Cold-Formed Steel Bolted Moment-Resisting Connections

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Background

Figure 1
Various shapes of cold-formed sections
(Yu et al., 2019).

The use of **Cold-Formed Steel** (CFS) members in building construction goes back to the middle of the 19th century in both the United States and England. However, the acceptance of such steel members as a construction material was still limited until around 1946 when the development of thin-walled cold-formed steel construction in the United States was realized by the issuance of various editions of the "Specification for the Design of Cold-Formed Steel Structural Members" of the American Iron and Steel Institute (AISI). Using this type of sections in construction has been of growing importance in the recent years due to their positive contribution to **lowering environmental risks** and **reducing the amount of carbon emissions and construction waste** compared to the typical Hot-rolled steel sections and to other materials such as concrete. Additionally, these sections can lead to **economic and design solutions with less material and waste** due to their **higher strength-to-weight ratio** and **flexibility** for obtaining unusual sectional shapes in comparison with hot-rolled ones (Figure 1). Moreover, While Hot-rolled steel profiles are formed at elevated temperature, the fabrication process of CFS counterparts can be performed at room temperature using **less energy** and **reducing cost**. Therefore, CFS structural systems are appropriate options for modular and multi-storey buildings from sustainable point of view.

CFS as Sustainable Building Material

Environment

- Construction-related carbon emissions
- Construction waste

Society

- Homelessness
- Affordability and availability of residential dwellings

Economy

- Construction and energy cost

Light steel (CFS) framing

CFS frame construction of stick-built structures (Fiorino et al., 2014)

Modular Construction

American School in Bucharest
www.algeco.ro

Research Motivation

Multi-storey mid-rise CFS building (Yu et al., 2019)
www.buildsteel.org

CFS shear wall systems application is restricted to **low- to mid-rise** buildings and they exhibit **poor ductility**, especially in seismic zones. Thus, **more ductile lateral-load systems** such as **CFS moment frames** can be a good solution

For **Multi-Storey Buildings**, it is essential to guarantee high level of **connectivity** between structural elements especially in seismic zones, hence **moment connections** play a key role in the performance of moment frames.

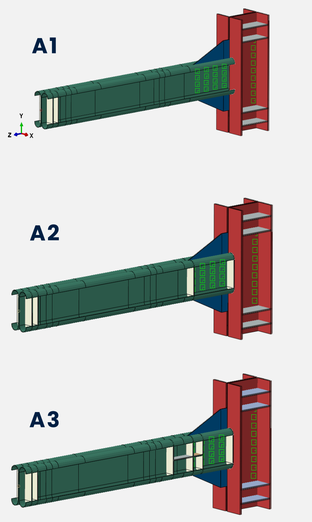
And Since **connections and joints** form the major part of design fabrication and erection which is almost **50%** **the total steel work**, the impact of connection design on sustainable buildings design cannot be ignored.

CFS MR frames connections design guidelines as well as experimental and numerical studies are limited.

Aim of Research

Study a new form of CFS moment connection that is CFS bolted beam-to-column with through plate moment resisting connection.

Methodology



Recent experimental test demonstrated that this type of connection has good performance and respects moment frames requirements for seismic regions which indicate that connections must be classified as semi-rigid or rigid. However, design guidelines as well as experimental and analytical studies for CFS connections are limited.

In this study, analytical models of the connection validated against previous experimental test have been created to discuss the behaviour of the connection and try to bridge the gap between research and industry. Geometry, Material, Bolts, analysis type and boundary and loading conditions have been considered carefully to simulate the behaviour of the connection

The geometry of the models includes several configurations: beam section, thickness of beam and gusset plate and stiffeners arrangements.

Nonlinear elastic-plastic stress-strain material model suggested in literature have been used to simulate the behaviour of material. The curves were constructed using coupon test results obtained from experimental test.

Geometry

Specimens	Beam Section [-]	Beam Thickness [mm]	Gusset Pl. Thickness [mm]	Beam Stiffeners Thickness [mm]
A1-3	Curved	3	8	8
B1-3	Curved	4	10	10
F1-3	Folded	3	8	8
G1-3	Folded	4	10	10

TABLE 1 - Specimens sectional details for numerical modelling

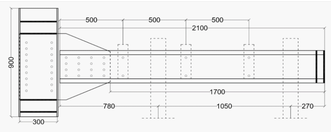
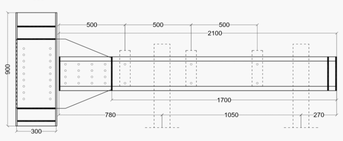
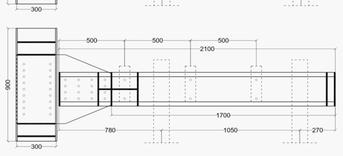
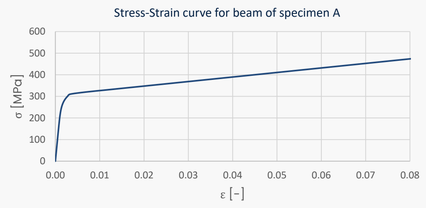
STIFFENERS CONFIGURATIONS	SIDE VIEW OF BEAM-TO-COLUMN CONNECTION SPECIMENS ALL DIMENSIONS IN [mm]
No stiffening 1	
Partial stiffening 2	
Optimum stiffening 3	

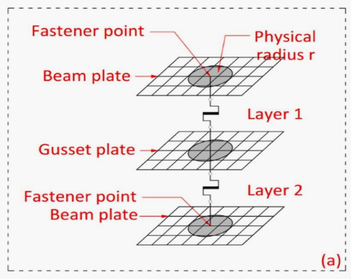
TABLE 2 - Stiffeners arrangements & dimensions of CFS beam-to-column connection specimens

Material & Bolts

Specimen	Beam A	Gusset A	Beam B	Gusset B
$\sigma_{0.2}$ [MPa]	313	353	322	308
$\varepsilon_{0.2}$ [-]	0.00349	0.00368	0.00353	0.00347
E [MPa]	210000	210000	210000	210000
E_0 [MPa]	2100	2100	2100	2100

TABLE 1 - Material properties for beam and gusset plate from coupon test - specimens A & B

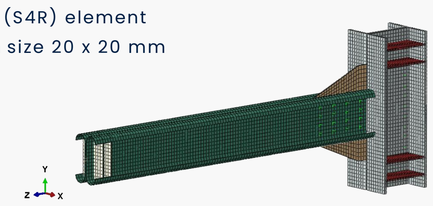


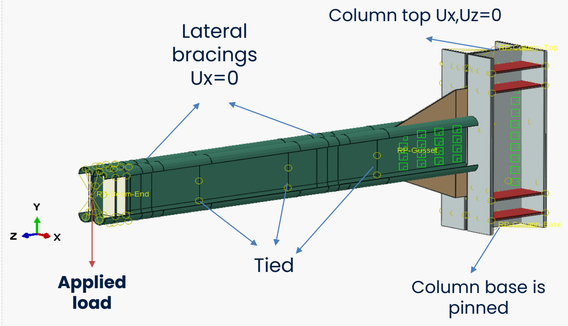


Single bolt modelling in ABAQUS (Ye et al., 2020)
Point-based fasteners with rigid multi-point constraints

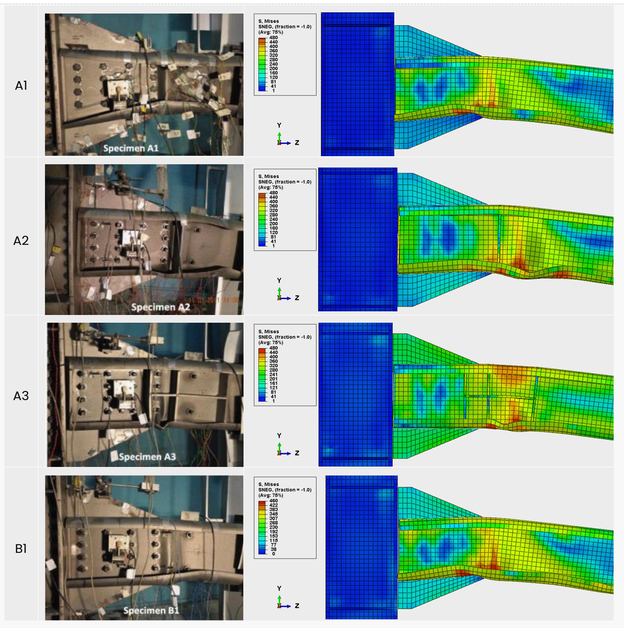
Analysis Type, Mesh & Boundary Conditions

- General, static
- Shell (S4R) element
- Mesh size 20 x 20 mm

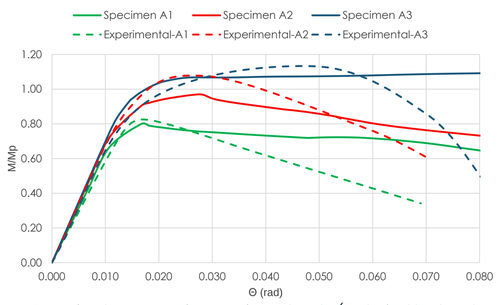




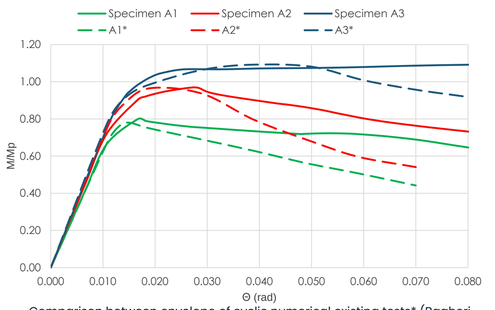
Results



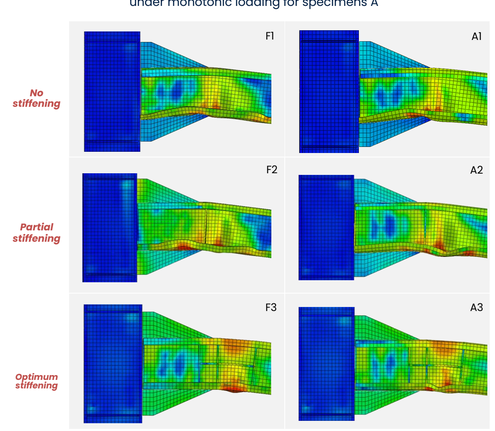
Failure deformations comparison between previous experimental test by (Bagheri Sabbagh et al., 2012b) and FE models under monotonic loading for A and B1 Specimens



Comparison between previous experimental test by (Bagheri Sabbagh et al., 2012b) cyclic envelop moment-rotation curves and FE models moment-rotation under monotonic loading for specimens A

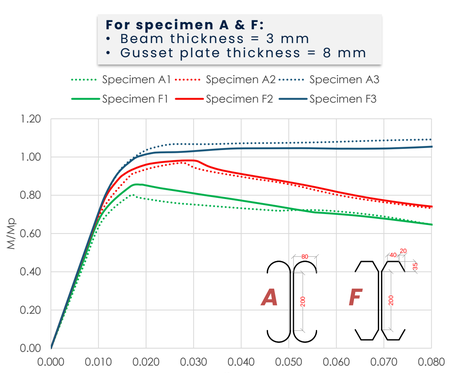


Comparison between envelope of cyclic numerical existing tests* (Bagheri Sabbagh et al., 2013) and FE moment-rotation results under monotonic load for A



Failure deformations for specimens A & F

For specimen A & F:
- Beam thickness = 3 mm
- Gusset plate thickness = 8 mm



Moment-Rotation curves for connections with curved flanges beam specimens A vs connections with folded flange beam specimens F

Future Work

The development of advanced CFS MR Bolted connection taking into account the following aspects:

- Reduction in bolts number
- Stiffeners shape, number and arrangments
- Geometry of gusset plate and reduction of its size.

The study of CFS MR connection behaviour and performance according to current standards and seismic provisions for MR frames connections.

The implementation of experimental test activity of the new proposed CFS MR Bolted connection to validate the numerical study and support recent research.

The promotion of CFS for building construction.

Related Literature

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