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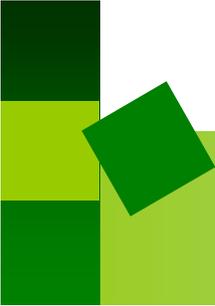
# **Laminated Veneer and Rubber Lumbers (LVRL): Manufacturing and Physic-mechanical Characteristics**

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# *Background: considering China*

## □ **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.



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

## □ Alternative materials for concrete sleepers are necessary.



# Manufacturing process

□ Poplar veneers

□ rubber sheets

➤ CR

➤ NBR

➤ NR

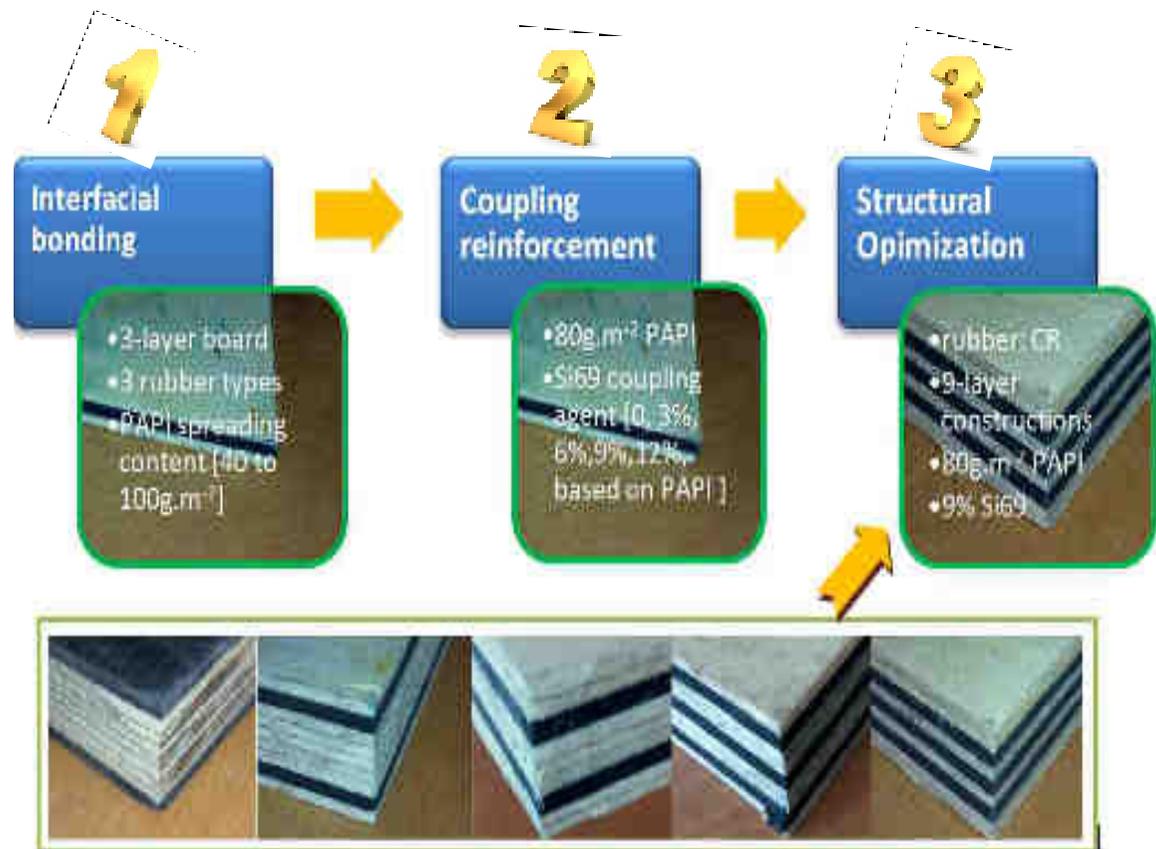
□ PF resin

□ PAPI resin

➤ 40 to 100 g/m<sup>2</sup>

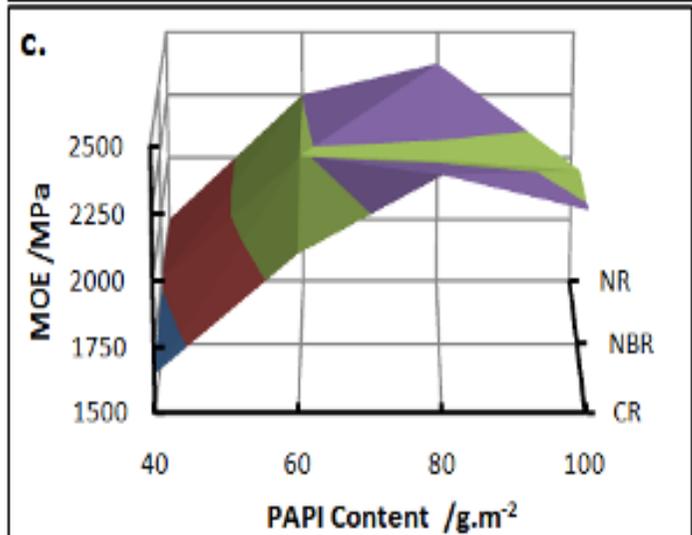
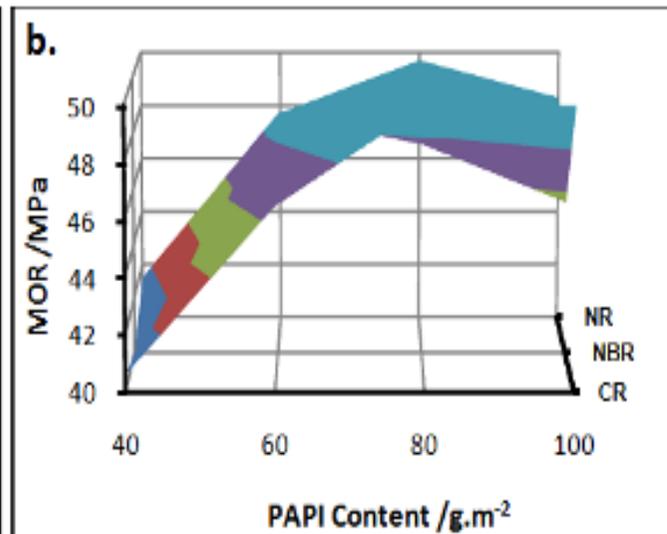
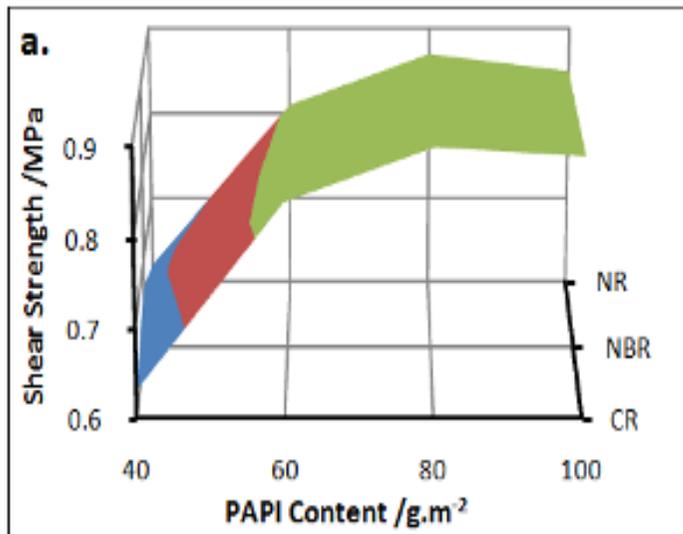
□ KH69 silane coupling agent

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



# 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<sup>-2</sup>

(2) Rubber: CR-chloroprene rubber

## Results of the second step: With KH69 Properties of 3-layer rubber-wood plywood

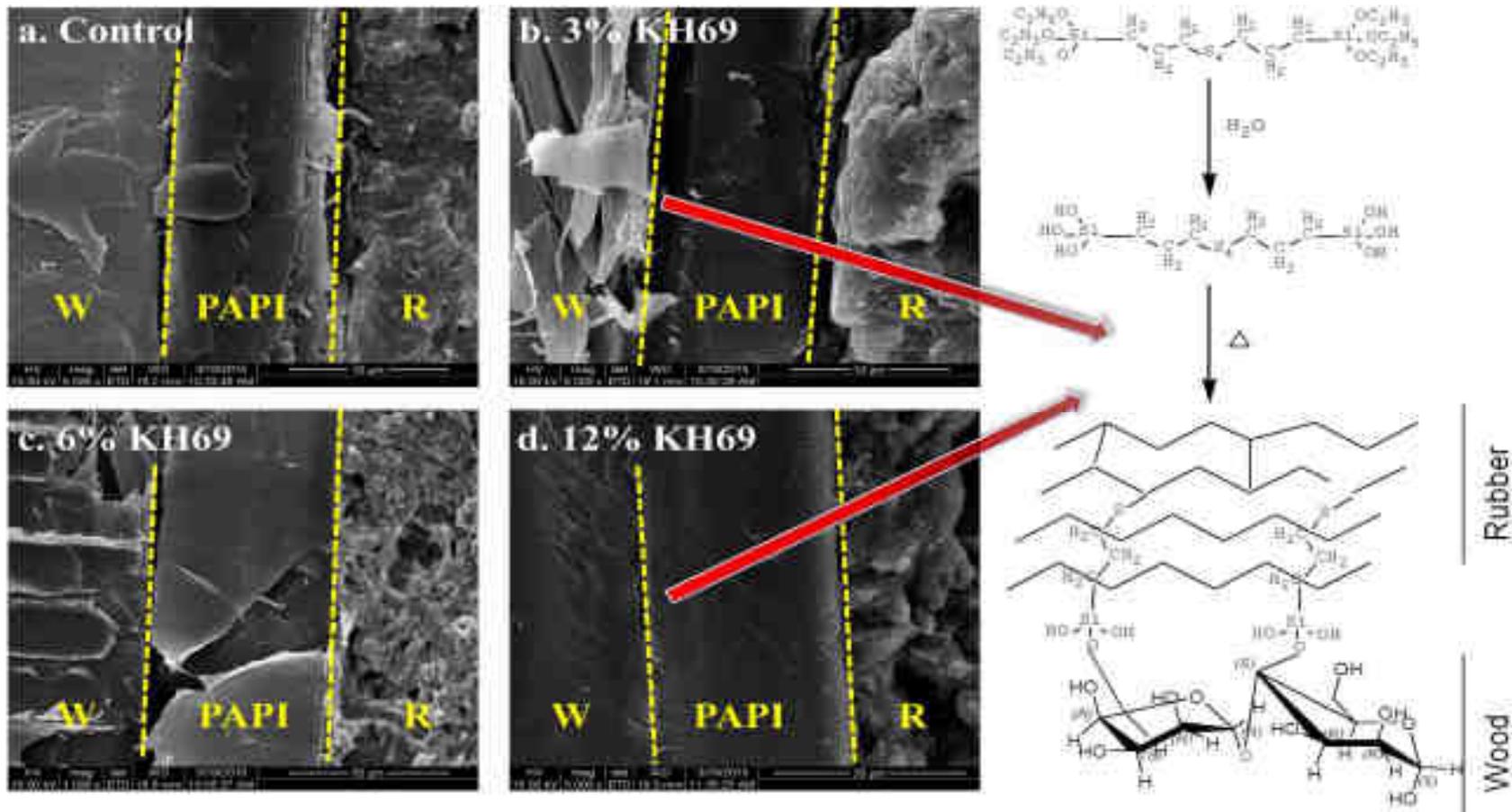
Performance	KH69 Silane coupling agent content ( % )				
	0	3	6	9	12
Shear strength/MPa	0.93(0.05)*	1.22(0.06)	1.45(0.11)	<b>1.63(0.12)</b>	1.51(0.09)
Bending strength-MOR/MPa	50.6(2.3)	56.8(2.8)	58.2(4.5)	<b>62.5(5.1)</b>	59.7(3.7)
Bending modulus-MOE/MPa	2395(46)	2510(37)	2620(44)	<b>2985(52)</b>	2755(28)



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

# 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*



① R-7W-R



② W-R-5W-R-W



③ 2W-R-3W-R-2W



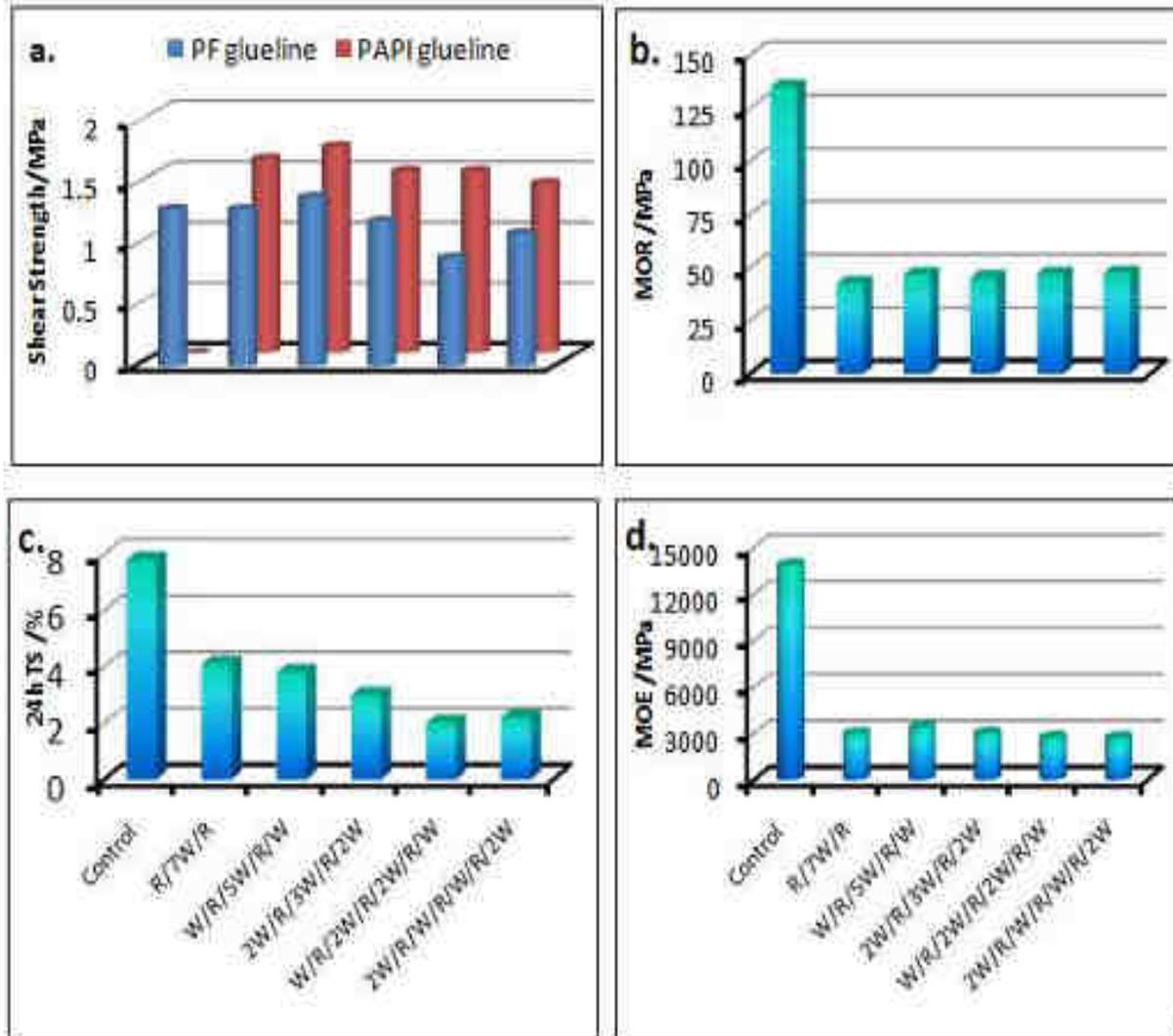
④ W-R-2W-R-2W-R-W



⑤ 2W-R-W-R-W-R-2W

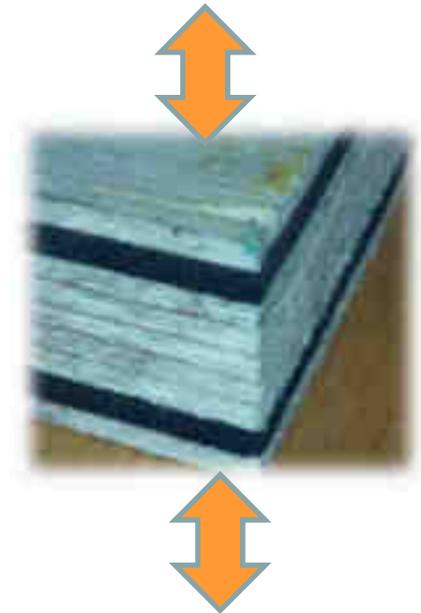
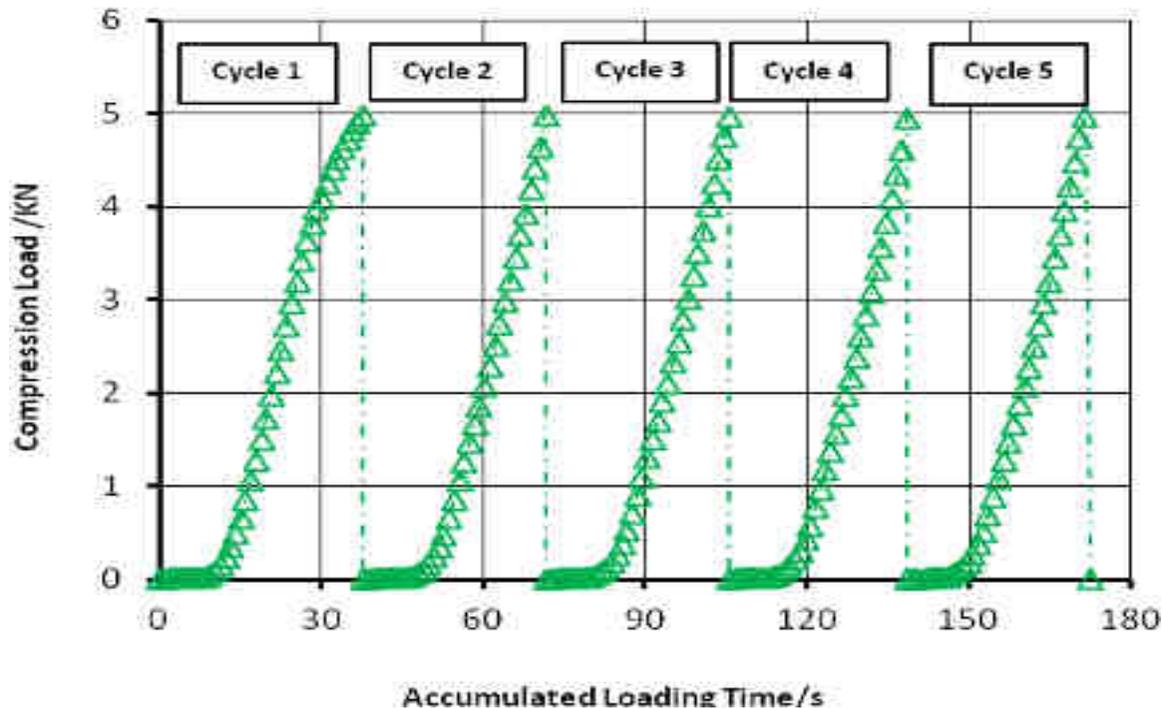
Five constructions of nine-layer plywood. Rubber sheets were put in various positions.

## Results of the third step: Properties of 9-layer LVRLs- Normal



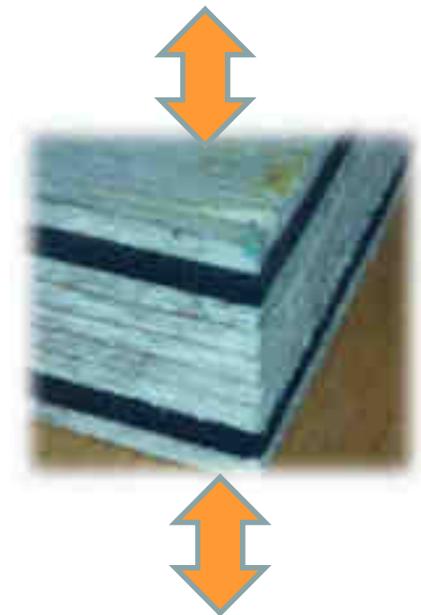
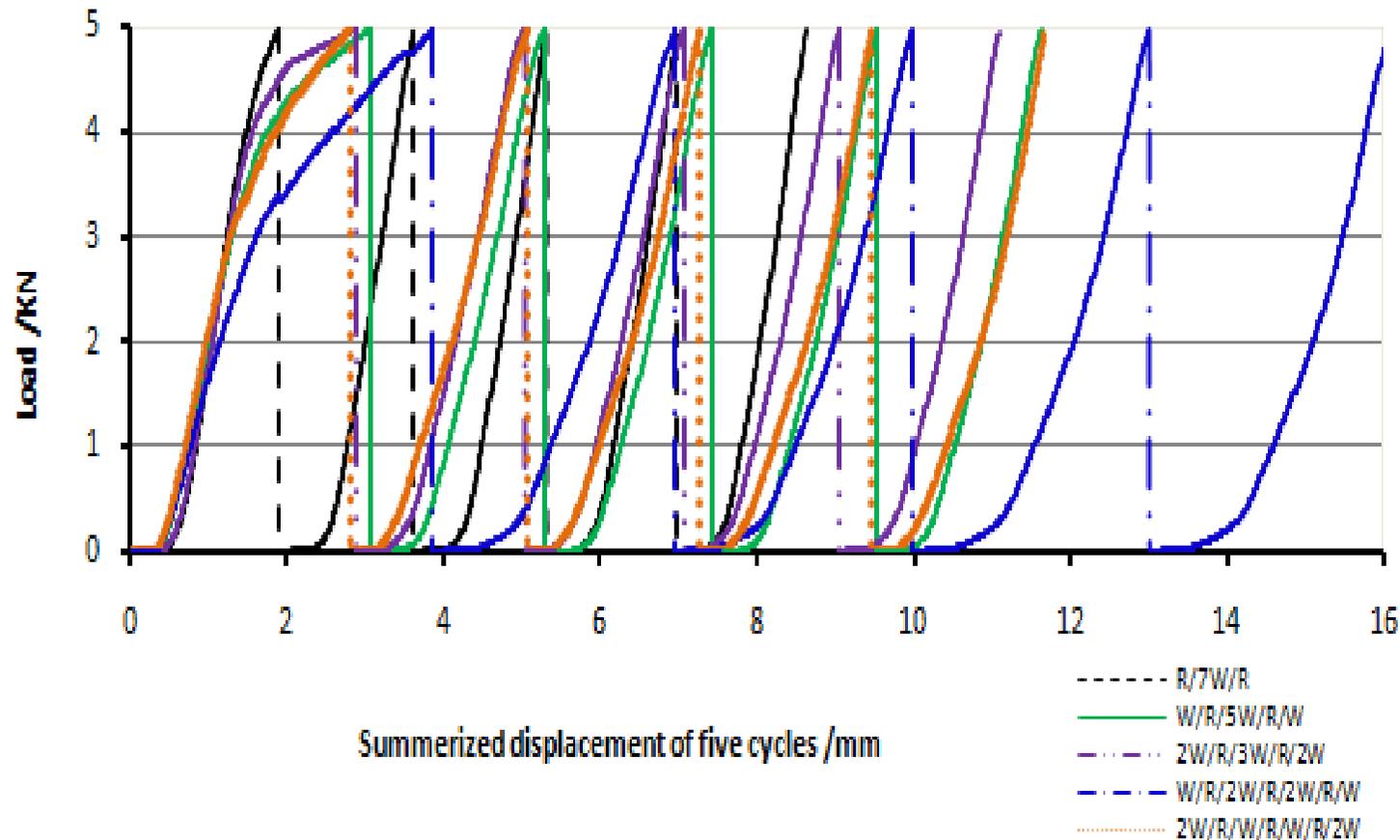
Mechanical and physical properties of five construction nine-layer plywood. LVRLs have better water-resisting properties.

## **Results of the third step:** **Properties of 9-layer LVRLs- recoverability**



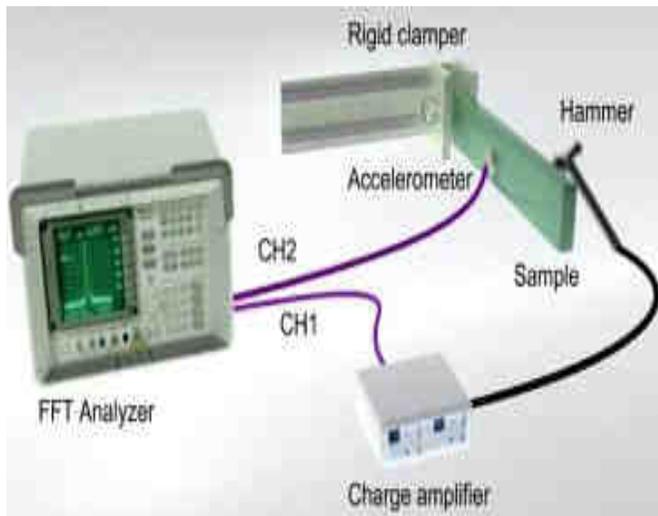
Schematic experimentation by five loading-unloading cycles to detect the recoverability of LLVRs imitating a railway sleeper under frequent transverse compressing by running trains.

## Results of the third step: Properties of 9-layer LVRLs- recoverability

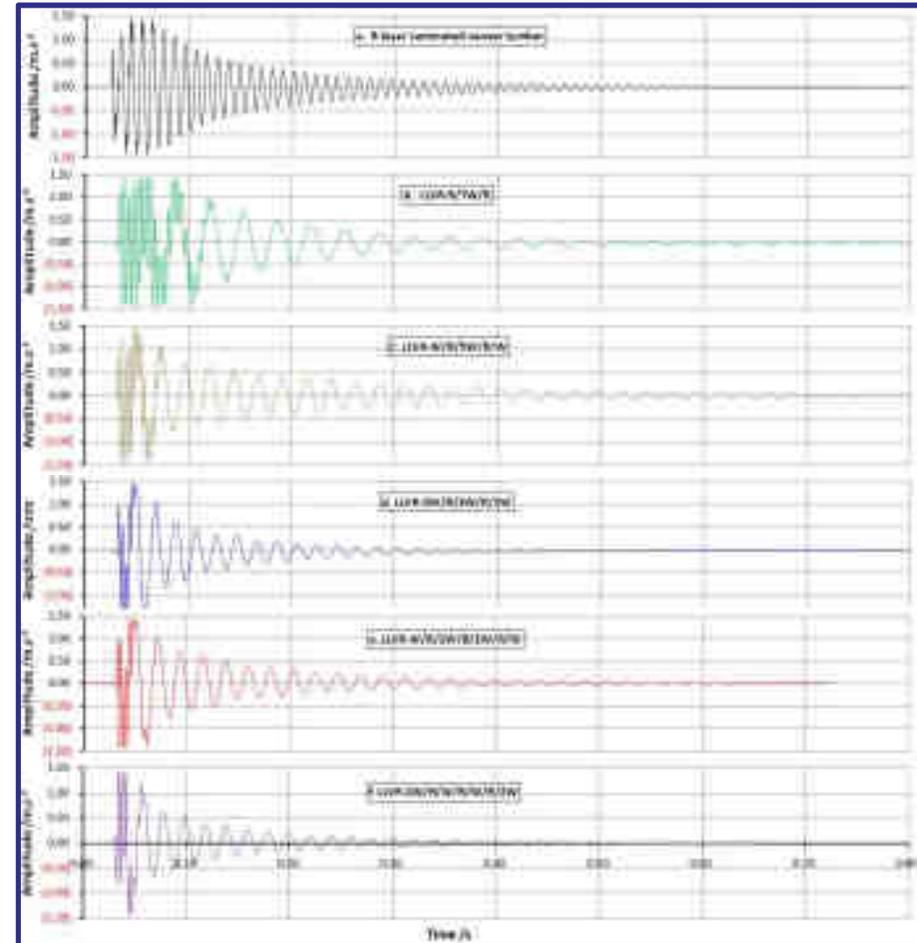


Load-deformation curves of five LVRLs for five continual compressing loading cycles.

## **Results of the third step:** **Properties of 9-layer LVRLs- Damping properties**

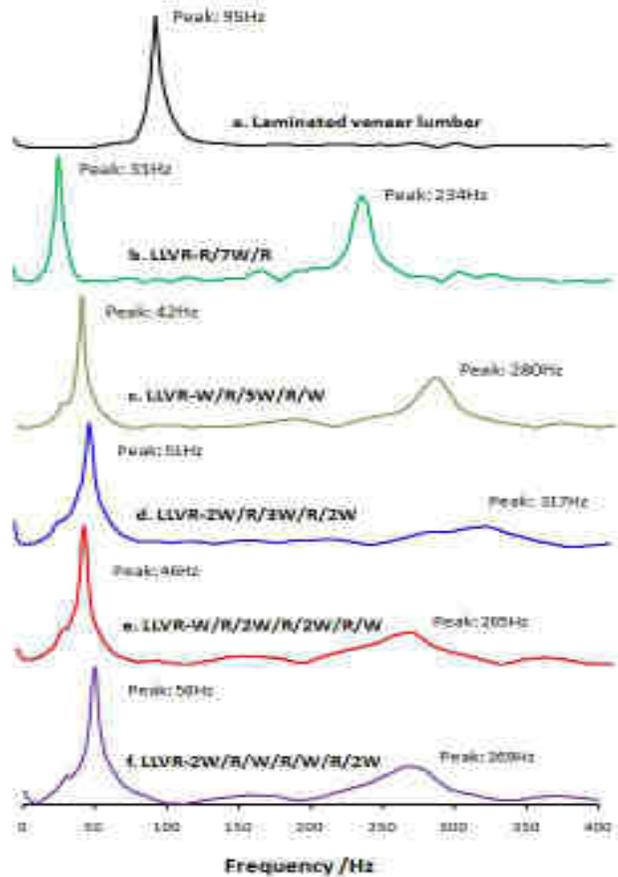


Schematic diagram of the modal vibration test system



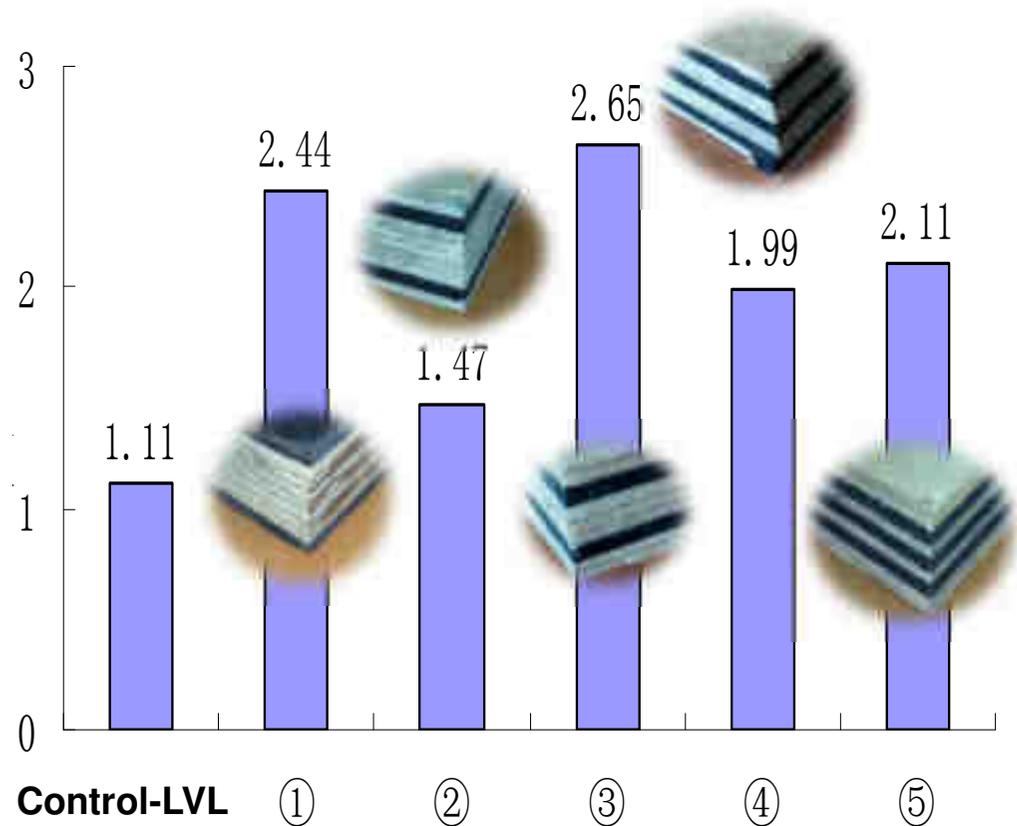
Time-domain spectra of LVRLs

## Results of the third step: Properties of 9-layer LVRLs- Damping properties

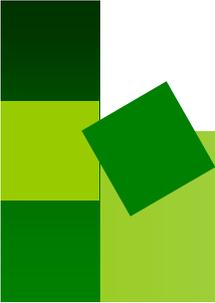


Frequency response

spectrograms of various LVRLs



damping ratios of various LVRLs



# *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<sup>-2</sup>, 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

