Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 156 (2016) 16 – 23

Procedia Engineering

www.elsevier.com/locate/procedia

9th International Conference „Bridges in Danube Basin 2016“, BDB 2016

# Finite Element Analysis of Cover Plate Joint under Ultimate Loading

Maitham Alibrahemy[a,b,c] *, Sébastien Durif[a,b] *, Philippe Bressolette[a,b] *, Abdelhamid Bouchaïr[a,b] *

[a]Clermont Université, Université Blaise Pascal, Institut Pascal, BP 10448, F-63000 Clermont-Ferrand, France
[b]CNRS, UMR 6602, Institut Pascal, F-63171 Aubière, France
[c] Department of Civil Engineering, College of engineering, University of Kerbala, Iraq.

**Abstract**

This paper presents a parametric study to investigate the mechanical behavior of bolted connection plates based on finite element analysis (FEA). Different parameters as end distances, bolt spacing, and plate thickness. EC3 (Eurocode 3) and AISC-LRFD (American Institute for Steel Construction - Load and Resistance Factor Design) specifications design ultimate loads are compared with finite elements results. Many failure modes are observed such as curling, bearing, net section failure, edge tearing of the connected plate etc. The comparisons showed the differences between the finite element results and the analytical formulae of design codes for each specimen. According to the finite element results, modified formulas are proposed to calculate the ultimate load and the failure type for the cover-plate bolted connections.



Peer-review under responsibility of the organizing committee of BDB 2016

*Keywords:* Cover-plate; failure type; finite element simulation; and single shear.

## 1. Introduction

For all bridge types, it is not easy to manufacture, transfer and construct the entire component in one piece. For that, joints are used to connect girders or bracing bridge components [1]. These connections may consist of fasteners like bolts, pins, rivets, or welds, and member elements, which are connected by one or several of these types of connections [2]. Welded or bolted connections with high- or normal strength bolts, or a combination of them, are used

* *E-mail address:* maitham@uokerbala.edu.iq, sebastien.durif@univ-bpclermont.fr, philippe.bressolette@univ-bpclermont.fr abdelhamid.bouchair@univ-bpclermont.fr


Peer-review under responsibility of the organizing committee of BDB 2016
doi:10.1016/j.proeng.2016.08.262

in the modern steel bridges and building [3].

Joint arrangements are usually chosen to resist normal forces, moments or shear forces between different types of members that influences the mechanical behavior of the whole structure and its cost [4].

In many steel bridges, to reach the target length of girders, the bolted connections are used to transfer forces (tension and compression) or/and bending moments between the connected members or splice small members. Cover-plate joints loaded in tension are used in bracing members of truss type bridges or as splice pate in tension flanges and webs. This connection type is designed to support the tension forces by bolt shear resistance, net and gross-section area of the connected plates, and shear resistance of the connected parts. High strength bolts can be used to mobilize the shear resistance and relative slip through the friction at the interface between the connected plates. Thus, when external shear force is applied, the frictional resistance prevents the relative slip between the plates [5].

The objective of this study is to analyze the behavior of cover-plate connections. A finite element model is developed and validated on the basis of published experimental results. The model is then used to make a parametric study to evaluate the effects of different parameters such as distances and spacing of bolts, plate thickness and steel grade. The obtained FE results are compared with different analytical formulae given by two design codes (EC3 and AISC-LRFD). The analysis is focused on a single shear bolted plate which is the basis representing the main failure modes observed in cover-plate connections. The comparison concerns mainly the ultimate capacity and the failure modes.

## 2. Analytical approaches

The failure modes observed in the cover-plate connections are listed hereafter with the analytical formulae used by the Eurocode 3 [2] and AISC-LRFD [6] to predict their corresponding strengths [7]:

- shear failure of the bolts,
- failure of connected members due to fracture or block shear and edge tearing of the connected plate or tearing of the connected plate between two bolt holes,
- excessive bearing deformation at the bolt hole, and
- tension failure in plate due to yielding or fracture of plate at gross section ($A_g$) or plate fracture cross the holes section (at net section area $A_n$).

The comparison between the geometrical requirements of the two codes shows that they have some common points and differences. In the two codes, enlarged holes are used depending on the bolt size [8]. For holes positions, the minimum end and edge distances (Fig. 1) are given in Table 1. For the maximum value, in joints not exposed to corrosive influences, there are no specified limits [9].

Table 1. Minimum distances design values

| Distance and spacing see fig. 1 | EC3 | AISC |
|---|---|---|
| End distance e1 | 1.2 $d_o$* | 1.2 $d_o$ |
| Edge distance e2 | 1.2 $d_o$ | 1.2 $d_o$ |
| Spacing p1 | 2.2 $d_o$ | 2.67-3 $d_o$ |
| Spacing p2 | 2.4 $d_o$ | 2.67-3 $d_o$ |

*$d_o$ is the bolt diameter

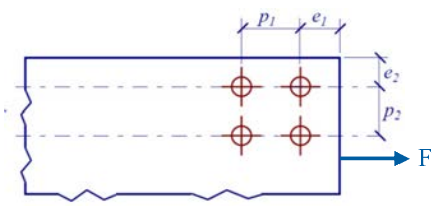


Fig. 1. Symbols of bolts spacing [9]