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BOLTED TIMBER-STEEL CONNECTIONS WITH SLOTTED HOLES

Edouard Cavene¹, Sébastien Durif¹, Evelyne Toussaint¹, Abdelhamid Bouchair¹

ABSTRACT: An experimental program is performed on steel-timber bolted connections using slotted-in steel plate or two lateral steel plates. The steel plates have circular holes alone or combined with slotted holes. The idea is to evaluate the influence of the slotted holes on the mechanical performance of the tested connections. The slotted holes are used to give a free relative displacement between the fasteners to limit the stresses due to geometrical variation (swelling and shrinkage) of wood in the direction perpendicular to grain. The results are observed considering the moment-rotation curves of all the specimens. Besides, DIC (Digital Image Correlation) technic is used at the surface of the specimen to observe the deformation of the specimen and to obtain the evolution of the centre of rotation of each connection. The results show that the slotted holes are promising solutions as they give higher strength compared to that of circular holes in the case of slotted-in steel plates.

KEYWORDS: Timber-steel connections, Slotted-holes, DIC, Moment resisting.

1 INTRODUCTION

In timber structures, various types of steel-timber connections exist and can be classified in two main families. The first one is made to be loaded in tension and present various failure modes: embedment, bending of bolts, block-shear and tension in the steel cross-section for example. This type of connection is largely studied in the literature [1]-[4]. The second one, representing the beam-to-column connections, is loaded in bending and shear. This type of connection with bending stiffness can transfer a part of the moment, allowing thus a reduction of the moment in the beam and, as a consequence, its cross-section. These connections transferring bending moments can be made using bolted steel plates slotted into the beam [5]. These plates with circular holes for bolts and dowels allow the transfer of the load between the steel and wood parts and consequently between the beam and the column.

Moreover, the wood is a hygroscopic material. Face to the hygrometric variation of the environment, the wood presents a variation of its internal hygrometry. This phenomenon creates deformations of the section mainly in the direction perpendicular to the grain due to swelling and shrinkage [6]. These deformations are restrained in the zone of connections due to the presence of bolts and circular holes in the steel plate used to connect the beam to the column. These restrained

deformations generate tension in the direction perpendicular to grain. As wood has a very limited resistance in this direction, this phenomenon is responsible of the appearance of cracks in the connection zone that reduces the resistance of the connection [7]. Nowadays, various technics of reinforcement are used to create prestresses or reinforcement in the direction perpendicular to grain, which include inserted screws in the section of the beam in the direction perpendicular to that of the bolts. This allows increasing the embedment resistance by increasing the tension perpendicular to the grain [8] [9]. But this type of reinforcement creates additional stress concentration in connection zone already highly stressed and is time consuming for projects.

The proposed idea is to limit the premature fracture in bolted timber-steel moment resistant connections due to swelling and shrinkage. To do so, it is proposed to allow the displacement in one direction (in general the vertical one) by using vertical slotted holes in the steel plate at the top half height of the beam instead of circular holes. By this way, swelling and shrinkage of wood can occur, in the direction perpendicular to grain, while the displacement in the direction parallel to grain is prevented in the beam, allowing a transmission of a moment in the connection. But releasing vertical stresses on a half-height of the beam can increase the stresses between the rows of bolts with circular holes and those with slotted holes and can influence the strength of this type of connections. Moreover, the use of slotted holes can have an influence on the position of the rotation centre during loading because of the release of the vertical displacement in the top half-height of the beam.

The present study analyses the influence of slotted holes in the steel plate of bolted timber-steel connection in term of resistance and position of the rotation centre. This study is based on an experimental campaign.

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2 EXPERIMENTAL TEST CAMPAIGN

The experimental campaign is based on 24 specimens tested under bending moment loading. Twelve connections present a steel plate slotted-in the beam section and twelve others have two steel plates on the outer parts of the beam (one on each side). For each type of connection, six specimens present only circular shapes in the steel plate and six others have slotted shapes in the top half-height of the timber beam. Figure 1 illustrates the geometry of the two types of plates. For each specimen, Digital Image Correlation technique has been used to measure the evolution of the rotation centre in the connection. The moment applied to the connection has been calculated using the distance between the centre of rotation and the position of the applied load.

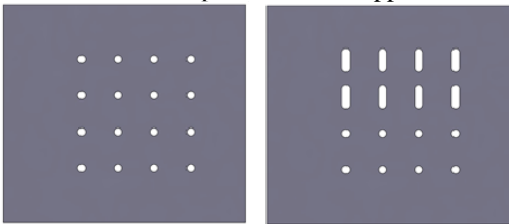


Figure 1: Plates with and without slotted holes.

3 RESULTS

The results are based on the moment-rotation curves of the tested specimens. Besides, the behaviour of the steel plate, bolts and timber are determined. This concern mainly the embedment and the bending strength of bolts.

3.1 MOMENT-ROTATION CURVES

An illustration of the moment-rotation curves for connections with slotted-in steel plate is given in Figure 2. It shows different phases in the behaviour representing the evolution of the fracture in wood element.

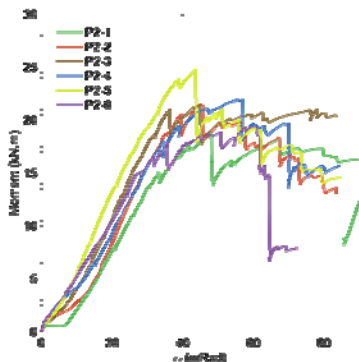


Figure 2: Moment-rotation curve for slotted in bolted timber-steel connection with slotted holes.

3.2 CENTRE OF ROTATION POSITION

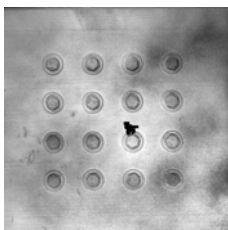


Figure 3: Evolution of the centre of rotation in the connection with slotted holes (slotted-in steel plate).

DIC technic is used to determine the position of the centre of rotation for all the tested specimens. The evolution of this position is observed for all the loading steps, at least at maximum load (see Figure 3).

4 CONCLUSIONS

The tests show a large rotation capacity with a conservation of the resisting capacity. Moreover, for the bolted connections with slotted-in steel plate and slotted holes, an increase of 15% of the strength is observed in comparison with the connections using only circular holes. This result can be explained by a changing of type of failure due to the limitation of tension perpendicular to the grain in timber along the slotted holes.

For the bolted timber-steel connection with lateral plates, the slotted holes do not present any significant difference of strength. The presence of slotted holes in the steel plate has non influence on the location of the centre of rotation, compared to the solution using only circular holes.

The presence of slotted holes in the top half part of the plate in bolted connections with slotted-in steel plate allows hydric deformation of wood. The present study needs to be completed by numerical modeling to evaluate the forces distribution in the fasteners with and without slotted holes, considering various geometries of wood and steel elements.

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