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Technical Report

Charring Model for Plantation Oak MASSLAM

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1 Executive Summary

Australian Sustainable Hardwoods (ASH) has engaged Halliwell to prepare a technical report assessing the charring rate and effective char depth of glue-laminated timber (GLT) beams and columns manufactured from Plantation Oak timber when exposed to fire conditions in accordance with AS 1530.4:2014. ASH brands its GLT products under the brand name MASSLAM, and as such, the GLT elements manufactured from Plantation Oak will be referred to as Plantation Oak MASSLAM throughout this report.

AS/NZS 1720.4:2019 provides a method for determining the charring rate of timber, including GLT. However, its application is conditional on the GLT being manufactured in accordance with AS/NZS 1328.1, using approved structural adhesives such as phenol, resorcinol, phenol-resorcinol, or poly-phenolic adhesives. However, the Plantation Oak MASSLAM is bonded using Henkel Purbond HBS polyurethane adhesive, which does not fall within the list of approved adhesives under AS/NZS 1328.1. Therefore, the standard charring models outlined in the code are not applicable. To address this, bespoke fire testing was conducted to evaluate the fire performance characteristics.

The referenced test, FRT220217, involved exposing a representative Plantation Oak MASSLAM beam to a standard fire curve, with thermocouples embedded at various depths to monitor internal temperatures and identify the progression of charring. The data collected was used to establish a conservative linear charring model.

The analysis resulted in a charring rate of 0.673 mm/min, and when accounting for the zero-strength layer (ZSL), the effective char depth (in mm) is defined by the following model:

$$d_{eff} = 0.673 \times t + 7$$

This model provides a basis for evaluating the residual section of Plantation Oak MASSLAM when exposed to AS 1530.4:2014 fire conditions and can be used to support structural fire design in accordance with AS/NZS 1720.4:2019.

The outcome of this assessment is valid till 30 June 2030.

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2 Introduction

2.1 General

Australian Sustainable Hardwoods (ASH) has engaged Halliwell to prepare a technical report outlining the charring rate and effective char depth of glue-laminated timber (GLT) beams and columns manufactured from Plantation Oak timber when exposed to fire conditions in accordance with AS 1530.4:2014.

While AS/NZS 1720.4:2019 provides a method for determining the charring rate of timber, including GLT, its application is conditional on the GLT being manufactured in accordance with AS/NZS 1328.1, using approved structural adhesives such as phenol, resorcinol, phenol-resorcinol, or poly-phenolic adhesives. However, the Plantation Oak MASSLAM is bonded using Henkel Purbond HBS polyurethane adhesive, which does not fall within the list of approved adhesives under AS/NZS 1328.1.

Due to this deviation, an experimental investigation was undertaken to determine the charring behaviour of ASH's Plantation Oak GLT. This report presents the findings of that investigation and subsequently develops an appropriate charring model specific to the Plantation Oak MASSLAM.

2.2 The scope and limitations of this report

The scope of the technical report is limited to the below:

- This report provides the expected charring rate for Plantation Oak MASSLAM when exposed to AS 1530.4:2014 fire conditions only. The response of these GLT for any other fire scenario is not part of the scope of this report.
- The outcome of this report is only applicable for beams and columns made of Plantation Oak GLT.
- The outcomes of this report can be used to determine the fire resistance level (FRL) of Plantation Oak MASSLAM beams and columns in accordance with AS/NZS 1720.4:2019.
- The design of Plantation Oak MASSLAM beams and columns is not part of the scope of this report.
- This report has been prepared based on information provided by the report sponsor including test reports, fire assessment reports and material properties. We have not independently verified the accuracy of this information and therefore cannot be held responsible for any errors or omissions that may be present in this report as a result.
- This report was prepared at the request of Australian Sustainable Hardwoods (ASH) for their specific purposes. Structural engineers, fire safety engineers, building certifiers, approval authorities, and other third parties are responsible for determining the suitability of using the outcomes of this report for a given construction circumstance.

- The client must withdraw this report from circulation if the component or element of structure is the subject of a fire test by a test authority in accordance with the standard against which this report is being prepared and the results are not in agreement with this report. They must also withdraw this report if they get to know any information that could adversely affect the conclusions of this report.

3 Background Information

3.1 General

This technical report was prepared based on the test evidence listed in Table 1.

Table 1 Test evidence

Report	Issuing authority	Test date
FRT220217 R1.0	Warringtonfire	31 January 2023

3.2 Evidence

3.2.1 Fire test report

The fire test report FRT220217, dated 28 February 2023 and issued by Warringtonfire, outlines the fire resistance performance of a composite floor system tested in accordance with AS 1530.4:2014. The tested assembly measured 2950 mm × 4350 mm and comprised a 100 mm thick concrete slab reinforced with SL72 mesh, 21 mm plywood sheathing, and glue-laminated timber (GLT) beams measuring 240 mm wide × 370 mm deep × 4350 mm long. The GLT beams were produced by Australian Sustainable Hardwoods (ASH) using Plantation Shining Gum (Plantation Oak) and bonded with a polyurethane adhesive. The test also included a 1000 mm long instrumented GLT beam to monitor internal temperature development and charring behaviour.

The results were used to assess the system's structural adequacy, integrity, and insulation performance, and provided valuable data on the charring characteristics of Plantation Oak MASSLAM. The fire exposure duration was 121 minutes, carried out in accordance with AS 1530.4:2014.

4 Technical discussion

This technical report aims to develop a charring rate model for Plantation GLT produced by ASH. As the GLT uses Henkel Purbond HBS polyurethane adhesive, which is not included in the list of approved structural adhesives under AS/NZS 1328.1, the charring rate models prescribed in AS/NZS 1720.4:2019 cannot be applied. Consequently, an experimental investigation was necessary to determine the charring behaviour of this material.

To support this, the results from fire test FRT220217 were utilised. As detailed in Section 3.2.1, the test assembly included a 1000 mm long instrumented Plantation Oak MASSLAM beam, specifically designed to capture temperature data for charring analysis. Figure 1 illustrates the internal thermocouple (TC) layout, with TCs strategically positioned along both the vertical and horizontal axes of the beam at various depths.

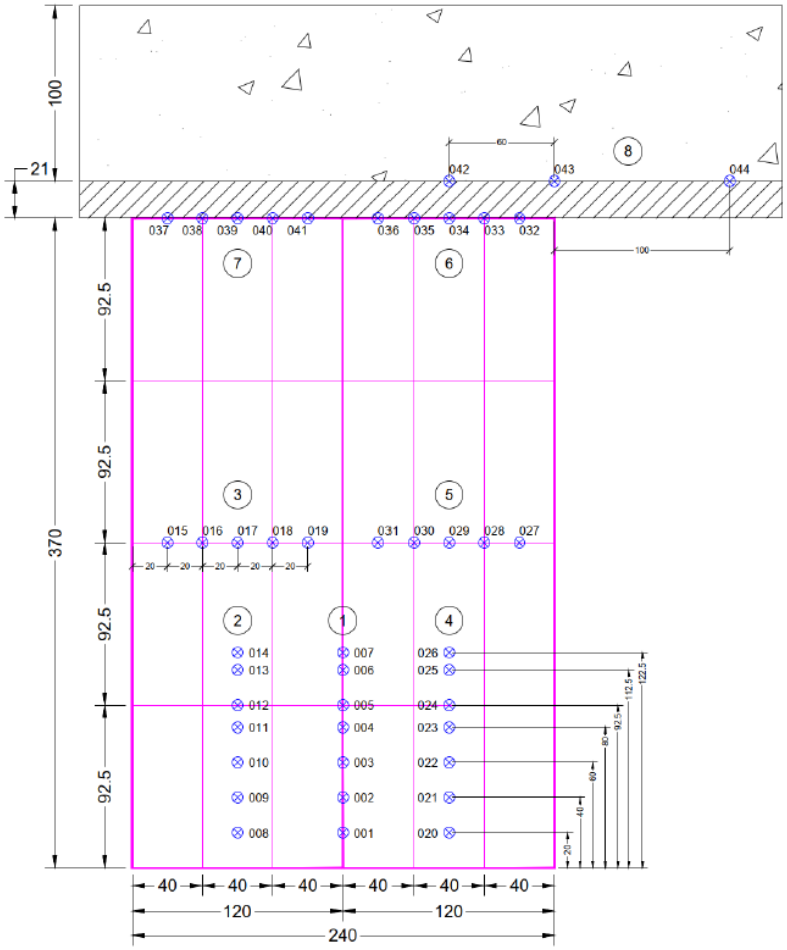

Figure 1 Internal thermocouple locations

These thermocouples were used to evaluate the thermal penetration and charring behaviour of the GLT specimen. Charring was considered to occur when the temperature at a given depth reached 300 °C. By analysing the time taken for each internal thermocouple to reach this threshold, the progression of the char front within the beam could be determined, enabling the derivation of a representative charring rate model for Plantation Oak MASSLAM.

Table 2 Internal thermocouple measurements

	Thermocouple ID	Depth (mm)	Time to reach 300 °C (in minutes)
Along vertical axis – Set 1	TC_01	20	36.6
	TC_02	40	74.3
	TC_03	60	112.7
	TC_04	80	–
	TC_05	92.5	–
	TC_06	112.5	–
	TC_07	122.5	–
Along vertical axis – Set 2	TC_08	20	26.5
	TC_09	40	60.4
	TC_10	60	86.6
	TC_11	80	87.3
	TC_12	92.5	90.6
	TC_13	112.5	113.1
	TC_14	122.5	120.3
Along vertical axis – Set 3	TC_20	20	30.9
	TC_21	40	63.6
	TC_22	60	88.5
	TC_23	80	114.4
	TC_24	92.5	121.0
	TC_25	112.5	–
	TC_26	122.5	–
Along horizontal axis – Set 1	TC_15	20	45.6
	TC_16	40	95.3
	TC_17	60	111.8
	TC_18	80	–
	TC_19	100	–

Along horizontal axis – Set 2	TC_27	20	60.3
	TC_28	40	95.4
	TC_29	60	–
	TC_30	80	–
	TC_31	100	–

Table 2 presents the internal thermocouple measurements, showing the time at which each thermocouple reached the 300 °C threshold – indicating the point at which charring initiated at the corresponding depth.

Of the thermocouples installed, data from TC_11, TC_12, TC_13, TC_14, TC_23, and TC_24 were excluded from the analysis. Although these thermocouples were positioned along the vertical axis from the bottom face of the beam, they were located approximately 60 mm from the beam's sides. As a result, these positions may have experienced early temperature rise due to horizontal char front penetration, rather than from direct vertical heat transfer. This makes their data non-representative of one-dimensional vertical charring. To maintain the accuracy of the char rate analysis, these thermocouples were therefore excluded from the dataset.

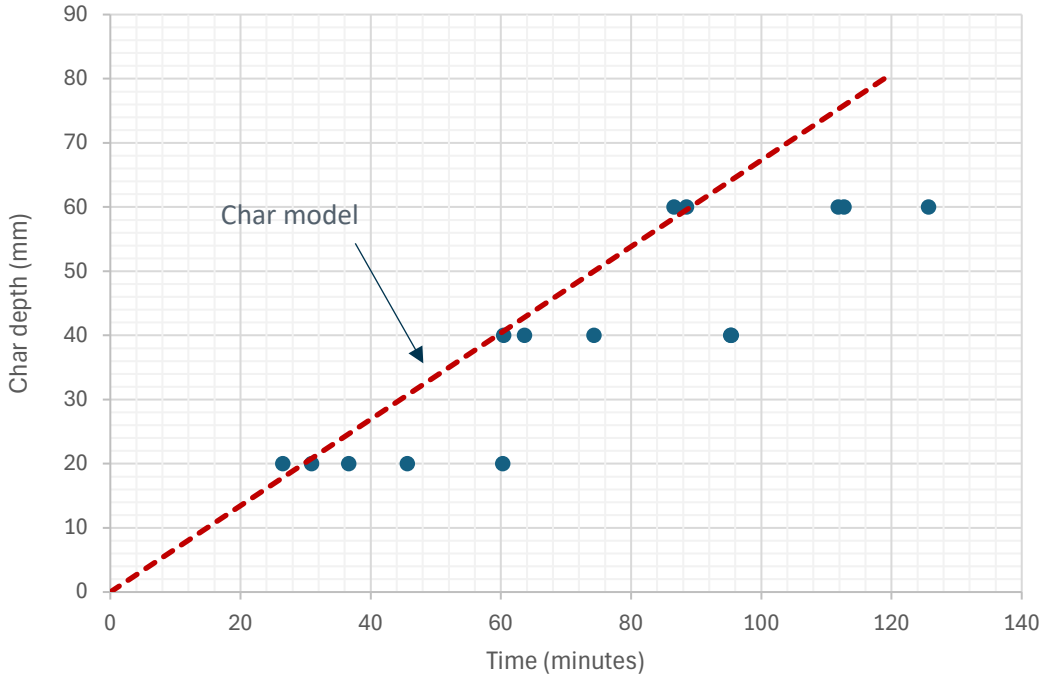

Figure 2 Proposed char model

Figure 2 presents the plotted data points showing the measured char depths against the corresponding time to reach each char depth, based on internal thermocouple readings. The proposed charring rate model is also plotted on the same graph for comparison. As shown, the proposed model demonstrates a conservative trend, with most data points falling below the model line. This indicates that the developed model provides a robust and reliable representation of the charring behaviour of Plantation Oak MASSLAM under standard fire exposure conditions.

Based on the results, the developed charring model for Plantation Oak MASSLAM under AS 1530.4:2014 fire exposure is expressed as:

$$d = 0.673 \times t$$

where:

- d = char depth (mm)
- t = time of exposure (min)

To account for the zero-strength layer (ZSL) as per AS/NZS 1720.4:2019, the effective char depth is calculated using:

$$d_{eff} = 0.673 \times t + 7$$

5 Conclusions

This report has established a charring rate model for Plantation Oak MASSLAM when exposed to standard fire conditions in accordance with AS 1530.4:2014. Due to the use of a non-listed adhesive (Henkel Purbond HBS polyurethane), standard charring models from AS/NZS 1720.4:2019 could not be directly applied, necessitating an experimental investigation.

Based on results of fire test report FRT220217, a linear charring rate of 0.673 mm/min has been developed. When accounting for the zero-strength layer ZSL, the effective char depth (in mm) is given by:

$$d_{eff} = 0.673 \times t + 7$$

This model provides a basis for evaluating the residual section of Plantation Oak MASSLAM when exposed to AS 1530.4:2014 fire conditions and can be used to support structural fire design in accordance with AS/NZS 1720.4:2019.

Appendix A – Experience and Qualifications of Halliwell

Halliwell Fire Science within the Halliwell is a group of highly qualified international experts in fire safety science and engineering with extensive experience in passive fire product/system development, fire testing and fire assessments. Our team is well-versed in providing research-based expert services related to fire testing and fire assessments conforming to Australian, New Zealand and European test standards.

Role	Personnel	Qualifications and relevant experience
Author	Dr. Imran Ahamed	BSc (Civil Engineering) PhD (Structural Fire Engineering) CPEng (Structural and Fire Safety) MIEAust NER, RPEQ, RPEV IFE Level 3 Certificate in passive fire protection 10 years of experience in fire research, testing and assessments
Reviewer	Dr. Ryan Hilditch	BSc (Fire Safety Engineering) PhD (Fire Safety Engineering) CPEng (Fire Safety) MIEAust NER, RPEQ, APEC Eng, IntPE(Aus) 15 years of experience in fire safety strategy and quantitative assessments