JAMES COOK UNIVERSITY

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Civil Engineering

STRENGTHENING OF CIRCULAR SECTION TIMBER GIRDERS USING FIBRE REINFORCED POLYMERS

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1 Introduction

Talk about timber being a huge part of structures up until the introduction of concrete.

Timber has been a dominant material in engineering and construction for many centuries, and continues to be a major material used in housing, floors and furniture.

However, the use of timber in structures has decreased majorly over the past century due to the introduction of materials such as concrete. This is predominately due to the environmental disadvantages of timber; very combustible, susceptible to severe weathering, maximum life span of 50years, strength limitations; size limitations and insect infestation.

1.1 Objectives

The aim of this research is to determine the structural behaviour of circular section timber girders with different notched angles. Using these results, methods of strengthening the notched girders using FRP can be tested.

The overall scope of this experiment is to determine the effectiveness of strengthening timber girders on current bridge structures, using FRP.

2 Literature Review

2.1 Timber Bridges

Timber has been a dominant material in construction since prehistoric times, and was most likely the first material used to construct a bridge [3]. The use of wood as a structural material was prominent throughout the middle ages to the 20th century, where the use for timber in structures declined in the 1960's due to the introduction of steel and concrete [3, 1].

Timber as a dominant material in structures spanned centuries due to its strength, light-weight, and energy-absorbing properties, which are particularly desirable for bridge construction. Wood has the capability of supporting short-term overloads without any harmful effects to the material. In severe fire exposure, large timber members have fire resistance qualities are equivalent or higher compared to most other materials. Timber is a economically competitive with most other materials as it is naturally grown and lower in cost than materials such as steel and concrete. A major advantage for constructing bridges using timber is its durability in most weather conditions, as long as it is protected from moisture. There is no effect or damage caused to Wood by continuous freezing and thawing, and obtains the ability to resists harmful effects of de-icing agents. This is a huge advantage for the use of timber in bridges as such weather conditions commonly cause deterioration in other bridge materials. The construction of timber bridges is fairly simple and cost effective, as no special equipment is required for installation and can usually be constructed little labour [3].

There have been many bridges built during the 19th century that have lasted over 100 years when they were protected from direct exposure to the elements. Covering wood has become a common practice as it increases the lifespan tremendously, however the use of chemicals to preservative wood has come to light and has been more widely used. By using modern application techniques, chemicals can preserve timber bridges and severely reduce deterioration for over 50 years. This is a major benefit as there is little to no maintenance or painting required for wood treated with preservatives [3].

Overall, timber's short term properties and lifespan are desirable for bridge construction. However, in the long-term the life-span of a timber bridge is severely shortened due to its susceptibility to extreme deterioration caused by rotting, weathering and insect attack [1, 3]. Due to these long-term effects, timber bridges require substantial maintenance throughout their structural life [1]. Another major issue faced today is that, there is an increasing difficulty in obtaining large sections of wood and sawn timber as tree plantations reduce and the drive for forest preservation increases [1, 3].

Nowadays, the short life-span, high maintenance requirements and limited supply of timber have ultimately caused the preferred material for bridge construction to veer towards combination of steel and pre-stressed concrete.

2.1.1 Common Defects and Failures

2.2 Timber Properties

2.2.1 Flexural

2.2.2 Shear

2.2.3 Rectangular Section Member Design

2.2.4 Circular Section Members

A typical bending capacity formula for a round girder is as follows.

$\phi M = \phi k_1 k_4 k_6 k_9 k_{12} k_{20} k_{21} k_{22} f_b' Z$

Where k1, k4, k6, k12 are as for working stress design and

k9 = Strength Sharing Factor

k20 = Immaturity Factor

k21 = Shaving Factor

k22 = Processing Factor = 1

2.2.5 Octagonal Section Members

$\phi M = \phi k_1 k_4 k_6 k_9 k_{12} f_b' Z$

2.3 Notching

Notching or sniping is when the lower corners of a member are cut to make insertion easier, as well as to increase the stability of the member when sitting on a pier. Figure X below shows an example of a notched member over a pier.

One of the major issues faced with notches are they significantly reduce the load-carrying and shear capacities of timber beams [2].

2.3.1 Notch Types

There are four main types of notching, rectangular end notch, tapered end notch, rounded end notch and notch in span.

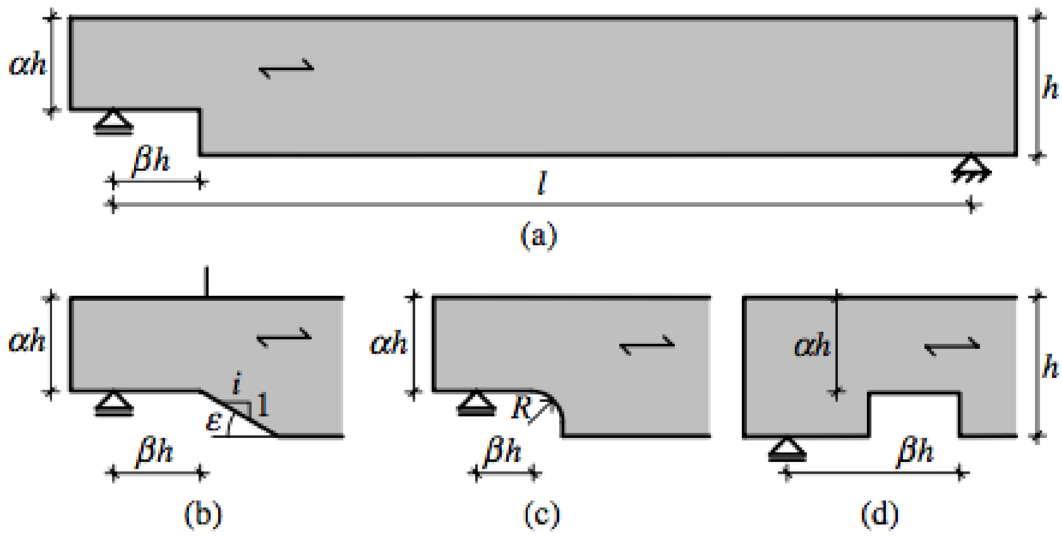

Figure 1: Notching Types; (a) rectangular end notch; (b) tapered end notch; (c) rounded end notch; (d) notch in span

Australian Standard AS1720.1 recommends the use of a flat 1:4 gradient slope and the end of the notch, which theoretically increases the shear capacity of the member by 3 times when compares to a ”square” notch. However, all references are based on rectangular sections, and do not cover round or octagonal members as are prominent in most rail and road bridges [1].

2.3.2 Notch Design

$\frac{6M^*}{bd_n^2} + \frac{6V^*}{bd_n} \leq \phi g_{40} k_1 k_4 k_6 k_{12} f'_{sj}$

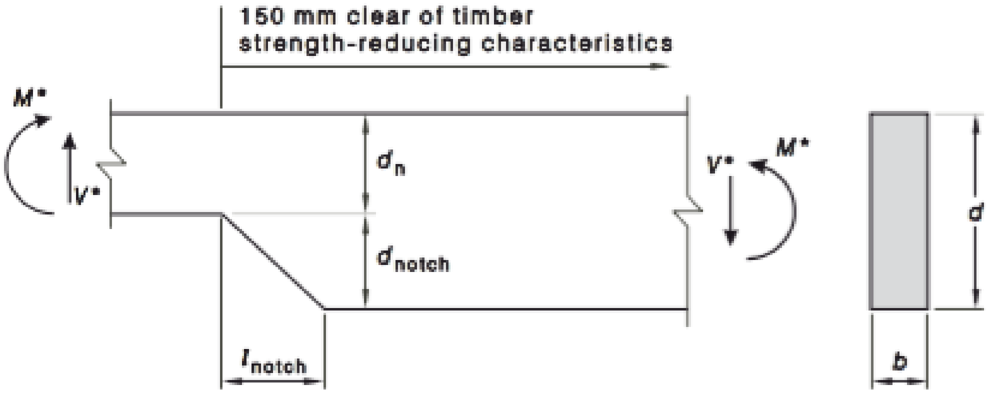

Figure 2: Notation for Notch

Notch Angle Slope	g_{40}	
	$d_{notch} \geq 0.1d$	$d_{notch} < 0.1d$
$l_{notch}/d_{notch} = 0$	$9.0/d^{0.45}$	$3.2/d_{notch}^2$
$l_{notch}/d_{notch} = 2$	$9.0/d^{0.33}$	$4.2/d_{notch}^2$
$l_{notch}/d_{notch} = 4$	$9.0/d^{0.24}$	$5.2/d_{notch}^2$

2.4 Timber Strengthening

Many methods of timber strengthening has been tested, however there are no current recorded efforts in testing members

2.5 Fibre Reinforced Polymers (FRP)

2.5.1 CFRP

2.5.2 GFRP

2.5.3 BFRP

2.5.4 AFRP

2.6 Analysis

3 Methodology

4 Project Management Plan

5 Expected Results/Conclusions

References

[1] Department of Transport and Main Roads . Timber bridge maintenance manual, February 2005.

[2] Robert Jockwer, RenÃ© Steiger, and Andrea Frangi. State-of-the-Art Review of Approaches for the Design of Timber Beams with Notches. *Journal of Structural Engineering*, (11/03/2015).

[3] Michael A. Ritter. *Timber bridges :design, construction, inspection, and maintenance /*. Washington, DC :, 1990.