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Elastoplastic analysis of elementary bolted steel tee-stub connections

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ABSTRACT

Elementary bolted steel tee-stub connections proportioned according to EC3 were studied by means of a three dimensional finite element model using the ANSYS software package. The specimens reflect different geometric and strength parameters as well as bolt pre-stressing conditions. Within each specimen, the parameters considered were the flange thickness and the distance between the bolt's line to the end of the flange. The elastoplastic response, up to the ultimate state, was analysed and aspects relative to stiffness, strength, bolt loads, prying forces, interaction between flanges and evolution of the equivalent von Mises stress distribution within the flange and bolt were examined. Comparisons between experimental values and Eurocode3 (EC3) predictions indicate that the design procedure still needs to be improved, owing to the complex phenomena embodied.

1. Introduction

1.1. Background to the study

Modern design codes, such as Eurocode3 (EC3) [1], have introduced new design rules for beam-to-column bolted steel connections. For the case of endplate bolted steel connections with fewer bolts required (4 bolts in the tension region and only 2 bolts in the compression zone), as shown in Fig. 1, the beam tension flange force is assumed to be transmitted over a small region of the endplate (and the column flange) and the response of this portion can be represented by elementary bolted steel tee-stub connections.

The design procedure adopted in EC3 show that yield failures in a bolted steel tee-sub connection may occur by one of the three typical failure modes reported in Fig. 2. These are plastic failure of the endplate or the column flange (Mode (1)), yielding of the endplate or column flange followed by bolt fracture (Mode (2)) or bolt fracture (Mode (3)).

Experimental and finite element (FE) studies, either on isolated tee-stub connections or on tension zone in bolted steel beam-to-column connections, have been carried out in different research centres for many years. Recent FE studies include the works of Bursi and Jaspart [2–4], Bahaari and Sherbourne [5–11], Choi and Chung [12], Yang et al. [13], Mistakidis [14] and Swanson et al. [15]. The above studies were mostly concerned with the accomplishment of a reliable FE model and gave some basis for its implementation.

In line with these developments, Bursi and Jaspart [2] have evaluated the EC3 design applications by testing and numerically analysing the behaviour of two bolted steel tee-stub connections shown in Fig. 3. The authors provided the necessary experimental data to perform realistic simulations. The specimens which were cut from IPE300 and HEB220 sections were designed to fail according to the failure modes reported in Fig. 2(a) and (b), respectively. When comparing the load–displacement relationships of both tests data and predicted by EC3, the authors recognised that the EC3 model was totally unable to predict the load–displacement evolution and did not permit a complete agreement between predicted and test data. To examine the degree of accuracy and limitations of the EC3 design procedure (see Appendix A for eventual relations used), the same authors [3] have applied the design procedure to 14 endplate beam-to-column connections bolted to a rigid base. Once again, the authors observed that the model underestimates the initial stiffness. However, it was also stated that the design model was on the safe side, as far as the plastic failure moments are concerned, and that discrepancies are largely concentrated in thin endplates.

In EC3, the design of the tension region is based upon yield line analysis using empirically determined yield line patterns. However, the different yield line patterns are associated with different yield line formulae and, therefore, lead to different strength capacities. In addition, drastic hypotheses have been adopted in plastic regime. For instance, in mode (1), a rigid plastic model was assumed for the

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