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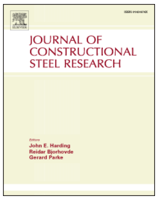

Cyclic behaviour characterization of web panel components in bolted end-plate steel joints

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ABSTRACT

This paper addresses the characterization of the behaviour of the column web panel components in bolted end-plate steel joints subject to cyclic loading. Based on experimental test results, a calibrated parametric FE model of a double extended beam-to-column end-plate steel joint is implemented, that allows characterizing the behaviour of the joints both globally and in terms of the dissipative components. The numerical models have been developed using the ABAQUS FE package considering a detailed representation of the various joints components and taking into account the different sources of geometrical and material nonlinearities. Finally, based on the integration of the stress and displacement fields in predefined paths along the column web, a detailed extraction procedure for the cyclic force-deformation behaviour of the column web panel components is proposed, however extensible to other components. These relationships are needed for implementation in a components based approach that accounts for cyclic loading conditions.

1. Introduction

Partial-strength joints subject to static monotonic loading are well characterized in modern codes of practice, such as Eurocode 3 part 1–8 (EC3-1-8) [1] within the framework of the component method. However, in the presence of cyclic load reversals there is no direct and easy approach to characterize their cyclic behaviour and energy dissipation. This need mostly results from the seismic action, where the cyclic behaviour of the members and connections play an important role, along with ductility, tenacity, rotation capacity or energy dissipation of the dissipative members or joints.

When partial-strength joints are used in steel moment-resisting frames (MRF), there may be a shift of the plastic hinge location from the beams or columns to the joints. When this shift occur, it is of critical importance to take into account the characteristics of beam-to-column joints. The use of partial-strength joints is a common and relatively low cost solution to apply in MRF, in comparison with their full-strength counterparts. Previous studies have shown that, if adequately detailed, these connections may also become attractive alternatives for structures located in seismic regions, allowing a precise control of the location and response of the dissipative elements [2]. Furthermore, Shen and Astaneh-Asl [4] argued that, when properly designed, bolted joints may exhibit high ductility and good energy-dissipation capacity under cyclic loading, providing that brittle components have sufficient overstrength in order to prevent undesirable failure modes. In this case, proper assessment of the behaviour is crucial due to the controlling role that these joints will play, as the main dissipative components in the structure, in the structural response during a seismic event. In fact, design codes, such as Eurocode 8 (EC8) [3], allow the use of partial-strength joints, providing that a set of design requirements is met. Firstly, advanced structural analyses are required, such as non-linear static (pushover) or non-linear time history analyses, although detailed information is missing concerning the adoption of these types of analyses, particularly when dealing with steel frames with partial-strength connections. Additionally, EC8 (sections 6.5.5(6), 6.5.5(7) and 6.6.4(4)) requires experimental evidence of the behaviour of the joints whenever dissipative connections are considered in the seismic design process, which is very difficult to accomplish in design practice. It is therefore clear that this kind of joints require more research to achieve adequate detailed guidance to overcome these difficulties.

The findings in the research presented in this paper can contribute to the development of a simplified design method for partial-strength steel joints. Based on the component method, which takes directly into account the cyclic behaviour of each dissipative component and, simultaneously, provides adequate overstrength for the non-dissipative components (capacity design), thus ensuring that the idealized behaviour of the joint can be considered in the global analysis of the structure in a simplified manner. However first is necessary to extract the behaviour of the basic components.

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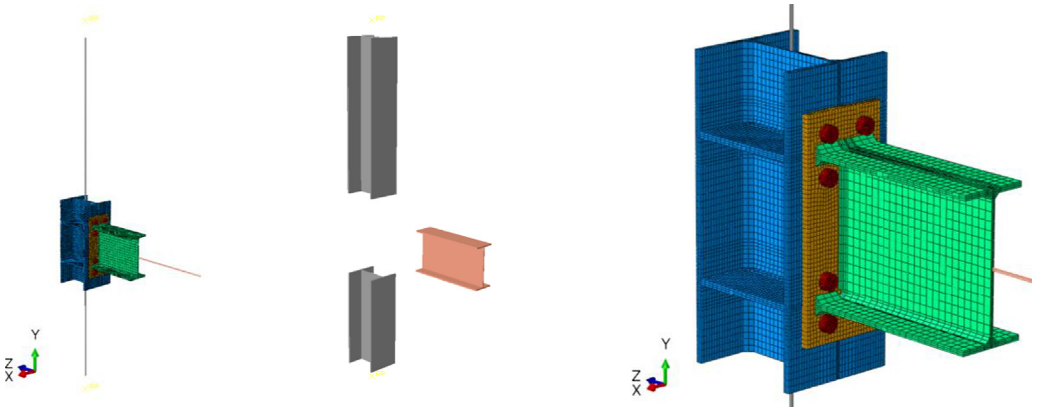
This paper aims to contribute to the mechanical characterization of components in double-extended beam-to-column joints using a detailed parametric numerical model developed in ABAQUS [5] taking advantage of the Python scripting interface in ABAQUS. The model is applied to end-plate beam-to-column joints and considers a three dimensional detailed representation of the various joint components taking into account several phenomena involved in the connection behaviour, namely the nonlinearities related to the geometry, contact and material properties. A combined isotropic and kinematic material-hardening model is used. The calibration of the numerical model, which is based on the results of an experimental research programme, is comprehensively described in this paper.

In the following sections, the cyclic behaviour of the joints is characterized, both at the global joint response and in terms of the critical components, comparing the results of the experimental and numerical models. Using the validated FE models, a detailed procedure is described to isolate the column web components under cyclic loading, namely the column web panel in shear and the column web in transverse compression or tension, and to identify their mechanical behaviour analysing the stress and deformation fields in the FE models. The derived force-displacement relationships, of the individual dissipative components, can be directly applied to a mechanical model of the joint, to characterize its behaviour, provided it is ensured that the non-dissipative components remain elastic.



a) Global FE model b) Detail of the cross sections of the wire elements c) Detailed view of the Joint zone

Fig. 1. Meshed parts of the FE model.

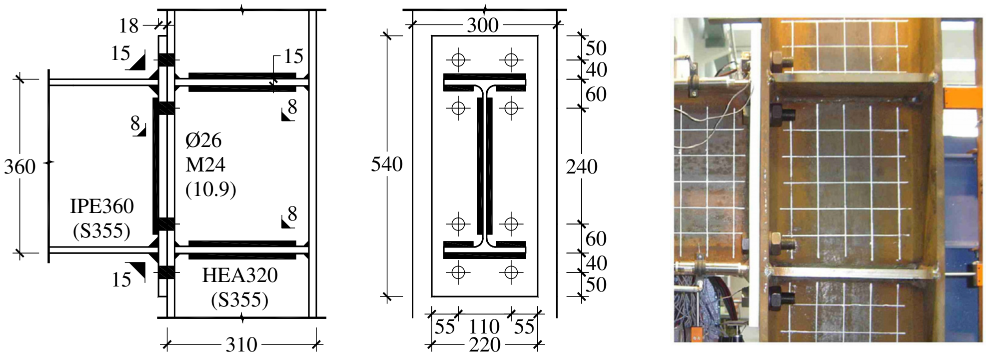


Fig. 2. Detail of the joint for Groups 1 and 2.

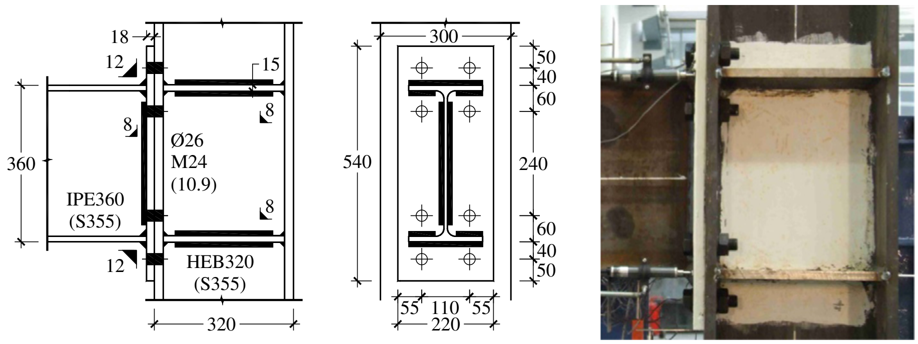


Fig. 3. Detail of the joint for Group 3.