AXIAL BEHAVIOUR OF HYBRID COLUMN-SPLICE CONNECTION FOR TUBULAR GFRP MEMBERS

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Introduction

Glass fibre reinforced polymer (GFRP) structural members manufactured from pultrusion process are credited with high strength-to-weight ratio, excellent corrosion resistance, cost-effectiveness and availability in various section shapes. However, their application is limited by the difficulty to connect them, especially tubular members. This paper contributes to solving the problem by proposing a column-splice connection for tubular GFRP members and investigating its performance under axial loadings.

Fig. 1 illustrates the proposed column-splice connection. It consists of a bonded sleeve joint (BSJ) coupling steel and GFRP tubes adhesively, and a bolted flange joint (BFJ) connecting two steel tubes with flange plates by bolts. This paper investigates axial behaviour of the BSJ and the BFJ individually to understand their performance for further connection design.

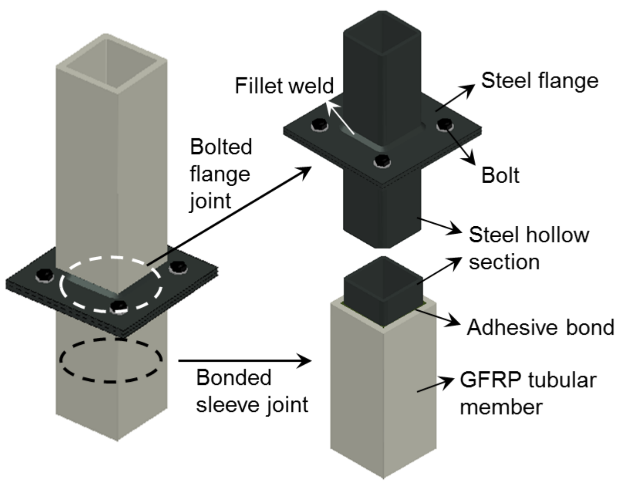

Fig. 1: Proposed column-splice connection for tubular GFRP members

Experimental study of BSJs

The bonded sleeve joint (BSJ) specimens, illustrated in Fig. 2, were fabricated from pultruded GFRP square tubes, grade 350 steel square hollow sections (SHS) and Sikadur 30 two-component structural adhesive. Material properties are listed in Table 1. Four different bond lengths (50, 100, 140 and 180mm) were covered, each with two identical specimens. Only compression tests were conducted on BSJs, as trial finite element (FE) studies revealed identical tensile and compressive behaviours. As shown in Fig. 2, specimens were loaded by a 500kN Amsler machine under displacement control, with load cell displacement measured by two LVDTs.

Table 1: Material properties

Material	Young's modulus (GPa)	Strength[1] (MPa)
GFRP[2]	30.2	306.5
Sikadur 30 [1]	11.2	22.4
Steel SHS	197.1	441.3
Steel flange	218.8	332.4
M12 bolt	235.0	1043.1

1 Yield strength for steels
2 Parameters in axial direction

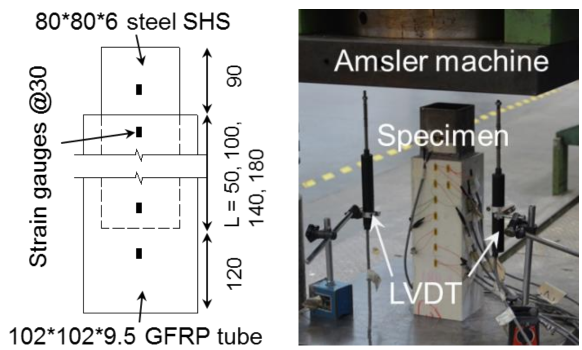

Fig. 2: Geometries of BSJ specimens (left, units in mm) and test setup (right)

Cohesive failure within the adhesive layer was observed for all BSJs (Fig. 3). Reading from strain gauges indicated the GFRP and steel components in elastic range. Load-displacement responses were featured by linear increase to peak load before brittle failure. Post failure residual strength, provided by friction of the crack surface, were recorded 10~50kN depending on the bond length (longer ones associated with larger friction forces). Axial joint capacities (P_u) of the eight specimens are plotted in Fig. 4 against bond lengths (L). It is noted that the increase of P_u with L slows down dramatically after L = 100mm, indicating an effective bond length.

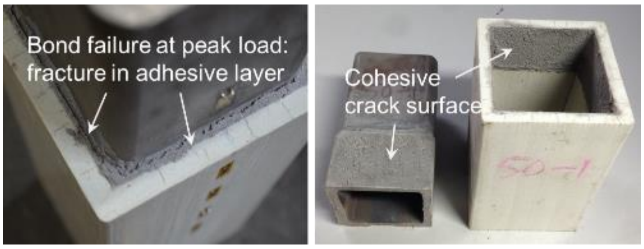

Fig. 3: Cohesive failure of BSJs

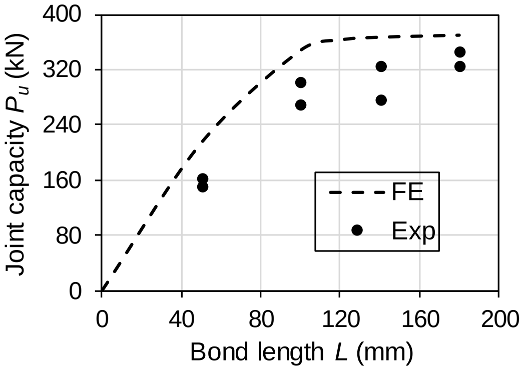

Fig. 4: BSJ axial joint capacity versus bond length

Finite Element (FE) Modelling of BSJs

FE analysis of the BSJs featured using cohesive zone modelling for the bond behaviour, adopting the well-accepted bilinear bond-slip relationship (Fig. 5). The key coordinates, peak shear stress (τ_f), the corresponding slip (δ_1) and debonding slip (δ_f), were determined in a previous study employing the same adhesive and layer thickness [1].

FE modelling produced load-displacement curves which were linear increase-to-complete failure. FE results of the joint capacity were also plotted in Fig. 4 against bond length. Compared to experimental results, FE modelling presented fairly good estimation of joint capacities, though slightly overestimated, and succeeded in reproducing an effective bond length around 100mm.

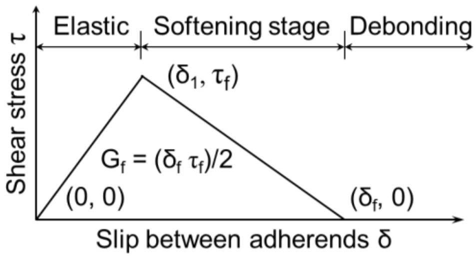

Fig. 5: The bilinear bond-slip relationship

Design and FE modelling of BFJs

Two types of bolt arrangement were designed for the steel SHS bolted flange joint (BFJ) specimens, as shown in Fig. 6. The flange plates were 6mm in thickness and made of grade 250 steel. The SHSs were identical with those in BSJs and the bolts were grade 8.8 M12 hex ones (material properties provided in Table 1).

Besides employing isotropic bilinear work hardening material models for the steels, FE modelling also accounted for contacts between the assembled components and pretensioning of the bolts. Only tensile performance were studied, as compressive ones would be governed by the column (rather than connection). Tension-displacement curves were plotted in Fig. 6 for the four-bolt (BFJ-4) and eight-bolt (BFJ-8) specimens. From FE results, yielding of both BFJ-4 and BFJ-8 was incurred by plastic deformation of the steel flanges, while only slight yielding was observed for the bolts.

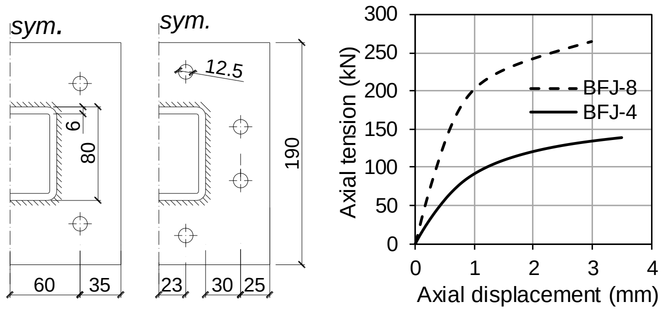

Fig. 6: Dimensions (units in mm, left) and tensile load-displacement behaviour (right) of BFJs

Connection Design Consideration

In pursuit of ductile failure for the proposed column-splice connection (Fig. 1), substantial yielding of the BFJ should occur before bond failure. A bond length no less than the effective value is recommended to acquire sufficient bond strength. Parametric study by FE analysis indicated that using a high strain-capacity adhesive (higher G_f in Fig. 5) improves both bond strength and effective bond length.

Conclusions

A column-splice connection for tubular GFRP members, comprised of BSJ and BFJ, was developed and investigated under axial loadings. An effective bond length for the BSJ was discovered from both experimental tests and FE modelling. Behaviour of the BFJs with four and eight-bolt configurations, designed to provide system ductility through steel yielding, was studied by FE analysis.

References

1. Yu T, Fernando D, Teng J, Zhao X. Experimental study on CFRP-to-steel bonded interfaces. Composites Part B: Engineering. 2012; 43(5):2279-89.