmir, India.
E-mail addresses: misba.gul@islamicuniversity.edu.in (M. Gul), shakeelahmad@nitsri.ac.in (S.A. Waseem), bhat_javed@nitsri.ac.in (J.A. Bhat).

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