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Optimization of bolted connections configurations of frames composed of cold-formed sections

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STATEMENT

Disclaimer

This thesis is submitted as partial fulfillment of Master of Science degree in Structural Engineering, Faculty of Engineering, Ain Shams University.

The work included in this thesis was carried out by the author during the period from September 2016 to March 2019 and no part of it has been submitted for a degree or qualification at any other scientific entity.

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ABSTRACT

Portal frames manufactured from hot-rolled steel are widely used in industrial buildings since the plastic analysis theory was developed, so knee connection behavior of these industrial frames has been well researched. With the increased use of portal frames composed of cold-formed sections, the development of structural connecting systems has become a more important research objective, that are favorable to connection elements and the behavior of bolted frame connections should be well understand. Bolted moment connections have been very popular for their better distribution of straining action and for better full filling serviceability requirements. However a clear understanding of the behavior of every single element in the connection as well as the interaction between them is not clear due to their complex behavior.

In this research, an overall literature review has been conducted to identify the state of knowledge and gather the required data. 3-D finite element models using ANSYS software (ver.17.2) that accounts for both geometrical and material non-linearities are developed. The proposed 3-D finite element models were calibrated by comparing their results with the experimental work that had already been done by other researches and showed a good correlation. An extensive theoretical study is conducted on knee connection of industrial portal frames, which are composed of double C-profile with gusset plate connected by bolts. The back-to-back lipped C sections connected by gusset plates are used as beams and columns members. For the ease of construction, the C-profile webs are connected only with bolts, while the flanges are not connected. The study aimed to study the effect of various geometrical factors on both the connection capacity and the connection failure modes.

The studied parameters are: 1) gusset plate thickness, 2) bolt diameter, 3) bolts pitches, 4) effect of increase grade of gusset plate, 5) effect of connection

pretension, 6) effect of the edge distance. In order to develop analytical design equations, regression analysis for the results is performed and design formulae are proposed for the connection moment capacity. Six modes of failure were identified among the finite element models:

- BFsw—Bearing Failure of section web.
- LTBgp—Lateral Torsional Buckling of gusset plate.
- LBcs—Local buckling of connected Section.
- BFgp—Bearing Failure of gusset plate
- LTBcs—Lateral Torsional Buckling of connected section
- TFsw—Tearing Failure in Section Web around bolt hole.

It is shown that the bearing failure is the dominant mode of failure, as loading increases, the knee connections failure can occur prematurely through lateral torsional buckling of the gusset plate at low applied loads. At the ultimate loading phase, local buckling failure of the connected sections occurs. Several observations were found and some useful recommendations for optimum connection configuration are given. A simple interaction design procedure to calculate the resistance of the joint connection under moment, shear and normal based on the bolt bearing failure for different bolt pitches is proposed. Results show that the proposed design procedure is simple and can predict the ultimate bolt bearing capacity of connection for different lipped C profile with different bolt diameters. Finally, a summary of the work carried out in this thesis, along with the general conclusions obtained from this study are presented.

KEYWORDS

Cold-formed Steel portal frame, Knee connection, Lateral torsional Buckling, Local Buckling, Finite element analysis, Finite element model, Bolt bearing failure

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