ACIAR PROJECT FST/2019/128

Review of Certification Requirements for Prominent Engineered Wood Products (Plywood, LVL, and Glulam):

Requirements, Processes & Case Study

Coconut and other non-traditional forest resources for the manufacture of Engineered Wood Products (EWP)

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May 2022

Review of Certification Requirements for Prominent EWPs

Executive Summary

The certification of structural products involves the evaluation of manufactured materials and quality assurance (QA) procedures for their conformance with the relevant product design standards. It consists of both product and procedural scrutiny where product performance is equally as important as the quality management system (QMS). The aim of this report is to detail the procedures required for the certification of three prominent structural engineered wooden products (EWPs), namely:

- Plywood,
- Laminated Veneer Lumber (LVL), and
- Glued laminated timber (Glulam).

This report is comprised of two parts, where Part A discusses the certification process relevant to EWPs with specific reference to plywood, LVL and Glulam. Part B illustrates the requirements considered through Part A with an exemplar case study on Glulam beams manufactured by Eco Cottages Pty Ltd. The case study in Part B applies the requirements discussed through Part A to the specific application of Glulam beams for the client Eco Cottages.

A selection of certification bodies was interviewed as part of the study to define the critical components of the EWP certification process. The process can be divided into:

- Product performance,
- Management practices, and
- Markings.

Disclaimer

The content of this report pertains to the expected requirements for manufacturers and is based on the specifications of the relevant standards and testing methods. Information, documentation and testing required will vary between certifiers and it is important to discuss the requirements with the selected certifier prior to engaging any external services.

The findings of Part B in this report are based on the specific requirements of the cypress (*Callitris columellaris*) Glulam product manufactured by Eco Cottages Pty Ltd. Part B is an exemplar scenario to provide knowledge and awareness of the procedures involved in certifying Glulam beams.

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Introduction

With the ever-increasing shift from conventional construction methods and materials to 'greener' and more sustainable alternatives, engineered wood product (EWP) producers are observing a steady increase in market demand. Mass timber construction is becoming a more readily considered building strategy locally in Queensland and across Australia.

With the increased demand coming from the construction industry, national and international suppliers of timber products are rushing to provide the sector with the needed materials. As the number of national and international providers increases, consumers are spoilt for choice on materials with little knowledge on how to determine quality and value for money.

The Australian National Construction Code (NCC) requires structural product manufacturers to provide evidence that the products meet a "performance requirement" [1]. Certification represents one method by which the claimed performance indicators are supported by evidence and documented.

This report is broken down into two parts and aims at:

- Discussing the requirements for certifying selected EWPs as structural products with respect to Australian/ New Zealand standards (*Part A*).
- Detailing the processes involved with obtaining certification status as well as the requirements for on-going surveillance to maintain certification (*Part A*).
- Discuss the types of certification schemes available to manufacturers and the variability concerned with this coverage (*Part A*).
- Outline the use quality management systems (QMS) and their importance as a quality tracking tool (*Part A*).
- Illustrating part of the process outlining in Part A with a case study for certification of Glulam beams to AS/NZS1328.1 [2] (*Part B*).

The intention of this document is to educate the reader on the certification requirements and advantages available to EWP manufacturers, as well as provide guidance from which to begin the process of product certification.

Part A: Requirements of EWP certification

1. The importance of certification

With the vast number of choices available on today's market, instilling confidence in a product is a key way to stay ahead of the crowd. One way to ensure this is through product certification [3]. Quality management practices such as those detailed in ISO9001 [4] provide organisations with a strategic benefit by providing measures to maintain or improve product performance. More than one million organisations across 145 countries have currently implemented the ISO9001 [4] operating procedures within their facilities [3]. The use of certification is not only a means of creating confidence for the local consumer markets but also creates a common platform for establishing quality products manufactured and sold across the country. Certification provides a clear indicator to the customer that the product has been evaluated and is part of a regular quality assessment process.

The conformity assessment standard, ISO17067 [5], states that product certification is the provision of evaluated documentation and processes as conducted by a third-party organisation. The standard states that certification is an indication of specific requirements being demonstrated which broadly represents both product and process conformance. Product conformance refers to the tested performance to standardised evaluation methods, while process conformance relates to the quality assurance (QA) practices and associated documentation of said processes by the manufacturer. Due to the importance on information generated through the certification process, a high level of scrutiny is placed on the certification organisations through their own governing bodies such as the Joint Accreditation System, Australia and New Zealand (JAS-ANZ).

Certification organisations are to be certified themselves in accordance with ISO17065 [6]. The level of involvement the certifier will take is dependent on the product certification scheme, the scheme refers to the amount of coverage that certifier has in regards to product quality management [5]. This presents the argument that certification does not refer to one particular definition or body of work. Certifiers are then accredited to carry out the assessment requirements of the specific standards that govern the conformity of the manufactured products within their scheme scope. The schemes detailed in ISO17067 [5] are presented in Table 1. Each certification scheme, numbered 1 to 6, provides a different level of scrutiny to the certification process. Based on the information presented in the table, all certification schemes provide activities 1 to 5, related to the selection and development of a testing regime, evaluation of product properties, and review and decision on the client's conformance and certification status. The listed scheme's point of difference relates to the 6th activity, surveillance. Schemes 1 and 2 provide little to no surveillance of products post, qualification testing. This places the responsibility to monitor quality of batches solely on the manufacturer. Schemes 3 and 4 differ on their surveillance approach being either solely factory based or a combination of both factory and market product inspection and testing. Scheme type 5 scheme provides the optimal coverage where surveillance is conducted for products inspected in both the factory and on the market as well as including regular audits of manufacturing processes and procedures. The 6th scheme type pertains to document-based surveillance where audits will commonly include review of factory QA documentation.

Table 1: Product certification scheme range [5].

CONFORMITY ASSESSMENT ACTIVITIES		SCHEME TYPE						
		1a	1b	2	3	4	5	6
1)	Selection (planning, preparation, requirements)	x	x	x	x	x	x	x
2)	Determination of characteristics (testing, inspection, etc.)	x	x	x	x	x	x	x
3)	Review (examination of results of stage 2)	x	x	x	x	x	x	x
4)	Decision on certification (granting, maintaining, managing)	x	x	x	x	x	x	x
5)	Attestation, licensing							
	a) Issuing certification conformity	x	x	x	x	x	x	x
	b) Granting right to use certificates	x	x	x	x	x	x	x
	c) Issuing certificate of conformity on batches		x					
	d) Granting right to use marks of conformity		x	x	x	x	x	x
6)	Surveillance							
	a) Testing or inspection of samples from market			x		x	x	
	b) Testing or inspection of samples from factory				x	x	x	
	c) Assessment of production and processes				x	x	x	x
	d) Management system audit and random inspection						x	x

2. Quality management system (QMS)

This section refers to the interrelated processes of the quality management system (QMS) for manufacturers and presents ways in which quality can be monitored [4]. QMSs provide manufacturers a means of demonstrating their ability to consistently provide materials and products that can meet the requirements of the relevant standardised design methods. Through both the initial process and on-going surveillance for certification, evaluating the manufacturers' ability to produce quality and consistent products is conducted through a review of the organisation's documents. By having a robust QMS that details production runs, changes to manufacturing processes, as well as being aware of both internal and external issues conveys to the certifier that the organisation has a robust quality process in place and is aware of the resources required at each level.

QMSs allow the manufacturer to maintain control over the interrelationships and interdependencies within the manufacturing process where risks can be managed and mitigated. ISO9001 [4] references the Plan-Do-Check-Act (PDCA) cycle with focus on risk-based thinking and management. Figure 1 presents a PDCA cycle diagram showing the influence each of the stages of the PDCA contributes to. Note that, in other words, QMSs are important risk management techniques to minimise non-conforming products [4]. A PDCA cycle provides a means of documenting the manufacturing procedures through the four stages of the cycle.

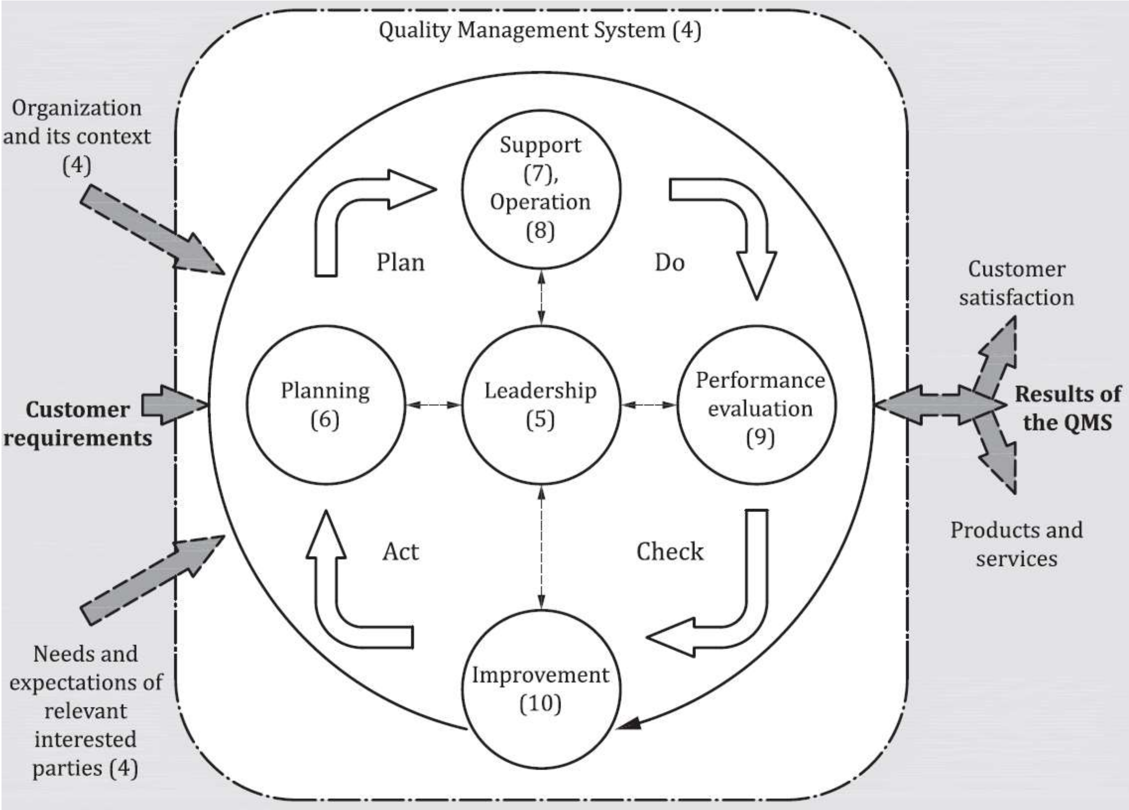

Figure 1: PDCA cycle flow diagram [4].

The PDCA cycle is initiated with some conditions which require a 'planning' phase (top-left quadrant in Figure 1). At this point, the objectives and processes are established, and resources needed for the requirements addressed. The result of this planning phase is developing a series of processes and instructions for 'Doing' the task (top-right quadrant in Figure 1). A result would be to evaluate the produced materials through a performance evaluation stage, leading into 'Check' (bottom-right quadrant in Figure 1). By checking the result of the produced materials, one of two decisions is commonly made. The first leads to the requirements for further improvement where changes to the product development procedures are required through some 'Action' (bottom-left quadrant in Figure 1), therefore leading back to further planning. The alternative (if not improvements were required) would be that the output of the QMS and PDCA cycle results in a developed and evaluated product for market or to meet a client's request.

3. Certification considerations

As previously introduced, the certification process is comprised of product performance and QA practices. The outputs of each of the performance and practice indicators, evaluated in accordance with the relevant standards, completes the requirements to obtain certification status according to ISO9001 [4]. This section of the report details these requirements and how they are evaluated. As mentioned previously, a manufacturer should approach certification organisations to discuss the level of expectation associated with each requirement as it may vary between organisations.

3.1. Product performance

The performance properties of the three selected EWPs (Plywood, LVL and Glulam) can be mainly separated into:

- Mechanical performance,
- Bond integrity, and
- Formaldehyde emissions (only applies if formaldehyde adhesive is used).

Table 2 summarises the Australian standards to evaluate the performance properties listed above, as well as the relevant design standards of each product.

Table 2: Relevant standards for the determination of product performance for plywood, LVL, and Glulam.

MEASURED PROPERTY	PLYWOOD	LVL	GLULAM
DESIGN/ SPECIFICATIONS	AS 1720.1 (2010), AS/NZS 2269.0 (2012)	AS 1720.1 (2010), AS/NZS 4357.0 (2005)	AS 1720.1 (2010), AS/NZS 1328.1 (1998)
MECHANICAL PERFORMANCE	AS/NZS 2269.1 (2012)	AS/NZS 4357.2 (2006)	AS/NZS 1328.1 (1998), AS/NZS 4063.1 (2010), AS 5068 (2006)
BOND QUALITY	AS/NZS 2098.2 (2012), AS/NZS 2269.0 (2012)	AS/NZS 2098.2 (2012), AS/NZS 2269.0 (2012)	AS/NZS 1328.1 (1998), AS 5068 (2006)
FORMALDEHYDE EMISSIONS	AS/NZS 2098.11 (2005)	AS/NZS 4357.4 (2005)	Not applicable[1]
CHARACTERISTIC ANALYSIS	AS/NZS 2269.2 (2012)	AS/NZS 4357.3 (2006)	AS/NZS 4063.2 (2010)

[1] Due to the low number of glue lines in a Glulam product compared to plywood and LVL, formaldehyde emissions are considerably lower and typically not required for product certification [7]. It should also be noted that this is not addressed in the Australian standards for this type of product.

3.1.1. Stress grading

Across the three product types, the performance in regard to the characteristic mechanical properties is a key design criterion. The characteristic values are obtained through testing a minimum number of samples specified in the standards (Table 2). The characteristic mechanical properties are then used to assign a F and GL stress grade for plywood and Glulam, respectively, given in Section 5 (plywood) and Section 7 (Glulam) of AS1720.1 [8]. The characteristic values for LVL are typically provided directly by the manufacturer with no stress grade specified in the AS1720.1 [8].

Table 3 and Table 4 present the stress grades and their associated design properties (corresponding to the minimum characteristic values to be achieved) for plywood and Glulam, respectively.

Table 3: Plywood characteristic values for F-grades in Section 5 of AS1720.1 [8].

Stress grade	Characteristic values, MPa						
	Bending (f'_b)	Tension (f'_t)	Panel shear (f'_s)	Compression in the plane of the sheet (f'_c)	Bearing normal to the plane of the sheet (f'_p)	Short duration average modulus of elasticity (*E*)	Short duration average modulus of rigidity (*G*)
F34	90	54	6.0	68	31	21 500	1 075
F27	70	45	6.0	55	27	18 500	925
F22	60	36	5.5	45	23	16 000	800
F17	45	27	5.1	36	20	14 000	700
F14	36	22	4.8	27	15	12 000	625
F11	31	18	4.5	22	12	10 500	525
F8	25	15	4.2	20	9.7	9 100	455
F7	20	12	3.9	15	7.7	7 900	395

Table 4: Glulam characteristic values for GL-grades in Section 7 of AS1720.1 [8].

Stress grade	Characteristic values, MPa					
	Bending (f'_b)	Tension parallel to grain (f'_t)	Shear in beam (f'_s)	Compression parallel to grain (f'_c)	Short duration average modulus of elasticity parallel to the grain (*E*)	Short duration average modulus of rigidity for beams (*G*)
GL18	45	25	5.0	45	18500	1230
GL17	40	20	4.2	33	16700	1110
GL13	33	16	4.2	26	13300	900
GL12	25	11	4.2	22	11500	770
GL10	22	8	3.7	18	10000	670
GL8	19	6	3.7	14	8000	530

From Table 3 and Table 4***Error! Reference source not found.***, the mechanical properties to be investigated for certification can be extracted, with the key properties consisting of [9]:

- Bending strength.
- Tension strength.
- Shear strength.
- Compression strength.
- Modulus of elasticity parallel to grain.

The specifics of the testing regime implemented will depend on the EWP and its intended application (e.g., direction of testing and orientation), and would need to be discussed and agreed upon with the certification organisation.

Note that regarding finger jointed products, AS5068 [10] specifies that, evaluation of a finger joints (FJ) mechanical performance should be conducted in either bending or tension. The joint structural tests will therefore result in bending and tension characteristic values that may be used by the certifier to assign a stress grade of the entire jointed product, based on the characteristic values. Alternatively, the extracted characteristic values from the FJ can be used in Glulam design in the determination of the expected stress grade following the methodology in Clause 2.4.3.2 of AS/NZS1328.1 [2].

3.1.2. Bond integrity

3.1.2.1. Glueline between lamellas

The approach used to determine the integrity of the glueline between bonded lamellas varies between veneer-based and board-based products, although all approaches aim at providing appropriate stresses to the glueline to evaluate its bond strength under selected environmental conditions. AS/NZS1328.1 [2] states that "the adhesive shall be capable of producing strong and durable joints which maintains the bond integrity through the intended lifetime of the structure". These approaches are listed below:

- *Plywood and LVL (veneer-based panels)*: a steaming or boiling process. While the AS/NZS 2098.2 proposes different steaming or boiling processes for different bond types, for structural product, a type A bond test in the standard is required.
- *Glulam (laminated board product):* a water impregnation and drying process to stress the glueline.

3.1.2.2. Evaluation of joints

EWPs of lengths greater than the feedstock material is obtainable through various joints, typically using FJ and scarf (SJ) joints. The two are commonly used for different products where a SJ would be primarily used in veneer-based products and a FJ would be more suited towards products manufactured from solid boards. The inclusion of these jointing applications is acceptable for both veneer and board-based EWPs with the expectation that they meet the bond integrity requirements outlined by their respective design standards. Joints are evaluated for both their structural performance and bond integrity as detailed in Table 2.

The bond integrity performance assessment of FJs detailed in AS5068 [10] is only evaluated for a Service classes 2 and 3. The testing consists of a vacuum and pressure water impregnation cycle over a period of 6 hours. At the conclusion of this cycling, FJs are tested in bending or tension to expose the stressed joint. The joint is then visually evaluated to calculate the wood failure percentage. AS5068 [10] specifies wood fibre tolerances for both hardwood and softwoods as shown in Table 5.

Table 5: Wood fibre bond compliance values.

	AVERAGE (%)	MINIMUM (%)
HARDWOOD	40	20
SOFTWOOD	60	30

3.1.3. Formaldehyde emissions

Both the National Pollutant Inventory [11] and the International Agency for Research on Cancer [12] has classified formaldehyde as a known carcinogen. It should be stressed that the cancer causing properties of formaldehyde are only evident at very high concentrations and therefore is important for it to be measured. The levels commonly found within plywood/ LVL is often hundreds of times lower than a dangerous amount [13], as reflected by the emission class limiting values in Table 6.

In the circumstances where the adhesive used in manufacturing is a resorcinol based adhesive type (i.e., containing phenol resorcinol formaldehyde resin) the emissions of the adhesive must be quantified. As formaldehyde is a readily used ingredient is some type-A bonded products, the determination of formaldehyde levels is considered across a range of countries. The testing method used for formaldehyde determination in Australia is the desiccator method, a methodology detailed in ASNZS2098.11 [14] and ASNZS4357.4 [15] which first originated from the Japanese agricultural standards JIS1460 [16]. The limit values and the corresponding product grade are detailed in Table 6.

Table 6: Formaldehyde emissions specifications [17].

LIMITING VALUE	EMISSION CLASS
< 0.4 MG/L (0.3 MG/L AVERAGE)	Super E_0
< 0.5 MG/L	E_0
< 0.1 MG/L	E_1

In the desiccator method, the samples are introduced to a desiccator chamber with a container of water alongside the samples. The release of formaldehyde is measuring after a set period of time while the samples are conditioned according to the relevant standard.

3.2. Management practices

3.2.1. Operation controls

This section details the controls specific to the operations of the manufacturer to instil consistent product development and reinforce the QA procedure. These controls include the following:

- *Design and development:* The processes followed to develop products should be documented by the manufacturer. The documentation should also specify the equipment and resources required to manufacture products.
- *Machinery maintenance:* The manufacturer should ensure and document that all manufacturing equipment is regularly checked, serviced, and calibrated as necessary.
- *Client communication forms:* An important post-manufacturing component of the sale process is client feedback and accessibility. Having means in place to communicate with clients and gain feedback on product performance provides an added layer of QA.

Note that documenting the above items is not only a requirement of the certification process (both for the initial and ongoing surveillance) but also allows manufacturers to develop a database of processes and product information which can double quality tracing information and training material for new staff.

3.2.2. Quality assurance (QA)

It is the manufacturers responsibility to maintain ongoing product evaluations in line with the relevant standardised testing methods [4]. For ongoing monitoring of manufactured product performance, a similar approach to the initial testing requirements must be adopted by the manufacturer, but at a reduced scale. Tests commonly required by certifiers as part of this ongoing quality confirmation process are detailed in Table 7. The QA process conducted by the manufacturer should involve:

- Determination of critical product properties to monitor.
- The frequency at which properties should be evaluated.
- The correct methods for evaluation.

Table 7: Regular quality assurance requirements.

PARAMETER	PLYWOOD	LVL	GLULAM
BOND QUALITY	AS/NZS 2098.2 (2012)	AS/NZS 2098.2 (2012)	AS 1328.1 (1998)[1]
MECHANICAL PROPERTIES	AS/NZS 2269.1 (2012)	AS/NZS 4357.2 (2006)	AS/NZS 4063.1 (2010), AS 5068 (2006),
RECOMMENDATION	PLYWOOD	LVL	GLULAM
MOISTURE CONTENT	AS/NZS 2098.1 (2006)	AS/NZS 2098.1 (2006)[20]	AS/NZS 1080.1 (2012)[21]
MANUFACTURING CONDITIONS	Regular checks and records of temperature and humidity during manufacturing		

[1] The test method used is dependent on the service class which is a measure of exposure intensity. AS/NZS1328.1 [2] Table 2.1 states the test methods required for each service class exposure.

It should be noted that during the initial testing to obtain certification (qualification testing) all Glulam samples are submitted to the same testing regime regardless of their service class. The methodology only changes for routine assessments as discussed in Clause 2.6.3 AS/NZS1328.1 [2]. The figure depicts the service class exposure scenarios that a product application would suit. As detailed in Figure 2, the service classes relate to the environmental exposure level considered for the scenario shown. A service class 1 equates to similar conditions to room temperature (20°C and a maximum relative humidity (RH) of 65%). A service class 2 is a increased RH environment where an 85% RH is the maximum resulting in an equilibrium moisture content (EMC) of approximately 20% (when at 20°C room temperature). Lastly the service class 3 results in a greater EMC than a service class 2 where the product is expected to be fully exposed, above ground.

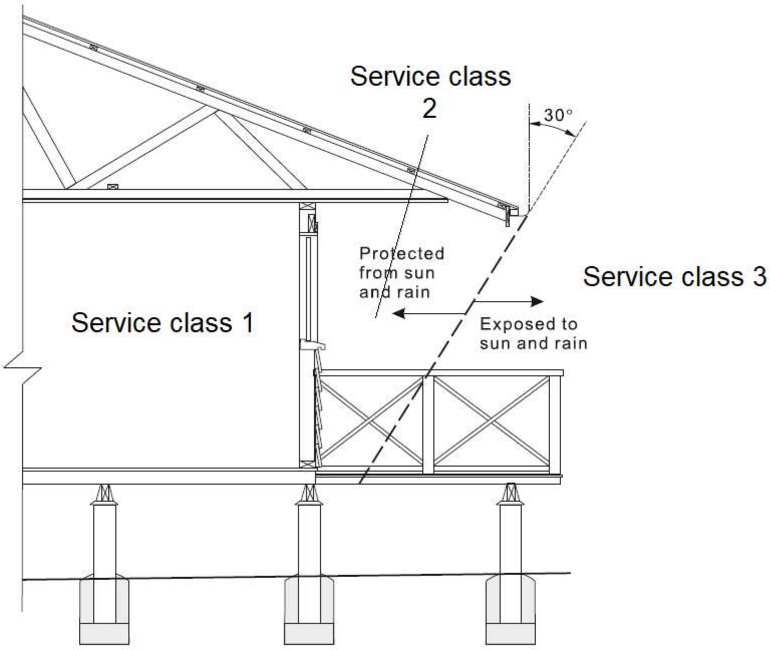

Figure 2: Service class exposure scenarios [10].

When manufacturing parameters are altered by the manufacturer (such as adhesive type, feedstock properties, applications, etc.) testing similar to the initial type testing arrangements should be re-conducted to confirm grading and expected performance. It is recommended that manufacturing conditions be recorded where possible [4].

3.3. Labelling

Labels are an important and informative aspect of manufactured EWPs as they contain descriptive information related to product performance and conformance. Figure 3 presents a marking template for the general labelling of certified EWPs.

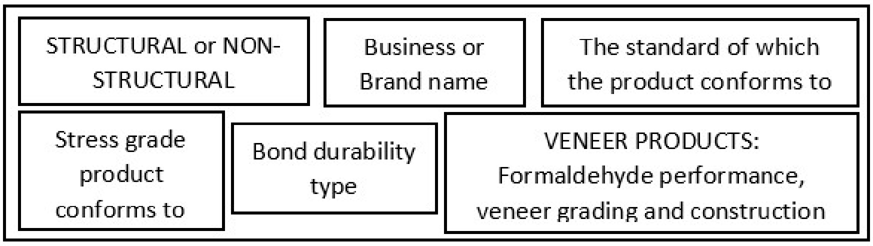

Figure 3: Marking example showing product performance aspects from certification.

The information contained in the mark should be clear and concise to ensure all appropriate details about the product can be extracted from it. The example shown in Figure 3 specifies either a structural or non-structural product, the name of the business or brand, the standard for which the product has been designed and tested to, the stress grade, and the bond integrity type. In addition to these product descriptors, veneer based products should also include the outer layer (face and back) veneer grade as well as their formaldehyde emissions rating [17]. Plywood products should also state the veneer construction strategy used. Markings are a licenced agreement between the certifier and the client based on the scope of the certification scheme (ISO 27065 and ISO 17067). The use and display of the certifiers' mark by the client is a means of conveying compliance to the tested methods as specified by the mark.

Part B: Case study – Eco Cottages

1. Introduction

The work described in this report has been conducted by the Forest Product Innovation (FPI) team at the Salisbury Research Facility (SRF) – a group within Agri-Science Queensland, Queensland Department of Agriculture and Fisheries (DAF). As a partner in the DAF led, Australian Centre for International Agricultural Research (ACIAR) project (HF11414) titled "Coconut and other non-traditional forest resources for the manufacture of engineered wood products", Eco Cottages Pty. Ltd. has sought assistance in the pursual of certification for their cypress pine (*Callitris Glaucophylla*) glued laminated timber (GLT) beams. The aim of this report is to investigate the performance of the cypress GLT beams when tested for initial qualification, in accordance with AS/NZS 1328.1 (1998) *Glued Laminated Structural Timber, Part 1: Performance requirements and minimum product requirements*. In this report, the following properties were assessed:

- Tensile strength of the finger jointed (FJ) boards, providing the data to translate to the tensile strength of the GLT beams from Method 2 in Clause 2.4.3.2 of AS/NZS 1328.1 (1998).
- Finger joint bending strength, determined as per Clause 2.5 of AS/NZS 1328.1 (1998).
- Shear strength of the GLT beams, determined from Method 1 in Clause 2.4.3.1 of AS/NZS 1328.1 (1998).
- Bending strength and stiffness of the GLT beams, determined from Method 1 in Clause 2.4.3.1 of AS/NZS 1328.1 (1998).
- Glueline integrity, determined as per Clause 2.6.2 of AS/NZS 1328.1 (1998).

This report describes the methodology used and presents a summary of the results obtained. Detailed results are included as appendices to this report.

2. Materials and methods

2.1. Materials

Table 8 presents the sample numbers, testing methods and specimen sizes per investigated properties. All samples were manufactured and supplied by Eco Cottages. The applicable standards have also been noted against the corresponding test method. Note that (1) the depth of the GLT beams was less than 300 mm, as requested in the AS/NZS 1328.1 (1998), and reflected the beam size produced by Eco Cottages, and (2) as agreed with the client, the number of samples of the GLT beams tested in shear and bending was lower than the required number of 30 samples in AS/NZS 4063.2 (2010) *Characterisation of Structural Timber – Part 2: Determination of characteristic values*.

The cross-sectional dimensions of each sample was measured before each test. The tested specimens were stored indoor, at ambient temperature and relative humidity, before testing.

The finger jointed board lengths used for tensile testing and FJ assessment are referred to in this report as "laminates".

Table 8: Material details.

TEST METHOD	APPLICABLE STANDARDS	NO. SAMPLES	NOMINAL SPECIMEN DIMENSIONS (LENGTH X DEPTH X THICKNESS) – MM
LAMINATE TENSION STRENGTH	AS/NZS 1328.1, AS/NZS 4063.1 & AS 5068	30	4,000 x 90 x 45
LAMINATE BENDING STRENGTH	AS/NZS 1328.1 & AS 5068	30	1,000 x 90 x 45
GLT SHEAR STRENGTH	AS/NZS 1328.1 & AS/NZS 4063.1	10	2,500 x 250 x 85
GLT BENDING STRENGTH & STIFFNESS	AS/NZS 1328.1 & AS/NZS 4063.1	10	5,500 x 250 x 85
DELAMINATION ASSESSMENT	AS/NZS 1328.1	20	75 x 85 x 250 (5 glue lines)

2.2. Testing methods

2.2.1. Tensile strength

Due to the maximum specimen size that can be accommodated in the tensile rig at the SRF, and as agreed with the client, Method 2 in Clause 2.4.3.2 of AS/NZS 1328.1 (1998) would be adopted to characterise the tensile strength of the GLT beams. Testing was therefore conducted on FJ laminates to determine the characteristic tension strength $f'_{t,ej}$ of the FJ. While AS/NZS 1328.1 (1998) states that $f'_{t,ej}$ is to be determined in accordance with AS 5068 (2006) *Timber – Finger joints in structural products – Production requirements*, a different approach was followed here by testing laminates with more than one FJ, as in AS 5068 (2006). The laminate test span (L) was chosen as 2,720 mm (i.e., 8 times the depth d + 2,000 mm) in accordance with Clause 2.5 of AS/NZS 4063.1 (2010) *Characterisation of structural timber, Part 1: Test methods*, and conservatively consisted of 4 FJs per tested length. The distance between FJs was 810 mm. The samples were gripped at both ends and an axial tensile load was applied using the SRF tensile rig fitted with a 250kN load cell. The load was increased at a constant rate to achieve failure within 2 to 5 minutes. Figure 4 shows the test setup.

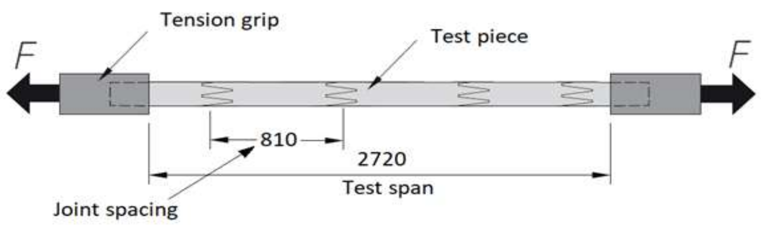

Figure 4: Schematic of tensile test on finger jointed laminate.

The tensile strength ($f'_{t,fj}$) of each sample was determined from Eq. 1:

$$f'_{t,fj} = \frac{F_{ult}}{bd} \qquad \text{Eq. 1}$$

where F_{ult} is the maximum applied load , and b and d are the measured thickness and depth of the sample, respectively. All failures were assessed in accordance with the failure of FJ in Appendix D of AS 5068 (2006).

2.2.2. FJ bending strength

The FJ bending strength testing was assessed using a 3-point bending test method, where the laminates were positioned flatwise and with the FJ positioned at the centre span point of the sample, in accordance with Appendix B of AS 5068 (2006), in reference to Clause 2.5 of AS/NZS 1328.1 (1998). This testing configuration is similar to the orientation of the laminate within a GLT beam which has the boards orientated flatwise. A test span (L) of 540 mm (12d) was adopted with testing conducted using a Shimadzu AG-X universal testing machine fitted with a 100 kN load cell. The load was applied at a rate of 2.5 mm/min to achieve failure within 2 to 5 minutes. The test setup is shown in Figure 5.

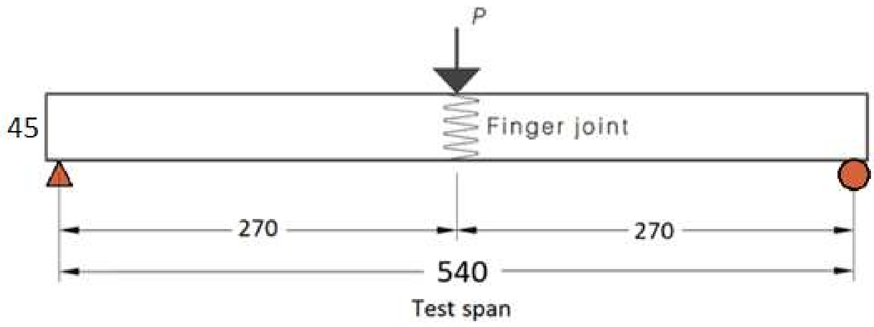

Figure 5: Schematic diagram of 4-point finger joint bending test setup.

The bending strength ($f'_{b,fj}$) of each sample was determined from Eq. 2:

$$f'_{b,fj} = \frac{1.5 \times F_{ult} L}{bd^2} \qquad \text{Eq. 2}$$

2.2.3. Beam shear strength

The beam shear strength was assessed in accordance with Clause 2.7 in AS/NZS 4063.1 (2010), in reference to Method 1 in Clause 2.4.3.1 in AS/NZS 1328.1 (1998). Testing was conducted using a 3-point bending test method, where the beams were loaded edgewise, as used in practice, into a Shimadzu UDH-30 universal testing machine fitted with a 300kN load cell. A test span (L) of 1,500 mm (6d) was adopted. The load was increased at a constant rate to achieve failure within 2 to 5 minutes. Figure 6 shows the test setup. The failure mode, i.e., shear failure or mode other than shear, was recorded for each test.

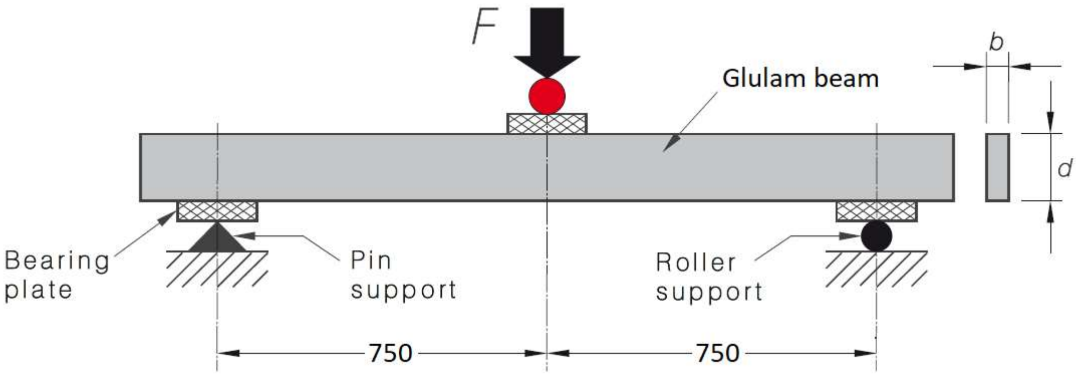

Figure 6: Schematic of beam shear test setup for GLT sample.

The beam shear strength ($f_{v,j}$) of each sample was determined from Eq. 3:

$$f_{v,j} = \frac{0.75 F_{ult}}{bd} \qquad \text{Eq. 3}$$

2.2.4. Bending strength and stiffness

The bending strength and stiffness were assessed in accordance with the test method outlined in Clause 2.4 in AS/NZS 4063.1 (2010)), in reference to Method 1 in Clause 2.4.3.1 in AS/NZS 1328.1 (1998). Testing was conducted using a 4-point bending test method, with the beams orientated edgewise to account for their in-service use. Testing was conducted using the same testing machine as the shear beams in Section **Error! Reference source not found.** over a test span (L) of 4,500 mm (18d). The beam deflection was measured at mid-span and the neutral axis by taking the average reading of 2 laser transducers positioned on each side of the beam. The test setup is illustrated in Figure 7.

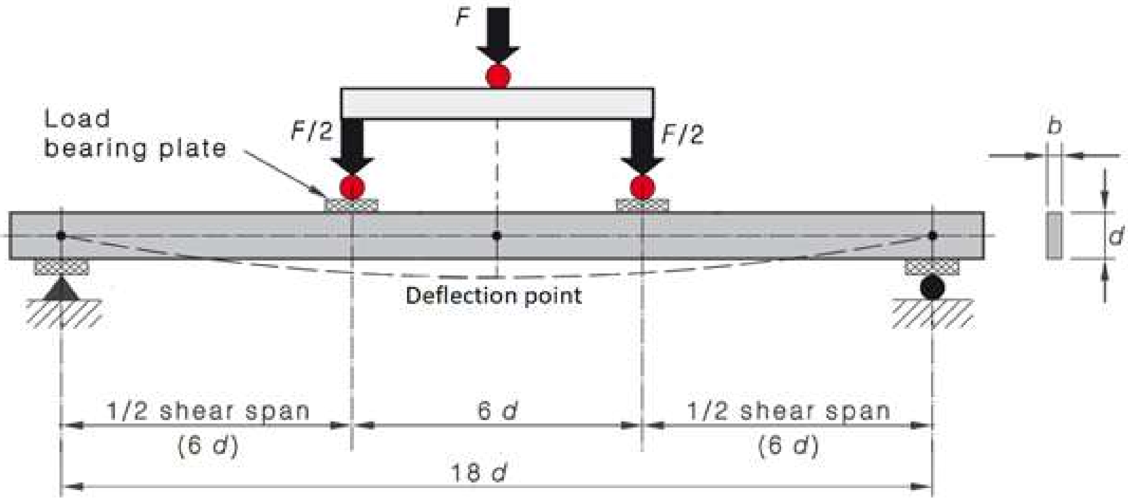

Figure 7: Schematic diagram of bending strength and stiffness test setup for GLT samples.

If failure originated in the constant bending zone (i.e., between loading points), the bending strength (MOR) ($f_{b,j}$) was calculated from Eq. 4:

$$f_{b,j} = \frac{F_{ult}L}{bd^2} \qquad \text{Eq. 4}$$

However, if failure originated outside of the constant bending zone (i.e., between a support and its nearest loading point), $f_{b,j}$ was calculated as:

$$f_{b,j} = \frac{3F_{ult}(L - 2L_v)}{2bd^2}, \qquad \text{Eq. 5}$$

where L_v is the distance from the centre of the test span to the point of failure.

The apparent modulus of elasticity (MOE) (E) of each sample was determined from Eq. 6:

$$E = \frac{23}{108}\left(\frac{L}{d}\right)^3 \left(\frac{\Delta F}{\Delta e}\right)\frac{1}{b} \qquad \text{Eq. 6}$$

where $\frac{\Delta F}{\Delta e}$ refers to the load vs mid-span displacement slope calculated by performing a linear interpolation on the load vs displacement curve between $0.1F_{ult}$ and $0.4F_{ult}$.

2.2.5. Delamination

Based on a Service Class 3 GLT member, the glue line integrity was assessed in accordance with method A of Appendix C in AS/NZS 1328.1 (1998), as stipulated in Clause 2.6.2 of the same standard. After bending and shear testing of the supplied GLT beams, sections unaffected by the failure mode were identified and delamination specimens were cut from the tested beams, based on the sample size requirements in the AS/NZS 1328.1 (1998) outlined in Table 8. The process for a method A exposure consists of submitting the samples to a pressure vessel (Figure 8) where they were submerged in room temperature water. Initially a vacuum of 70 to 85 kPa was drawn for a period of 5 minutes at the conclusion of which a pressure of 550 kPa was applied for 1 hour. This process was then repeated a second time for a total water impregnation cycle of 130 minutes. At the conclusion of the water impregnation cycling detailed above, samples were then dried for a period of 21 to 22 hours in the kiln drier shown in Figure 9, at a temperature of 60°C to 70°C and circulating air velocity of 2 to 3 m/s.

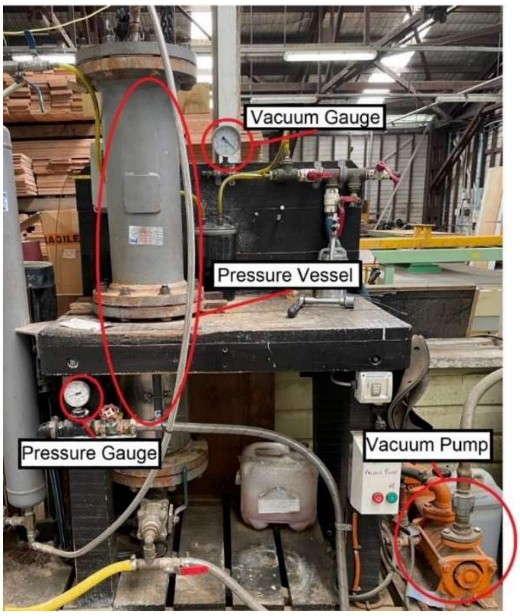

Figure 8: Water impregnation cycling equipment and experimental setup.

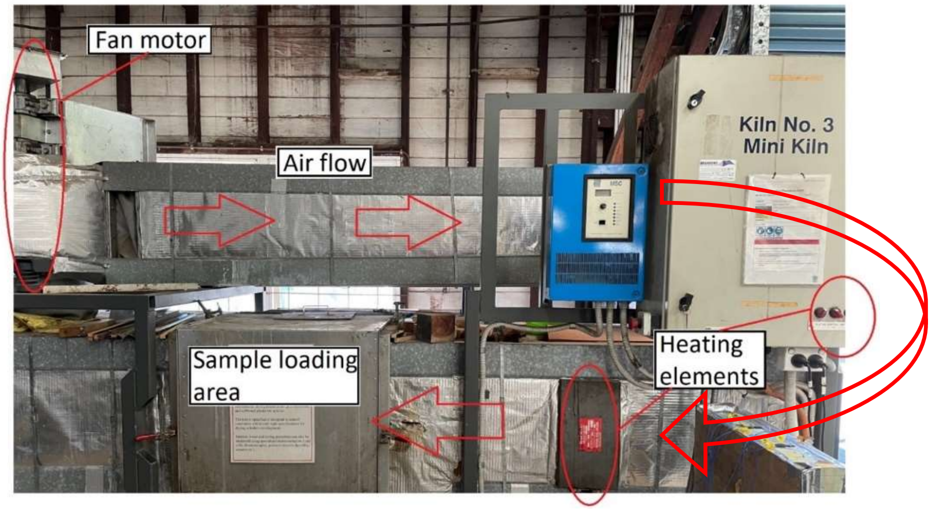

Figure 9: Drying apparatus under controlled temperature and air velocity conditions.

As detailed in Appendix C of AS/NZS 1328.1 (1998) (Table C2) for method A, two initial cycles are required for assessment. Therefore, at the conclusion of both water impregnation and drying, as detailed previously, the overall process was repeated a second time. At the conclusion of the two processes, the length of delaminated glue lines on the end grain surface was measured as shown in Figure 10.

Figure 10: Evaluation process of measuring delamination of cycled test block.

The total delamination was expressed as a percentage of the total length of glue lines in the sample ($l_{tot,glueline}$) against the amount of delamination recorded for the entire sample ($l_{tot,delam}$). The total delamination ($D_{max,j}$) of each sample was determined from Eq. 7:

$$D_{total,j} = 100 \times \frac{l_{tot,delam}}{l_{tot,glueline}} \qquad \text{Eq. 7}$$

Assessment of the results after the two cycles were compared against a 5% allowable maximum total delamination, as detailed in Clause 2.6.4 of AS/NZS 1328.1 (1998). If $D_{total,j}$ was greater than 5%, then the sample was exposed to a third complete cycle. The new $D_{total,j}$ shall be less than 10% for the sample to pass the delamination test.

In addition to the total delamination, Clause 2.6.4 in AS/NZS 1328.1 (1998) requires the maximum delamination ($D_{max,j}$) in any single glue line to be below 40% of the total glue line length. $D_{max,j}$ of each tested glue line was determined from Eq. 8:

$$D_{total,j} = 100 \times \frac{l_{max,delam}}{2l_{glueline}} \qquad \text{Eq. 8}$$

where $l_{max,delam}$ is the maximum delamination length along a single glue line of length $l_{glueline}$ (nominally 85 mm).

2.3. Evaluation of characteristic values

At the conclusion of the testing detailed through Section 2.2, the characteristic strength values were conducted in accordance with AS/NZS 4063.2 (2010) adopting Method 3 in Appendix B for conducting the statistical evaluation. While AS/NZS 4063.2 (2010) outlines the required minimum number of test specimens as 30 for each test method for the calculation of characteristic values, DAF was supplied 10 GLT beams for shear and a further 10 for MOE/ MOR determination. Characteristic values were therefore determined based on the number of specimens tested as a informative reference only.

Note that for a GLT beam tested in shear, when a samples failure was attributed to a mode other than shear, the strength value was not included in the statistical analysis of the results as offered in Clause 2.7 of AS/NZS 4063.1 (2010).

The characteristic value for the bending MOE of the GLT beams was determined using equations detailed in Clause B3.0 of Appendix B of AS/NZS 4063.2 (2010).

3. Results

3.1. Mechanical properties

Table 9 summarises the mechanical properties of the tested laminates and GLT beams. The results are displayed as the mean, characteristic value and coefficient of variation (*V*). Full results are attached in the appendices.

Table 9: Summary results for the testing laminates and GLT beams.

PARAMETER	MEAN	CHARACTERISTIC VALUE	V
	(MPa)	(MPa)	(%)
$f'_{t,f}$	19.5	11.5	20
$f'_{b,f}$	48.5	32.8	19
f_v	5.1[1]	3.7[1]	15[1]
f_b	30.3	23.6	15
E	8,954	8,795	8

[1] The results of the shear testing are from 8 of the 10 beams (80%) due to 2 beams failing in bending rather than shear. These 2 samples have therefore been removed in the calculations presented in the table.

3.2. Delamination assessment

Of the 20 samples evaluated, 19 (95%) produced total delamination results <5% after 2 cycles in accordance with the method outlined in Section 2.2.5. The sample that failed the assessment criteria returned a value of 5.5% after the second cycle. As detailed in Section 2.2.5 and AS/NZS 1328.1 (1998) the sample was then subjected to a third cycle where delamination was recorded as 6.4% and within the assessment criteria of Clause 2.6.4 to "Pass". In summary all 20 samples tested produced a "Pass" after the required number of cycles. The values for total delamination percentage are presented in the appendices.

4. Conclusions

The product performance testing as required by AS/NZS 1328.1 (1998) was conducted for both mechanical properties and bond integrity of cypress finger jointed laminates and GLT beams manufactured by Eco Cottages. The results of the mechanical performance testing and bond integrity tests are summarised as follows:

- Beam shear testing resulted in 80% of the tested material failing in shear. Two of the 10 beams tested produced a bending failure and were disregarded for the analysis.
- Delamination assessment found all (100%) of the samples passed the maximum allowable glue line delamination and total delamination cut off for a service class 3 product after the required number of cycles.

This report serves as a preliminary report on the performance of the Cypress GLT beams and the laminates they are developed from. The following steps from this point are to conduct further qualification testing in liaison with the Engineered Wood Product Association of Australasia (EWPAA). Planned discussions on testing regime are to take place before the end of April 2022.

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