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Extended end-plate to concrete-filled rectangular column joint using long bolts

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ABSTRACT

This paper presents a research on a solution of extended end-plate joints, used to connect I-shaped beams to filled-concrete rectangular hollow section columns. In the joint, long bolts throughout the column are used to connect the beam end-plates. The main idea is to avoid intermediate connecting elements (e.g. a reverse U channel) or special bolts (e.g. blind bolts/flowdrill connectors) that are usually adopted in the beam to rectangular hollow section column joints using end-plates. Moreover, it expects that the rigidity and resistance of the proposed joint are improved in comparison with the traditional solution (using reverse U channel or special bolts), so the joints could be adopted in seismic resistant moment frames.

First, a test program within a RFCS European project titled HSS-SERF "High Strength Steel in Seismic Resistant Building Frames", 2009–2013, was defined. Within the test program, specimens subjected to significant bending moments (and shear) or to shear only were tested. Then, analytical developments based on the component method approach and aimed at predicting the joint response have been carried out; their validity have been demonstrated through comparisons with the test results.

1. Introduction

In order to connect the beam end-plates to the rectangular hollow section columns (with or without concrete inside), the following solutions are usually adopted in the construction (Fig. 1): use of special bolts (blind bolts/flowdrill connectors) or use of intermediate elements (such as reverse U channels). These solutions are adopted to overcome the difficulty of placing bolts when the column section is a closed one. In the blind-bolt/flowdrill bolt joints, the beam end-plates are directly connected to the column faces as these bolts do not need an access to the inner side of the column wall. With respect to the joints using the U channels, a U channel is welded to the column and then the beam end-plates are attached to the U channel face by normal bolts. Design rules for these joint configurations are not yet covered in the current Eurocode 3, part 1–8 but these kinds of joint have been widely investigated in the literature (e.g. [1–15] among others). However, it can be pointed out that the two above joint solutions have some disadvantages, in particular their cost and their generally low stiffness and resistance in bending. Indeed, the use of special bolts or of additional pieces of the reverse U channel is costly. On the other hand, the mechanical behavior of the mentioned joint solutions are mainly governed by the column or U channel faces component, subjected to the transverse tension forces through the bolts, which presents generally a rather weak stiffness and resistance. Accordingly, the above joint solutions are normally not suitable to be used for moment resistant frames in seismic areas.

To avoid the disadvantages of the above solutions, it is proposed to use long bolts/threaded bars throughout the column, connecting the beam end-plates (Fig. 2). In the solution, the concrete core works together with the column face to support the tension force in the bolts, so the stiffness and resistance of the joints are improved. It is expected that the proposed joint configuration can be used in moment resistant frames in seismic zones. Regarding the configuration, it appears that the fabrication cost of this joint may be reduced in comparison with the joints using special bolts or U channels. However, the difficulty related to the erection on site of the proposed joint can be identified. In particular with respect to the joints of internal columns where the two beams in the two sides must be assembly in the same time. Accordingly, the erection cost of the joints may be increased.

The use of long bolts for beam-to-column connections is still rare in the construction and no design procedure exists in the current Eurocodes. The present paper summarizes the research on the proposed joint configuration, from the experimental tests to the development of the design procedure. Section 2 presents the application of the component method to the joint configuration; in which the additional rules that are needed to complete the design procedure are highlighted. Sections 3 and 4 present the analytical developments for the additional rules and their validation by experimental results. Section 5 is finally

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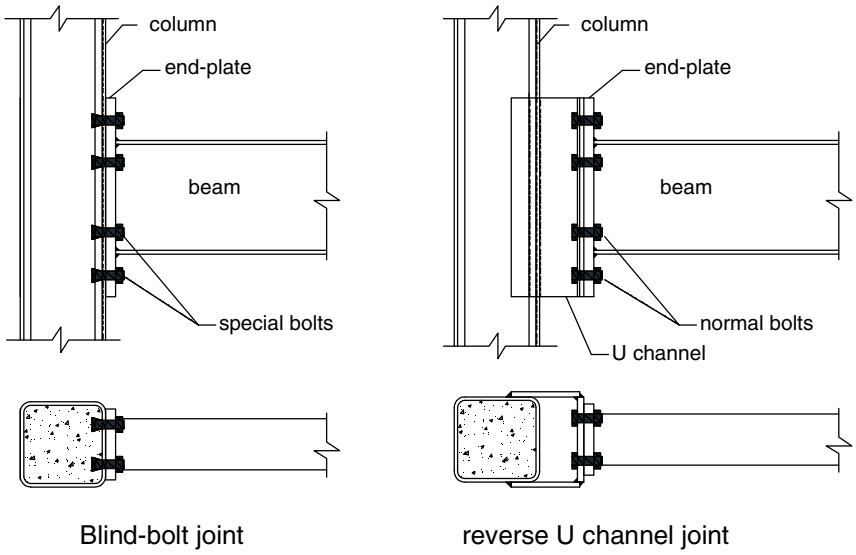

Fig. 1. Blind-bolt and reverse U channel joints.

devoted to the concluding remarks. In the paper, in order to distinguish with the long bolts of the proposed joint, the term "normal" bolts meaning the bolts that are classically used in beam-to-column joints.

2. Component method application

Let us consider a joint where the end-plates are directly attached to the column face (or U channel face) by normal bolts as a reference case of which the design rule has been widely considered in literature (e.g. [1–15]). The following points can be highlighted as the main differences between the reference joints and the investigated joint.

- *Behavior of the column component* (Fig. 3): under the tension force in the long bolts, the concrete core works together with the steel tube, resulting the "column in transverse compression" component. With double side joints under unbalanced bending moments, this "column in transverse compression" component is simultaneously subjected to two forces: the forces due to the long bolts and the force due to the beam flange. In the referent case, under the tension force in the bolts, the role of the concrete core is very limited, the front face of the column is under bending while the lateral faces are in transverse tension. It can believe that the resistance and stiffness of the column in transverse compression with the contribution of the concrete core are much higher than the ones of the column face (steel tube) in bending. Therefore, the above difference is one major reason showing the improvement of the proposed joints in comparison with the traditional ones, in the term of stiffness and resistance.
- *Effect of the preloading in the bolt*: The preloading in the long bolts has a global effect within the joint, increasing the joint stiffness. Moreover, the bolt length is quite important; it means that the loss of the preloading which could be expected is less important. The above remarks are not observed from the referent case, the effect of the bolt pretension is also ignored in Eurocode 3, part 1–8.
- *Behavior of the joint under shear load*: The long bolts pass throughout the steel tube and the concrete core, so the bolts take also the role of connectors that are generally needed to transfer shear load from the steel column to the concrete core in the traditional solutions.

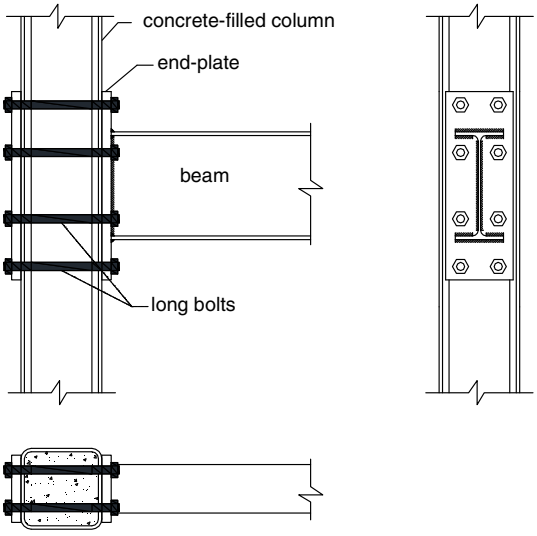

Fig. 2. Proposed joint configuration.

From the above observations, and based on the basic components given in EN1993-1-8 [16] and EN1994-1-1 [17], the component identification and the associated design rules for the proposed joint configuration can be summarized in Tables 1, 2 and 3, respectively for three cases: joint under bending, joint under shear and load introduction. The design rules of the basic components of Eurocodes are not reminded herein, while the additional rules will be presented in the next sections.

The above design rules can be applied for the joint during exploitation time. Concerning the construction phase, the following detailing rules should be highlighted.

Repartition plate: in one side joints (at exterior columns), the use of a repartition plate is recommended in order to avoid the local effect of the force in the bolts to the column face and concrete core. The dimensions of this plate can be identical with the end-plate.

Bolt type: Threaded bars can be used for the proposed joint instead of the long bolts, without changing the joint behavior and design rules.

Erection procedure: In comparison with the traditional joints, the erection on site of the proposed joint is more complex. The following procedure is proposed to be adopted: (1) assembling the steel beam to the steel column using the long bolts, in this step the bolts are not