Discussion: Novel loading tests on full-scale tapered member portal frames

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Contribution by R. C. Hairsine

In the paper by Rankin *et al.* (2009), the authors report that they modelled the tapered frame as an assembly of prismatic elements.

For the purpose of comparison, I wanted to make design calculations using commercially available software capable of dealing with tapered members for analysis (Cads, 2008a) and design checking to BS 5950 (Cads, 2008b). Unfortunately, the design loads in the original paper were given in terms of intensity (kN/m^2), without specifying the frame spacing/loaded width or how the self-weight of the frame was catered for in the calculations. A useful comparison was thus not possible. Additionally, whilst the authors imply that they considered both

- (a) lateral-torsional buckling between consecutive restraints to either flange to clause 4.8
- (b) and annex G restrained buckling between compression flange restraints (i.e. buckling in torsional mode about the intermediate tension flange restraints)

they do not say clearly which was critical. However, my calculations carried out on test frame 1 with an assumed bay width indicate that the purlin and rail stays introduced by the authors preclude any annex G torsional buckling mode. Buckling of the column length above the stayed sheeting rail restraint appears to be the critical design condition. However, Figures 14 and 16 of Rankin *et al.* (2009) appear to show that the lateral restraint has failed and the positional restraint of the column inside the compression flange assumed in the design was only partially effective due to buckling of the sheeting rail. This has potentially serious implications for long-span hot-rolled haunched portal frames as well as for tapered frames, and warrants more attention. Perhaps this failure would be prevented by the presence of attached sheeting in a real structure?

Authors' reply

We apologise for inadvertently omitting to state that the bay spacing between the frames was 6.0 m. Vertical loads can be

calculated by multiplying the intensity of loading (in kN/m^2) by the $18 \text{ m} \times 6 \text{ m}$ loaded area. Similarly, both frames were 5.0 m high to the eaves so the horizontal loading can be calculated by multiplying the intensity of horizontal loading by the $5 \text{ m} \times 6 \text{ m}$ loaded area.

Regarding the frame self-weights, these were calculated to be a very small proportion of the ultimate applied loadings ($<4\%$) and thus, so that the same datum was used for comparison of the test results with the analytical predictions, loads were applied at the purlin and sheeting rail loading points in both the experiments and the analyses. Normally, for design purposes, the self-weight loading would be distributed to the node points between the prismatic elements of the frame model.

The main objective of the paper was publication of experimental results. It is the authors' intention to carry out further analyses of these experiments using commercially available software and hopefully follow up with an analytical paper.

It is interesting that the contributor's analyses found that buckling of the column length above the stayed sheeting rail restraint appears to be the critical design condition. This would agree with the critical conditions observed in the tests and, indeed, the authors' analyses.

The criteria for lateral-torsional buckling of the frame members between restraint positions and local buckling at each cross-section were checked. Failure of test frame 1 was predicted to occur by lateral-torsional buckling of the column above the stayed sheeting rail. This failure mode actually did occur, as shown in Figure 14 of the original paper. Local buckling of the compression flange, as exhibited in Figures 15 and 16, and failure of the sheeting rail, also shown in Figure 16, were considered to be secondary failures, brought about by out-of-plane movements and rotation of the column compression flange as load was maintained on the test frame beyond the initial point of lateral-torsional buckling failure. The positional restraint offered by the stayed sheeting rail was considered to be fully effective until failure of the column occurred.

The authors' opinion is that reliance should not be placed on prevention of this failure mode in either long-span hot-rolled haunched portal frames or tapered member portal frames by the presence of attached sheeting in a real structure. Attached sheeting may perhaps help in the prevention of secondary failure of the sheeting rail but, more importantly, would be unlikely to enhance the lateral-torsional buckling capacity of the column length above the stayed sheeting rail restraint.

REFERENCES

- Cads (Computer and Design Services Ltd) (2008a) *CADS A3D MAX*. Cads, Broadstone, Dorset.
- Cads (2008b) *CADS SWMD (Steelwork Member Designer)*. Cads, Broadstone, Dorset.
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