Project Title:	Application of Polygonal High Strength Concrete-filled Composite Column in Seismic-resistant Building in Hong Kong
Principal Investigator:	Dr. Tak Ming CHAN
Project ID:	CICR/02/15
Research Institution:	The Hong Kong Polytechnic University
Subject Area:	Construction Productivity

Objective

- To investigate the confinement performance on polygonal high strength concrete-filled steel tubular (CFST) columns under monotonic load;
- To investigate the energy dissipative performance on polygonal CFST beam-columns under cyclic load for seismic application;
- To develop statistically validated design rules on confinement and energy dissipation readily available for use in construction industry;
- To promote the use of EN 1994-1-1 on composite steel-concrete construction and EN 1998-1 on seismic design in Hong Kong.

Background

Composite steel-concrete construction system has favourable advantages over the traditional systems. It combines the structural and construction efficiency from both the reinforced-concrete and steel construction. In particular, it promotes faster construction cycle by minimising on-site labour activities as it encourages the use of pre-fabricated units and also reduces the amount of formworks. The optimised structural performance on strength and stiffness from the composite action reduces the structural member size, which leads to enlarge usable floor space and reduce the foundation size. This will further minimise the on-site ground work activities and the concrete component will also provide the required fire resistance. One of the key components in a composite system is the concrete-filled steel tubular members (CFSTs). This structural arrangement allows casting concrete into the steel hollow section without any use of temporary formworks which reduce cost and time.

Methodology

Physical Testing

To develop statistically validated design rules, a comprehensive set of experimental evidences are crucially required to justify and validate the design models. A thorough experimental investigation was carried out in this project to investigate the performance of the octagonal shaped high strength composite column fabricated from flat steel plates.

To address the cross-section classification of octagonal hollow sections and to assess the confinement effect, 38 stub column tests including eight hollow specimens, nine plain concrete specimens and twenty-one concrete-filled specimens under monotonic compression were conducted with the aid of the in-house 450 tons MTS compression machine and the 300 tons/1000 tons (tension/compression) servo-controlled multipurpose testing machine.

To investigate the energy dissipative performance, 17 beam and beam-column tests were performed under monotonic or cyclic loading with the aid of the in-house 300 tons/1000 tons (tension/compression) servo-controlled multipurpose testing machine as well as the tailored testing system.

Development of Design Guidance

In this project, it has developed the following key design rules, thereby enabling an informed choice for their use in composite steel-concrete construction in Hong Kong: (1) design rules on compressive resistance on polygonal high strength concrete-filled composite column (CFCC) under monotonic load with due considerations of the confinement effect and (2) hysteretic model under cyclic load for seismic application.

Results and Findings

Axial Compression Behaviour of Hollow Steel Stub Columns

Eight tubular steel stub columns with cross-section shapes of octagonal, circular and square were tested under monotonic axial compression test. It was observed that the stocky octagonal cross-section shows a very similar cross-sectional capability in compression comparing with circular cross-section, and has a better performance compared to square cross-section with a same equivalent width.

Axial Compression Behaviour of CFST Stub Columns

Twenty-one CFST stub columns with cross-section shapes of octagonal, circular and square were tested under monotonic axial compression test. The test results show that under a high confinement ratio, the confinement effectiveness of octagonal CFST in terms of enhancement in axial resistance is not comparable to that in circular CFST; but is much better than that in square CFST. However, when the high strength concrete was used where the confinement ratio decreased, the difference in the enhancement in load capacity between circular and octagonal CFST becomes negligible.

Octagonal CFST Beams and Beam-columns

Seventeen octagonal CFST beams and beam-columns infilled with different concrete grades as well as two hollow section counterparts were tested under cyclical lateral load with or without constant axial load. It is viable to extend the current design rules prescribed in EN 1994-1-1 and AISC 360-16 to the design of octagonal CFST beams and beam-columns with slight underestimated capacity. For conservativeness, a reduction factor may need to be incorporated for the design of octagonal CFST members made with high strength concrete. EN 1994-1-1 and AISC 360-16 predict the effective flexural stiffness of CFST beams and beam-columns quite well with acceptable effectiveness and conservatism.

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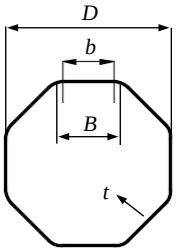
Recommendations

Cross-section Slenderness Limit for Octagonal Hollow Sections

A new slenderness limit for plate buckling in octagonal cross-section was proposed.

$$b / t \leq 29.8\sqrt{\left(235 / f_{\mathrm{y}}\right)}$$



Axial Capacity Equations Considering Confinement Effect

Based on the test observations, the design formula for circular CFST in EN 1994-1-1, could be modified for the design of octagonal CFST.

Octagonal CFST Beams and Beam-columns

It is viable to extend the current design rules prescribed in EN 1994-1-1 to the design of octagonal CFST beams and beam-columns with a slight underestimate of the capacity. For conservativeness, a reduction factor may need to be incorporated for the design of octagonal CFST members made with high strength concrete.