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THE BEHAVIOUR OF GLULAM BEAM STRENGTHENED USING FIBRE REINFORCED POLYMER

DALILA BINTI KAMARUZAMAN

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil – Structure)

FACULTY OF CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI MALAYSIA

NOVEMBER 2007

I declare that this thesis entitled "*The Behaviour of Glulam Beam Strengthened Using Fibre Reinforced Polymer*' is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dedicated to my beloved family,

Abah, Umi, Abe, Ina, Apih, Kimah, Bibah and Fatin

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ABSTRACT

Fibre Reinforced Polymer (FRP) materials are becoming popular in the Civil Engineering community due to their favourable characteristics such as high strength-to weight ratio, electromagnetic neutrality, and good corrosion resistance. FRP rods and plate are being used as reinforcement of newly-constructed concrete members in aggressive environments or as surface reinforcement for strengthening purposes of existing concrete. However, the use of FRP in timber structure is quite new in Malaysia and this study investigates the possibility of using Glass FRP (GFRP) rods as glued-in reinforcement of glulam beams. This study presents the behaviour of glulam beam reinforced with GFRP rods at different position. Specimens of glulam beam are tested with and without GFRP rods as reinforcement. Flexural behaviour of GFRP reinforced glulam beams are compared with unreinforced glulam beams and solid beams that are used as control specimen. The experimental results shows that by using the GFRP rods as glued-in reinforcement for the glulam beam have some influence in increasing the ultimate capacity and stiffness of the beam, and also shows some decreases in deflection.

ABSTRAK

Polimer bertetulang gentian (FRP) adalah semakin popular penggunaannya dalam bidang Kejuruteraan Awam disebabkan sifatnya yang mempunyai nisbah kekuatan-berat yang tinggi, kestabilan elektromagnet dan ketahanan terhadap kakisan. Rod FRP dan plat biasa digunakan sebagai tetulang di dalam pembinaan bangunan konkrit baru yang terdedah kepada persekitaran yang agresif atau sebagai pengukuh pada permukaan konkrit bagi bangunan yang sedia ada. Walau bagaimanapun, penggunaan FRP dalam struktur kayu masih lagi baru di Malaysia dan kajian ini dijalankan untuk melihat kebolehgunaan polimer bertetulang gentian kaca (GFRP) sebagai tetulang di dalam rasuk kayu berperekat. Kajian ini mengemukakan kelakuan rasuk kayu berperekat yang menggunakan rod GFRP sebagai tetulang dan di letakkan pada kedudukan yang berbeza. Spesimen rasuk kayu berperekat diuji dengan kehadiran dan tanpa kehadiran GFRP sebagai tetulang. Kelakunan lenturan rasuk kayu berperekat bertetulang dibandingkan dengan rasuk kayu berperekat tanpa tetulang dan rasuk kayu padu sebagai spesimen kawalan. Keputusan ujikaji menunjukkan bahawa penggunaan GFRP sebagai tetulang telah memberikan kesan dalam meningkatkan keupayaan beban muktamad dan kekakuan rasuk, dan juga menunjukkan pengurangan dalam pesongan rasuk.

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A	= cross-sectional area.
ASTM	= American Standard for Testing of Material.
a	= length from support to point load.
BMD	= bending moment diagram.
BS	= British Standard.
b	= width.
E	= modulus of elasticity.
h	= height of sample.
I	= Second moment of inertia.
L	= length of span.
M	= moment.
m.c.	= moisture content.
MOE	= modulus of elasticity.
MOR	= modulus of rupture.
MS	= Malaysia Standard.
P	= maximum load.
P_L	= proportional load limit.
PRF	= Phenol Resorcinol Formaldehyde.

SFD = shear force diagram.

SG = strength group.

WBF = weather and boil proof.

Δ = deflection.

s = modulus of rupture.

s_c = compressive strength.

s_t = tensile strength.

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CHAPTER I

INTRODUCTION

1.1 Foreword

Timber is one of the oldest building materials ever used by mankind. Timber is a discontinuous, heterogeneous, orthotropic, inelastic, and hygroscopic material [1]. From earliest recorded times timber has been a ubiquitous material that had been used by ancient Egyptian as early as 2500 BC. History shows that the unique characteristics and the proportionally large quantity of wood have made it a natural material for houses, bridges, vehicles, furniture, tools and decorative objects. It has been used for its cheap price, high strength to weight ratio, decoration and availability.

Wood technology in foreign countries such as western country and Japan are more advanced. They utilize wood not only for structural material, but also as an aesthetical material. The most utilize structural technology for wood is glued-laminated structural member or known as “glulam” [2].

Glulam, are a highly engineered wood product. Essentially, they are made up of material glued together from smaller pieces of wood, either straight or curved form, with the grain of all laminations parallel to the length of the member. Glulam members are different from plywood in which the grain direction of adjacent plies of veneer is at right angles to each other. In Malaysia, glulam has been identified as one of the potential means to promote structural timber construction in the country. Among the advantages of glulam are its efficiency and effectiveness in material utilization, excellent fire performance, aesthetic appeal and versatility [3]. This study will focus on the behaviour of glulam beam strengthened using fibre reinforced polymer (FRP).

1.2 Problem Statement

A glulam structural member is made with layer of smaller piece of wood with the use of strong adhesive for lamination [2]. Lamination of glulam structural member may be of any thickness or length made up of different types of wood or formed curved or camber. Glulam is different from plywood as the grain of all lamination is essentially parallel to the length of glulam member.

When deciding to use a structural glulam member such as a glulam beam, designers will design the glulam using the data of prefabricated glulam beam from the manufacturers or standards code of practice available such as BS5268 or MS544. When designing using data of prefabricated glulam beam, designers will be confined to designing the glulam timber beam using specification and calculation provided by the manufacturer. Wood species that used for the glulam are totally dependent by the manufacture.

Using standard code of practice, the determination of the number of wood species used is one grade species for the whole section; therefore it does not consider a glulam beam made up of different wood species. When using a standard code of practice such as BS5268, designers is required to determine permissible bending stress, bearing stress, deflection and shear stress. All calculation is based on the stress grade of the one wood species that is used. However, not all laminations of a stress grade wood have the same modulus of elasticity and it was a difficult to predict the effect.

The problem here is that it is hard to find a solid timber which is bigger than the one that available in commercial sizes. In order to get the desired size, it has to be specially ordered from the manufacturer and this can increase the cost. In order to deal with the problem, glulam had been introduced as solution to the problem. Other problem that needs to be considered is the strength of the glulam beam laminated with hardwood at the outer layer and softwood at inner layer.

Glulam beams loaded by bending moments fail at the tension side at the position of knots or finger joints. Due to this failure mode glulam beams are mainly reinforced at the tension side to strengthen the weak cross-sections. The reinforcement for glulam beams should have a high modulus of elasticity (MOE) and a large tensile strain at failure. Materials considered in the past were steel, glass fibre reinforced polymer (GFRP) and since a few years carbon fibre reinforced polymer (CFRP) and aramid fibre reinforced polymer (AFRP). Fibre reinforced polymer (FRP) has the advantage of a high MOE and a high tensile strength although it is generally lower than steel. The disadvantage of steel is the low yield strength leading to plastic deformations before the timber fails. FRP reinforcements do not show this behaviour. An effective reinforcement leads to a plastic behaviour on the timber compression side. In unreinforced glulam beams this effect hardly occurs and design models therefore do not take into account this effect. Therefore, for FRP reinforced beams different design models are necessary.

When considering all the factors above, the study is conducted to determine the behaviour of glulam beam strengthened using fibre reinforced polymer. The study will also determine the permissible stress and strain of glulam beam and the flexural strength of the glulam beam.

1.3 Aim and Objectives

The aim of this study is to determine the behaviour of the glulam beam strengthened using Fibre Reinforced Polymer (FRP).

The objective of the study is as follow:

(i) Determine the capacity of loading for glulam strengthened using fibre reinforced polymer
(ii) Determine the position of reinforcement that will give the highest strength
(iii) To compare the bending strength of solid timber, unreinforced glulam and reinforced glulam beam.

1.4 Scope of Study

The scope of study will implement the following confinement and specification:

(i) Study of the structural glulam is confined to straight beam only
(ii) Using tropical Malaysian wood species of Kekatong for analysis
(iii) Using glulam laminated with hardwood and glulam laminated with different species of tropical wood
(iv) FRP rod will be used as reinforcement

1.5 Significant of Study

Using different wood species that is from different strength group of timber to make a glulam will give a significant economic value where some cost can be saved. When it is hard to obtain large solid timber in the market, the use of smaller sections or portions of different wood to form a glulam is an option that can be considered. The depletion of natural wood sources can be cut down if designer can make use of every wood resource. With this way, utilizing every inch of wood resources is necessary in order to reduce wastage. This study is to expose local hardwood and glulam technology to local wood user as a valid and renewable structural material for construction. This study is also to explore any other material that can be used as reinforcement for timber structural member.