UNIVERSITI PUTRA MALAYSIA

TENSILE STRENGTH AND FAILURE CHARACTERISTICS OF COMMON ROOF TRUSS JOINTS

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Chairman : Mohd Ariff Jamaludin, Ph.D.

Faculty : Forestry

Timber joints have always been the weak link in timber construction. Although the load carrying capacity of the timber structure is greater than the applied load, the structural system can fail if the joints are weak. Finger jointing of short off-cut timbers for structural purposes like lightweight roof trusses is an economical method to minimise wastage and to increase recovery rate. The objective of this research was to evaluate the strength and failure characteristics of truss joints made from solid and finger jointed kempas (*Koompassia malaccensis*) with metal plate connectors.

This research assessed the strength properties of truss joints comprising solid and finger-jointed kempas which were jointed with nail plate connectors. The influence of the location of finger joints in the joint system on both the strength and failure characteristics were also studied. Eight joint types, each

having ten replications were tested for joint strengths and failure modes. The type of joint were solid butt-joint (SB), solid T-joint (ST), finger jointed butt-joint type 1 (FB1), finger jointed butt-joint type 2 (FB2) and finger jointed butt-joint type 3 (FB3), finger jointed T-joint type 1 (FT1), finger jointed T-joint type 2 (FT2) and finger jointed T-joint type 3 (FT3).

From this study, specific gravity and moisture content of the samples were not significantly different with each other suggesting that both properties did not significantly influenced the strength and mode of failure of the joints. As such, the differences on their effect on the strength of the joint design was assumed to be minimal.

Types of joint had significantly influence over the maximum strength of the joint system used in the study. Joint made up of solid kempas with butt joint was significantly stronger than that of T-joint. Overlapping the finger joints with nail plate connectors had markly increased the strength of the butt joint.

T-joint using solid kempas (without finger jointing) was significantly stronger than T-joints having finger jointed members (FT1, FT2 and FT3). The maximum load of these joints were reduced to nearly 50% of the solid timber T-joint. Generally, the wood surface failed at the middle member between the T-joint member and the nail plate connector where some parts of the fibrous material were ripped off from the horizontal member.

There were three types of failure modes associated with joint systems used in this study: tooth withdrawal, nail plate failure and wood failure. Fifty percent of the failure was categorised as tooth withdrawal, whilst both 25% were of types nail plate failure and wood failure respectively.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KEKUATAN REGANGAN DAN CIRI KEGAGALAN SAMBUNGAN LAZIM KEKUDA BUMBUNG

Oleh

MAHADZIR ABDUL RAHMAN

Februari 2002

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Sambungan kayu kerap merupakan kelemahan dalam rangkaian binaan kayu. Walaupun keupayaan memikul beban struktur kayu melebihi beban yang dikenakan, sistem binaan boleh mengalami kegagalan jika sambungannya lemah. Penyambungan jejari lebihan kayu yang pendek untuk struktur seperti kekuda bumbung ringan adalah satu kaedah yang ekonomi untuk mengurangkan pembaziran dan meningkatkan kadar pulangan. Objektif kajian ini adalah untuk mempelajari sifat kekuatan dan ciri kegagalan pada kayu padat dan kayu sambungan jejari spesies kempas (*Koompassia malaccensis*) pada sistem sambungan kekuda menggunakan plat paku.

Penyelidikan ini menilai sifat kekuatan sambungan kekuda pada kayu padat dan kayu sambungan jejari kempas yang disambung menggunakan plat paku. Pengaruh posisi sambungan jejari terhadap sifat kekuatan dan ciri

kegagalan pada sistem sambungan juga dikaji. Lapan jenis sambungan dengan sepuluh replikasi setiap satunya telah diuji untuk mengetahui kekuatan dan mod kegagalannya. Sampel-sampel berkenaan adalah kayu padat sambungan hujung bertemu hujung (SB), kayu padat sambungan-T (ST), kayu yang disambung jejari sambungan hujung bertemu hujung jenis 1 (FB1), kayu yang disambung jejari sambungan hujung bertemu hujung jenis 2 (FB2), kayu yang disambung jejari sambungan hujung bertemu hujung jenis 3 (FB3), kayu yang disambung jejari sambungan-T jenis 1 (FT1), kayu yang disambung jejari sambungan-T jenis 2 (FT2) dan kayu yang disambung jejari sambungan-T jenis 3 (FT3).

Hasil daripada kajian menunjukkan perbezaan ketumpatan tentu dan kandungan lembapan untuk semua sampel adalah tidak ketara antara satu sama lain dan boleh dikatakan bahawa kedua-dua sifat ini tidak ketara mempengaruhi sifat kekuatan dan ciri kegagalan semua sambungan. Oleh itu, kesan mereka keatas kekuatan sambungan diandaikan adalah minima.

Jenis-jenis sambungan mempunyai pengaruh yang ketara terhadap kekuatan maksimum sistem penyambungan dalam kajian ini. Penyambungan dari kayu kempas padat dengan sambungan hujung bertemu hujung adalah ketara lebih kuat berbanding sambungan-T. Penindihan sambungan jejari dengan plat paku telah menunjukkan peningkatan kekuatan sambungan hujung bertemu hujung.

Sambungan-T yang menggunakan kayu kempas padat (tanpa sambungan jejari) adalah ketara lebih kuat jika dibandingkan dengan sambungan-T yang mempunyai anggota sambungan jejari (FT1, FT2 dan FT3). Beban maksimum untuk semua anggota yang disambung jejari kebanyakannya berkurangan hampir 50% jika dibandingkan dengan kayu padat sambungan-T. Pada amnya, kegagalan permukaan kayu berlaku pada bahagian tengah antara komponen-T dengan plat paku di mana sebahagian gentian kayu dari komponen melintang terkoyak keluar.

Tiga jenis mod kegagalan dalam sistem sambungan di dapati daripada kajian ini: gigi plat paku tercabut daripada kayu, kegagalan kayu dan kegagalan plat paku. Lima puluh peratus daripada kegagalan dikategorikan sebagai kegagalan yang di sebabkan oleh gigi plat tercabut daripada kayu, sementara masing-masing 25% lagi adalah di sebabkan oleh kegagalan plat paku dan kagagalan kayu.

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I certify that an Examination Committee met on 7th February 2002 to conduct the final examination of Mahadzir Abdul Rahman on his Master of Science thesis entitled "Tensile Strength and Failure Characteristics of Common Roof Truss Joints" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other Institutions.

Mahadzir Abdul Rahman

Date: 26 APR 2002

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LIST OF ABRERIATION

Symbols

AS	- Australian Standard
ANSI	- American National Standards Institute
ASTM	- American Society for Testing and Materials
BS	- British Standard
kN	- Kilo Newton
MS	- Malaysian Standard
PRF	- Phenol Resorcinol Formaldehyde
SIRIM	- Standards and Industrial Research Institute of Malaysia
USDA	- United States Department of Agriculture
SB	- Solid timber butt-joint
FB1	- Butt-joint design type 1 with finger jointed timber members
FB2	- Butt-joint design type 2 with finger jointed timber members
FB3	- Butt-joint design type 3 with finger jointed timber members
SB	- Solid Timber T-joint
FT1	- T-joint design type 1 with finger jointed timber members
FT2	- T-joint design type 2 with finger jointed timber members
FT3	- T-joint design type 3 with finger jointed timber members

CHAPTER I

INTRODUCTION

1.1 General

Timber jointing is the process of fastening together two or more pieces of timber using either mechanical fasteners such as nails, bolts, truss plate connectors or glue and many others. The former is generally known as mechanical joints and the latter as glued joints. Jointing plays a very important role in the construction of a timber structure which may be either a building, a tower or a bridge.

Timber joints have always been the weak link in timber construction and in the design of large timber structures, the joint being heavily stressed when loaded, are often the critical points. This is because all timber structures are made of elements that must be connected together for the transfer of loads between them. The designer must not only know the strength of the wood members of the joint but also the strength of the wide variety of connectors when acting along, across, or at an angle to the grain.

Normally, when design of a joint in a structural assembly begins, the designer first thinks about how much load that a joint can carry or transfer. Then, the designer considers the stress, or the load per unit cross-sectional area of the joint members. The designer must also consider the stress in the joint, load carrying capacity and resultant stresses.

Although the load-carrying capacity of any timber structure is governed by the strength of the timber members, and the strength of the fastener or combination of both, timber joints have very often been the weak link in timber construction (Chu, 1987). In the design of large timber structures, careful considerations should be given to the design of joints as the strength and stability or rigidity of any structure depends heavily on the fastenings that hold its parts together.

In designing wood structures an engineer is responsible not only for the design of the various members but also for the connections. On a typical structural project it is not surprising to find that the design of the connections may comprise half of the work. Furthermore, it is estimated that as much as 90% (Halperin and Bible, 1994) of the structural failures experienced in wood frame buildings originated at the connections.

1.2 Justification

Wood jointing plays an important role in timber structure. Strength of the timber structure mostly depends on the wood joints other than the strength of the timber itself. Metal plate connectors are the most popular fasteners for roof truss joints today. However, only limited studies on the jointing of tropical hardwood using metal plate connectors are published (Mohd Shukari, et.al. 1997,a, b). Much more researches of timber joints especially in tropical timber would be needed to fill in the gaps identified in the previous research.

Roof trusses are constructed to be used for long terms, almost all local fabricators give warranty for ten years. So it must be able to withstand degradation for that period. When the designers and users of wood joint structural members consider their confidence in the load-carrying performance of the product in service, the adequacy of the End-joints and T-joints are usually their number one concern (Prins, 1982). This is because all the timber structures are made of elements that must be connected together for the transfer of loads between them.

In roof truss manufacturing, joints are the most important elements. The strength of joints represent the quality of roof truss. If the joint fails, the roof trusses fail too. It will give more implication to the building structures because the building may collapse.

Usage of timbers beside steels in Malaysia are increasing due to expansion in construction industry mainly for housing, shop house, factory and infrastructure like hospital, school and government office. With the anticipated rise in demand for structural timber by the construction industry today, there is a need for data on working stress and strength properties of joints for efficient use in structural design. Therefore, this study was carried out to determine the strength and examine failure characteristics of tropical timber joints using nail plates in roof truss system.

1.3 Objectives

The objective of this research was to study the strength and failure characteristics of nail plated roof truss joints of different designs. The specific objectives of this study are stated below:

i) To determine the strength and examine the failure characteristics of different solid kempas (*Koompassia malaccensis*) truss joint system using metal plate connectors.

ii) To study the strength and failure characteristics of different finger jointed kempas truss joint system with nail plate connectors.

iii) To compare the strength and failure characteristics of solid kempas and different types of finger jointed kempas truss joints.

CHAPTER II

LITERATURE REVIEW

2.1 Timber Trusses

The earliest remaining visual record of a timber truss is a carving in Trojan's column, in Rome (built AD 104), of a bridge over the Danube River. Supposedly, this bridge was constructed of about 20 trussed timber arches spanning 30 to 40 meter each. The timber trusses of the nineteenth century used iron bolts and rods for fasteners, although they were dependent primarily on skillful carpentry to obtain the well-fitted joints necessary for the transference of both compression and tension stresses. Modern timber connectors have eliminated the need for the skilled artisans of that period.

Apart from the solid floor joist, light timber trusses are the most widely used timber structural component. There are different types available for commercial and particularly for domestic use and modern manufacturing techniques utilising patented connector plates enable the truss to be produced in large quantities with subsequent economic benefits.

Timber trusses represent another common type of fabricated wood component. Heavy wood trusses have a long history of performance, but light timber trusses are more popular today. The majority of residential timber structures and many commercial and industrial buildings use some form of closely spaced light timber trusses in roof floor systems. Common spans for this trusses range up to 25 m, but larger spans are possible.

2.2 Truss Rafters

The definition of trussed rafters is given in BS 5268: Part 3: 1985 which is the code of practice for trussed rafter roofs; as "light-weight triangulated frameworks spaced at intervals generally not exceeding 600 mm and made from timber members fastened together in one plane". Pre-fabricated trusses have revolutionised residential roof framing over the last four decades. Today, 75 to 80 percent of all new homes are constructed with metal plate connected wood truss (Smulski 1996, Hoover 2000).

Trussed rafters are engineered components fabricated using strength-graded timber fixed with truss plate connectors. Individual truss designs are prepared by the trussed rafter manufacturer using sophisticated computer programs developed by "System Owners" who also supply the fasteners.