

Resilience of Multistory Steel Building Frames prone to Extreme Actions

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Buildings must be designed not only for seismic, wind and gravity actions but also for accidental scenarios that may trigger local failures and lead to disproportionate collapse. While seismic design often provides some inherent robustness, many structures in non-seismic areas, detailed mainly for gravity demands, have proven highly vulnerable. This is especially true for multi-storey steel frames, where economical solutions such as shear tabs or fin plates remain widely used.

Extensive research has shown that these common joints cannot sustain the large rotations and tying forces required during column-loss events. Guidelines suggest relying on slab arching and membrane effects as a last line of defence, but these mechanisms are insufficient for typical gravity connections. One reason these details persist is that robustness checks are seldom performed in practice. Few engineers explicitly verify robustness, although working groups such as CEN/TC250 WG6 are now preparing regulations to make such checks mandatory.

To address this, the thesis proposes an alternative solution: the bolted unstiffened extended end-plate joint with thin end plate. The joint was investigated through a multi-scale methodology: macro-components based on T-stub behaviour were calibrated against tests, assembled into joint models, and then simplified into a fibre-hinge representation suitable for global analyses. This approach is practical for design offices, as it can be implemented directly in software like SAP2000, whereas detailed Abaqus-type models remain unrealistic for everyday practice.

Parametric studies on representative archetypes showed that the proposed extended end-plate solution can sustain large deformations, develop catenary action, and ensure robustness against column loss. In contrast, shear tab connections fail prematurely, even with slab participation. Composite slabs improve redistribution but cannot compensate for the weakness of such joints. Robustness capacity was also found to decrease with building height, underlining the importance of joint detailing in taller structures. Although extended end-plate joints are somewhat more costly, their safety and performance advantages clearly outweigh this difference.

Beyond proposing a new joint, the thesis contributes methodologically by highlighting the limits of current acceptance criteria, which are largely adapted from seismic design and not appropriate for monotonic column-loss loading. A vertical-limit procedure, coupled with rotation and strain checks, is introduced as an initial step toward more rational robustness verification.

By combining calibrated macro-component modelling with system-level analyses, the thesis bridges advanced research tools and engineering practice. The results provide a practical and codifiable basis for improving the robustness of steel and composite frames and support ongoing efforts to introduce explicit robustness design checks into future Eurocode provisions.