Journal of Constructional Steel Research 103 (2014) 61–76

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Behaviour of stiffened flange cleat joints

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ARTICLE INFO

Article history:
Received 7 January 2014
Accepted 12 July 2014
Available online 24 August 2014

Keywords:
Steel joints
Flange cleat
Stiffener
Experiment
New theoretical models

ABSTRACT

Currently bolted flange cleat beam-to-column joints are not sufficiently applied, especially in European construction practice. The assembly of this type of joints is simple, quick and inexpensive. Nevertheless, although there are nowadays several theoretical models available for the characterisation of the behaviour of the mentioned joints, there are no clear recommendations related to the selection of an optimum model.

The first aim of the present research is to validate the existing theoretical models of the flange cleats in bending as a component, as well as whole flange cleat joints. Validation is carried out by comparison with the experimental results. Additionally, research work was extended to include stiffened flange cleats and their influence on the total behaviour of the four different joint configurations. By upgrading the existing models, new original resistance models for stiffened cleats in bending are developed. In order to investigate the application of the component method on the joints with stiffened flange cleats, the experimental programme was extended to joint testing and a corresponding level arm is determined.

The methodology related to the behaviour assessment of four tested configurations of joints regarding resistance and stiffness is presented. Finally, the accuracy of the developed models for the characterisation of stiffness and resistance of the tested joint configurations is confirmed through comparison with the experimental results.

1. Introduction

Advantage of steel structures with bolted flange-cleat beam-to-column joints, Fig. 1, in comparison to those with other types of joints can be recognised by the fact that the erection of such a structure is simple, fast, cost effective and of high quality. During erection the seat flange cleat serves as a support for the beam and because there is no site welding, the erection does not depend on weather conditions.

However, in spite of above advantages, the lack of knowledge concerning the actual behaviour of partial strength semi-rigid flange cleat joints resulted in avoiding this type of joints in current practice.

In the past three decades simplified methods for the rotational behaviour assessment of the joints with angles have been developed, [1–3]. However, the Eurocode [4] only proposes that the characterisation of angle in bending is treated in a similar way as for the end plate, or equivalent T-stub.

1.1. Previous studies of the flange cleat joints

In the past decade series of complex tests of the steel joints have been carried out in Europe, [5–7], but only a few tests have been related to the bolted joints with angles. One of the significant contributions to this topic was given by Faella et al. [5]. The authors developed own theoretical model and showed that this model in comparison to the one adopted in Eurocode 3 gives an assessment which is much closer to the actual behaviour than the one provided by Eurocode 3. The comparisons are carried out on a relatively limited number of similar test specimens. Unlike in Europe, in North America this type of joints is frequently used in practice, especially in seismically active areas. Consequently, in North America laboratory tests are oriented in this direction [8,9].

1.2. Scope and aims of current study

The subject of this paper is to investigate the entire static behaviour of the angle-cleat in bending as a component as well as in the function of the flange-cleat beam-to-column joint subjected to bending. For this purpose, unstiffened and stiffened cleats were considered, Fig. 2.

The tests on cleats in bending were carried out on four different types of cleats. The test specimens for the simulation of real behaviour of this component were cleat pairs in tension. The second part of the experimental investigation was related to the testing of flange-cleat beam-to-column joints. The four joint configurations considering the application and the position of the stiffened flange cleat in the joint were tested.

The basic objective of this study was to obtain the real behaviour of different types of angle cleats in bending ($F - \Delta$ curve) as well as the real behaviour of various configurations of flange-cleat beam-to-column joints ($M_j - \Phi$ curve). The differences in behaviour between

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http://dx.doi.org/10.1016/j.jcsr.2014.07.011

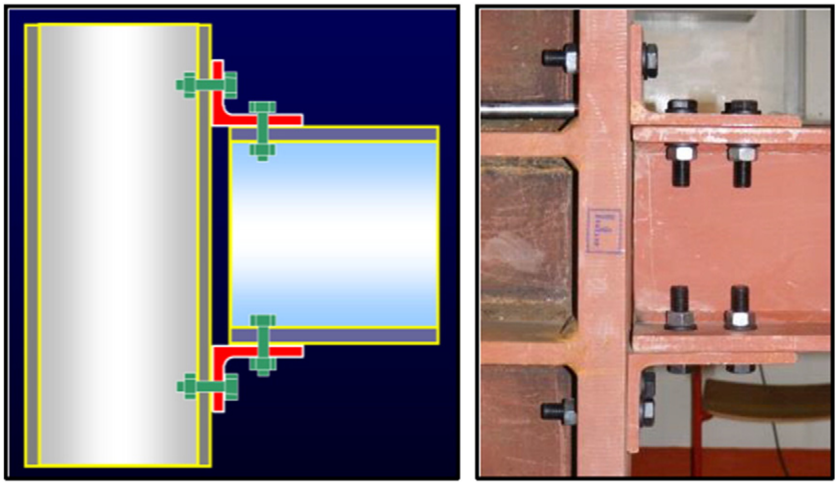

Fig. 1. Bolted flange-cleat beam-to-column joint.

the unstiffened and stiffened flange cleats were determined. In addition, differences in the behaviour of the tested configurations of joints, and the effect of stiffened flange cleat with respect to the position in the joints are quantified. Recorded experimental curves for the tested angles and joints enabled the evaluation of the component method. Finally, the recorded behaviour of the upper flange cleat in the joint and the behaviour of the 'pure' component-angle cleat in bending are compared.

The most important objective of this study was to find out the difference between the experimentally recorded behaviour of the flange-cleat in bending and the theoretical models, both existing and proposed herein. Furthermore, based on the obtained experimental data, an evaluation of the existing and presently developed theoretical models for the characterisation of the behaviour of tested flange cleat in tension and joints in bending is carried out.

2. Existing theoretical models for flange cleat in bending

Development of new original models for an implementation of the stiffened cleats in beam-to-column joints is primary based on original test results (see Section 5) and partly on existing models. Due to that fact a short overview of existing theoretical models is given in this chapter.

2.1. Resistance models

The failure of the angle-cleat in bending is analogical to the failure of the end plate in bending or the equivalent T-stub. The evaluation of the plastic (design) resistance of bolted T-stub connections is based on the well-known yield line principle. Angle in bending can fail according to three possible 'plastic' collapse mechanisms [5]. Type-1 mechanism is characterised by the formation of two plastic hinge lines: one is located at the bolt axis, due to the bending moment caused by the prying forces, and the other one at the angle corner. The formation of one plastic hinge line at the angle corner and the simultaneous failure of the bolts are characteristic for type-2 mechanism. The third collapse mechanism involves bolt failure only. The following models for the assessment of resistance of top flange cleat in bending, Fig. 3, are analysed:

1. AISC model,
2. Eurocode model (Method 1, Method 2),
3. Swanson (modified Kulak) model,
4. Chen model,
5. Faella model,
6. Girão Coelho model.

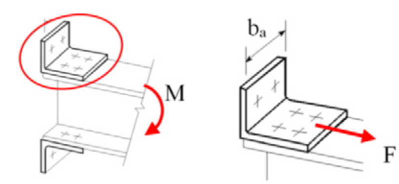

Fig. 3. Top flange cleat in bending

So, this paragraph presents a shortly description of the main characteristics of the outlined models. The prying model adopted in 'AISC-LRFD Manual of Steel Construction' [10] is based on the model developed by Kulak et al. [11]. In order to account for the stiffness of the bolt head, it is assumed that the force in the bolt is acting on the angle leg at the inside edge of the bolt shank rather than at the centreline of the bolt.

Fig. 2. Unstiffened and stiffened cleats.