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Research paper

Effect of bolt configurations on stiffness for steel-wood-steel connection loaded parallel to grain for softwoods in Malaysia

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Abstract: Steel-wood-steel connection is widely seen in many applications, such as timber structures. The stiffness of steel-wood-steel connection loaded parallel to grain for softwoods originated from Malaysia was investigated in this study. Numerical models have been developed in ABAQUS to study the stiffness connection. Softwoods of Damar Minyak and Podo have been selected in this analysis. The comprehensive study focused on the effect of bolt configurations on stiffness. Numerical analysis is carried out and the developed model has been validated with the previous study. Further investigations have been made by using the validated model. From this model, numerical analysis of the stiffness values have been made for various bolt configurations, including bolt diameter, end distance, bolt spacing, number of rows and bolts and edge distance. The result shows that the stiffness of bolted timber connections for softwood depends on the bolt diameter, number of rows and bolts, end distance and edge

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distance. Based on the result, stiffness increased as the diameter of the bolt, end distance, number of rows and bolts and edge distance increased. It is also discovered that the stiffness equation in Eurocode 5 (EC5) is inadequate as the equation only considered parameters which are wood density and bolt diameter. Other connection parameters such as geometry are not considered in the EC5 equation.

Keywords: stiffness, finite element analysis, bolt connection, steel-wood-steel, softwood, Eurocode 5

1. Introduction

The mechanical performances of timber connections are particularly crucial for timber engineers involved in the design of the wood structures. In general, joints are often one of the critical concerns when designing timber structures. The mechanism of the connection must be well understood to design a safe connection and avoid catastrophic failure. In Malaysia, a few types of softwoods have commercial significance in construction, such as Damar Minyak and Podo [1]. According to Malaysian Grading Rules [2], softwood can be referred to as coniferous timbers that lack fibres and vessels. Values of the properties vary for different species of trees, whether it is softwood or hardwood [3]. Properties of wood can be quantifiable, such as density, strength grouping, air-drying rates, shrinkage, durability rating, and kiln-drying schedules. Softwood is collected from gymnosperms and has a lower density than hardwood [4].

Bolted connections, in general, are made of two or more structural components connected with a specified number of bolts. The connectors transfer the loads from one part of the structure to another. In order to design the connection, many variables are involved, for example, the bolt diameter or number of the bolts. The majority of the research in the past has focused on the load carrying capacity of the connections. For example, Johansen (1949) did exceptional research, attempting to establish formulas to calculate the maximum load for one single bolt. His work was based on a double shear connection with different possible failure modes, including bearing failure, splitting failure, net tension failure, shear-out failure and block shear failure [5].

Various studies have been conducted numerically or experimentally to explore the characteristics of bolted timber connections when they are loaded perpendicularly or parallel to grain [6–9], but most of the research did not focus on the displacement-related properties such as stiffness. This information is critical for designers who are interested in designing for high wind loads and earthquakes, where stiffness and ductility, in addition to other serviceability issues, become a major issue. Furthermore, in Eurocode 5 (EC5) [10], it is stated that stiffness for bolt in timber depends on bolt diameter and wood density only. For each dowel with two shear planes, value for K_{ser} (in N/mm) in timber to timber and wood-based panel-to-timber connections for bolts with or without clearance is shown in Eq. (1.1).

$$K_{\text{ser}} = \rho^{1.5} \cdot \frac{d}{23} \tag{1.1}$$

where ρ is wood density and d is the bolt diameter.