Developments in Adhesive Systems for Finger-Jointed & Glulam Wood Products

Wood Manufacturing 2007

28-30 March 2007, Rotorua, New Zealand
2-4 April 2007, Melbourne, Australia

Walter Stampfli, General Manager
www.purbond.com

Projects

“Wave” Railway Station in Berne, Switzerland

Spruce
Face gluing
PURBOND® HB 181
Year 2005
Projects

Salt Storage “Saldome”, Switzerland (1)

Projects

Eden Project, England
Purbond is a joint venture between Collano and National Starch & Chemical.

Background

Adhesive systems for engineered wood

Purbond is a joint venture between Collano and National Starch & Chemical.
History of Glulam

- **Technology:**
  - ~1900 Development of the Engineered Wood Technology (Karl Friederich Otto Hetzer, Germany)
  - ~1930 DIN 1052
  - ~1940 Development of Finger Jointing

- **Adhesive for Engineered Wood:**
  - ~1900 Casein adhesive
  - ~1930 Urea-formaldehyde adhesive
  - ~1940 Resorcinol-formaldehyde adhesive
  - ~1970 Melamine-formaldehyde adhesive
  - ~1990 1K-PUR adhesive

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PURBOND – History of 1 C PUR Adhesives

- 1937 Invented by Bayer, Germany
- 1953 1C PUR adhesives for wood, leather, fabric etc.
- 1985 First applications of 1C PUR adhesives for glulam
- 1994 First 1C PUR - PURBOND HB 110 adhesive approved for engineered wood applications at the Otto Graf-Institute
- 2007 app 13 approved 1C PUR-adhesives from 4 different companies in Europe are approved in Germany – 8 products from Purbond

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**Definition: Engineered Wood**

- Load bearing glulam
- Finger jointed solid wood beams and post
- Elements for walls, ceilings, floors
- I-Beams / I-Joist

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**Engineered Wood Elements in Europe**

<table>
<thead>
<tr>
<th>Finger jointed beams</th>
<th>Log beams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glulam</td>
<td>I-Beams, I-Joists</td>
</tr>
<tr>
<td>Cross- / Duo- &amp; Triobeams</td>
<td>Special elements</td>
</tr>
</tbody>
</table>

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Adhesive systems for engineered wood

Tendency Ecology

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Increased Health and Environmental Awareness

- Formaldehyde under discussion – WHO, France regulation
- Building requirements for indoor air quality are increasing (i.e. Formaldehyde free)
- Customers are more sensitive and choose „green“ and „sustainable“ product
- Voluntary certification schemes help the producer to differentiate and add value
- Examples of voluntary Environmental Quality Seals:
  ⇒ natureplus
  ⇒ GREENGUARD
  ⇒ JAIA F****
IARC CLASSIFIES FORMALDEHYDE AS CARCINOGENIC TO HUMANS

(http://www.iarc.fr/ENG/Press_Releases/pr153a.html)
Situation in France – Statement FEICA
February 28, 2007

Following conclusions of a CIRC study on formaldehyde in 2004, the French authorities decided not to wait for the decision of the EU classification group and for the application of REACH.

By means of a national decree (arrêté) on 13th July 2006 the French authorities consider “exposure to formaldehyde at the work place” as carcinogenic (cat 1 and 2). This national decree refers to the fair labour standards act (code du travail) which lays down rules for preventing the risks of exposure to CMR substances (cat 1 and 2). As a consequence to the decree the employer has the obligation to prevent and measure any exposure of his workers to formaldehyde. If technical feasible he also has the obligation to substitute formaldehyde.

PURBOND is used at different customers with products newly certified by natureplus

⇒ The adhesive was tested and met the high demands for air quality

⇒ adhered wood products bonded with PUR meet the highest standards in terms of air quality resulting in obtaining health and environmental quality seals
The mission of GREENGUARD Environmental Institute (GEI) is to improve public health and quality of life through programs that improve indoor air. In accordance with that mission, GEI currently has three third-party certification programs.

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**E1:** presently widely accepted emission limit in Europe and in other regions

**Recommendation of GREENGUARD RAL-UZ 76 ‘Blauer Engel’**

**F**** in Japan:** Recommendation of **natureplus**

**Recommendation by the state of California**

**Recommendation of GREENGUARD for children and schools**

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**Recommended Formaldehyde Emission Limit**

<table>
<thead>
<tr>
<th>ppm</th>
<th>0.02</th>
<th>0.04</th>
<th>0.06</th>
<th>0.08</th>
<th>0.1</th>
<th>0.12</th>
</tr>
</thead>
</table>

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JAIA F****

Which Adhesives can apply for Approval

- Positive list for application
  1. PVA emulsion
  2. Vinyl copolymer emulsion
  3. Acrylic emulsion
  4. Rubber based latex
  5. Epoxy modified rubber based latex
  6. Water based polymer - Isocyanate
  7. alpha-olefin type
  8. Epoxy resin
  9. Polyurethane
  10. Modified silicone
  11. Silyl modified polyurethane
  12. Hot melt

- Negative list of raw materials
  1. Urea/Melamine/Phenol/Resorcinol resin
  2. Preservatives derived from Formaldehyde
  3. Methyolol containing monomer
  4. Rongalite (Sodium Formaldehyde Sulphoxylate)

PURBUND Adhesives fulfils the requirements and are approved as a F**** by JAIA

Formaldehyde Free

Polyurethane adhesives from Purbond are absolutely free of Formaldehyde

JAIA F☆☆☆☆☆ for all PURBOND® adhesives
- Formaldehyde Standard: (Japan Adhesive Industry Association) Independent Control Standard against Indoor Air Pollution.
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Trend of Wood as Construction Material in the Future

Wood + PUR → Healthy living and working

The right material
The right adhesive

Adhesive systems for engineered wood

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PURBOND® HB-products are the first approved - in 1994 - one component polyurethane adhesives acc. German DIN Standards.

Purbond stands for the high quality and innovative brand for certified Engineered Wood Products (EWP).
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Purbond Worldwide

Purbond Centre of Competence: Research & Development
Purbond Centre of Competence:
Pilot production

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Purbond Centre of Competence:
Engineering Department

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Purbond is a joint venture between Collano and National Starch & Chemical.

Application

Application of PURBOND Adhesives

- Finger Jointing
- Face Lamination
- Edge gluing
- Special applications
- Manual application

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Finger Jointing

Advantages:
- High quality and reliability of the adhesive joint
- Reduction of time / costs for handling (no mixing), cleaning of gluing equipment
- Raise of productivity
- Safe, clean and no waste

Finger Jointing through Contact Free Application (KEBA)

The adhesive is applied contact free over nozzles transverse to the profile laid. Purbond invented the KEBA-system, certified by MPA, Stuttgart.

Advantages:
- Clearly less contamination of equipment
- One-sided order possible
- High process security
- Improves productivity
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**Edge Gluing**

*Advantages:*
- Fast production
- Raise of productivity
- Safe and clean workplace
- No sunken glueline

**Face Gluing**

- Glulam
- Duo- Trio or Crossbeams

*Advantages:*
- high aesthetic and quality needs
- Higher flexibility in production process
- Safe and clean production
Special Applications

- I-beams/I-joists
- Large Format Panels
- Special Elements

**Advantages:**
- Custom-made products
- Small pressing power (vacuum press)
- Fast, safe and efficient

Manual Applications

**Advantages:**
- Simple application
- Custom requirements specified applicator head
- Easy to use
- Movable Unit
- High flexibility
- Easy to start
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Adhesive systems for engineered wood

Technology

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Technology of 1C PUR

\[
\text{Prepolymer (Isocyanate)} + \text{H}_2\text{O} \rightarrow \text{Intermediate product (Amine)} + \text{CO}_2 \uparrow
\]

Polyurea / polyurethane chain

Carbon dioxide (Bubble formation)
Technology of 1C PUR

Bonding process

- Chemical reaction with water (ambient or wood humidity)

Curing Kinetics

Conversion

100 %

Time

High humidity

Low humidity or low temperature
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### Characteristics

**Open Time at different Temperature level**

![Graph showing Open Time at different Temperature levels](image)

- **Temperature [°C]**: 0, 5, 10, 15, 20, 25, 30, 35, 40
- **Open Time [Sec.]**: 0, 5, 10, 15, 20, 25, 30, 35, 40

### Schematic Morphology of Polyurethanes - Strong and Non-Brittle

**Hard segments**
- Urethane groups
- Urea groups
- Physical network with H-bridges

**Soft segments**
- Polyether polyole
- Chemical network
Advantages and Benefits for the EWP Manufacturer (1)

- Optimised spreading rate  - reduced use of resources
  - less material to handle
- Fast curing system  - flowing / in-line process
  - improved productivity
- No mixing  - increased reliability of the production process
- No cleaning cabinet  - reduced cost
  - less space required
- No waste water  - reduced cost
  - no pollution
- Minimum quantity of adhesive residue at the application unit  - efficient use of resources
  - clean production line
  - simple disposal of residue

Advantages and Benefits for the EWP Manufacturer (2)

- No odour  - pleasant working environment
- Wide application range  - one single adhesive technology in the production process
  - no time consuming daily adhesive switch
- Bond hardness similar to wood hardness  - longer tool life / improved machining
Advantages and Benefits for the End-user (Building Owner / Inhabitant)

- Clear, transparent bond - aesthetically appealing
  - very similar to natural wood
- Toxicologically harmless, chemically stable - no emissions during use, equivalent to natural wood: Frauenhofer Institute for Wood Research, Germany
- No harmful emissions when burning - reduced risk in case of fire and no environmental issues for thermal disposal at the end of the life cycle
Performance

The quality of an adhesive bond can be defined according to ultimate strength, resistance to degradation by moisture, resistance to heat and elastic behaviour.

1. Strength
2. Durability
3. Long-term performance
4. Elastic behaviour and resistance to creep

Strength – Methods for determination

- Strength is conventionally determined acc. to the following methods:
  - Europe: EN 302-1 (tensile lap-shear)
  - US/CAN: ASTM D905 (compressive block-shear)
Strength – Methods for determination

- Requirements are defined in National Standards
  - Europe: EN 301 and prEN 15425
  - North America: ASTM D2559
  - Canada: CSA O112.9

- Requirements include
  - Ultimate strength on dry specimens
  - Ultimate strength after different cycling periods
  - Wood failure ratio

Strength – Test Requirements vs Real-World

- It is assumed that wood fibre tear is an indicator for a strong and durable bond line

- Wood fibre tear is initiated mainly by stress concentrations, which depend on
  - Specimen geometry
  - Ductility of adhesive system
  - Elastic behavior of adherent and adhesive system

- **Ductility and brittleness** of a bond line are important parameters but are not sufficiently considered for adhesive qualification

(A) = conventional lap-joint to EN 302-1

(B) = scarf-joint to former DIN 53253

**Lap-joint:**
- Strength of wood is measured
- Results in maximum wood fibre tear
- Shows high stress concentrations

**Scarf-joint:**
- Shear strength of adhesive is measured
- No wood fibre tear in all adhesive systems
- Shows low stress concentration
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Strength – A Comparison of Lap- and Scarf-joints

<table>
<thead>
<tr>
<th>Adhesive System</th>
<th>Lap-joint</th>
<th>Scarf-joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kasein</td>
<td>4.5</td>
<td>6.5</td>
</tr>
<tr>
<td>PVAc</td>
<td>6.5</td>
<td>8.5</td>
</tr>
<tr>
<td>MUF</td>
<td>7.5</td>
<td>9.5</td>
</tr>
<tr>
<td>PRF</td>
<td>8.5</td>
<td>10.5</td>
</tr>
<tr>
<td>PUR</td>
<td>9.5</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Strength – Conclusion

- Ductility in the case of a bond line means the joint’s capability to produce a uniform stress distribution for a given load
- Uniform stress distribution increases the load-bearing capacity
- Uniform stress distribution increases service life
- High stress concentrations result in wood failure, which is therefore a good indicator of the strength of brittle adhesives
- Ductile adhesives distribute stress evenly
Durability = Long-Term Performance

- **Live-Load** (varying load)
  - Ductility vs brittleness
  - Bond line degradation

- **Dead-Load** (constant load)
  - Resistance to creep
  - Bond line degradation

- **Weathering** (exposure to water and UV-rays)

- **Climate Extremes** (high / low humidity high / low temperatures)

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**Durability – Examination of a 20-Year-Old Fully Exposed Beam**

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Durability – Examination of a 20-Year-Old Fully Exposed Beam

Delamination after:
- Cold water
- Vacuum-pressure treatment
- Hot-air drying

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Delamination%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2%</td>
</tr>
<tr>
<td>2</td>
<td>0.0%</td>
</tr>
<tr>
<td>3</td>
<td>0.8%</td>
</tr>
<tr>
<td>4</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
Long-Term Performance – Investigation of Glulam Bridges

- 4 glulam bridges – structure fully exposed to the elements
- 3 Glulam-bridges bonded with PURBOND HB Products
- 1 Glulam-bridges bonded with Phenol-Resorcinol

→ An investigation of their state after around 10 years in use
→ Inspected by the Swiss Federal Research and Testing Institute (EMPA)
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### Table: Long-Term Performance – Investigation of Glulam Bridges

<table>
<thead>
<tr>
<th>Nr</th>
<th>Object</th>
<th>Year</th>
<th>Wood / Adhesive</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pedestrian bridge, Walde, CH</td>
<td>1993</td>
<td>Spruce / 1C-PUR</td>
<td>No delamination</td>
</tr>
<tr>
<td>2</td>
<td>Pedestrian bridge, Grindelwald, CH</td>
<td>1994</td>
<td>Spruce / 1C-PUR</td>
<td>No delamination</td>
</tr>
<tr>
<td>3</td>
<td>Pedestrian bridge 1, Hessen, DE</td>
<td>1998</td>
<td>Larch / PRF</td>
<td>No delamination</td>
</tr>
<tr>
<td>4</td>
<td>Pedestrian bridge 2, Hessen, DE</td>
<td>1997</td>
<td>Larch / 1C-PUR</td>
<td>No delamination</td>
</tr>
</tbody>
</table>

**Bridges 3 and 4 – identical construction but different adhesive systems**

#### Table 5: Shear strength

<table>
<thead>
<tr>
<th>Sample Nr.</th>
<th>Dimension</th>
<th>$K^{(1)}$</th>
<th>Shear strength $f_y$ [N/mm²]</th>
<th>Shear strength $f_{y,shear}$ [N/mm²]</th>
<th>wmc $u$ [%]</th>
<th>Wood Fiber Perc. [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t$ [mm]</td>
<td>$t$ [mm]</td>
<td>$A$ [mm²]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>28.98</td>
<td>25.35</td>
<td>734.64</td>
<td>0.91</td>
<td>9.91</td>
<td>8.99</td>
</tr>
<tr>
<td>2</td>
<td>27.40</td>
<td>27.10</td>
<td>742.54</td>
<td>0.90</td>
<td>11.38</td>
<td>10.26</td>
</tr>
<tr>
<td>3</td>
<td>29.06</td>
<td>26.66</td>
<td>774.74</td>
<td>0.91</td>
<td>10.90</td>
<td>9.80</td>
</tr>
<tr>
<td>4</td>
<td>26.83</td>
<td>25.94</td>
<td>695.97</td>
<td>0.90</td>
<td>10.13</td>
<td>9.19</td>
</tr>
</tbody>
</table>

$^{(1)}$ correction factor – corrects the shear value of specimen if the dimension $t$ in fiber direction is less than 50 mm

#### Table 6: Shear strength

<table>
<thead>
<tr>
<th>Sample Nr.</th>
<th>Dimension</th>
<th>$K^{(1)}$</th>
<th>Shear strength $f_y$ [N/mm²]</th>
<th>Shear strength $f_{y,shear}$ [N/mm²]</th>
<th>wmc $u$ [%]</th>
<th>Wood Fiber Perc. [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t$ [mm]</td>
<td>$t$ [mm]</td>
<td>$A$ [mm²]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PUR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>26.03</td>
<td>26.70</td>
<td>719.03</td>
<td>0.90</td>
<td>8.52</td>
<td>7.66</td>
</tr>
<tr>
<td>2</td>
<td>28.92</td>
<td>25.51</td>
<td>758.00</td>
<td>0.91</td>
<td>twisted specimen</td>
<td>10.82</td>
</tr>
<tr>
<td>3</td>
<td>21.09</td>
<td>27.61</td>
<td>562.29</td>
<td>0.87</td>
<td>11.45</td>
<td>9.99</td>
</tr>
<tr>
<td>4</td>
<td>28.54</td>
<td>26.70</td>
<td>762.02</td>
<td>0.91</td>
<td>9.93</td>
<td>8.99</td>
</tr>
</tbody>
</table>

$^{(1)}$ correction factor – corrects the shear value of specimen with length is fiber direction of less than 50 mm
Creep Resistance - Test Over a Period of Ten Years at Otto Graf Institute

- 4-point bending test
- Full-Scale
- Deflection measurements: 4 beams bonded with PUR and 2 beams bonded with PRF
- 1993 – today (ongoing)
- Load = 6173 lb (2'800 kg)
- Shear stress = 1.2 N/mm²

Creep Resistance - Test Over a Period of Ten Years at Otto Graf Institute

Test set-up
Deformation factors $K_{def} = \frac{f_t}{f_0} - 1$

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Creep Resistance - Test Over a Period of Ten Years at Otto Graf Institute

- DIN 1052 defines a deformation factor $k_{def}$ of 0.8 to calculate final deformation under permanent load.
- For all beams, the increase of deflection decreases significantly during the test period and in the last 3 years only very little or absolutely no increase of deflection was recorded.
- At $k_{def} \leq 0.8$ the increase of deflection has stopped.
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Projects

DOKA Formwork I-beams

I-beams since 1997

Chesa Futura, St. Moritz, Switzerland

Spruce
Finger jointing and Face gluing
PURBOND® HB 110 and HB 530
Year 2001
Projects

Salt Storage, Deusa, Germany

Spruce
Finger jointing and Face gluing
PURBOND® HB 110 and HB 530
Year 2004

Restaurant in Austria

Spruce
Finger jointing and Face gluing
PURBOND® HB 110 and HB 530
Year 2005

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Projects

Spittelgasse Vienna, Austria

Spruce
Finger jointing and Face gluing
PURBOND® HB 110 and HB 530
Year 2005

Hospice, Austria

Spruce
Finger jointing and Face gluing
PURBOND® HB 110 and HB 530
Year 2005
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**Projects**

**Olympic Games Village 2005, Torino, Italy**

- Spruce
- Finger jointing and Face gluing
- PURBOND® HB 110 and HB 530
- Year 2005

**Road-bridge, Switzerland**

- Spruce
- Face gluing
- PURBOND® HB 181
- Year 2006
Projects

LIGNOTREND – Aomori Home Component, Japan

Sugi (Japanese Cedar)
Cross panel bonding
PURBOND® HB 530
Year 2004

Bridge in China

Southern Yellow Pine
Finger jointing and Face gluing
PURBOND® HB 181
Year 2005
Projects

Bridge in China

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Summary

- Wood is in trend
- 1-C PUR together with wood fits excellent
- With the 1-C PUR technology it is proven that you can fulfill the requirements for engineered wood products
- Application systems are developed that it can be applied 1 C-PUR safely
- 1-C PUR makes sure that the people at the production are save
- 1-C PUR fulfills modern requirement for building components – indoor pollution
Adhesive systems
for engineered wood

At the heart of engineered wood

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