CROSS Safety Report

Overestimation of lateral torsional buckling restraints

This month's report relates to a concern about the load capacity of a new temporary structure designed by another firm.

Report

A contractor asked a reporter to review additional loads on a new temporary structure designed by another firm. After reviewing the design, the reporter found that the structure would not be able to support the additional loads. In fact, it appeared the structure would be overloaded with the original design loads. The reporter tells us that the structure was to be loaded to the design values in the following weeks.

This concern was brought to the attention of the design engineer. After correspondence, it became clear that they had used an unbraced length of 375mm instead of 6600mm (larger by a factor of 18). They were relying on temporary beams bolted to the top flange for lateral top flange restraint (**Figures 2 and 3**). The reporter considers that the problem with this assumption was:

1) On plan, there were only two beams per bay, and they were both evenly and heavily loaded (**Figure 1**).
2) The lateral restraint points were not braced back to the support points (there was no diaphragm action).
3) The connections were not designed to be moment-resisting.
4) The load application was eccentric, introducing additional torsion, which had also not been considered (**Figure 2**).

After several escalating emails, phone calls and warning letters to the client and contractor, the design engineer finally decided to reinforce the main beams (less than one week before it would have been fully loaded). During the final meeting with the design engineer, it became apparent to the reporter that:

1) There was an overreliance on the fact that this exact design had been used previously (with smaller loads).
2) There was still a misunderstanding of what constitutes lateral torsional buckling restraints. The discussions between the reporter and the designer had been misunderstood.
3) There had been a reliance on finite element analysis (FEA) with a limited understanding of the issues. The design engineer had used FEA a week earlier, after the initial concerns were raised, to provide additional confirmation of their arrangement. This was a static analysis, and the designer had only reviewed the deflected shape. The design engineer claimed that the beams would buckle toward each other, and the reporter's concerns were not valid. The reporter suggested that a nonlinear analysis would have been more appropriate.

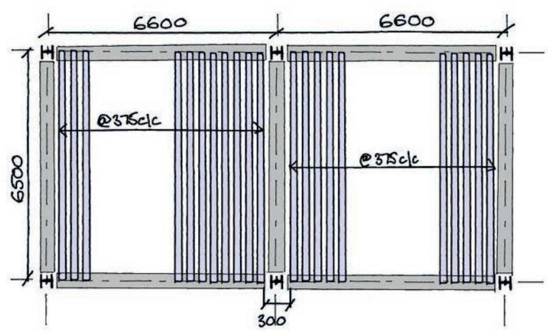


FIGURE 1: Plan view of temporary works structure

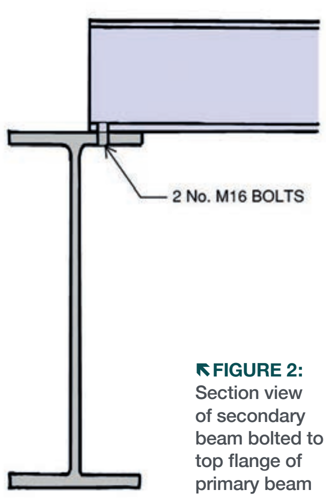


FIGURE 2: Section view of secondary beam bolted to top flange of primary beam

In the reporter's view, the lessons to be learned are:

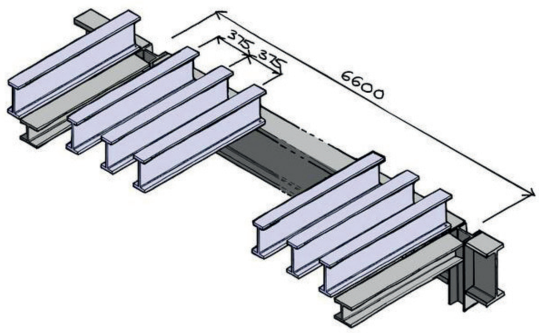
1) Ensure unbraced length assumptions follow sound engineering principles.
2) Ensure that any analysis is appropriate for the problem you are trying to solve or verify.

This incident was a near miss, but it could have been a different story.

Key learning outcomes

For civil and structural design engineers:

- The bending capacity of beams is fundamentally dependent on avoiding buckling. If restraint is required, then it should be provided and detailed to ensure that it is effective in practice
- LTB restraint should be designed by suitably qualified and experienced individuals ensuring unbraced length assumptions follow sound engineering principles
- Ensure that any analysis is appropriate for the problem you are trying to solve or verify
- Guidance related to the lateral restraint and LTB of steel beams can be found in *P360 Stability of steel beams and columns* published by the SCI



↗FIGURE 3: 3D isometric showing isolated area of temporary structure

The full CROSS Safety Report, including links to guidance mentioned, is available on the CROSS website (report ID: 795) at **www.cross-safety.org/uk/safety-information/cross-safety-report/overestimation-lateral-torsional-buckling-restraints-795**.

Expert Panel comments

The design and detailing of steel members to resist lateral torsional buckling (LTB) is one of the more complicated aspects of steel design. Determining unbraced lengths is often misunderstood by designers with little experience in steel design.

The fundamental issue in the scenario described by the reporter is that just interconnecting the two beams does not constitute lateral restraint since there is nothing to prevent the two beams mutually moving sideways together.

To prevent such movement, you would typically need cross bracing in plan in the plane of the top flanges, or the beams supposed to be providing restraint would need to be connected back to something stiff.

The Expert Panel feel that a nonlinear analysis should not be resorted to in this case, as it is a conceptual problem. Besides the bracing of the compression flange of the beam, the detailing of the supports is also crucial for safeguarding the stability against LTB. If the transfer of forces in the bracing system to the supporting structure and the necessary torsional restraint of the girder are insufficient, the onsite structure will not align with the model used in the structural analysis.

Engineers often forget that restraint to buckling is provided by stiffness and it is merely a convenience that we design restraint to a code provision of a force (for example, 2.5% of the force in the member being stabilised, as a rule of thumb). We also often forget that the onset of buckling can be dictated by initial imperfections that are rarely captured in an analysis model.

The lack of understanding of steel beam grillages was picked out as a significant weakness in the industry by The Bragg Report back in the 1970s. This got a lot of focus in the design codes at the time, which is now enshrined in BS 5975-1:2024 (see **Further guidance**). BS 5975-1:2024 remains current as a permissible stress code for the design of temporary works. It is a very useful way to access conceptual checks, and indeed even complete temporary works designs.

Further guidance related to the lateral restraint and LTB of steel beams can be found in *P360 Stability of steel beams and columns* (see **Further guidance**) published by the Steel Construction Institute (SCI). The SCI also often run courses and webinars on LTB for those who wish to learn more.

Further guidance

British Standards

→| **BS 5975-1:2024: Temporary works – Management procedures for the control of temporary works. Code of practice:** https://knowledge.bsigroup.com/products/temporary-works-management-procedures-for-the-control-of-temporary-works-code-of-practice

Steel Construction Institute

→| **P360 Stability of Steel Beams and Columns:** https://www.steelconstruction.info/images/0/0e/Sci_p360.pdf

What is CROSS?

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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

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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.

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