Laminated Veneer and Rubber Lumbers (LVRL): Manufacturing and Physic-mechanical Characteristics

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Contents

- Background
- LVRL manufacturing process
- LVRL properties
- Conclusions
Hi-speed railway: a fast-growing transportation industry.

Mileage of hi-speed railway will be 38 thousand kilometers in 2025, almost two times the figure in 2015. Quantitative high performance sleepers are needed to meet the requirement. So far, concrete sleepers are overwhelming to make railway sleepers in China.
Background: considering China

- Characteristics of concrete sleepers
  - high strength
  - hardness
  - **low flexibility**
  - easy to erode
  - environmental impact.

Alternative materials for concrete sleepers are necessary.

The ballasts paved under concrete sleepers tend to be destroyed by running trains, which may bring potential hazards to trains.
Manufacturing process

The **three-step** process for LVRL manufacturing:

- Poplar veneers
- Rubber sheets
  - CR
  - NBR
  - NR
- PF resin
- PAPI resin
  - 40 to 100 g/m²
- KH69 silane coupling agent
Results of the first step: Without KH69
Properties of 3-layer rubber-wood plywood

Three-layer plywood

Chosen conditions:
(1) PAPI resin content: 80g.m⁻²
(2) Rubber: CR-chloroprene rubber
Results of the second step: With KH69
Properties of 3-layer rubber-wood plywood

When 9% Silane coupling agent was used, board properties were the best.

<table>
<thead>
<tr>
<th>Performance</th>
<th>KH69 Silane coupling agent content ( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Shear strength/MPa</td>
<td>0.93(0.05)*</td>
</tr>
<tr>
<td>Bending strength-MOR/MPa</td>
<td>50.6(2.3)</td>
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<tr>
<td>Bending modulus-MOE/MPa</td>
<td>2395(46)</td>
</tr>
</tbody>
</table>
Results of the second step: With KH69
Properties of 3-layer rubber-wood plywood

SEM and Coupling mechanism between wood and rubber
Results of the third step:
Properties of 9-layer LVRLs

Five constructions of nine-layer plywood.
Rubber sheets were put in various positions.
Results of the third step: Properties of 9-layer LVRLs - Normal

Mechanical and physical properties of five construction nine-layer plywood. LVRLs have better water-resisting properties.
Results of the third step: 
Properties of 9-layer LVRLs- recoverability

Schematic experimentation by five loading-unloading cycles to detect the recoverability of LLVRs imitating a railway sleeper under frequent transverse compressing by running trains.
Results of the third step: Properties of 9-layer LVRLs - recoverability

Load-deformation curves of five LVRLs for five continual compressing loading cycles.
**Results of the third step:**

**Properties of 9-layer LVRLs - Damping properties**

Schematic diagram of the modal vibration test system

Time-domain spectra of LVRLs
Results of the third step:
Properties of 9-layer LVRLs - Damping properties

Frequency response spectrograms of various LVRLs

<table>
<thead>
<tr>
<th>Control-LVL</th>
<th>①</th>
<th>②</th>
<th>③</th>
<th>④</th>
<th>⑤</th>
</tr>
</thead>
<tbody>
<tr>
<td>damping ratios of various LVRLs</td>
<td>1.11</td>
<td>1.47</td>
<td>2.65</td>
<td>1.99</td>
<td>2.11</td>
</tr>
</tbody>
</table>
Conclusions

A. By applying a layered gluing system of PAPI and PF resins, wood veneers and rubber sheets can be successfully laminated to create lumber materials.

B. CR shows the strongest bonding with wood veneers compared to NBR or NR, and wood-rubber interfacial adhesion can be further strengthened by adding KH69 silane.

C. An optimized process was established in this study for LVRL fabrication (rubber type CR, PAPI content of 80g.m⁻², and KH69 content of 9 wt%). The nine-ply LVRLs (containing two or three CR layers) of five balanced constructions showed outstanding physic-mechanical properties with prominent toughening and buffering.

D. As such, the material and processes proposed in this study are a favourable potential alternative to sawn logs or concrete for railway sleeper fabrication.
Thanks