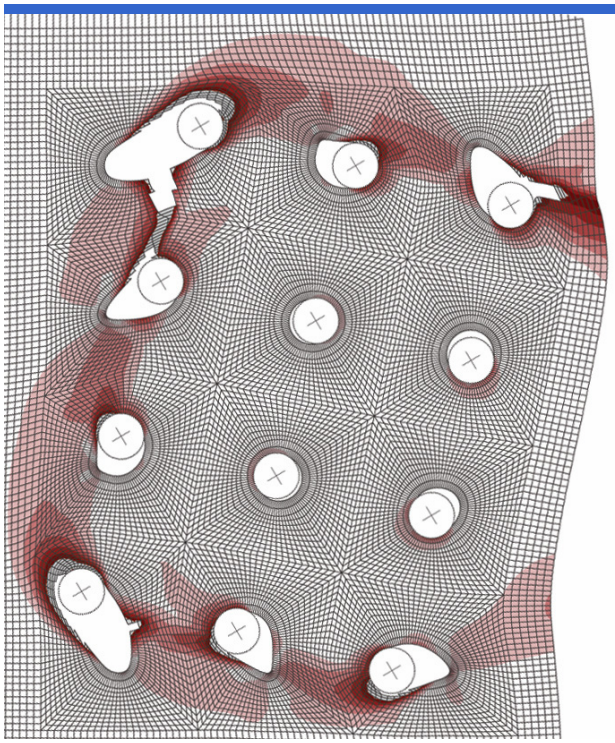
Block Tearing in Bolted Shear Connections

A Finite Element Investigation



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Preface

This thesis is submitted as a fulfilment of the requirements for the *Master of Science* in *Civil Engineering* Degree. The project was carried out in a period of 5 months and 2 weeks starting on the 1^{st} of September 2014. It was written in cooperation with two sister projects, one carried out by *B. Eng. Tim Alstrøm* and *B. Eng. Lars Henrik Nørager Raaschou* and another by *B. Eng. Wisam Elias Neaman* and *B. Eng. Taha Belal Eljaja* as part of their respective degree fulfilment requirements. The former deals with experimental investigation of block tearing by concentric loading while the latter investigates excentric load cases. Results obtained by *M.Sc. Steen Winterskov-Andersen*, *B.Eng. Jakob Schimdt Olsen* and *B.Eng Thomas Holm Skov* are also used throughout this project. All projects were supervised by *Professor and Head of Section for Structural Engineering Jeppe Jönsson*, (BYG•DTU).

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Finally, I wish to thank *my family* for their unending support and encouragement throughout my studies.

Sincerely,
Bálint

Abstract

The objective of the present thesis is finite element modelling of the block failure mechanism. Experimental investigations of block failure in bolted gusset plate connections, which have been conducted at the Technical University of Denmark, serve as the basis for simplified 2D models. The commercial finite element software Abaqus/CAE 6.13-4 is employed in this endeavour.

Special attention is given to the effects of eccentric load cases on the formation of the failure mechanism. Plates with bolt groups containing 8 and 12 bolts are investigated with the applied load at different eccentricities. Furthermore, the investigation includes concentric load cases in plates with 4, 6 and 9 bolts. Additionally, bolt hole ovalisation is investigated for plates with 1 and 2 bolt connections.

An inverse modelling approach is used for accurately determining the material properties used in the aforementioned models. These are based on uniaxial tensile tests conducted on coupons machined from the tested gusset plates. A Matlab® script is created for aiding the transformation of the force - displacement data, obtained during the tensile tests, into *true stress - true plastic strain* data pairs. Which are used as input in the commercial finite element software Abaqus/CAE 6.13-4.

The manipulation of the *load - deflection* curves includes corrections for errors introduced by the testing machine and a weighted extrapolation method for obtaining the true stresses after the onset of diffuse necking. The methodology presented for modelling tensile tests is consistent and applicable in both 2D and 3D modeling space. Additionally, in combination with the script, the *force - displacement* curves of the finite element models may be fitted to the experimental results with little effort. The mesh sensitivity analysis conducted for the tensile tests suggests that reasonably accurate results may be obtained with both 2D and 3D models beyond the onset of diffuse necking.

The block failure mechanism is predicted successfully in all of the investigated situations, however, the force - displacement responses do not fit perfectly with the experimental results. In some cases due to the effect

of bolt pretension, while in others, the material definition is the limiting factor. Nonetheless, the extrapolated *true stress - true plastic strain* curves determined from the tensile tests bring improvement in all cases investigated.