STRENGTH OF STRUCTURAL TIMBER MEMBERS WITH FINGER-JOINTS AND METAL PLATE CONNECTORS

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For the glory of Jesus Christ, the Architect and Builder,
to my loved ones, and for the advancement of timber engineering.

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ABSTRACT

Finger jointing of short off-cuts for structural purposes particularly for lightweight roof truss and prefabricated timber house is likely an economical method of minimizing waste and generating benefits. The primary goal of this research is on the possibility of using finger-jointed timber with metal plate connectors for structural purposes, i.e. in trusses: internal members, top and bottom chord. This research assessed the strength properties of finger-jointed strength group B timber and the influence of number of joints and its positioning on strength. The glue applied for finger jointing is polymer isocyanate adhesive or commercially known as Koyo glue. Bending, compression and tension tests were carried out and the results show that the efficiency of the joints in relation to the strength of the unjointed specimens were greatly influenced by the positioning and number of joints. The results obtained from tests indicated that modulus of rupture decreases with the presence of finger joint while modulus of elasticity is not affected. Tests on the performance of connection with metal plate using finger-jointed timber showed small difference in the basic working load as compared to the unjointed specimens. The study suggests that the combination use of finger-jointed timber with metal plate connector for structural purposes is acceptable depending on the joint efficiency, the position and number of the finger joint in the member, and the type of stresses (i.e. compression, tension or bending) in the member.

ABSTRAK

Sambungan jejari kayu-kayu pendek untuk pembinaan struktur terutamanya kekuda bumbung ringan dan rumah kayu pasang-siap adalah kaedah ekonomikal yang boleh meminimumkan pembaziran dan mendatangkan keuntungan. Matlamat utama penyelidikan ini adalah untuk mengkaji samada kayu sambungan jejari boleh digunakan bersama dengan penyambung plat keluli untuk kegunaan struktur, contohnya sebagai komponen struktur dalam kekuda bumbung seperti anggota dalaman, perentas atas dan bawah. Penyelidikan ini menguji kekuatan sambungan jejari kayu kumpulan kekuatan B dan pengaruh bilangan sambungan serta posisinya ke atas kekuatan. Glu yang digunakan bagi sambungan jejari kayu adalah glu polimer isosinat atau nama komersilnya glu Koyo. Ujian-ujian lenturan, mampatan dan tegangan menunjukkan bahawa effisiensi sambungan jejari berbanding dengan kekuatan kayu tanpa sambungan sangat dipengaruhi oleh bilangan sambungan dan posisinya. Keputusan ujian juga mendapati bahawa modulus kepecahan menyusut dengan adanya sambungan jejari sementara modulus keanjalan tidak dipengaruhi. Ujian prestasi penyambung plat keluli menggunakan kayu sambungan jejari menunjukkan bahawa hanya terdapat sedikit perbezaan dalam beban kerja asas berbanding dengan kayu tanpa sambungan jejari. Oleh itu, penyelidikan ini mencadangkan bahawa kombinasi penggunaan kayu sambungan jejari dengan penyambung plat keluli untuk kegunaan struktur boleh diterima berpandukan kepada effisiensi sambungan, posisi dan bilangan sambungan jejari dalam satu anggota serta jenis-jenis tegasan (contohnya mampatan, tegangan atau lenturan) dalam anggota.

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LIST OF NOTATIONS

SYMBOLS

A	-	area
A-A	-	cross section
b	-	width of specimen
CV	-	coefficient of variation
d	-	depth of specimen
e	-	eccentricity
E	-	modulus of elasticity
f	-	load factor
F	-	force
F_{max}	-	maximum load at failure
FS	-	factor of safety
$F_{//}$	-	load parallel to grain
$F_{\perp}$	-	load perpendicular to grain
F_{θ}	-	load at an angle to grain
F/Δ	-	slope at proportional limit of stress strain curve
k	-	initial stiffness
l	-	length
L	-	clear span of beam
L_o	-	distance between loading head
m_1	-	stiffness at large slip
m_0	-	intercept of the asymptote with slope m_1

MC	-	moisture content
n	-	number of finger joints
n	-	number of specimens
N	-	total number of single shear units (teeth) acting in one member of the joint
p	-	pitch
P	-	load
P	-	point coincide with tooth belonging to plate
P'	-	point coincide with tooth belonging to member
r_i	-	distance between point i and P(P')
r_j	-	distance between point j and P(P')
R	-	reaction
SD	-	standard deviation
t	-	tip width
u	-	displacement under a correspondent force
u_i	-	displacements of point i in the x-direction
u_j	-	displacements of point j in the x-direction
v_i	-	displacements of point i in the y-direction
v_j	-	displacements of point j in the y-direction
$\overline{X}$	-	mean value
X_{max}	-	maximum average load
%	-	percentage
//	-	parallel to grain
$\perp$	-	perpendicular to grain
$\lvert\Delta\rvert$	-	absolute displacement or slip
Δ_x	-	relative displacement in the x-direction
Δ_y	-	relative displacement in the y-direction
θ	-	angle between plate major axis and x-axis

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CHAPTER I

INTRODUCTION

1.1 General

The use of wood for structural purposes has been challenged significantly since the last few decades due to the fast development of new building materials such as steel, concrete and composite materials. With the environmental awakening of many people in this millennium end, the harvesting of timber has aroused tremendous disputes due to a number of irresponsible loggers who logs for their own gain without replanting the trees (Anon., 1990a) thus reducing the availability of timber and increasing its cost. On the other hand, timber construction industry in particularly the manufacture of lightweight trusses using metal plate connectors is generating a substantial amount of wastage in their off-cuts. This calls for new development in timber engineering by finger-jointing these off-cuts to be used as structural components, i.e. internal members, bottom chord and top chord of a metal plate connected wood truss.

In order to produce long lengths of structural timber from commercially available stock lengths it is necessary to end joint the pieces with a joint possessing known structural characteristics. There is at present, an increasing demand for methods of end-jointing sawn timber for structural purposes. This

will enable any length of either solid or laminated timber to be obtained and which can also be used to join off-cuts of timber, which would otherwise be wasted.

1.2 Background

The application of metal plate connectors widely for truss construction, or commonly known as truss plate connectors has become the most efficient and cost effective method of connecting lightweight timber trusses. Metal plate connectors have been widely used in Malaysia by timber industry especially for the manufacture of prefabricated truss.

Metal plate connected wood truss is an engineering designed wood structure which requires right choice of timber species, correct fabrication, proper handling and careful erection. The problems of connections have always been dominant and in the structural aspect, connection is considered the most critical part. Through the years numerous researches and development have been done resulting in inventions of new mechanical jointing products, such as the metal plate connector (Meeks, 1979).

The metal plate connected wood truss fabrication industry has been in existence for about forty years and has struggled through many severe problems. The second greatest problem that exists in the metal plate connected wood truss fabricator is timber. According to Atwell (1979), there is a 6% wastage of the total timber used. For instance, if the wood truss industry uses 5 billion board meter of timber per year and the average cost is US$300.00 per thousand board meter, there is US$1.5 billion worth of timber being consumed. A 6% scrap factor represents US$90 million worth of timber that the fabricator has to pay someone to haul away. With today's technological

and engineering advancement, surely there must be a solution in recycling that 6% scrap which could perhaps give a better pay off. Finger-jointing this "6% scrap" to make components of a metal plate connected wood truss could be the solution. However, to date, very little research on metal plate connectors and finger joint relating to Malaysian timber has been done.

1.3 Problem Statement

Metal plate connectors are proprietary in their nature and therefore each plate has its own design values given by its manufacturer. These design values namely the shear transfer value (tooth-pick up), basic working load and plate strength are developed by the plate's manufacturer based on the plate's properties and their local timber joint group. Metal plate connectors that are being used in the Malaysian truss industry are mainly imported from Australia and United States of America. Though there has been countless studies made in this field abroad, there are very limited studies in the case of tropical woods in Malaysia. With the lack of research in metal plate connection for tropical timber, the above mentioned design parameters are left unverified. On the other hand, inadequate supply of timber today has forced fabricators to look into the possibility of finger jointing off-cuts to obtain long length timber for structural purposes in particularly for the truss industry. What are the factors affecting the tensile strength in a metal plate connected joint? What is the strength properties of a finger-jointed timber and is there any strength reduction when the position of the finger joint varies with the load placement? Is the use of finger jointed timber with metal plate connectors possible? What is the behaviour and performance of a connection with metal plate if finger-jointed timber is used? What happens if the position of the finger joint coincides with the plate area or outside the area of the plate? This research attempts to answer these questions.

1.4 Research Objectives

The objectives of the research are categorised into four main components as follows:

i.) To investigate the suitability of using finger jointed timber with metal plate connectors for structural purposes in particularly for trusses and prefabricated timber houses by assessing the strength properties as in bending, compression and tension of finger jointed members compared to unjointed members.

ii.) To investigate the strength differences that may occur when the position of the finger joints changes.

iii.) To investigate the performance of finger jointed timber with metal plate connectors.

iv.) To determine the basic working load per tooth for a particular metal plate type in a strength group timber by means of tensile loading parallel and perpendicular to the grain for both unjointed and finger jointed members and to investigate the variation.

1.5 Research Scope

This is an experimental base research. It assesses the strength performance of finger jointed strength group B timber in relation to their suitability for use with metal plate connectors. Experiments carried out are divided into two categories. The first category involved strength properties tests such as bending, tensile and compression for both unjointed and finger jointed specimens in order to evaluate their strength variation. The second category are on the performance of connection with metal plate tests involving tensile loading parallel and perpendicular to the grain for unjointed and finger jointed strength group B timber members.

1.6 Significance of Study

There is currently a shortage of timber supply especially large logs that can produce long lengths of timber. In almost all sawmills and truss fabrication factories there are extensive loss of off-cuts that are deliberately thrown into the boiler resulting in wastage. This research seeks to resolve this problem by developing strength properties of finger jointed strength group B timber and studying the possibility of this material to be used for structural purposes especially for constructing lightweight trusses and prefabricated timber houses. This research can be considered as the first step to the solution of off-cuts wastage in the timber construction industry. Furthermore it is a preliminary work on metal plate connection and finger joint that could lead to the enhancement of the Malaysian Standard for Structural Use of Timber, MS544:1999 (Draft).

CHAPTER II

MECHANICAL PROPERTIES OF TIMBER

2.1 General

This chapter explains the mechanical properties of wood which is the main material used in the study. Hence, mode of failures and factors that affect the strength of timber joint are discussed to give better perception and verification to the results and findings of this research.

2.2 Mechanical Properties

Qualities of a material that are significant in the application of strength of materials and how a material responds to load and deformation are termed as the mechanical properties of material. Some of these properties are the yield stress, ultimate stress, modulus of elasticity and rigidity, stiffness, toughness, strength and etc. The subject of mechanical properties of a material ultimately zooms down to the strength of the material which focused on the material's resistance to externally applied forces.

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