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CHEMISTRY AND CHEMICAL ENGINEERING DIVISION





PROPOSED FIRE PERFORMANCE ASSESSMENT METHODOLOGY FOR QUALIFYING CROSS-LAMINATED TIMBER ADHESIVES DEVELOPED FOR THE AMERICAN WOOD COUNCIL:

MASS PLYWOOD PANEL EXPERIMENTAL RESULTS

FINAL REPORT Consisting of 42 Pages

SwRI^{*} Project No.: 01.23086.01.001c Test Date: September 27, 2017 Report Date: October 27, 2017

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EXECUTIVE SUMMARY

SwRI developed a full-scale room fire test method for assessing the performance of crosslaminated timber (CLT) adhesives for the American Wood Council (AWC). A mass plywood panel (MPP) manufactured by Hexion, Inc., and Freres Lumber Company, Inc., was evaluated to this proposed test method on September 27, 2017, at Southwest Research Institute's (SwRI's) Fire Technology Department, located in San Antonio, TX.

SwRI constructed a test room within one of its large open buildings. The building is approximately 40×60 ft by 36 ft high, and is connected to a pollution abatement system for safe and effective removal of combustion products. The interior dimensions of the test room were approximately 9×19 ft by 8 ft high, with a ventilation opening in the front narrow wall, which was nominally 36 in. wide by 75 in. high. The room was built directly on the test facility floor, which was protect with gypsum board inside the room. The walls of the test room were lined with several layers each of type X gypsum board and ceramic fiber blanket. The 8×16 ft mass plywood panel (MPP) was simply supported along the narrow ends, but allowed to deflect freely between the two sidewalls. Before the start of the test, concrete blocks were placed on the MPP to impose a distributed structural load of 20 psf (0.96 kN/m²). A 2 × 6 ft by 1 ft high propane gas diffusion burner was located in the back section of the room, and provided the target fire exposure. Instrumentation included thermocouples, directional flame thermometers (DFTs), and a propane gas flow sensor. Temperatures were monitored within the MPP at the center of the panel, at five locations 4 in. below the ceiling, in the front right corner of the test room, and at the ventilation opening (door thermocouple tree). Heat fluxes were measured with four DFTs located 1 ft. below the ceiling on the sidewalls (two on each side).

Testing was performed on an 8×16 ft MPP, consisting of seven 1 in. thick Douglas fir structural composite lumber panels, each bonded with phenol formaldehyde resin supplied by Georgia-Pacific using a hot press. The structural composite lumber panels were bonded together into the mass plywood panel (total thickness of 6 7/8 in. or 175 mm) using Hexion, Inc., EcoBindTM 6500 with WonderbondTM Hardener M650Y, with average density of 36 pcf and average moisture content of 11.2% at the time of testing. The test duration was 240 min, and no delamination was observed during the cooling phase (\geq 58 min) of the tests.

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1 INTRODUCTION

SwRI developed a full-scale room fire test method for assessing the performance of crosslaminated timber (CLT) adhesives for the American Wood Council (AWC). A mass plywood panel (MPP) manufactured by Hexion, Inc., and Freres Lumber Company, Inc., was evaluated to this proposed test method on September 27, 2017, at Southwest Research Institute's (SwRI's) Fire Technology Department, located in San Antonio, Texas.

This report describes the proposed test method and the results of the testing for the MPP. The results presented in this report apply only to the materials tested, in the manner tested, and not to any similar materials or material combinations.

2 TEST APPARATUS

2.1 Test Room

SwRI constructed a test room within one of its large open buildings. The building is approximately 40×60 ft by 36 ft high, and is connected to a pollution abatement system for safe and effective removal of combustion products. The building has a false ceiling at 30 ft with a gap of approximately 18 in. around the perimeter. The interior dimensions of the test room were approximately 9 ft 4 in. \times 19 ft by 8 ft high. The dimensions of the ventilation opening in the front narrow wall was nominally 36 in. wide by 75 in. high. The test room was built directly on the concrete floor of the building, which was protected with two layers of 5/8 in. type X gypsum board. The front wall of the test room faced the back wall of the building, and was located at approximately 20 ft from the back wall. Combustion products were extracted from the plenum above the false ceiling at the back of the building, nearest the test room ventilation opening. A 6-ft wide strip of the false ceiling was removed near the exhaust duct to facilitate collection of combustion products generated in the fire.

Figure A-1 in Appendix A shows a picture of the finished test room taken from the ventilation opening in the front wall. Two steel I-beams (12×41 lbs/ft) welded together (see Figure A-2) were located at approximately 15 ft from the front wall to subdivide the test room into two sections. The ceiling of the front section was left open and allowed for the exposure of a 16 ft long by 8 ft wide mass timber ceiling panel. The MPP was simply supported by the front wall at one end (bearing length \approx 6 in.), and by the steel I-beam at the other end (bearing length \approx 5 1/4 in.). The sides of the panel were not supported, and the MPP was allowed to deflect freely between the two sidewalls. A gas burner to create the desired fire exposure was located in the back section of the room, as shown in Figure A-1. Construction details for the test room walls, floor and ceiling are as follows:

- *Front Wall*—The front wall of the test room consisted of 8 ft tall, 6 in. deep, 16 gauge steel studs, 12 in. on center, with 16 gauge track top and bottom. The interior surface of the frame was covered with three layers of 5/8-in. type X gypsum board (National Gypsum Fire-Shield[®]), 20-gauge galvanized sheet steel, and three layers of 1 in. thick ceramic fiber blanket (Morgan Thermal Ceramics 6 pcf Cerablanket[®]). The exterior surface was covered with two layers of 5/8 in. type X gypsum board, 20-gauge galvanized sheet steel (top half only), and one layer of 1 in. thick ceramic fiber blanket (additional layers of blanket were used at the soffit and above the ventilation opening).
- *Sidewalls*—The sidewalls of the test room consisted of three layers of 4 ft wide by 10 ft tall 5/8 in. type X gypsum board attached to steel racks. The interior surface of the gypsum board was covered with three layers of 1 in. thick ceramic fiber blanket. An additional layer of blanket was attached to the sidewalls in the back section of the test room. In the front section of the test room, the web of a 6 in. steel stud covered with 16-gauge track was attached to the sidewalls at 8 ft above the floor. The bottom of the covered studs was protected with three layers of 5/8 in. type X gypsum board. Two layers were used to protect the vertical and top surfaces. The studs and track mounted along the sidewalls were used to reduce the width of the opening in the front section of the test room from 9 ft 4 in. to 8 ft 5 in. and prevent damage from falling debris to instrumentation attached to or located close to the sidewalls.
- *Back Wall*—The back wall of the test room consisted of 8 ft tall, 3 5/8 in. deep, 18-gauge steel studs, 12 in. on center, with 18-gauge track top and bottom. The interior surface of the frame was covered with four layers of 5/8-in. type X gypsum board and three layers of 1 in. thick ceramic fiber blanket. The exterior surface was not finished. An opening at the bottom of the back wall allowed the 2-in. propane pipe nipple from the burner to pass-through to connect to the supply hose outside the test room. The opening was sealed with ceramic fiber blanket.
- *I-beams*—The space between the exposed surfaces of the flanges and web were filled with several layers of 5/8 in. type X gypsum board, and the beams were then wrapped with four layers of 1 in. thick ceramic fiber blanket.
- *Back Section Ceiling*—The ceiling above the burner consisted of a spare 4.5×8 ft CLT panel, protected with four layers of 5/8 in. type X gypsum board and four layers of 1 in. thick ceramic fiber blanket. The front edge of the CLT panel was supported by one of the two I-beams. At the back edge, the CLT panel was attached to a $3 \frac{1}{2} \times 3 \frac{1}{2} \times \frac{1}{4}$ -in. angle iron welded to the racks supporting the sidewalls.

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Fastener details are as follows:

- First layer of gypsum board: 1 7/8 in. #6 type S bugle head drywall screws.
- Second layer of gypsum board: 2 1/2 in. #6 type S bugle head drywall screws.
- Third and fourth layer of gypsum board: 3 in. #8 type S bugle head drywall screws.
- First and second layer of ceramic fiber blanket: 4 1/2 in. coarse thread screws with 1 in. washers.
- Third and fourth layer of ceramic fiber blanket: 12-gauge galvanized steel wire bent into horseshoe shape.

Screw spacing was approximately 12 in. Wires were used where needed. All joints were staggered with at least 1 ft separation.

2.2 Gas Burner

A gas burner was constructed to create the exposing fire. The burner consisted of a 6×2 ft by 1 ft tall steel box with open top. Five pieces of 3×3 in. steel square tubing (1/4 in. wall) were welded to the bottom plate, elevating the burner approximately 3 in, above the floor (see Figure A-3). The burner was supplied with propane through a 2 in. pipe. The gas flow was evenly distributed to eight downward-facing release points as shown in Figure 1. The burner was filled with coarse gravel to ensure relatively uniform propane flow at the top surface (see Figure A-3).



Figure 1. Schematic of Burner Illustrating Distribution of Propane Flow.

2.3 Instrumentation

2.3.1 Room Interior Thermocouples

Three sets of thermocouples (TCs) were used to measure gas temperatures inside the compartment:

- *Hot Gas Layer (HGL) Thermocouples*—Five Duro-Sense 1/8 in. diameter, Inconel sheathed, exposed junction, type K TCs were located 4 in. below the MPP ceiling (see Figure A-4; note that this is a picture from one of the calibration tests performed prior to the AWC test series, in which the same TCs were used to measure the HGL temperature). One TC was located at the center of the MPP ceiling, and the other TCs were located at the four quadrants (as measured from the entire MPP dimension, not just the exposed area).
- *Door Thermocouple Tree*—Six Duro-Sense 1/8 in. diameter, Inconel sheathed, grounded junction, type K TCs were located in the open doorway (see Figure A-5). The TCs were used to measure the inflowing and outflowing gas temperatures at 0.5, 1.5, 2.5, 3.5, 4.5, and 5.5 ft above the test room floor.
- *Room Thermocouple Tree*—Eight self-renewing, fast-response, type K TCs from Nanmac Corporation were used to measure the temperature profile inside the room. The thermocouple junctions were located at 12 in. from the front wall and 4 in. from the right sidewall. The TCs were used to measure the room gas temperatures at 0.5, 1.5, 2.5, 3.5, 4.5, 5.5, 6.5, and 7.5 ft above the test room floor (see Figure A-6).

2.3.2 Thermocouples Embedded in MPP

Seven Duro-Sense 1/16 in. diameter, Inconel sheathed, grounded junction, type K TCs were embedded at different depths from the top (unexposed side) surface of the MPP (see Figure A-7, note that this is from another test performed as part of the AWC test series). The thermocouples were located at the following depths from the top surface: 164, 152, 140, 129, 117, 105, and 70 mm deep (same as other CLT panels tested as part of the AWC test series, but these depths may not coincide with glue lines in the MPP panel).

2.3.3 Directional Flame Thermometers

Directional flame thermometers (DFTs) were used to measure heat fluxes to four locations, two on the right wall and two on the left wall. The DFTs were placed approximately 1 ft below the ceiling, and aligned with the HGL TCs at the quadrants. Each DFT consisted of ceramic fiber insulation sandwiched in between two Inconel plates (see Figure A-8). Inconel-sheathed TCs are attached to the interior of the plates. Since the thermal properties of the plates and the insulation are known, the incident heat flux can be calculated based on the measured plate temperatures. The process is described in ASTM E3057. In this report, it is assumed the gas temperature at a DFT is equal to the HGL temperature measured at the nearest quadrant, and the convection coefficient is equal to $10 \text{ W/m}^2 \cdot \text{K}$. In addition to the incident heat flux, the radiant heat flux emitted by the exposed plate is also reported to facilitate comparison with plate thermometer measurements. The emitted heat flux was calculated from:

$$\dot{q}_{e}^{"} \approx \epsilon \sigma T_{s}^{4}$$

ġ _e	=	Emitted heat flux (kW/m^2) ;
3	=	Surface emissivity of the Inconel plate (≈ 0.85);
σ	=	Boltzmann constant (5.67 \cdot 10 ⁻¹¹ kW/m ² ·K ⁴); and
T _s	=	Plate temperature (K)

2.3.4 Heat Release Rate Measurements

A gas sampling probe and flow sensor were installed in the exhaust duct of the building, in an attempt to measure heat release rate (HRR) based on oxygen consumption calorimetry. Unfortunately, during the test the plume hit the false ceiling, and, as a result, part of the combustion products drifted toward the front of the building and were not extracted by the exhaust system. To account for the fraction of fire effluents that is not collected, a correction factor was established as a function of the measured HRR of the fire based on gas burner calibration data. The accuracy of the adjusted HRRs is estimated to be $\pm 10\%$.

2.3.5 Video and Photographic Documentation

Two video cameras were used to obtain footage of the fire compartment from two angles. The primary video camera was used to obtain general video footage of the fire for the entire duration of the test. The second video camera was directed at the ceiling to monitor delamination, but was only used during the cooling phase when the burner HRR was reduced back to 250 kW (see Section 3 below). Photographic documentation was obtained prior to, during, and following the test.

3 BURNER HEAT RELEASE RATE PROFILE

The propane was supplied from two tanks via a vaporizer, a regulator, and a 2 in. diameter pipe with several shut-off valves and a control valve. The propane flow rate was manually controlled, and measured with a Coriolis mass flow sensor (Micro Motion, Inc., Boulder, Colorado, Model CMF050M315NQFUEZZ). The burner profile developed for AWC is shown in Table 1 and Figure 2.

Start	End	HRR
(min)	(min)	(kW)
0	13	250
13	38	1075
38	58	1377
58	88	834
88	End of Test	250

Table 1. Burner HRR Step Profile.





4 TEST SAMPLE

The MPP measured 8×16 ft, and consisted of seven 1 in. thick Douglas fir structural composite lumber panels, each bonded with phenyl formaldehyde resin supplied by Georgia-Pacific using a hot press. The structural composite lumber panels were bonded together into the MPP (total thickness of 6 7/8 in. or 175 mm) using Hexion, Inc., EcoBindTM 6500 with WonderbondTM Hardener M650Y (a melamine formaldehyde resin system, technical data sheet and product bulletin are provided in Appendix B).

The nominal density and moisture content measurements for the MPP sample are given in Table 2. The moisture content was measured shortly before the start of the test with a Delmhorst RDM³ moisture meter.

Physical Quantity	Measured Values
Nominal Density (pcf)	36
Front Left Moisture Content (%)	11.6
Front Right Moisture Content (%)	10.8
Ceiling Center Moisture Content (%)	10.8
Back Left Moisture Content (%)	11.5
Back Right Moisture Content (%)	11.4
Average Moisture Content (%)	11.2

 Table 2. Nominal Densities and Moisture Contents.

5 TEST RESULTS

Prior to the test, concrete blocks were placed on the MPP to impose a distributed structural load of 20 psf (0.96 kN/m²) as shown in Figure A-9. The test was conducted Wednesday, September 27, 2017. The data acquisition system was started at approximately 9:16 AM, and the burner flow was initiated at approximately 9:20 AM. Temperature and relative humidity in the laboratory at the start of the test were 74.8 °F (24 °C) and 84.7%, respectively. The test was terminated at approximately 1:20 PM.

Photographs and graphical test results are provided in Appendix C and D, respectively. Delamination was not observed in the cooling phase. Table 3 summarizes HGL TC temperatures and Table 4 summarizes DFT heat fluxes at specific times during the test, which coincide with the burner step-profile.

Post-test samples were cut from areas in the MPP close to the HGL TC locations. Photographs of the samples provide a qualitative indication of the char depth and can be found in Appendix D. The absence of a (thick) char layer in these pictures should not be interpreted as evidence of delamination since significant amounts of char fell off during extinguishing, post-test removal of the MPP from the test room, and cutting of the samples.

Char depths based on average residual wood thickness measurements on four sides of the sample are provided in Table 5. Since the heat fluxes and temperatures were lower in the front of the room compared to the center and the back, the char depths generally increase from front to back.

Figure D-10 shows the HRR measurements. A peak HRR of 2740 kW was recorded at approximately 15 min, i.e., 2 min after the burner HRR increase from 250 kW to 1075 kW. However, the peak was short-lived as a protective char layer quickly developed. The validity of the HRR measurements can be confirmed by comparing the effective heat of combustion to literature values. Hexion, Inc., and Frees Lumber Company, Inc. 7 SwRI Project No. 01.23086.01.001c

The effective heat of combustion is equal to the total heat released divided by the total mass lost over the four-hour test duration. The total heat released is equal to 3306 MJ (area under the blue curve in Figure D-10 minus area under the red curve). Assuming an average char depth of 59 mm (from Table 5), exposed area of 7×14 ft (accounting for the ceramic fiber protection around the perimeter), and a char yield of 15%, the total mass lost is estimated at 264 kg. The corresponding effective heat of combustion is 12.5 MJ/kg, which is consistent with literature values for Douglas fir plywood.

Test Time	HGL TC Temperatures (°C)			
	Min.	Avg.	Max.	
13 min	239	250	258	
38 min	933	981	1025	
58 min	1000	1069	1131	
88 min	899	918	937	
\geq 120 min	402	415	432	

 Table 3. Summary of HGL TC Temperature Data.

Table 4.	Summary	of DFT	Heat	Flux Data.
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Test Time	Incident Heat Flux (kW/m2)				
	Front Left	Front Right	Back Left	Back Right	
38 min	104	105	130	129	
58 min	148	148	199	202	
88 min	86	87	102	99	
\geq 120 min	11	11	14	14	

Table 5. Test Duration and Measured Char Depths.

Physical Quantity	Measured Values
Test Duration (min)	240
Front Left Char Depth (mm)	48.3
Front Right Char Depth (mm)	49.8
Ceiling Center Char Depth (mm)	55.8
Back Left Char Depth (mm)	70.8
Back Right Char Depth (mm)	74.8

APPENDIX A GENERAL PHOTOGRAPHS (CONSISTING OF 5 PAGES)



Figure A-1. View into Finished Test Room Through Open Door in Front Wall.



Figure A-2. Double Beam Separating Burner Section from Specimen Exposure Area.



Figure A-3. Gas Burner.



Figure A-4. Hot Gas Layer Thermocouple (AWC Calibration Test).



Figure A-5. Door Thermocouple Tree.



Figure A-6. Room Thermocouple Tree.



Figure A-7. Embedded Thermocouples (CLT Panel from AWC Test Series).



Figure A-8. Directional Flame Thermometers (DFTs).



Figure A-9. Applied Structural Load (CLT Panel from AWC Test Series).

APPENDIX B ADHESIVE DATA SHEET AND PRODUCT BULLETIN (CONSISTING OF 5 PAGES)

Technical Data Sheet



EcoBind[™] 6500 with Wonderbond[™] Hardener M650Y

Description

EcoBind[™] 6500 with Wonderbond[™] Hardener M650Y is a liquid melamine formaldehyde resin system designed for separate application directly to the substrate for the manufacture of engineered wood products including gluelaminated timber (glulam), cross-laminated timber (CLT) and finger jointed lumber. When properly applied and cured at temperatures above 65°F, the durable weather-proof, heat-resistant structural bond necessary for ambient cure glulam and CLT is created. EcoBind[™] 6500 with Wonderbond[™] Hardener M650Y is also well suited to operations using radio frequency cure.

Typical Physical Properties (at time of manufacture)

Property	Specification	Test Method
6500		
Viscosity	1900-2200cps	Brookfield RV #4 spindle/20 rpm/25°C @ 1 min
рН	9.6-10.0	25°C (77°F)
Solids	69-71%	Convection Oven, 105°C (221°F), 180 minutes
Density	10.2-10.6 lbs/gal	Gardner Weight per Gallon (US) Cup @ 25°C
M650Y		
Viscosity	2400-3000cps	Brookfield RV #4 spindle/20 rpm/25°C @ 1 min
рН	1.2-1.8	25°C (77°F)
Solids	14%	Calculated
Density	9.0 lbs/gal	Gardner Weight per Gallon (US) Cup @ 25°C

Performance Properties

Property	Specification	
ASTM D 2559	Douglas fir, Southern yellow pine	
ASTM D 1151 Exposure 3 and 20	Douglas fir	
ASTM D 1183 Test Condition D	Douglas fir	
CSA 0112.9-10 B ₂ Creep	Douglas fir	
CSA 0112.9-10		
CSA 0177-06 small-scale bondline fire perf	ormance equivalency tests	

ASTM D7247-16 according to the criteria set in ANSI 405-13, ANSI PRG 320-12, ASTM D5456-14 and ASTM D 5055-13

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Before using any Hexion Inc. product, please be sure to read the Safety Data Sheet which was included with the shipment.

For more information contact your local Hexion Sales Representative or Customer Service Center (866) 443-9466.

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Product Bulletin

Ecobind 6500 and Wonderbond Hardener M-650Y (Cold Set)



Description

Ecobind 6500 is a liquid melamine formaldehyde resin that is used with a liquid hardener M-650Y in the manufacture of glued laminated beams (glulam). When the adhesive system is applied according to the instructions in this Bulletin, a structural bond is achieved. Ecobind 6500 with Wonderbond Hardener M-650Y is well suited for ambient temperature cure above 60°F.

Third Party Test Methods

Ecobind 6500 with Wonderbond Hardener M-650Y has been independently tested and demonstrated to meet the requirements of the following methods.

- ANSI/AITC 405-2005
 - ASTM D2559
 - ASTM D1151 Exposure 3 and 20
 ASTM D1183 Test Condition D

(Douglas-fir, Southern yellow pine)

- (Douglas-fir) (Douglas-fir)
- D (Douglas-fir) (Douglas-fir)
- CSA 0112.9-04
- CSA O177-06 small-scale bondline fire performance equivalency tests
- ASTM D7247-07a according to the criteria set in ASTM D5055-07

Resin Storage

The recommended storage temperature for Ecobind 6500 resin is 70-80°F.

Ecobind 6500 does not show a tendency for fillers to settle during extended storage, therefore mixing is not required.

Table 4

Table 1			
Storage Temperature	Usable Life		
50°F (4°C)	4 months		
70°F (24°C)	3 months		
90°F (32°C)	2 months		

GREENGUARD Certified products are certified to GREENGUARD standards for low chemical emissions into indoor air during product usage. For more information, visit ul.com/gg.

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Hardener Storage

Wonderbond Hardener M-650Y can be stored for 6 months in the original containers. It should be protected against freezing and should not be stored below 10°C (50°F) or above 32°C (90°F) for extended periods.

Physical Data

Ecobind 6500 resin is a brownish-colored liquid that is typically within the manufactured viscosity range of 1800 - 2200 cps at 25°C (Brookfield RVT model, #4 spindle, 20 rpm). The weight per gallon is 10.4. The viscosity will decrease with an increase in temperature, as shown in the figure below.



Wonderbond Hardener M-650Y is a yellow liquid that is typically within the viscosity range of 2500 - 3500 cps at 25°C (Brookfield RVT model, #4 spindle, 20 rpm). The pH is approximately 1.3, and the weight per gallon is 9.0. The viscosity will decrease with an increase in temperature, as shown in the figure below.



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Mixing Instructions

Mixing the resin with the hardener prior to application is not recommended

For gluing operations use a separate application machine with direct application of the resin and hardener:

Lumber Preparation

The lumber moisture content for face bonding applications should range between 8% and 15%, with a variation of less than 4% between adjacent surfaces.

Lumber should be free of dirt and other foreign substances prior to gluing. All lumber should have a maximum thickness variation of 0.008 inches across the width.

Spread Rates, Assembly Times and Clamp Times

In face bond applications the recommended adhesive spread rate is 70 lbs/1000 ft² at temperatures below 80°F, and above 80°F, 80- lbs/1000 ft2 is recommended.

Assembly time is the time elapsing between adhesive application and pressure application. It can be subdivided into open assembly time (the adhesive is exposed to open air) and closed assembly time (the boards are brought into contact but not under pressure).

In general, open assembly time should be kept as short as possible and limited to a maximum of 15 minutes. On the other hand, closed assembly time is often beneficial, particularly when dense wood is being bonded. The maximum total assembly time depends on the adhesive mix ratio, adhesive spread rate, temperature and moisture content of the lumber, and the temperature, relative humidity, and air circulation in the gluing area.

Table 2 Maximum Total Assembly Time Tolerance with Minimum Clamp Time of Ecobind 6500/ Wonderbond Hardener 650Y at Specified Applied Ratio

For Ambient Temperature (Cold Set) Applications

	Glue Spread Rate			
Lumber Temperature	Applied Ratio	70- lbs / 1000 ft ²	80- lbs/ 1000 ft ²	Minimum Clamp
	(Resin:Hardener)			time (Hours)
60°F	1.5:1	90-minutes	n/a	5-Hours
70°F	2.0:1	90-minutes	90-minutes	5-Hours
80°F	2.0:1	90-minutes	90-minutes	4-Hours
90°F	2.5:1	n/a	60-minutes	3-Hours

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Pressure

The clamping pressure when face bonding softwoods should be 120-150 psi, with the preferred pressure 135 psi.

Cure Time (Cold Set Glulam)

Table 2 lists the minimum clamp time at glueline temperatures above 60°F. The minimum total cure time can be all clamp time or it can include both clamp time and post cure. Post cure at least 24-hours to achieve full performance cure.

Maintain clamping pressure for as many hours as required by the table. Place thermocouples in the center of the coolest glue line to check the temperature. Heating is needed when the instrument reads below 60°F. Consider that the glue line starts curing when the temperature reaches 60°F. The Following example shows the use of the table:

- Instrument reads 45-50°F when beam is locked up. Heating is started. When the temperature reaches 60°F, start timing. Beam is held at 60-65°F for 2 hours and heated to 70-75°F and held for 3 hours. Pressure may now be released.

Cleaning

Application equipment should not be cleaned at the end of the working day, only the extruders and strainers and as needed while in use. If the glue thickens in the application equipment, the equipment should be immediately emptied and cleaned before the adhesive hardens.

Cured glue is insoluble, but will become brittle and can be scraped off.

Warm water (50-60°C, or 120-140°F) is recommended for cleaning the mixed adhesive, resin and/or hardener. Prior to rinsing any water onto the equipment, drain cold water from the pipes and ensure that the water will be warm.

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APPENDIX C TEST PHOTOGRAPHS (Consisting of 11 Pages)



Figure C-1. Prior to Testing.



Figure C-2. Test at 1 min.



Figure C-3. Test at 12 min.



Figure C-4. Test at 13 min 45 s: Ignition of Gypsum Board Paper at Burner.



Figure C-5. Test at 14 min 40 s: Flames on Floor Spread to Door.



Figure C-6. Test at 37 min.



Figure C-7. Test at 39 min.



Figure C-8. Test at 57 min.



Figure C-9. Test at 60 min.



Figure C-10. Test at 87 min.



Figure C-11. Test at 89 min.



Figure C-12. Test at 120 min.



Figure C-13. Test at 150 min.



Figure C-14. Test at 180 min.



Figure C-15. Test at 210 min.



Figure C-16. Test at 240 min.



Figure C-17. Test at 242 min.



Figure C-22. Post-Test Picture of MPP Following Extinguishment.

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Figure C-23. Post-Test Picture of Char Layer (Right Side).



Figure C-24. Post-Test Picture of MPP Removed from Test Structure.



Figure C-25. Char Depth: Front Left – Front Right - Original.



Figure C-26. Char Depth: Back Left – Ceiling Center – Back Right.

APPENDIX D GRAPHICAL TEST RESULTS (CONSISTING OF 5 PAGES)



Figure D-1. Door TC Tree Temperatures (Door TC-66 dropped out during test).



Figure D-2. Room TC Tree Temperatures.







Figure D-4. DFT Exposed Plate Temperatures.







Figure D-6. Front Left DFT Heat Flux.







Figure D-8. Back Left DFT Heat Flux.



Figure D-9. Embedded TC Temperatures.



Figure D-10. Estimated Heat Release Rate (See Section 2.3.4).