PULL-OUT BEHAVIOUR OF ADHESIVES BONDED STRUCTURAL CONNECTOR

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By

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A Project Report Submitted in Partial Fulfillment of the Requirement for the Degree of Bachelor of Wood Science Technology

Faculty of Forestry

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Specially dedicated to my

Parent,

Zakaria Bin Mohd Yunus

&

Norzihan Binti Ismail

Family and friends

ABSTRACT

Connections for timber structures using concealed bonded-in rods offer one possible solution to the development of more efficient joining methods. However the importance of certain basic joint characteristics, and the influence of adhesive type and properties, are not yet fully understood and as such design criteria are lacking. This paper describes a comprehensive experimental and numerical investigation into the fundamental material and joint geometry characteristics of rods bonded in to timber. The adhesive type and performance are both considered, along with test configuration and joint parameters that included rod and timber species. It was found that epoxy adhesives out-performed all other types investigated, and pull-out strengths can be significantly improved through careful selection and optimization of the joint geometry. Balau sample exhibited higher pull-out strength with a means of 10.43 MPa (τta) and 15.65 MPa (τra). This indicates that the shear strength values of the tested specimens were affected by the density of wood species although the results indicate a declining value of average shear strength due to the adhesive type. There is a strong correlation between the density of the wood and mean shear strength. Failure mode in softwood and hardwood is mostly related to the anatomical properties of the wood which influences the wettability of adhesive that has been use.

ABSTRAK

Teknik rod terikat untuk menyambungkan struktur kayu yang tersembunyi menawarkan satu jalan penyelesaian adalah kaedah penyambungan yang lebih cekap. Walau bagaimanapun, kepentingan ciri-ciri bersama asas tertentu, pengaruh seperti jenis dan sifat pelekat, masih belum difahami sepenuhnya dan kriteria reka bentuk sedemikian masih pada jumlah yang kecil. Dengan ini ia memberikan penyiasatan eksperimen yang berangka komprehensif ke dalam bahan asas dan ciri geometri bersama rod yang terikat pada kayu. Jenis ikatan dan prestasi kedua-duanya dipertimbangkan, dengan ujian konfigurasi dan parameter berserta dengan jenis rod dan kayu. Melaui ini didapati bahawa pelekat epoksi dan dikaji ke atas semua jenis dan kekuatan tarik keluar dapat dipertingkatkan dengan ketara melalui pemilihan dan pengoptimalan geometri. Sampel Balau mempamerkan kekuatan Tarik yang tinggi dengan nilai 10.43 MPa (τta) dan 15.65 MPa (τra). Ini menunjukkan bahawa nilai kekuatan spesimen yang diuji telah dipengaruhi oleh ketumpatan spesies kayu walaupun hasilnya menunjukkan penurunan nilai kekuatan purata geseran disebabkan oleh jenis pelekat. Terdapat persamaan yang kuat antara ketumpatan kayu dan kekuatan geseran. Tahap kegagalan dalam kayu lembut dan kayu keras kebanyakannya berkaitan dengan sifat-sifat anatomi kayu yang mempengaruhi kebolehbenturan pelekat yang telah digunakan.

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APPROVAL SHEET

I certify that this research project report entitled **"PULL-OUT BEHAVIOUR OF ADHESIVES BONDED STRUCTURAL CONNECTOR"** by Mohamad Muzammil Bin Zakaria has been examined and approved as a partial fulfilment of the requirement for the degree of Bachelor of Wood Science and Technology in the Faculty of Forestry, university Putra Malaysia.

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CFRP	Carbon fiber-reinforcement plastic
GFRP	Glass fiber reinforcement plastic
PU	Polyurethanes
PRF	Phenol-resorcinol formaldehyde
EPX	Epoxy
RH	Relative humidity
LVL	Laminated veneer lumber

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Structural timber has undergone a technological revival in terms of its application and processing in recent years. This has been largely a result of rising industry costs and ever increasing environmental awareness, encouraging more efficient utilization of home grown timber resources. These have produced efficient structural composite lumber (SCL) materials such as laminated veneer lumber (LVL), laminated strand lumber (LSL) and parallel strand lumber (PSL) other forms of composite timber such as glulam are also experiencing a revived interest (Broughton and Hutchinson, 2001b).

Prefabricated connection systems offer several potential advantages over traditional connection methods, in terms of both the appearance and the strength of the connection. Furthermore, factory-made jointing arrangements of a hidden nature have the potential to give close control over quality of manufacture. It is clear that, as the structural capabilities of modern timber products become more widely realized high-performance connection systems must be available to facilitate the exploitation of these materials.

The use of traditional connections such as bolts and nails in conjunction with steel plates in an exposed fashion can result in very unsightly, bulky and inefficient connections in larger structures. The appearance can destroy the elegance of the chosen structural form. Concealment, on the other hand, not only offers aesthetic benefits, but also brings other advantages, including resistance against environmental degradation and fire. Concealed connection method, also generally provide a wider scope for employment of prefabrication, thus providing the opportunity for closer control over manufacture and resultant quality (Bainbridge and Mettem, 1998).

As identified through a recent review of innovative and improved connection methods, the use of bonded-in rods is an important feature of many of the timber engineering techniques for connections using adhesives (Bainbridge *et al.,* 2002). Adhesive bonding technology has been studied for many years and it has played an essential role in the development and growth of the rehabilitation and repairing techniques of timber structures involving adhesive joints instead of mechanical joints. The widespread use of adhesive bonding can be attributed to its inherent advantages, such as, the fact that an adhesive joint can distribute the applied load over the entire bonded area and with a more uniform distribution of stress, it requires little or no damage to the adherents, adds very little weight to the structure, has a superior fatigue resistance to other joining methods, is suitable for joining dissimilar materials, and can reduce manufacturing costs (Custodio *et al.,* 2009).

Such as specific adhesion practical applications on site generally utilize epoxy, polyurethane adhesives and additionally some polyester products for structural bonding applications on timber. Of these varieties, epoxy adhesives have been used for more than forty years and they are currently still the most widely used choice for bonding structural timber on site. Epoxy types intended to be used for site bonding of timber components implies that in practice they have to be able to cure at moderately low temperatures.

These are required for practical reasons to include good gap-filling shrink resistant properties, excellent tensile/shear strength, high dry and wet strength, and good resistance against moisture and certain chemicals. Another class of adhesive products commonly used for interventions on site is two-component polyurethanes. In contrast, monocomponent polyurethanes, although largely used in manufacturing plants to construct glulam components, are not, in general, preferred for applications on site owing to their tendency to develop gas bubbles within the thick glue line, thus compromising the cohesive strength of the bonded components.

Phenol–resorcinol based (PRF) adhesives were occasionally used to repair timber on site, for instance to bond glued-in rods or to glue side plates for beam reinforcement. Although these applications have not been widely used they are mentioned in order to present a complete picture (Pizzo and Smedley, 2015).

The nature of wood surfaces is difficult to control nearby as opposed to what might be experienced in an assembling plant, specifically where there is successful control of the surfaces to be fortified. Frequently the surfaces are newly machined by sanding or planing in a perfect domain with the right temperature and dampness, which empowers the dampness substance of the wood surfaces to be controlled and encourages a decent holding surface. This is as opposed to the conditions nearby where the majority of the above elements might be variable as well as not effortlessly controllable.

1.2 Problem Statement and Justification

A variety of adhesives have been tested to glue in rods. In early years, traditional wood adhesives based on phenol-resorcinol (PRF) or epoxies (EPX) were used, while later work has included also the use of polyurethanes (PUR). In experiments conducted within a large European research project in the late 1990s, (GIROD), three types of adhesives were used suggested namely, PRF, EPX and PUR.

Characterizing an adhesive only by terms like EPX or PUR is nonsufficient. There are many adhesives available of each type and them ‘‘can show all types of constitutive behavior’’ (Steiger *et. al,* 2007). The pull-out strength of the Glued-in rod is obviously related to the adhesive type, but also to the used wood species, since different adherents may develop different bonding strength with different adhesives.

Generally speaking, and to a varying degree depending on the specific adhesive used, bond strength can be affected by shrinkage during initial hardening, by the adhesive's sensitivity to elevated temperatures, by its limited gap-filling qualities and by the sensitivity to moisture content changes due to changes in local climatic conditions.

These effects have to be taken into account in design. According to MS544 part 5 in timber joint there are no data on glued-in rod connection for Malaysia timber. Because of that, this research has been conduct to study the use of different adhesive in glue-in rod to Malaysia timber at local climatic temperature.

1.3 Objectives

The objective of this research is to investigate the relationship between the adhesive and local climatic conditions toward Malaysia timber. In order to achieve the objective, the following specific objective required to be fulfilled.

1. To determine the shear strength of glued-in rod connection using Malaysian timber.
2. To evaluate the failure modes of bonded-in connections a function of various type of structural adhesives.

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