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FLEXURAL BEHAVIOUR OF RECTANGULAR CFST BEAMS STRENGTHENED WITH INNOVATIVE STEEL PLATE REINFORCEMENTS

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Abstract

Concrete-filled steel tube (CFST) is an excellent composite member in resisting bending. However, CFST beams experience reduced flexural stiffness due to concrete tensile cracking at early loading stage, which hinders its full potential. This study proposes an innovative method to improve the flexural performance of CFST beams by embedding longitudinal steel plates into the tensile zone of the concrete core. The objectives of this study are to investigate the effectiveness of the proposed method and evaluate the influence of the quantity, height, and thickness of the steel plates. A total of eight rectangular CFST specimens were experimentally tested under pure bending. All specimens are embedded with steel plates except one, which acts as a control. Outcomes from the experimental tests reveal that the use of embedded steel plates can enhance the flexural performance of the CFST beams. The specimens with embedded steel plates develop better moment-deflection relationship and demonstrate higher strength capacity and stiffness compared to the control specimen. Also, the performance of the CFST beams improves with increasing the quantity, height, and thickness of the steel plates. An improvement of 17.4% in the moment capacity can be observed when embedding the CFST beam with just one steel plate and further optimized up to 43.4% by adding three embedded steel plates. Furthermore, it was found that increasing the thickness of the steel plates is the most effective, followed by quantity and height. Additionally, the theoretical ultimate moment was calculated based on the plastic stress model. The theoretical ultimate moment was around 5% lower than the experimental result, with a standard deviation of 0.025. Therefore, it is recommended for determining the ultimate capacity of the CFST beams with embedded steel plates. Overall, the proposed method of embedding steel plates works efficiently in enhancing the flexural performance of the CFST beams.

Keywords: CFST beam, Embedded steel plate, Flexural load, Moment capacity, Strengthening scheme.

1. Introduction

The application of CFST has thrived over the past few years. The construction industry particularly has incorporated CFST in various engineering structures such as buildings including high-rise and super high-rise buildings, bridges and other structures owing to its outstanding properties [1]. This composite structural member utilised steel tube as the outer part and filled with concrete, therefore complementing one another through composite action. The enhanced performance of CFST is due to the excellent dominant properties of concrete and steel. According to past research, CFSTs possess a significant flexural strength making them an ideal to be used as flexural members in resisting bending stress [2-4]. Modifying the CFST composite members with the sole purpose of enhancing their flexural performance and addressing their downsides has gained a lot of interest. Therefore, different strengthening schemes have been proposed by utilising additional materials to improve the CFST members such as steel wrapping using carbon fibre reinforced polymer (CFRP), stiffening measures, external steel plating and reinforcements.

The steel wrapping scheme is the most prominent strengthening technique, which is done by wrapping CFRP onto the steel tube, either externally [5-7] or internally [8]. An experimental study performed by Al Zand et al. [9] on the CFST beams partially strengthened with unidirectional and multiple CFRP concluded that the flexural strength and stiffness of the enhanced specimens improved remarkably. However, the high cost and the need for expertise for applying such material on CFST members reflect the drawbacks [10]. An economical strengthening scheme proposed by Al Zand et al. [11, 12] was the employment of stiffening measures to address the local buckling. This was done by employing single and double v-groove stiffeners on all four sides of the steel tube and testing it under bending. It was revealed that the local buckling was delayed, and the flexural capacity and stiffness of the CFST beam has improved. In addition, Al Zand et al. [13] introduced an innovative steel tube section made from combined C-section pieces, in which the lips transformed into internal stiffeners of slender CFST beams filled with normal and recycled aggregate concrete (RAC). Experimental outcomes concluded that the strength capacity of beams with RAC was marginally lower than the normal concrete, nonetheless the stiffeners have successfully delayed the occurrence of local buckling. Research by AL-Shaar and Göğüş [10] proposed an external steel plating method by bolting steel plates on retrofitted self-compacting CFST beams subjected to flexural load. This method enhances the stiffness, ductility, energy absorption and flexural strength of the CFST beam, ranging from 1% to 46%.

The use of steel plates for upgrading and repairing materials are cost-effective, require simple fabrication and installation process. However, improper welding of longitudinal steel plates may produce residual stresses and inflict imperfections to the steel tube [14]. Other than that, welding heat from steel plates have an impact on stress distribution and could be crucial for structures subjected to fatigue stresses [6]. Also, the concrete core of a CFST member experienced early tensile cracking under flexural load, which hampered its bending stiffness and eventually affect the moment capacity. Therefore, this research will investigate the possibility of embedding longitudinal steel plates into the bottom section of the concrete core to improve the bending resistance of the CFST beam. The embedded steel plates are only spot welded at both ends of the internal surface of the steel tube. This method has been adopted in an experimental study performed by Abdullah et al. [15] on CFST columns subjected to eccentric compression and the ultimate load of the