# Structural Behaviour of External Diaphragm Connection between Steel I-section Beams and Circular Hollow Section Columns under Cyclic Loading

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## Why Hollow Sections?

- Better strength to weight ratio
- Aesthetically pleasing
- Wide and diverse applications

**BUT** these advantages are often under-exploited due to:

- The perceived difficulties on cost effective connections between I-beams and hollow section columns.
- Relative lack of design guidance and of experimental data related with the cyclic inelastic behaviour of these connections.

## Aims and Objectives

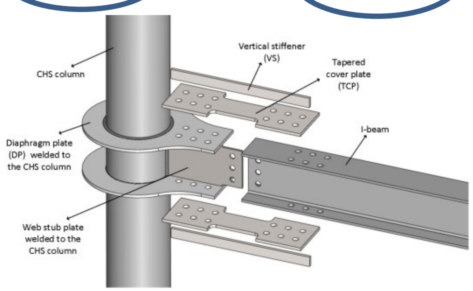
- Design a cost effective connection between steel I-beam and circular hollow section (CHS) column.

External Diaphragm Connection
- Practical & cost effective
- Damage Control Performance (DCP)
  - Minimum post-seismic repair for the main structural members in CHS frames.
  - Replaceable links (components) in the connection to dissipate the seismic energy

- Determine the hysteretic (energy dissipative) behaviour of the external diaphragm connection type by full scale laboratory tests.
- Calibrate the non-linear finite element models (ABAQUS) against experimental results for parametric analyses on key geometric parameters with an aim of achieving optimum design arrangement.
- Derive design expressions in line with CIDECT design guide and Eurocode 3 Part 1-8 (CEN 2005) which will be calibrated against experimental data in accordance with Eurocode 0 (CEN 2002).

## Development of The Joint Design

Joint Development Process
- Delay web-stub distortion → Oversized holes in web-stub
- Multi-fuse energy dissipation mechanism → Replaceable links : Tapered cover plates (TCPs)
- Delay beam yielding → Oversized holes in TCPs
- Eliminate column web panel distortion → Efficient diaphragm plate dimensions
- Eliminate stress concentration in diaphragm plates → Efficient diaphragm plate dimensions




General view of the components of I-beam to CHS joint

## Experimental Progress

Six laboratory tests are conducted for the proposed connection to investigate its hysteretic behaviour. All tests have the same exact specimen and differ only in the type of tapered cover plates employed to connect the diaphragm plates to the I-beam flanges.

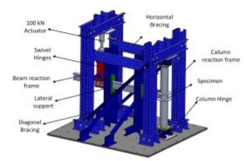
The six tests investigate the effect of (X) on the overall joint behaviour
- different steel grades of
- different sizes of bolt-holes in
- use of stiffeners welded to

→ Tapered Cover Plates (TCPs)

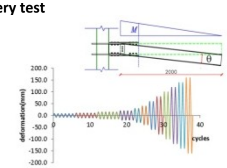
The components of each test specimen are:

| Component | Steel Grade | Geometry |
|---|---|---|
| CHS | S355 | 244X10mm<br>Length = 2000mm |
| I-beam | S355 | UB 203X133X30<br>Length = 2000mm |
| 2 x Diaphragm Collar Plates | S355 | Ring width = 90mm<br>Thickness = 15mm |
| Web Stub | S355 | Thickness = 8mm<br>Oversized holes (16+6mm) |
| 2 x Tapered Cover Plates (TCPs)* | S235 or S355* | Thickness = 12mm<br>Normal holes (22mm) or oversized (22+6mm)* |
| 2 x Vertical Stiffeners (VSs)* | S235 or S355* | Height = 40mm<br>Thickness = 12mm |

*** TCPs and VSs are different for every test**

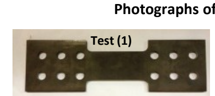



**General layout of the test arrangement**

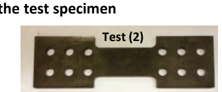



**Loading protocol based on AISC**

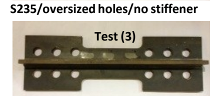
**Photographs of the test specimen**



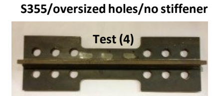

S235/oversized holes/no stiffener



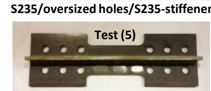

S355/oversized holes/no stiffener



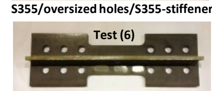

S235/oversized holes/S235-stiffener




S355/oversized holes/S355-stiffener




S235/normal holes/S235-stiffener

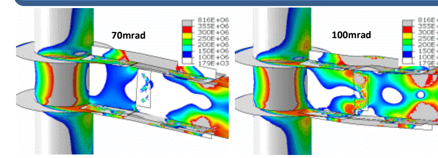



S355/normal holes/S355-stiffener

**Types of TCPs used in laboratory experiments**

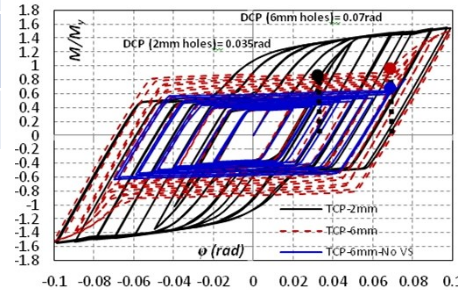
Experimental results for the six proposed tests will be reported in near future.

## Finite Element Analysis

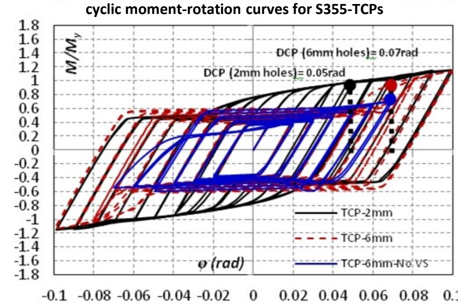



**Von-Mises stress distribution for the connection FE model in ABAQUS (TCPs with stiffeners and oversized holes)**

- Failure occurs in TCP at 100mrad rotation.
- web distortion is delayed till 70mrad rotation.




cyclic moment-rotation curves for S355-TCPs




cyclic moment-rotation curves for S235-TCPs

## Conclusions

- Multi-fuse energy mechanism is created and failure occurs in the replaceable link of the connection (TCPs).
- The VSs delay buckling of TCPs and improve the moment-rotation behaviour.
- The oversize holes in the web connection delay web distortion.
- Oversize holes in TCPs increase the DCP rotation limit.
- Reduced TCP/VS steel grades increase the DCP rotation limit.

## Acknowledgement

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