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PERFORMANCE OF PULL-OUT GLUED-IN ROD FOR DIFFERENT GRAIN ANGLE DIRECTIONS AND ROD DIAMETERS OF MENGKULANG GLULAM

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ABSTRACT

The most crucial aspects when designing glued-in rod (GiR) connection on glulam timber structure is to ensure the efficiency of detail design parameters consideration. Question arise on whether the GiR is practical enough to be used in structures that may involve the connection at different and incline direction to the grain such as notches, curved and arch beam and others. The effect of load-to-grain direction is considered as one of these parameters. It governs the strength performance of GiR as shear stresses along the jointing part will tend to act differently. Since there has been no research carried out on mengkulang (*Tarrietia javanica*) glulam experimental pull-out strength at different grain directions, this study is important to provide fundamental information of GiR connection practices for glulam structures. Thus, pull-out tests on 150 numbers of GiR with selected rod diameters (12, 16 and 20 mm) for five different angles (0°, 45°, 60°, 75° and 90°) made of Mengkulang glulam were conducted in this study. The adhesive used was epoxy resin, Sikadur-30 and the rod is high strength of mild threaded steel rod. The rod was subjected to constant cross-head displacement of 2mm/min and set up to pull-push loading configuration. The test is carried out until failure in the specimen by using the Universal Testing Machine with load capacity of 1000kN. The result shows that the load-to-grain direction and rod diameter had linear correlation to the strength of pull-out test. The load acting on 0° to the grain direction demonstrated the strongest bond overall with able to cater the highest load and displacement. The load was up to 136.87kN for 0° and the lowest 69.84kN recorded for 90° grain direction, while 45°, 60° and 75° were in between these two angles. The difference between these angles however, did not vary significantly. Sequentially, the highest load was recorded for 20 mm rod diameter and decreased with smaller rod diameter. The shear stress along the timber-adhesive interface was found to be the weakest compared to adhesive-rod interface which showed the failure occurred due to some part of timber along the joint had sheared out together with steel rod when subjected to pull-out test. Timber-Adhesive failure is concluded as dominant mode of failure in this study by 36.11% failed.

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

The full-scale manufacture of glue-laminated timber (Glulam) structures requires efficient connection systems to join the members. Variations are limitless for connection but nowadays, the advances of improved hybrid joints have been well underway. Modern timber engineering requires a good connection system, and this need has spurred recent research on the use of glued-in rod (GiR) in glulam structures. The adaptions of GiR connection systems are usually in timber trusses, frame systems and glulam structures of large scale. This connection system is known for its ability to withstand high loading transition without initial settlement (Tanaka *et al.*, 2012). In addition, according to Harvey and Ansel (2003), the usage of GiR was also to avoid failure such as cracks along the apex zone of the curve beam, at splice and end connections. One of the obstacles that had to be overcome was the fact that there were no establishments of any technical requirements for GiRs and limited studies were done on tropical timber as majority researches only incorporate softwoods. Rajcic & Stepinac (2015) and Zhu (2014) agreed on the truth that when it comes to testing the ability of GiR in timber, only Laminated-Veneer Lumber (LVL) or Glulam made of softwood are used rather than hardwood. According to Yang *et al.*, (2014), over the years, a majority of tests involving GiRs had been carried out with the aim to determine the influences of material and geometrical properties that affect the strength of pull-out test. Despite all those studies, there are limited keen in finding behaviour of GiR in timber element with respect to its grain angle directions. However, latest studies from 2013 to recent years have started to highlight the load-to-grain directions as one of the key problem of design rules. This parameter has gained more intention over these recent years whereas Stepinac *et al.*, (2016), Steiger *et al.*, (2015) and Stepinac *et al.*, (2013) had reserved this parameter when it comes to summarizing of GiR connection. Certainty, the directions of shear stress acts at interface are influenced by the load-to-grain directions as reported by Zhu *et al.*, (2017), Stamatopoulos (2016), Ling *et al.*, (2014) and Za'ba *et al.*, (2012). Shear forces govern along the connection area (in between the layers and adhesive) had induced