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Experimental investigation on double skinned steel columns subjected to monotonic loading-a critical review

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ABSTRACT

The State of the art of Double Skinned concrete filled steel tubular columns is presented in this paper. Experimental data has been collected and compiled in a comprehensive format listing Parameters involved in the study. Areas of further research are presented . Also, results of ongoing experimental and numerical investigations by various authors including us are presented in this paper.

Introduction

Double skinned steel tubular (DSST) columns possess excellent earthquake-resistant properties such as high strength, high ductility, and large energy absorption capacity. In the last decades, they have gained increasing popularity in buildings, bridges and other structural applications such as scaffoldings etc.., the advantages of DSST columns can be attributed to the composite action between the steel tube and the infill material. The steel tube works not only as longitudinal reinforcing bars to resist the loads but also as ties or spirals to confine the infill material example concrete, mortar, FRP etc..,. Therefore, both strength and ductility of the infill material are enhanced. On the other hand, the risk of local buckling of the steel tube is significantly reduced because the rigid infill material prevents it from buckling inward. From the construction viewpoint, much economy can be achieved due to the absence of formwork, since the steel tube can serve as formwork for the in filled during construction. More mechanical and economical benefits can be achieved if DSST columns are constructed from high-strength materials. High-strength columns require a smaller cross-section to withstand the load, which is appreciated by architects and building engineers. In spite of the advantages, the application of high-strength DSST columns in the construction industry is still limited due to the lack of understanding of their structural behavior and insufficient recommendations in current design codes. In order to fully utilize the advantages of high-strength DSST columns, research needs exist to extensively investigate their behavior and to develop design specifications.

Circular Concrete-Filled Steel Tubes

Circular tubular columns have an advantage over all other sections when used in compression members, for a given cross sectional area, they have a large uniform flexural stiffness in all directions. Filling the tube with concrete will increase the ultimate strength of the member without significant increases in cost. The main effect of concrete is that it delays the local buckling of the tube wall and the concrete itself, in the restrained state, is able to sustain higher stresses and strains that when is unrestrained.

The use of CFTs provides large saving in cost by increasing the let table floor area by a reduction in the required cross section size. This is very important in the design of tall buildings in cities where the cost of letting spaces are extremely high. These are particularly significant in the lower storey of tall buildings where stubby columns usually exist. CFTs can provide an excellent monotonic and seismic resistance in two orthogonal directions. Using multiple bays of composite CFT framing in each primary direction of a low- to medium-rise building provides seismic redundancy while taking full advantage of the two-way framing capabilities of CFTs

Research On Double Skinned Steel Tubular Columns [1]

Six DSTC specimens with three different configurations were prepared and tested under concentric compression. The results are summarized below. The columns all had an outer diameter of 152.5mm, a height of 305mm, and the same steel tube inside. They were provided with GFRP tubes of different thicknesses outside, which had fibers only in the hoop direction. Tensile tests on steel coupons were conducted. It was found that the steel tube had a yield stress of 352.7MPa, an ultimate tensile strength of 380.4MPa and a Young’s modulus of 207.28GPa. The FRP tubes were prepared by the wet lay-up process; the FRP used had a nominal thickness of 0.17mm per ply, a tensile strength of 2300MPa and a Young’s modulus of 76GPa based on this nominal thickness according to the manufacturer’s data. The elastic modulus, compressive strength and strain at peak stress of the concrete averaged from three concrete cylinder tests (152.5mm x 305 mm) are 30.2 MPa, 39.6 MPa and 0.002628 respectively.

During the test, all specimens exhibited a smooth load-displacement curve until failure took place, when the outer GFRP ruptured and the load began to drop. The test results shows that, *Pco* is equal to the unconfined concrete strength times the area of the annular concrete section (=543.5 kN), while *Ps* is equal to the average ultimate load from three axial

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compression tests on hollow steel tubes (=273.8 kN). Therefore, the ultimate load of the hybrid column is 817.3 kN if the constituent parts do not interact and the confinement effect of the GFRP tube is negligible.

Based on the results of this study, the following conclusions were drawn within the scope of these tests:

1) This new hybrid structural member possesses good ductility and good energy dissipation capacity. When subjected to concentric compression, the concrete sandwiched between the two tubes may achieve significant enhancement in both strength and ductility over unconfined concrete. According to Teng et al. (2004), the concrete in a typical hybrid DSTC may be confined as effectively as that in an FRP-confined solid concrete cylinder.

2) The new hybrid member shows good ductility under four-point bending, although significant cracks will occur early in the loading process. Longitudinal fibers may be required in the outer GFRP tube if the new hybrid member is to be used to resist bending only. In addition, there may be a need to improve the bond between the concrete and the steel tube, such as through the use of mechanical shear connectors to prevent possible premature slips as observed in one of the beam tests presented in the paper.

3) Further tests, including eccentric compression tests, combined axial and cyclic lateral loading tests and shaking table tests, should be carried out in the future to develop a more complete understanding of the seismic performance of the new hybrid member and structural systems based on this new member form.

Research on mechanical behavior of double-skinned composite steel tubular columns[2]

The purpose of this experimental study is to investigate the behavior of the double-skinned concrete filled steel tubular (DSCFT) columns on the strength, stiffness and ductility performance. The diameter-thickness (D/t) ratio and the hollowness ratio were chosen as main parameters in designing the specimens. A total of 18 specimens were tested under varied combinations of axial and flexural loads, and two specimens were tested under a combination of constant axial load and cyclically increasing bending for comparison. Test results concluded that the DSCFT columns can effectively provide strength and deformation capacity even with a large D/t ratio.

Following conclusions were drawn from the above experiment,

1. Superposing the concrete and steel strength can predict the ultimate axial strength of DSCFT Conservatively. It is illustrated that steel tube can improve the confinement of the concrete, and the in-filled concrete can delay the occurrence of local buckling of the steel tube with a large D/T ratio.

2. The DSCFT columns can have an optimal strength performance if the applied axial load is less than 40% axial capacity.

3. Experimental results indicate that the behavior of DSCFT columns under cyclic loading is as good as that under the monotonic loading.

Research on hybrid FRP-concrete-steel double-skin tubular columns: cyclic axial compression tests [3]

In total, eight identical hybrid DSTCs were tested, covering four loading schemes; two specimens were prepared for each loading scheme. The specimens had an outer diameter (i.e. the outer diameter of the annular concrete section) of 205.3 mm, an inner diameter (i.e. the inner diameter of the annular concrete section and the outer diameter of the inner steel tube) of 140.3 mm, and a height of 400 mm. The outer glass FRP (GFRP) tube had fibers in the hoop direction only and was formed by a wet-layup process on hardened concrete. The nominal thickness of the two-ply FRP tube was 0.34 mm (i.e. the nominal thickness was taken to 0.17 mm per ply) while the thickness of the steel tube was 5.3 mm.

Conclusions

This paper has presented a series of cyclic axial compression tests on hybrid DSTCs. Hybrid DSTCs have been shown to be very ductile under cyclic loading and their envelope axial load-strain curves are almost the same as the corresponding monotonic axial stress-strain curve. It has also been shown that repeated unloading/reloading cycles have a cumulative effect on the permanent strain and the stress deterioration of the confined concrete in hybrid DSTCs. Interfacial slips between the steel tube and the concrete may lead to noticeable differences in the axial strain between them when the column is fully unloaded from an axial strain level that significantly exceeds the yield strain of the steel tube.

Research on Behaviour and Calculations of Concrete-Filled Double Skin Steel Tubular (Cfdst) Members [4]

The authors performed a series of tests on the CFDST columns subjected to static loading, including 37 specimens under axial compression, 13 specimens under bending and 42 specimens under eccentric compression, respectively (Han et al., 2004; Tao et al., 2004; Tao and Han, 2006; Tao and Yu, 2006). It was found that the behaviour of the CFDST columns is generally similar to that of the conventional CFST columns. This is owing to the fact that, generally, the section slenderness ratio of an inner steel tube is relatively small and it can provide sufficient support to the sandwiched concrete. Otherwise, the premature local buckling of inner steel tubes will have adverse effects on the load-carrying and deformation capacities of CFDST columns.

Concluding remarks

This paper briefly summarises some recent research outcomes of CFDST members presented by the authors and their collaborators. From the experimental and numerical results, it can be concluded that, when the hollow ratio (χ) of a CFDST is within the normal range of 0-0.5, the CFDST generally demonstrates a similar behaviour as that of a CFST, whilst the fire resistance of the CFDST is superior to that of the latter. Apart from the research results reported in this paper, ongoing numerical study is being carried out to analyse the post-fire behaviour of CFDST columns. Repair approach will be further recommended. The authors also believe that there is immediate research need to put forward suitable beam-to-column connections for CFDST columns, in which the load can be transferred and shared by the three components simultaneously. Durability is also a key issue need to be studied further for this type of composite construction

Research on Behaviour of Hybrid Double-Skin Tubular Columns Subjected To Combined Axial Compression And Cyclic Lateral Loading [5]

The experimental program consisted of 6 hybrid DSTCs. All these specimens had a circular section with a characteristic diameter *D* (the outer diameter of the annular concrete section) of 300 mm and a void ratio of 0.73 (the ratio between the inner diameter and the outer diameter of the annular concrete section). The inner steel tube had thickness *ts* of 6 mm and an outer diameter *Ds* of 219 mm, leading to a *Ds/ts* ratio of 36.5. The outer GFRP tube had an inner diameter of 300 mm and a thickness *tfrp* of 6 mm or 10 mm. The height was 1350 mm from the point of lateral loading to the top of the stiff RC column footing (4.5 times of the column diameter).

Conclusions

This paper has presented the results of 6 large-scale hybrid DSTCs with HSC tested under axial compression in combination with cyclic lateral loading. These test results suggest that hybrid DSTCs can still show excellent ductility and seismic resistance even when high strength concrete with a cylinder compressive strength of around 120 MPa is used.

Research on FRP-concrete-steel double-skin tubular columns: cyclic axial compression tests [6]

In total, eight identical hybrid DSTCs were tested, covering four loading schemes; two specimens were prepared for each loading scheme. The specimens had an outer diameter (i.e. the outer diameter of the annular concrete section) of 205.3 mm, an inner diameter (i.e. the inner diameter of the annular concrete section and the outer diameter of the inner steel tube) of 140.3 mm, and a height of 400 mm. The outer glass FRP (GFRP) tube had fibers in the hoop direction only and was formed by a wet-layup process on hardened concrete [2]. The nominal thickness of the two-ply FRP tube was 0.34 mm (i.e. the nominal thickness was taken to 0.17 mm per ply) while the thickness of the steel tube was 5.3 mm.

Conclusions

This paper has presented a series of cyclic axial compression tests on hybrid DSTCs. Hybrid DSTCs have been shown to be very ductile under cyclic loading and their envelope axial load-strain curves are almost the same as the corresponding monotonic axial stress-strain curve. It has also been shown that repeated unloading/reloading cycles have a cumulative effect on the permanent strain and the stress deterioration of the confined concrete in hybrid DSTCs. Interfacial slips between the steel tube and the concrete may lead to noticeable differences in the axial strain between them when the column is fully unloaded from an axial strain level that significantly exceeds the yield strain of the steel tube.

Work under progress by the Authors

In order to reveal the performance of double skinned composite steel columns. 45 specimens have been designed for cyclic loading experiment. Here the material used is cement mortor for infilling steel tubes.

The experimental investigation focuses on modes of failure and the most significant factors using the experiment with the help of software. The equation can be generated to find ultimate load carrying capacity. Axial shortening and ultimate stress carrying capacity of the specimen and the modeling can be analyzed.

In this experiment 3different thickness of double skinned steel tubes with 3different lengths (350mm, 450mm and 550mm) with and without 3different proportions of mortor infill are used. The 3 different mortar proportion used in the experiment are 1:3, 1:4, and 1:5. The results of the cyclic load test with and without mortar infill are compared.

Conclusions:

1. Superposing the steel strength can predict the ultimate axial strength of DSCFT Conservatively. It is illustrated that steel tube can improve the confinement of the cement, and the in-filled cement can delay the occurrence of local buckling of the steel tube with a large D/T ratio.
2. Ongoing numerical study is being carried out to analyze the post-fire behavior of DSST columns. Repair approach will be further recommended.
3. Durability is also a key issue need to be studied further for this type of composite construction
4. DSSTCs can still show excellent ductility and seismic resistance even when high strength ingredient is used.
5. Circular hollow section have many advantage as structural members due to the fact that the properties are same for all direction,
6. Circular DSST how a greater increases in strength and a greater enhancement of ductility than rectangular DSST,
7. It is noted that the short column shows a linear behavior up to yield load and after showed a non-linear behavior, A sudden drop in the load carrying capacity is found with Large deformation

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