

CROSS Safety Report

Errors in steelwork connection design risk unsafe beam sagging moments

This month's report concerns design issues encountered when reviewing connection designs. The reporter discovered a moment connection between a universal beam and a universal column, with the moment connection being made to the web of the column.

Reporter's submission

While reviewing connection designs, a reporter became concerned where there was a moment connection between a universal beam (UB) and a universal column (UC), but with the moment connection being made to the web of the column (**Figure 1**).

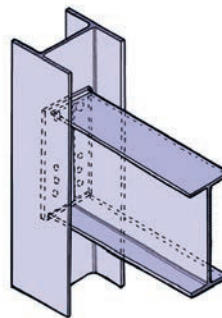
The reporter believes that where the connection software being used did not include the required connection type, largely due to it being a configuration not covered in the Steel Construction Institute's 'Green Book' design guidance¹, the connection designers opted to use a beam-to-beam (apex) connection, which was covered by the software.

The reporter believes this connection type might be being selected for the following reasons:

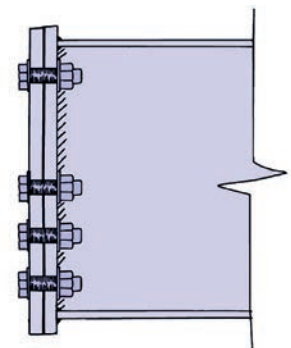
- 1) The software in use only shows a single beam with an end plate, along with the end plate of the accompanying beam, but no indication of the second beam (**Figure 2**), which may be confusing.
- 2) The connection title in the software is being ignored or misunderstood – as it does indicate it is a beam-to-beam connection, despite the graphic showing only one beam in the pair.
- 3) There is a lack of understanding or familiarity with the SCI Green Book(s) design and its associated scope and limitations.

The reporter highlights that Section 4.4 of SCI P398 states that bolted end plate connections 'as splices

→ **FIGURE 1:** Beam-to-column web moment connection that designer had detailed



→ **FIGURE 2:** Sketch of software output diagram that does not show second beam of beam-to-beam connection, which may be misleading



or as apex connections in portal frames, are effectively the beam side of the connections covered in Section 2, mirrored to form a pair'. It is the reporter's opinion that this makes clear the web of a column is not acting in the same manner as the end plate of an I-section beam.

The reporter remarks that the apex connection is based on an end plate which is connected to a top and bottom flange and a central (beam) web, and they note this is not the

case when considering a connection to a column web. The reporter is concerned the latter scenario has the potential to lead to some or all of the following errors:

- | incorrect bolt forces in the design
- | incorrect yield line patterns around the bolts in the column web
- | incorrect distribution of force in the compression zone in the column web
- | incorrect force distribution in the tension zone in the column web.

Key learning outcomes

For steel connection designers:

- | Connections can often be the weak link in structures, and can be a key interface between two design teams, so always need verification and good collaboration
- | If connection designs are not being carried out by the primary designer, it is important that all design loads and assumptions are communicated clearly to the connection designer
- | It is good practice for all designers to gain experience and skill in connection design
- | Designers should comply with existing best practice regarding connection design and ensure all forces are adequately accommodated by all parts of the connection
- | Computer analysis requires care in modelling, verification of models and software, and validation of results. Beware of overreliance on computer results

The reporter feels these errors could in turn lead to incorrect capacities in the calculations and an unsafe design. They note that even if there was not a failure in the connection, for smaller UC sections along with many UB sections, the web thickness is such that it is unclear if the web would be stiff enough to form a rigid moment connection. The reporter shares their concern that there is a danger of deformation of the column web allowing sufficient rotation at the connection such that the beam experiences higher sagging moments than was intended or designed for. Again, they consider this has the potential to lead to an unsafe design.

According to the reporter, the issue is not solely down to the connection designers. They believe designers of the structure may be using a wireframe model without due consideration of the fact that, while it is an excellent tool for the overall design of the structure, it makes certain assumptions about how the joints between members will behave and it does not model the local stress distribution at the connections. As such, it appears to the reporter that some designers are modelling moment connections between beams and

column webs without considering how the behaviour of the joint may affect the structural behaviour and with no thought as to how such a connection can be created, particularly without design guidance backed up by physical testing.

According to the reporter, the issue is also not limited to single-sided connections, since in a double-sided connection there is the need to consider the effect of pattern loading and this will still require that the column web resists the out-of-balance moment at the connection.

The reporter believes there is a need for greater understanding of connection designs and more consideration of the local stresses in the connection which are not modelled in the overall structural frame models. They also consider this example to be another example of overreliance on design software.

The full CROSS Safety Report, including links to guidance mentioned, is available on the CROSS website (report ID: 1403) at www.cross-safety.org/uk/safety-information/cross-safety-report/incorrect-steelwork-connection-design-type-leading-1403.

REFERENCES

1) **Steel Construction Institute (2013) P398: Joints in steel construction: Moment-resisting joints to Eurocode 3** [Online] Available at: https://steelconstruction.info/images/5/5d/SCI_P398.pdf (Accessed: October 2025)

2) **Collaborative Reporting for Safer Structures (2024) CROSS Safety Report 1327: Critically under designed moment splice connections** [Online] Available at: www.cross-safety.org/uk/safety-information/cross-safety-report/critically-under-designed-moment-splice-connections-1327 (Accessed: October 2025)

FURTHER INFORMATION

Below is a suggested resource list for anyone starting off in steel connection design:

- | **Steel Construction Institute (2013 & 2014) The Green Books** [Online] Available at: www.steelconstruction.info/The_Green_Books (Accessed: October 2025)
- | **Owens G.W. and Cheal B.D. (1989) Structural steelwork connections**, London: Butterworths
- | **Steel Construction Institute (2010–2025) Advisory Desk Notes** [Online] Available at: www.steelconstruction.info/Advisory_Desk_Notes (Accessed: October 2025)
- | **Kulak G.L., Fisher J.W. and Struik J.H.A. (1987) Guide to design criteria for bolted and riveted joints** (2nd edn.) [Online] Available at: www.boltcouncil.org/files/2ndEditionGuide.pdf (Accessed: October 2025)

Expert Panel comments

This report has similarities with *CROSS Safety Report 1327: Critically under designed moment splice connections*². In both reports, the connection design software did not have the capability to design the connection type that was required so a similar one was used, leading to a potential unsafe structure.

Clear communication

Typically, on projects it is the main structure designer who designs the structure and prescribes forces and limitations, e.g. prescribing the type of end restraint needed or type of bolts to be used to enable the fabricator to undertake the most efficient connection design. Indicative connection details are often provided on the construction drawings, particularly for a connection configuration that is not covered in any SCI design guidance.

There are often many ways that a connection can be detailed to achieve the assumptions made by the main designer in their global analysis regarding its stiffness and ensure that all load-effects are transmitted safely through the connection.

It is important communication is clear to avoid misinterpretation, and the main

designer should be afforded the opportunity to review fabrication details and calculations to check the design requirements have been fulfilled. An alternative is for the main designer to fully detail all connections.

Design responsibilities

This report highlights a more general issue with the traditional demarcation between main member design and connection design. While it is understandable, it means the main designer profession have difficulty developing their intuitive views of how the connections should 'work'. Ideally, they should know the modes of internal failure around connection interfaces and should be able to position stiffeners as appropriate.

The Panel is aware of cases of cantilever members being attached to the web of hot-rolled members where the connection designer thought that their sole obligation was to design the attachment weld and gave no thought to the effects on the thin web behind. The British Standard is quite clear that this has to be done, but there is some scope for ambiguity as to whose responsibility it is.

Sometimes the ambiguity can lead to disputes – as in the classic case of junctions

between hollow sections where the design of the main member is often driven by the required wall thickness for connections, but the main designer has based their selection of the hollow section on its axial capacity with a thin wall. Increasing a hollow section member from 10mm thick to 12mm raises tonnage by 20% simply because the demands of the connection have not been properly thought through.

Software use

If the software being used does not include such a connection type, largely due to it being a configuration not covered in SCI P398, there is likely a good reason. This should be understood by any competent steelwork designer. The web of any open section is generally going to be 'thin' and is typically only capable of carrying a shear connection unless it is stiffened out of plane.

As the reporter suggests, another reoccurring issue is the overreliance on design software and manipulating models to design a connection or a component that is outside the program's design capabilities. Careful consideration is required to identify what design implications there might be when this is done.

New Digital Theme Page

CROSS has received a significant number of reports relating to computational design that suggest there is a gap between the use of software and the understanding of it. This widening gap has the potential to lead to unsafe outcomes.

To help professionals engage with these risks, CROSS has collected these Safety Reports on digital engineering and computation design in a dedicated Theme Page. This Theme Page aims to help engineers understand common errors, learn how to mitigate them, and share their experiences for the benefit of others.

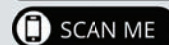
Professionals with awareness of a safety issue connected to digital engineering are encouraged to contribute to this growing knowledge base by submitting their own confidential reports to CROSS.

Explore the Theme Page at www.cross-safety.org/uk/digital-engineering.

What is CROSS?

Collaborative Reporting for Safer Structures (CROSS) helps professionals to make structures safer by publishing safety information based on the reports it receives and information in the public domain.

CROSS operates internationally in the UK, US, and Australasia. All regions cover structural safety, while CROSS-UK also covers fire safety.



How reporting to CROSS works

The secure and confidential safety reporting system allows professionals to share their experiences to help others.

Professionals can submit reports on safety issues related to buildings and

other structures in the built environment.

Reports typically relate to concerns, near misses or incidents. Find out more, including how to submit a safety report, at <https://bit.ly/cross-safety>. Your report will make a difference.

STRUCTURAL ENGINEERING OUTSOURCING SERVICES

- Structural Design Services
- BIM & Cad Services
- RC Detailing Services
- Eurocodes & British Standards
- Highly Competitive Rates
- UK & Ireland Specialists



London - Dublin - Cyprus - Greece



(+44) 02074594842
info@dma-services.com
www.dma-services.com