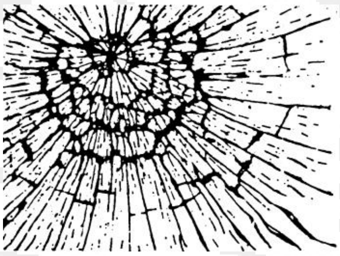

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8th International Conference on Structural Integrity and Fracture

11-12 July 2013
Melbourne, Australia

Hosted by Sir Lawrence Wackett Aerospace Research Centre,

RMIT University

Editor

Professor Chun H. Wang

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Proceedings of the 8th International Conference on Structural Integrity and Fracture

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Editorial

This proceedings contains the papers presented at the Eighth International Conference on Structural Integrity and Fracture (8th SIF) held on 11-126 July 2013 in Melbourne, Australia.

All papers have been peer reviewed by the conference Organising Committee and additional reviewers.

Safety is of paramount importance for a wide range of industries, including transport, energy generation and storage, civil construction, mining, bioengineering, to name but a few. Maintaining structural integrity cost-effectively demands continuing advancement in the knowledge of complex fracture mechanisms and damage accumulation over several size scales, innovations in damage detection, and new techniques for forecasting future performance. In addition, controlled fracture, rather than fracture control, is a key technology for mining and machining.

This conference aims to provide an opportunity for practioners, academics, and researchers to interact and discuss recent research advances in the scientific understanding and engineering applications of fracture mechanics and structural integrity methodologies. As with previous AFG conferences, the topics of interest include, but are not limited to, the following:

- Mechanisms of fracture, fatigue, creep, wear and corrosion damage
- Metals, ceramics, polymers
- Fibre-reinforced composites and nano materials
- Biological and biomedical materials
- Smart materials and thin films
- Environmental aspects of fracture and fatigue
- Structural integrity and life assessment methods
- Repair technologies, welding and joining
- Prognostic health management and asset management

In recognition of the immense contributions of Professor Francis Rose and Professor Brian Cotterell to fracture mechanics in Australia, the Australian Fracture Group Committee has unanimously voted to honour both Professor Rose and Professor Cotterell as the recipients of the Australian Fracture Group Achievement Awards at this conference.

I trust the collection of papers published in this proceedings serves as a useful reference to the advanced research and engineering community. I would like to take this opportunity to thank everyone who has contributed papers to 8th SIF.

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8th Structural Integrity and Fracture, Melbourne, 11-12 July 2013

Failure and Analysis of Composite Timber Beams with Box Section

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Keywords: *composite timber beam, box section, failure, deflection, four-point bend*

Abstract
This paper presents the results from a study on a particular type of long-spanning composite timber beams with box section, which can potentially used for floor joists. In this study, four-point bend tests of four composite timber beams of 2400×200×105 mm^3 were performed on a fixture with inner span of 700 and outer, 2100 mm. The beams consist of two wood flanges connected via two plywood webs, forming a rectangular hollow section. The wood flanges are made of MGP12 with thickness of 90 mm and depth of 45 mm (AS1720.1), and plywood webs, ID Code 7-24-3 with total thickness of three plies, 7.2 mm (AS2269.0-2008). The experiments demonstrated that with very strong rigid bonds joining the flanges and webs, the beams invariably failed from the buckling and then shearing of web. For the beam with weaker flange-web bonds, the beam will prematurely fail because of debonding. These observations are analysed in terms of stress distributions in the beams and the strength behaviours of individual components in the beams.

Introduction
Timber has been used as structural materials for many centuries, and particularly, in housing industry, timber beams and trusses are still the major materials for floor joists and roof structures of residential dwellings [1-7]. In Australia, with the increasing population and the desire for sustainable communities, it is now common for town planners to adopt smaller allotment sizes and developers have identified the economical advantages of constructing more highly populated estates. As a result of this development, two-storey homes have become common for many years, and now there is a growing trend towards multi-level homes to make better use of the smaller allotment sizes available.

Corresponding to this housing trend, there is an increasing demand for the designer to take advantage more effectively of the decreasing forestry resources. One solution is to increase the spans of timber beams and optimise the distribution of the cross-sectional timber materials, which, while uses more effectively the limited wood resources, also reduces the cost of the house building. This, in terms of structural integrity considerations, requires that the optimised timber beams possess higher strength-to-weight and stiffness-to-weight ratios. Timber beams with box-shaped cross-section are one of these optimised systems, which can achieve the same strength as the solid timber beams by using less timber materials, and therefore, have been adopted by the Australian housing industry for the housing design [6, 7]. To develop further this type of timber structures, it is important to understand the strength behaviour and failure process.

Box beams are composed of two timber flanges, which are connected together by two plywood webs. While the timber flanges carry most bending moments, the two plywood webs support the main portion of shear loads. In the box beam design, a conservative approach is employed, i.e. all bending stresses are carried by the flanges and all shear stresses by the webs [6, 7].

This paper aims to investigate the failure behaviours of timber beams with box-shaped cross-section. Four box-section beams were constructed and tested via a four-point-bend device. It is demonstrated that bond strength plays an important role in determining the failure modes, and therefore, the strength of box beams. For the well-bonded box beams, the nonlinearity initiates with the local buckling of plywood webs, and the shear in the plywood webs leads to the final failure.

Construction of Box-Section Timber Beams and Experiments

The four timber composite beams of 2400 × 200 × 105 mm^3 with box section were constructed for the experiments [8]. The beam consists of two machine grade pine (MGP12) flanges and two plywood (stress grade: F8 and identification code: 7-24-3) webs. While top and bottom pine flanges are used to support bending moment, the two plywood webs resist shear load. To investigate the full potential of the box structure, no stiffeners are included in the beams. As both the MGP and plywood were sourced commercially from local Bunnings shop, the maximum beam length available was 2400 mm, and was, therefore, chosen for this study. The MGP flanges were arranged in such a way that the tensile load is parallel to the grains, which can carry higher tensile load. Two flanges of 2400 × 45 × 90 mm^3 and two webs of 2400 × 200 × 7.2 mm^3 were joined together using Selleys 308 High Stress Wood glue instead of nails to achieve rigid bond because nail slip will reduce the stiffness of the composite beam [9, 10]. An assembled beam is shown in Fig 1a and Fig 1b shows the cross-section dimensions of the assembled timber composite beam.

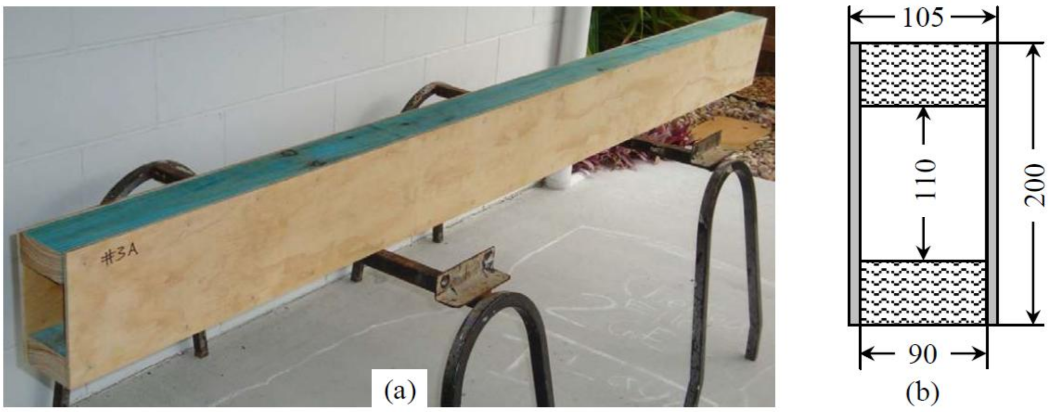

Fig 1. (a) Assembled timber composite beam and (b) its cross-section dimensions.

Fig 2. Four-point-bend device

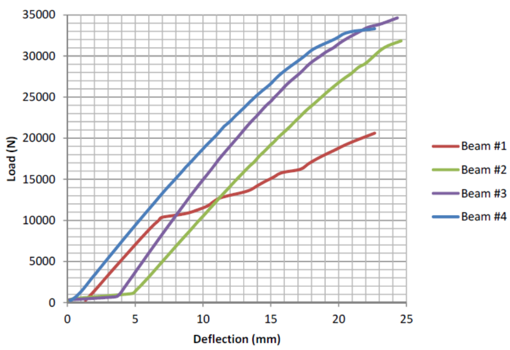

Fig 3. Load vs. deflection curves of the tested timber composite beams

The four timber composite beams were tested on a four-point-bend device as shown in Fig 2. The device was provided by a local timber product company, which outer and inner spans are 2100 and 700 mm, respectively. The beams were mounted on the loading frame and loaded monotonically by a hydraulic power unit until final failure. During the testing, the load versus deflection data were continuously recorded, and also the photographs were taken to record the failure process and failure modes.

Results and Discussion

Fig 3 shows the load versus deflection plots of the four timber composite beams under four-point-bend loading test. It can clearly be seen that except beam #1, the load-deflection behaviours of the other three beams are almost same. With the ultimate failure loads of 31.83, 34.64 and 33.31 kN for beams #2 to #4, all these three composite beams start to deviate from the linear load-deflection relationship at a load between 25 and 26 kN, which is consistent with the shear failure load calculated based on AS 1720.1 – 2010 [11].

The observations during the four-point-bend tests of beams #2 to #4 revealed a quite consistent failure process. As shown in Fig 4, the composite beams started to deviate from the linear load-deflection relationship at a load between 25 and 26 kN, where the beam webs buckled under shear load (combined with minor local compression load). Corresponding the buckling, a crack was initiated at the middle of the beam web where the maximum shear stress distributes (Fig. 4a). The crack propagated with further load increase and led to the complete split failure of the timber box beams when the load reached the ultimate failure load (Fig. 4b).

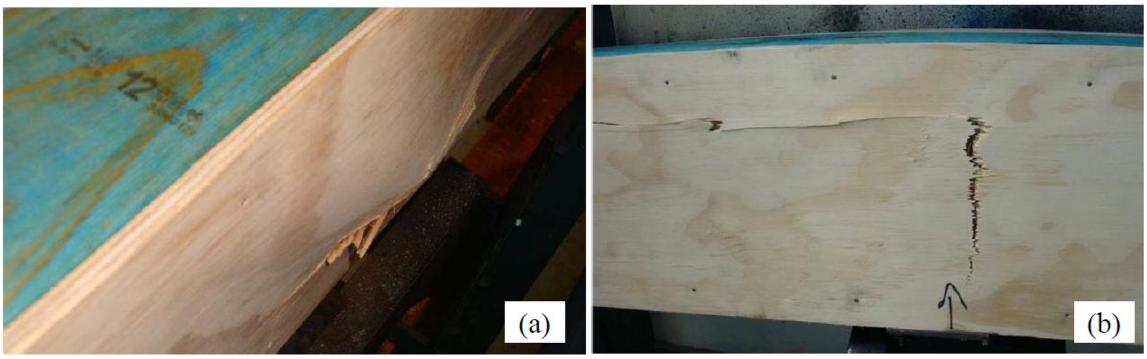

Fig 4. (a) Buckling and (b) shear failure of beam #4

As shown in Fig 3, the load-deflection results of box beam #1 are significantly different from the other three beams, where both the nonlinear load and ultimate failure load are significantly lower than those of the other three beams. The cause for this low failure load can be explained by its failure process and mode. As shown in Fig 5, the failure of the beam #1 did not follow the web buckling-cracking-splitting failure process but instead, was caused by the debonding of the interfaces between the flanges and webs. In fact, beam #1 debonded first on one side then the other. After the debonding on the first side, the beam has had to resist the load working as a C-section rather than a box beam. This is evident from the change in slope of the load-displacement relationship at an approximate load of 10.5 kN.


Fig 5. Beam #1 failed along both glue lines

The above described failure process observations and strength results have a number of implications for the design and applications of timber box beams. Because the beam failure results from the propagation of the buckling-induced crack in the beam web, both the web cracking resistance and the web stiffness play a very important role in controlling the beam strength. While the plywood web possesses superior cracking resistance due to its laminate structure, the web stiffness is influenced by many factors, including the geometries and sizes of the flanges and webs as well as the quality of the flange-web bonds. Obviously, thicker and shallower webs and/or thinner and deeper flanges will lead to higher stiffness, and therefore, increased resistance to cracking, and the strong flange-web bonds also increase web stiffness. Therefore, it is important to ensure the bondings between the flanges and webs are solid. This justifies the use of strong wood glue instead of nails because nails often slip leading to weaker bonding [9, 10]. Furthermore, a weak bond can change the failure mode and lead to reduced strength. This has been demonstrated by the premature failure of beam #1.

Conclusions

Four timber composite beams with box section have been constructed and tested on a four-point-bend device. The failure process observations and measured results revealed that the failure of the well-bonded timber box beams results from the propagation of the buckling-induced crack and follows the procedure of (1) buckling-induced cracking; (2) crack propagation; and (3) complete splitting failure due to shear. It is further identified that the load, where the load-deflection plot deviates from the linear relationship, corresponds to the buckling load, and the ultimate failure load to the complete splitting failure. Furthermore, the debonding of weak flange-web bonds will lead to the premature failure of the timber composite beams. It is, therefore, argued that the quality of flange-web bond also plays a very important role in controlling the strength behaviours of timber composite beams.

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