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Advanced study of non-linear semi-continuous beam–column endplate connection and metal-decking floor modelling

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ABSTRACT

An endplate beam–column connection was modelled with bilinear material properties using ANSYS finite element software to achieve the plastic state in order to obtain the moment–rotation curve and the rotational stiffness, which were validated with laboratory testing performed by Abidelah et al. (2012). Those results were used to model a rotational link element with both linear and non-linear material properties (taking into account the stiffness only and the moment–rotation curve, respectively) to model the connection in a one-span composite metal decking floor (a beam between two columns) and results were then compared.

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1. Introduction

Engineers commonly design connections as either pinned or fixed joints, as this highly simplifies the analysis and calculations. However, these are ideal situations that do not represent the most common steel connections used in construction (Fig. 1), which usually have a certain rotational moment capacity and are called semi-continuous connections [1–4].

With technological advances, the use of semi-continuous models for most common steel connections is becoming more popular, and all major analysis and design computer software programmes allow the user to input the connection stiffness. However, it is usually not possible to define this value as a non-linear property, and it must be input as the moment–rotation curve.

When trying to design a semi-continuous connection, the engineer has difficulty to find information on how this can be accomplished. In this research, a single connection tested in the laboratory [3] is modelled in Ansys finite element software, and its rotational properties (stiffness) are obtained.

New technologies have also lead to an increase in the use of composite steel–concrete elements, which have become more popular worldwide because the engineer can take advantage of the best properties and design structural elements of both materials [9]. Occasionally, the combined use of these two materials is merely for protective purposes (say, an encased steel column); however, the structural elements can be designed to work compositely so that much improved performance is obtained [2].

An example of the behaviour of a composite beam connection and the intricacy of its design are shown in Fig. 2, in which a composite beam to column internal support is modelled with rigid elements connected by springs, in accord with Eurocodes. There is a great increase in the stiffness if a bare steel beam–column connection is provided by the concrete slab continuously over the internal supports [3].

The main objective of this research is to determine the influence of modelling semi-continuous connections with non-linear properties as defined by the moment–rotation curve and to provide guidance on whether linear or non-linear properties should be used.

2. Connection study

2.1. Introduction

A steel endplate beam–column connection is modelled with solid185 (cubed) and solid187 (tetrahedral) solid elements in Ansys finite element software. The column size is 114 × 120 × 5 × 8 mm, and the beam size is 240 × 120 × 6.2 × 9.8 mm. The dimensions of the connection are shown in Fig. 3 and are taken from Abidelah et al. [8].

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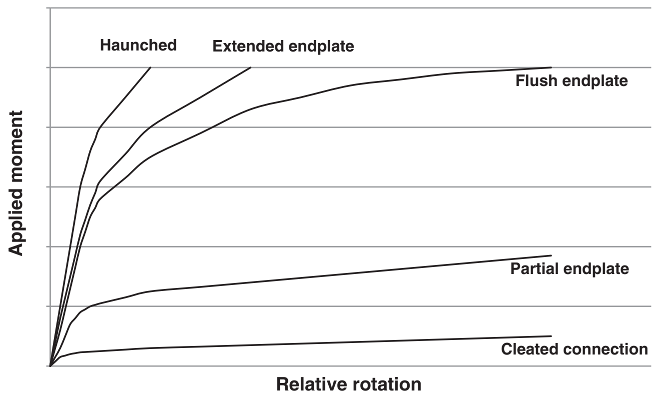

Fig. 1. Most typical steel beam–column connections.

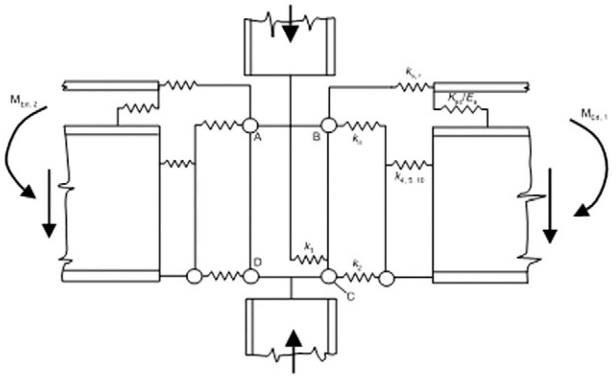

Fig. 2. An internal composite beam to column joint model. Johnson, R. and Anderson D., 2011 [3]

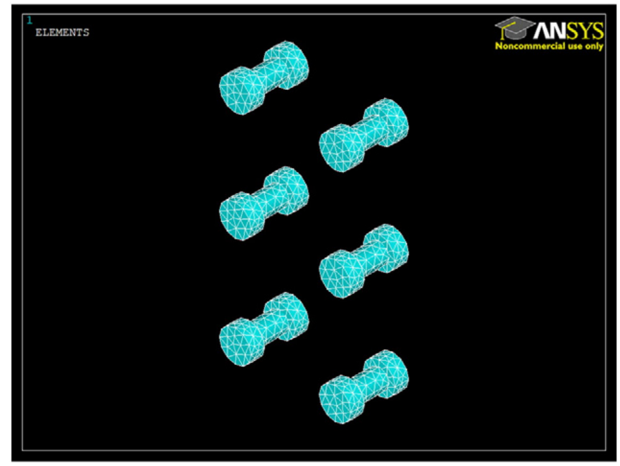

Fig. 4. Bolts modelled in Ansys finite element software.

The element material properties are defined as bilinear curves that harden after the yielding point, which allows the material to reach the plastic state. However, modelling materials as bilinear curves, although widely accepted and proven to give accurate results, does not provide the ultimate limit state results. Standard steel grade S355 is used inevery case except for the model validation, where the material properties obtained by experimentation are used instead.

An endplate (15 mm thick) is welded to the end of the beam so that full interaction may be considered and bolted through the column by M16 grade 8.8 bolts, whose head and nut are modelled as circular, as this is the correct assumption to represent the standard hexagonal shape with its diameter equal to the effective diameter of the bolt (Fig. 4).

To create the holes in the endplate and the column flange where the bolts are to be located, an identical shank volume is created and subtracted from the correspondent volumes. No gap or clearance between the shank and the endplate/column flange is considered.

For a full interaction between the elements, always-bonded contact pair elements (Fig. 5) are applied in the bolts between the shank and both the head and the nut, as well as between the endplate and the beam web (it is not necessary to apply these elements to the beam flanges, as full interaction is obtained by using the same key points and areas to generate the volumes). On the other hand, standard contact pair elements are applied to the endplate–column flange plane and the bolts-endplate/column flange interactions (Fig. 6) [5,6].

A full model representation is shown in Fig. 7, including supports and loading. The top and bottom ends of the column are totally restrained, acting as fixed supports. A point load is applied at the free end of the beam. This load will create a moment at the connection

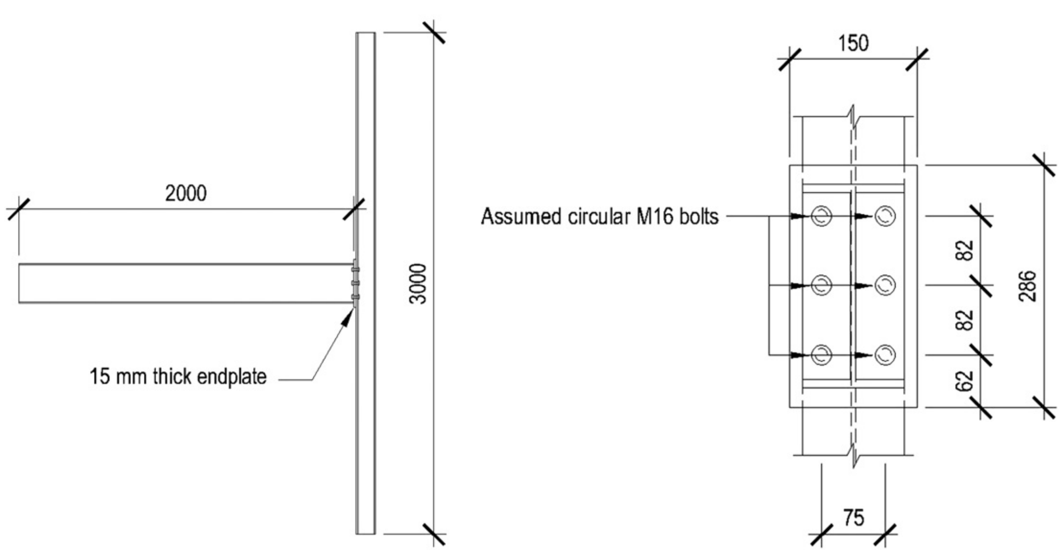

Fig. 3. The endplate connection dimensions.

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