BEHAVIOUR OF FRP-CONFINED CONCRETE-FILLED STEEL TUBULAR COLUMNS SUBJECTED TO COMBINED AXIAL AND CYCLIC LATERAL LOADS

T. Yu, Y.M. Hu and J.G. Teng
Department of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hong Kong, China
Email: ceyutao@polyu.edu.hk

Introduction

Concrete-filled steel tubes (CFSTs) are widely used as columns in many structural systems [1, 2]. In CFSTs, inward buckling deformations of the steel tube are prevented by the concrete core, but degradation in steel confinement, strength and ductility can result from inelastic outward local buckling deformations. When used as columns subject to combined axial and lateral loads, the critical regions are the ends of the column where the moments are the largest. Under seismic loading, plastic hinges form at the column ends and large plastic rotations without significant degradation in strength are demanded here. Against this background, Xiao [3] proposed a novel form of concrete-filled tubular columns, in which the end portions are confined with steel tube segments or fiber reinforced polymer (FRP) jackets. Here, by providing an FRP or steel jacket, both the inward and the outward local buckling deformations of the steel tube are constrained so that the ductility and possibly the strength of the column can be substantially enhanced in the end regions. In addition, the concrete is better confined with the additional confinement from the FRP or steel jacket. It is obvious that such external jacketing of CFSTs can be exploited in both structural strengthening and new construction.

Following Xiao's initial work [3], a number of other studies have been conducted (e.g. [4, 5]). These studies have clearly demonstrated the benefits of FRP jacketing of CFST columns, but much more research is still needed to develop a good understanding of the structural behaviour of and appropriate design methods for FRP-confined CFSTs. This paper presents the results of a series of large-scale cantilever column tests, where CFST columns with or without FRP jacketing at the column end were tested under constant axial compression in combination with monotonic or cyclic lateral loading. The test programme represented the first ever study which examined the effects of the loading scenario (i.e. monotonic versus cyclic lateral loading) and the stiffness of the FRP jacket in such columns.

Experimental programme

In total five large-scale columns were prepared and tested, among which two were tested under combined axial compression and monotonic lateral loading, while the other three were tested under combined axial compression and cyclic lateral loading. The two columns tested under monotonic lateral loading included one CFST specimen as the control specimen and one confined CFST specimen with a five-ply glass FRP (GFRP) jacket. The three columns under cyclic lateral loading included two specimens which were nominally identical to the two tested under monotonic loading so that the effect of the loading scenario can be examined; they also included an additional confined CFST specimen with a six-ply carbon FRP (CFRP) jacket so that the effect of FRP jacket stiffness can be examined. All the five columns had a circular section with a diameter of 318 mm, and a height of 1625 mm from the point of lateral loading to the top of the stiff reinforced concrete (RC) footing. The steel tubes used in all the specimens had a thickness of 3 mm, leading to a diameter-to-thickness ratio of 106. For the three confined CFST specimens, an FRP jacket was installed to provide additional confinement to the potential hinge region which was assumed to be 500 mm from the column footing. The GFRP jacket used had an elastic modulus of 80.1 GPa based on a nominal thickness of 0.17 mm per ply, while the CFRP jacket used had an elastic modulus of 237.8 GPa based on a nominal thickness of 0.34 mm per ply.

Test results and discussions

Effect of FRP jacketing

The FRP jacket was found to effectively delay or even prevent an elephant's foot local buckling failure at the end of a cantilevered CFST when the column was subjected to both constant axial compression and cyclic lateral loading. In columns with a relatively thick FRP jacket (i.e. 6-ply CFRP jacket), the buckling deformations were forced the by FRP jacket to appear above the FRP jacketed region (Figure 1). The hysteretic load-displacement curve of the specimen with a 6-ply CFRP jacket is shown in Figure 2, where the points corresponding to the appearance of bulges above the CFRP jacket are marked. It is evident that the confined CFT column possesses excellent ductility and energy-dissipation capacity

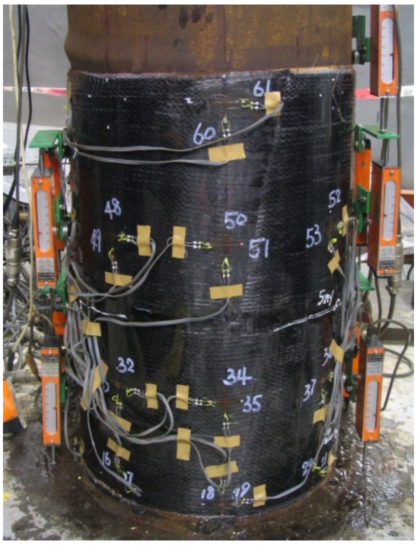

Figure 1. Failure mode of a confined CFST with a 6-ply CFRP jacket

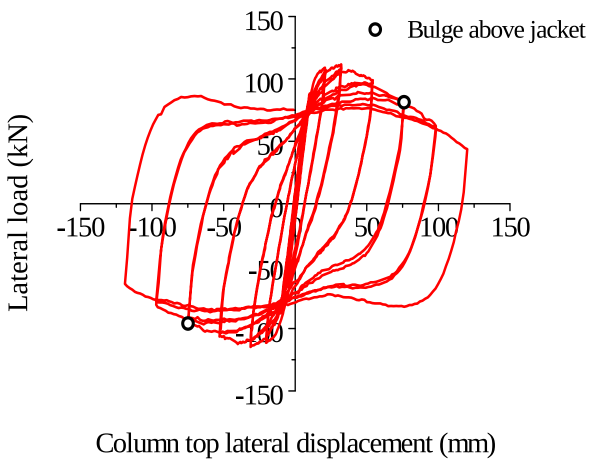

Figure 2. Lateral load-displacement curve of a confined CFST with a 6-ply CFRP jacket

Both the flexural strength of the section and the lateral load-carrying capacity of the column can be significantly enhanced by FRP confinement. Figure 3 illustrates this observation where the envelope moment-lateral displacement curves of the three columns under cyclic lateral loading are shown. In Figure 3, the end moments for all the three columns are normalized by the peak end moment of the unconfined CFST under monotonic lateral loading; the two confined CFSTs with a 5-ply GFRP and a 6-ply CFRP jacket respectively are referred to as "weakly-confined CFST" and "strongly-confined CFST" respectively.

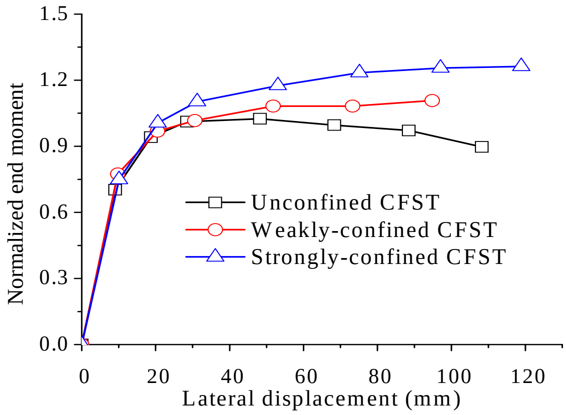

Figure 3. Envelope moment-lateral displacement curves of three columns

Effect of loading scenario

The test results showed that cyclic lateral loading introduces more severe localized deformation near the column end and may lead to earlier FRP rupture within that region. The performance of a confined CFST column subjected to cyclic lateral loading may not be as good as found from a monotonic lateral loading test.

Conclusions

This paper has presented a series of large-scale column tests, where CFST columns with or without FRP jacketing at the column end were tested under combined constant axial loading and monotonic/cyclic lateral loading. FRP jacketing has been shown to be a promising approach for improving the performance of CFST columns.

References

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