Design of CFRP-strengthened steel CHS tubular beams

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A B S T R A C T

External bonding of carbon fibre reinforced polymer (CFRP) sheets to the periphery of steel circular hollow sections (CHS) is a relatively new technique for structurally improving such sections. Design of CFRP sheets for strengthening tubular steel sections necessitates the prediction of the capacity of confined steel circular sections. This paper presents a design method for evaluating the capacity of CFRP-strengthened steel CHS subjected to bending. The hoop FRP reduces the effect of local buckling by restraining the tube wall. The influence of hoop CFRP is considered in the proposed method by taking its modulus of elasticity as a proportion of the elastic modulus of longitudinal CFRP. The excitation of the longitudinal CFRP minimises the effect of local buckling in the tube wall, which ultimately increases the local flexural stiffness and strength of the tube. The inclusion of the effects of strengthening parameters in current design rules, notably the Australian Standards AS/NZS 4600 (2005) and AS 4100 (1998) and the European Standard EC 3, is discussed. The strengthening effects considered here are those that arise from varying amount of CFRP, modulus of elasticity of the hoop fibre and steel yield strength. Strength curves for composite CFRP-steel CHS are provided to illustrate the extent of enhancement with the type of the parameter.

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1. Introduction

The potential of non-metallic fibre reinforced polymers (FRP) for flexural strengthening of concrete structures has been widely observed (Teng et al. [1]). Following the broad applications of FRP for strengthening and retrofit of existing concrete structures, there is a burgeoning interest in the use of FRP for strengthening of steel structures (Hollaway and Cadei [2], Zhao and Zhang [3], Zhao [4]). The high strength and stiffness of FRP relative to the weight allows ease of handling and hence, less time is required during strengthening interventions. Improved strength characteristics compared with the steel alone can be achieved by combining the desirable mechanical properties offered by FRP and steel.

Tubular steel structures are widely used in engineering components where light weight is required to carry prescribed loads. Due to their small wall thicknesses, they may be prone to local buckling failure. Most of the studies to date on FRP strengthening of steel structures have been limited to flexural non-tubular steel members (Miller et al. [5], Sen et al. [6], Tavakkolizadeh et al. [7], Phares et al. [8], Patnaik and Bauer [9], Colombi and Poggi [10]). Adhesive bonding of CFRP sheets to the periphery of steel circular hollow sections (CHS) provides a means to delay or eliminate local buckling of the thin-walled steel tubes. The recent studies undertaken by Jiao and Zhao [11], Photiou et al. [12], Shaat and Fam [13], Zhao et al. [14], Teng and Hu [15], Fawzia et al. [16], Tao et al. [17], Seica and Packer [18], Bambach et al. [19] and Haedir et al. [20] on FRP strengthening of steel hollow sections subjected to different types of loading conditions have revealed the important role of FRP in improving the load-carrying capacity.

In light of the experimental work highlighted above, there are limited design guidelines available for the design of CFRP reinforcement for suppressing local buckling in circular hollow sections. The intent of the present work is to develop a design rule that can relate the moment capacity of CFRP-reinforced steel circular hollow sections directly to strengthening parameters. The bending strength of the composite section is predicted by employing the modular ratio of the two materials and considering the limiting slenderness ratios into existing design formulae for steel hollow sections, such as those proposed by AS/NZS 4600 [21], AS 4100 [22] and EC 3 [23]. The transformed section method has been applied by various researchers [24–28,13] for estimating the strength of composite metallic sections containing FRP. A detailed summary of the limiting slenderness ratios for steel hollow sections has been given by Zhao et al. [29]. Simplified design expressions are derived for evaluating the bending capacity of circular hollow sections reinforced by CFRP sheets, as shown in Fig. 1(a). Further, strength design curves for steel hollow sections made of high strength steel have been developed by Rasmussen and Hancock [30,31]. In this study, design curves for CHS strengthened with CFRP are presented to illustrate the degree of strength enhancement arising from key parameters such as the amount of CFRP, modulus of elasticity of the CFRP and steel yield stress. The typical range of d^s/t^s considered is about 10 to 100.

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