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ULTIMATE CAPACITY OF STEEL FRAMES WITH BOLTED CONNECTIONS UNDER COLUMN LOSS SCENARIOS

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ABSTRACT

End plate bolted connections are widely used in steel framed constructions. They can be designed to range from flexible and partial resistant connections to stiff and full-strength connections. The main source of frame deformability in case of redistribution of the loads under a column removal may be the flexural yielding of the beam or the flexural yielding of the end-plate, depending on whether the plastic yield moment of the beam can be attained or not. In both cases, bolt fracture limits the strength and deformation capacity and may prevent the beam from developing significant (or full) catenary action under large deformations. The study presents the results of a parametric numerical study carried out on a set of bolted beam-to-column connections with extended end plates. The main parameters are the span to depth ratios for steel beams, capacity ratio for connections in terms of strength (i.e. partial strength and full strength). For partial strength connections, different configurations will be considered to cover all possible failure modes (i.e. complete yielding of the flange, bolt failure with yielding of the flange, and bolt failure). Numerical studies employ finite element models calibrated against experimental data. The results showed that, in order to ensure a ductile behaviour as required for developing a catenary action, the capacity design philosophy should be followed in the design of connections.

Keywords: T-stub, catenary action, strength capacity, deformation capacity, failure mode.

INTRODUCTION

The commonly adopted practice in the design and detailing of beam to column connections of steel frame buildings give satisfactory results in most normal loading conditions. Analytical tools, for example the component method from EN1993-1-8 [1], are enough accurate to predict the stiffness and strength, while ductility characteristic can be approximated using some simplified formulations or other means (e.g. finite element models or experimental testing). Supported by extensive research programs, the prediction of seismic response parameters was also continuously improved over the last decades. However, for some particular loading events, for example column removal conditions following a blast or impact, there are still many questions to be addressed and studied, including the ultimate strength and deformation capacity of connections, both under static and dynamic conditions. The capacity of beam to column connections to withstand the forces and deformations that may develop in the structure following a column removal represents a key factor in the development of alternate load paths (AP). The AP method, with its emphasis on continuity and ductility, is similar to current seismic design practice. However, there are specific problems which need to be considered [2]. Bolted end-plate connections, which are widely used in steel framed constructions, can be designed to range from flexible and partial resistant connections, to stiff and full strength connections. The interaction between the bolts (diameter, class, distance) and the end-plate/column flange (thickness, class) plays a key role in this classification. When steel frames are loaded in the post-elastic range, the main source of ductility may be the flexural yielding of the beam or the flexural yielding of the end-plate, depending on whether the plastic yield moment of the beam is achieved or not. In both cases, bolt fracture limits the strength and deformation capacity and prevents the beam from developing significant (or full) catenary action under large deformations. The study presented in the paper investigated the response of bolted beam to column connections under large deformations conditions associated with the loss of a column.

RESULTS AND CONCLUSIONS

The parametric numerical study was carried out on a set of bolted beam-to-column connections with extended end-plates. The numerical models were calibrated against experimental data obtained for two end plate bolted connection configurations (see Figure 1). The main parameters were the span to depth ratios for steel beams, the capacity ratio for connections in terms of strength and stiffness (i.e. partial strength and full strength/ rigid and semi-rigid), and the distribution of gravity loads on the beams. Figure 2 shows the vertical force vs. vertical displacement curves for two end plate connection configurations, with the increase in ultimate capacity as the bolt diameter increases from 16 mm to 20 mm.

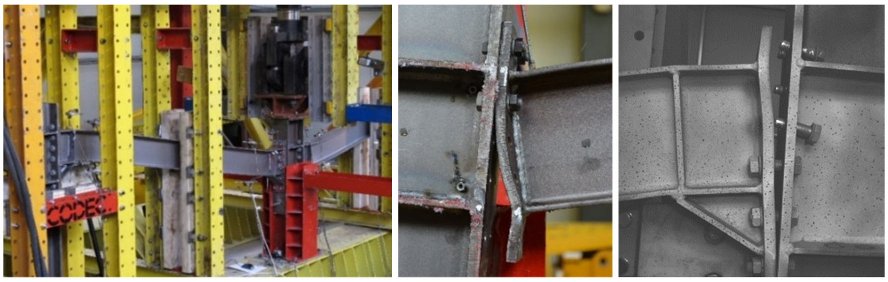

Fig. 1 - Experimental test set-up and column loss test results

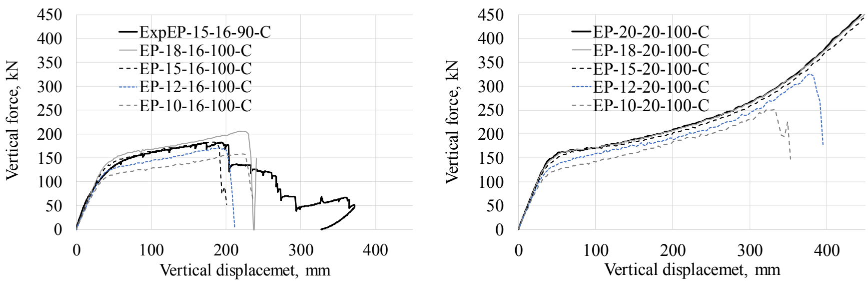

Fig. 2 - Vertical force vs. vertical displacement curves for end plate connections: a) 16 mm diameter bolts; b) 20 mm diameter bolts (bolts are class 10.9)

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