FACULTY OF CIVIL ENGINEERING & TECHNOLOGY FKTA
Universiti Malaysia Perlis (UniMAP)
FKTA Postgraduate Colloquium 2024
UNIVERSITI MALAYSIA PERLIS

Factors Affecting the Stiffness of Bolted Timber Connections

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KEYWORDS

Stiffness
Bolted connection
Timber
Eurocode 5
Joint

ABSTRACT

Bolted timber connections facilitate load transfer between structural components. This study aims to investigate the factors influencing the stiffness of these connections, which is critical for ensuring safety and performance in timber structures. The stiffness of bolted joints is primarily determined by load-slip behavior, influenced by variables such as bolt diameter, wood density, and joint configuration. A review of the literature highlights the effects of material properties, bolt arrangement, and plate thickness on stiffness. This study concludes that a combination of geometric and material parameters significantly impacts the stiffness and performance of bolted connections.

1. INTRODUCTION

Bolted connections often consist of multiple structural components that are joined together using a certain number of bolts. The structural components usually consist of two or more hardwood members that are interconnected or attached to metal plates. The connections facilitate the transfer of loads between different sections of the structure. When designing a connection to suit the requirements of a real-life situation, several variables come into consider, such as the diameter of the bolt or the number of bolts used. Prior studies have primarily concentrated on investigating the load-carrying capacity of these connections.

The stiffness of a fastener can be determined by calculating the ratio of its lateral load per shear plane to its slip. This relationship allows for calculating the slip under any given load (Porteous & Kermani, 2007). The term "slip modulus" is used in Eurocode 5 (EC5) to describe the stiffness property. The load-slip curves play a crucial role in determining the stiffness of a connection. They provide a description of the amount of displacement that will occur in response to a specific force. The process for acquiring the load-slip curves, along with the highest embedment strength, has been explained in EC5.

2. OBJECTIVE

To investigate the factors that affect the stiffness of bolted timber connections.

3. LITERATURE REVIEW

The performance of a timber structure is often determined by the stiffness and strength of its connections. The joints play a crucial role in a timber structure. Over time, there has been a rise in the variety of joints employed in timber buildings. Multiple types of joints are employed, such as nailed joints, bolted joints, screwed joints, glued joints, glued-in-rod joints, and large-finger joints (Thelandersson & Larsen, 2003).

Several factors influence the stiffness of bolted timber connectors. The load-carrying capacity and initial stiffness are influenced by the bolt diameter, wood thickness, and the distance washer-member-end (Cao et al., 2023; Matsubara et al., 2020). The initial stiffness force has a direct influence on the load factor and the separation load at the interface (Matsubara et al., 2020). The type of wood used impacts the spring constant of the washer embedment, affecting the joint's elastic stiffness (Matsubara & Teranishi, 2022). The rotational stiffness of a structure is influenced by factors such as connection configuration, bolt number, and plate thickness (He et al., 2011).

The stiffness of the members in bolted connections impacts the safety of both static and fatigue loads (Wileman et al., 1991). The failure mechanisms differ based on the direction of the load to the orientation of the grains (Cao et al., 2020). Joint stiffness in timber constructions is determined by the beam's flexural stiffness and the connection's rotational stiffness, which affects the transfer of moments. This was discussed by Leichti et al. in 2000. Comprehending these aspects is essential for accurately predicting load-deformation behaviour and effective connection design in timber engineering (Buchholz & Kuhlmann, 2023).

The wood density has a direct impact on both the embedding strength and the strength of a bolted joint when subjected to a lateral force. The study conducted by Dorn and Borst (2013) found that the load at the proportional limit, stiffness, and maximum load of bolted joints increased with the higher density of the wood

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species. Nevertheless, there are instances where the maximum load of a bolted connection perpendicular to the grain does not show a clear dependence on the wood density (Kawamoto et al., 1993).

4. DISCUSSION

The stiffness of bolted timber connections is influenced by multiple factors, including material properties, geometric parameters, and joint configurations. Wood density plays a critical role, as higher densities generally enhance embedding strength and stiffness, though this relationship may vary with grain orientation and loading direction (Dorn & Borst, 2013; Kawamoto et al., 1993). Geometric factors such as bolt diameter, wood thickness, and washer placement significantly affect initial stiffness and load-carrying capacity, while the connection configuration, including bolt number and plate thickness, impacts rotational stiffness and moment transfer (Cao et al., 2023; He et al., 2011). The load-slip relationship, as described by the slip modulus in Eurocode 5, is crucial for understanding deformation under loads and optimizing connection design. This review highlights the importance of selecting appropriate wood species, bolt dimensions, and connection types to ensure reliable structural performance and improved safety and efficiency in timber engineering.

5. CONCLUSION

This review shows that several factors affect the stiffness of a bolted joint. Various factors, including material properties, bolt diameter, moisture content, wood density, bolt arrangement, bolt number, and plate thickness, influence the stiffness of bolted timber connections.

ACKNOWLEDGEMENT

The authors would like to express their gratitude for the support from the Fundamental Research Grant Scheme (FRGS). Lastly, the author would like to thank his research supervisor, Dr. Nur Liza binti Rahim for her guidance, time, and patience.

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