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Timber Construction Project Example and Lessons Learned

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Outlines

- ◆ Examples of typical modern timber construction projects in China
- ◆ Examples of professional education of timber construction in China
- ◆ Research on timber construction of our team

Examples of Typical Modern Timber Construction Projects in China

The history of ancient Chinese timber construction is long



Nanzen Temple of Wutai Mountain
rebuilt in 782 AD, the earliest
existing timber construction in
China



Yingxian Timber Tower
1056 AD, the world's highest
timber tower



Forbidden City
1406 AD, the world's largest
and most complete ancient
timbre construction

- During the period from 1960 to 2000, timber construction in China developed slowly.
- After China joined the WTO in 2001, modern timber constructions began to develop in China.
- More and more modern timber constructions are being used as residential, tourist and public constructions.



Residential construction
Suzhou City
Light frame timber construction



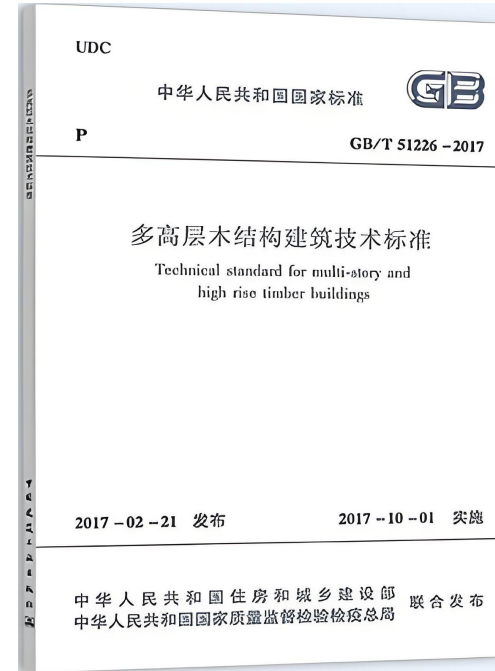
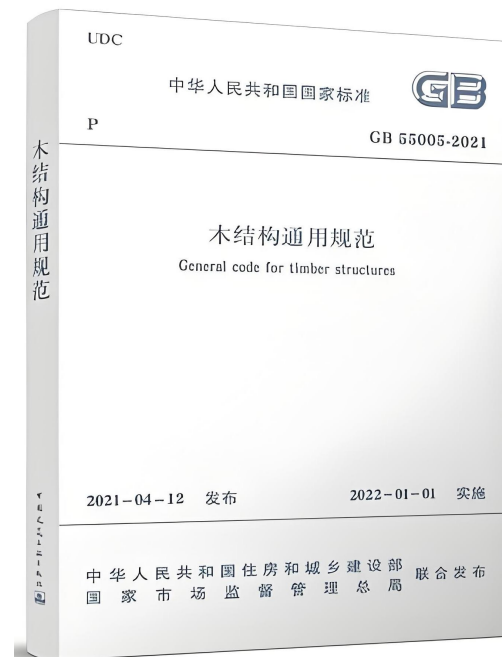
Tourist construction
Nanjing City
Log house



Public construction
Shanghai City
Glulam construction

The main reasons for developing modern timber construction in China

- The advantages of modern timber constructions
- The imported timber resources
- The government support and the conduct of scientific research, such as the establishment of 100 timber construction standards and codes.



Residential construction of light frame timber construction

-The earliest form of modern timber construction in China



Poland Street
Suzhou City, 2005

Residential construction of light frame timber construction

-The earliest form of modern timber construction in China



Huixingu Villa
Huzhou City

Tourist timber construction (Resort hotel)

-The most commonly form of modern timber construction in China

Nanjing
City



Nanchang
City



Changshu
City



Leshan
City



Tourist timber construction (Homestay)

-The most commonly form of modern timber construction in China

Huangshan
City



Yangzhou
City



Chendu
City



Wenzhou
City



Public timber construction (Sports construction)

-The developing form of modern timber construction in China

Sleigh racing track venue,
Winter Olympics
in Beijing,2022

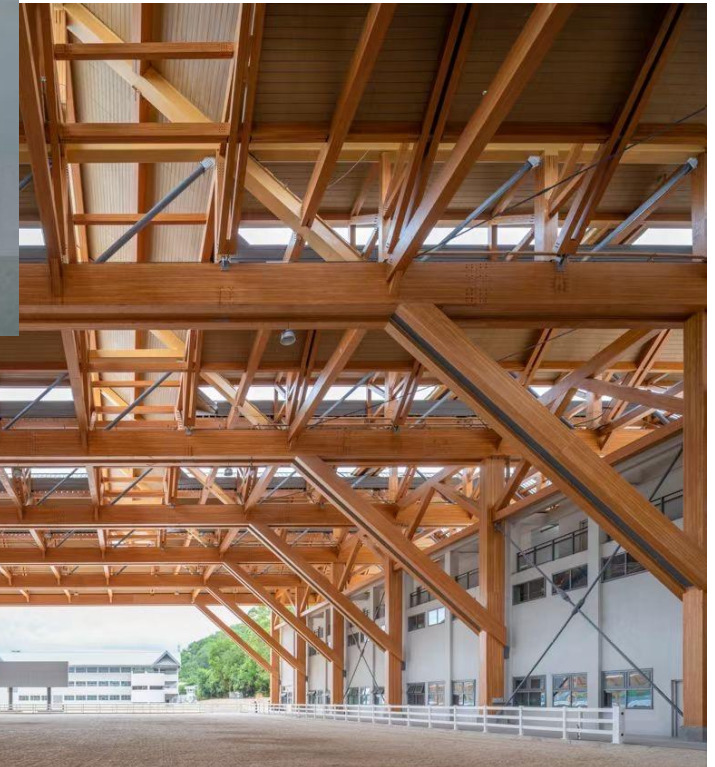


Middle School
Gymnasium
Changzhou

Indoor swimming
pool,
Shanghai



Indoor swimming
pool,
Changchun



Equestrian center
Shenzhen, 2025
The longest glulam beam is as
long as 96 m
The span of the beam is 66 m

Public timber construction (Sports construction)

-The developing form of modern timber construction in China



Speed skating stadium (under construction)

Shenyang

The glulam beam with span of 102 m



Public timber construction (Exhibition hall)

-The developing form of modern timber construction in China



Exhibition Main Hall, Yangzhou

The total construction area of the project is 13,750 m²,
with the timber structure accounting for 4,750 m².



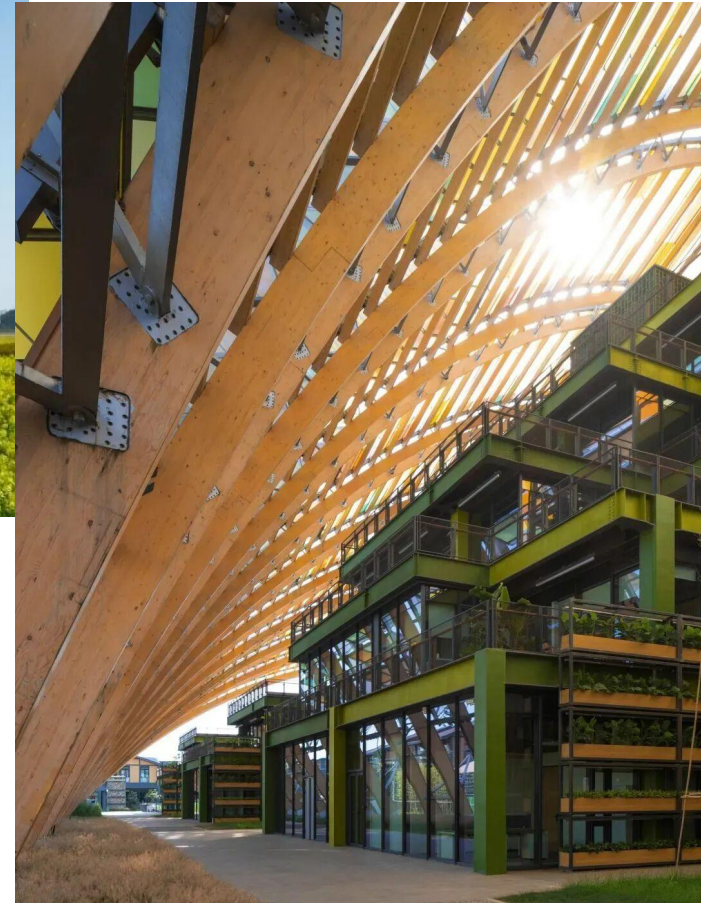
Public timber construction (Exhibition hall)

-The developing form of modern timber construction in China



Tianfu Agriculture Museum, Chengdu

The largest arch has a span of 118 m and a height of 43.25 m, making the main exhibition hall one of the largest timber structure worldwide in terms of span.



Public timber construction (Exhibition hall)

-The developing form of modern timber construction in China



Botanical garden, Taiyuan

Glulam dome structure, forming a net-shell spatial structure with largest span 89.5m.
The cross section of glulam are 200×400 mm (logitudinal) and 200×300 mm (transeverse),
respectively.

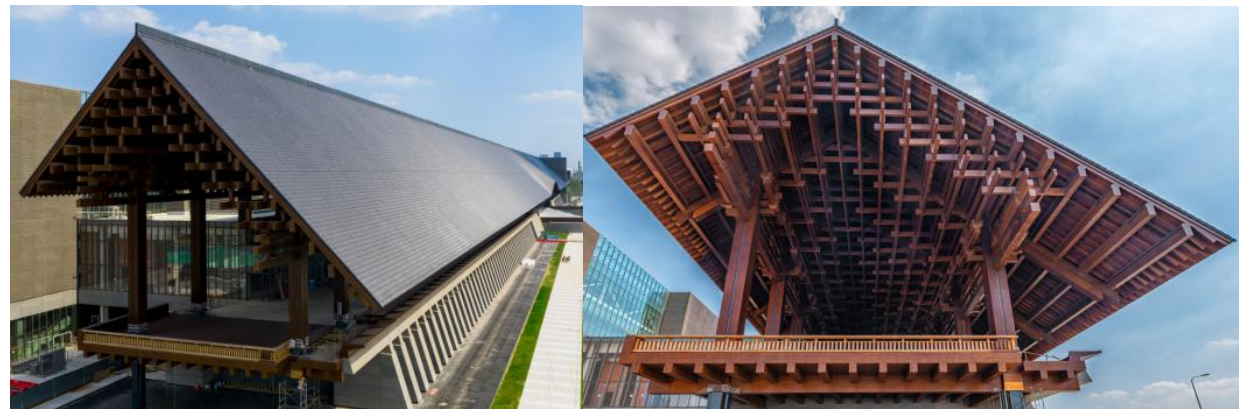


Gallery of International Convention Center

Length 430m, height 32m, span 16m.

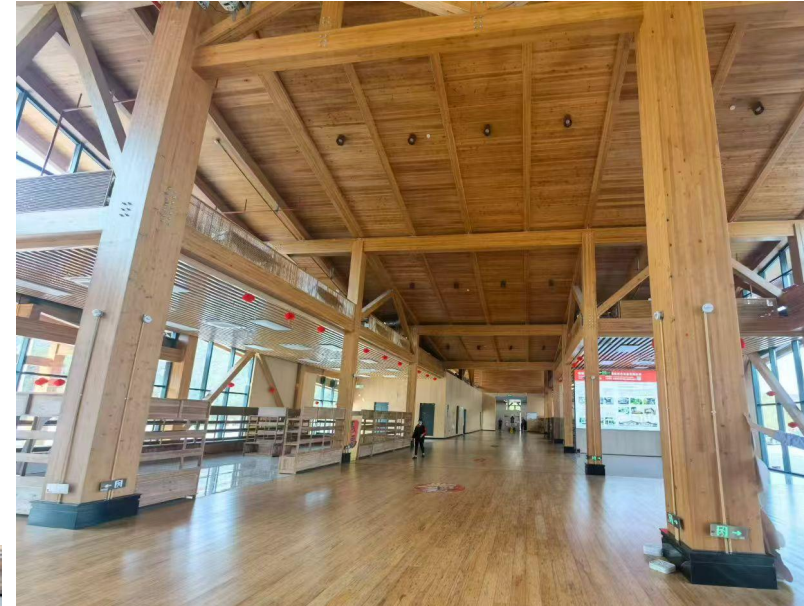
The largest single timber structure in Asia.

The amount of glulam exceeded 4,300 m³.



Public timber construction (Highway service area)

-The developing form of modern timber construction in China



Chinese fir glulam used as the
beams and columns

Two highway service areas under construction

Timber construction



Bamboo construction



Timber bridge

-The potential form of modern timber structure in China

Landscape bridge,
length 120 m,
span 75.7 m,
width 6 m, 2013



Landscape bridge,
length 140 m,
span 99 m,
width 9 m, 2018



Modern timber construction made of fast-growing Chinese fir or bamboo

-The important developing direction of modern timber construction in China

A residential construction made of Chinese fir



- China has abundant resources of fast-growing wood and bamboo, such as Chinese fir and bamboo, which are also the traditional building materials in China.
- Engineering wood/bamboo products, such as glulam, cross-laminated timber, bamboo scrimber, laminated bamboo products, develop well in China.



Modern timber construction made of fast-growing Chinese fir or baboom

-The important developing direction of modern timber structure in China



- Chinese fir glulam and panels were used as structural and decorative materials in these constructions.
- Compared with traditional Chinese fir construction, modern Chinese fir construction has better performance.



Traditional Chinese
fir construction

Modern timber construction made of fast-growing Chinese fir or baboom

-The important developing direction of modern timber structure in China



- A modern bamboo office construction, three stories, construction area 1,499 m².
- The engineering bamboo product, i.e. laminated bamboo product, were used as the beams (cross section: 240 by 600mm) and columns (cross section: 400 by 500mm).
- The laminated bamboo products are modified against decay, fire, and mould.

The development of mid-high rise timber/bamboo construction in China



- The highest modern timber construction in China, six stories, 23.55m high, 2020.
- Glulam was used as beams and columns (cross section 400 by 400 mm), and CLT was used as floor and wall panels (thickness 160 mm).

The development of mid-high rise timber/bamboo construction in China



- This timber building under construction will be the highest timber building in China.
- The timber structure part of this building is about 28 m high.

The development of mid-high rise timber/bamboo construction in China



- The highest modern bamboo construction worldwide, consisting of 6 standard floors and 1 attic floor.
- Laminated bamboo products were employed as the structural elements.

The development of glulam and cross-laminated timber (CLT) in China

- China currently has about 105 glulam production lines, with an annual output of 200,000 to 300,000 m³.
- Straight, curve and long span glulam can be fabricated in factories.
- Solid or hollow timber cylinder made of glulam are widely used as column in timber construction.



The development of glulam and cross-laminated timber (CLT) in China



- China currently has about 7 CLT production lines, with an annual output of 30,000 to 50,000 m³, and 2 CLT equipment manufacturing enterprises.
- In recent years, the output of CLT has been on the rise.



CLT panel with length of 12 m and width of 3.2 m

Some constructions using CLT in China



CLT public residential construction



CLT office construction

Some constructions using CLT in China



School construction



Rehabilitation hospital

Some buildings under construction using CLT in China



ECOLOGICAL COMMUNITY
Wuxi, China

Vivo Research Center
Dongguan, China

Examples of Professional Education of Timber Construction in China

Timber Construction Major establishment

- Nanjing Forestry University (NFU) pioneered the establishment of major (timber construction and material) in 2007.
- About 60 students are enrolled each year. After graduation, most of the students work in timber construction companies.
- Besides NFU, two other universities have launched the major, and many other universities are conducting research in the field of timber construction.



Curriculum system

Classroom teaching

- Timber structural materials and construction methods
- Timber construction structural design
- Timber structure architectural design

Practical teaching

- Curriculum design
- Field research and model construction
- Production practice

Development of innovation and entrepreneurship skills

- Timber construction design competition
- Innovation and entrepreneurship project
- Patent & Paper

International exchange project: UNB 3+1+1, UBC"Go Global"project

Cooperation with European and North American timber construction companies



Jointly carry out practice courses with Cadwork company



Visiting and practicing in Chinese timber companies



Assembly model of prefabricated timber construction

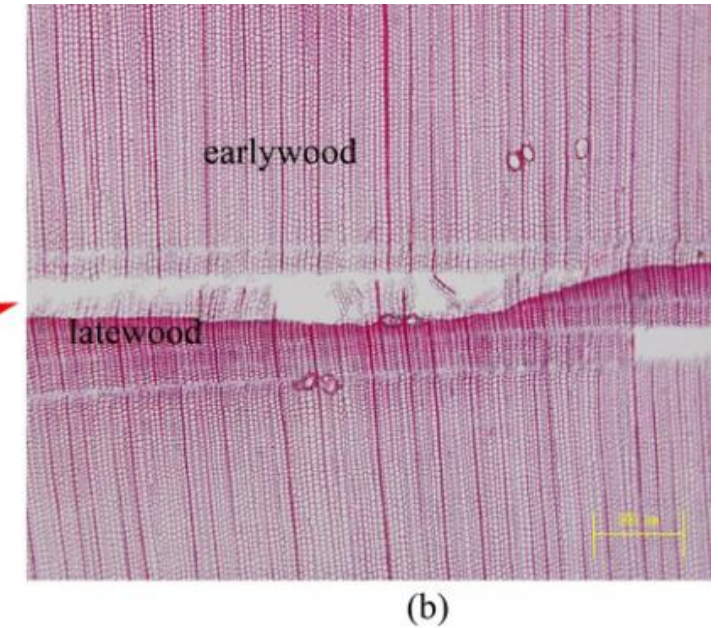
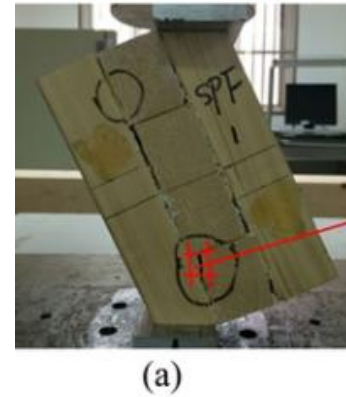
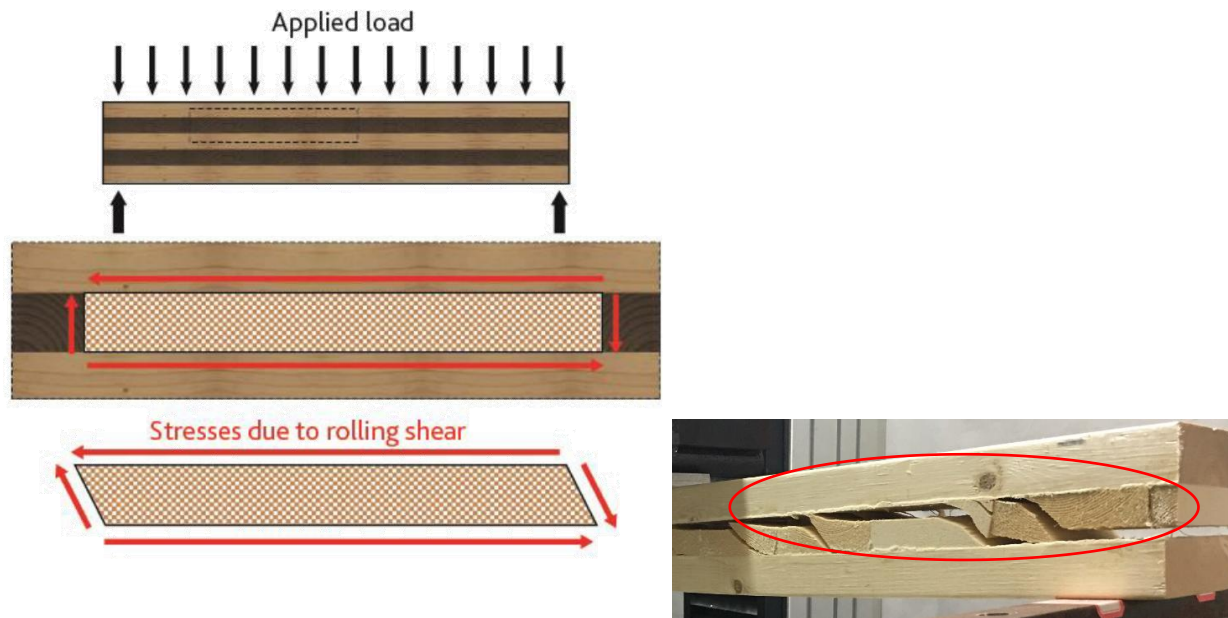


Research on Timber Construction of Our Team

Our researches of CLT

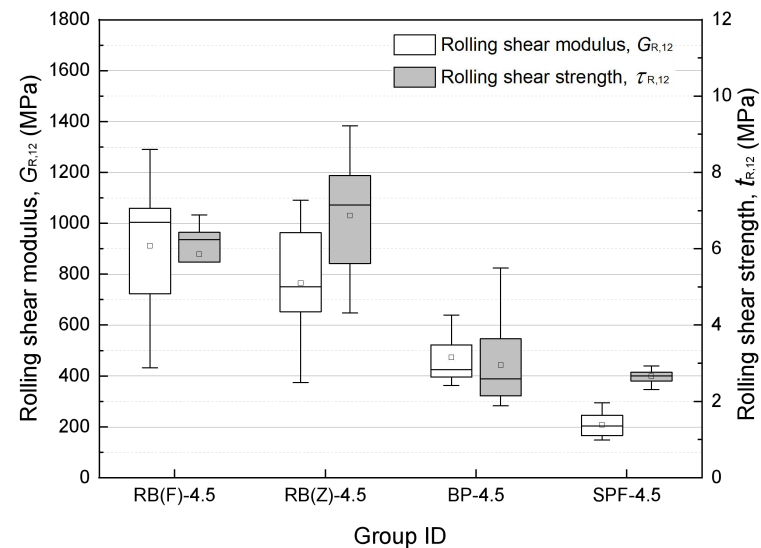
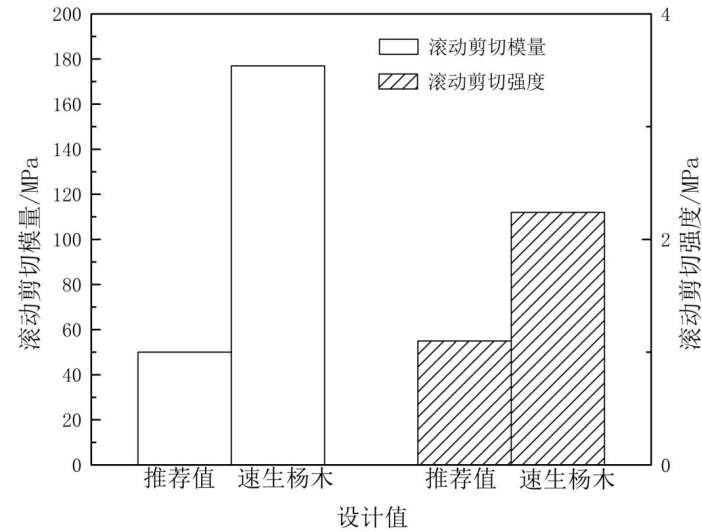
- Short-term mechanical properties
 - Rolling shear property: influence mechanism, test methods, and improve methods
 - Other mechanical properties: bending, compressive, and shear properties
- Long-term mechanical properties
 - Creep
 - Durable of load (DOL) effect
- Hybrid CLT (HCLT)
 - Lay materials: softwood+hardwood, timber+bamboo, timber+structural panel
- Connection performances
 - Self type screws (STS) connection
 - Connection performances: withdrawal and embedment performances
- Vibration performance

Mechanism of rolling shear failure in CLT

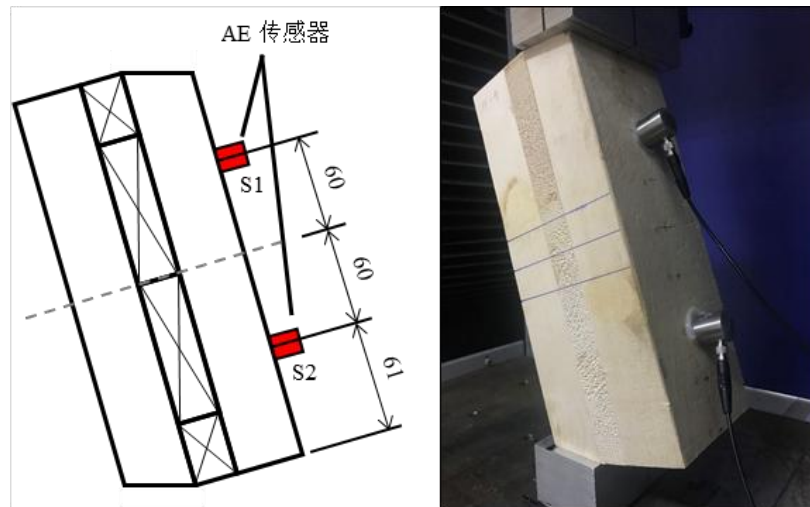
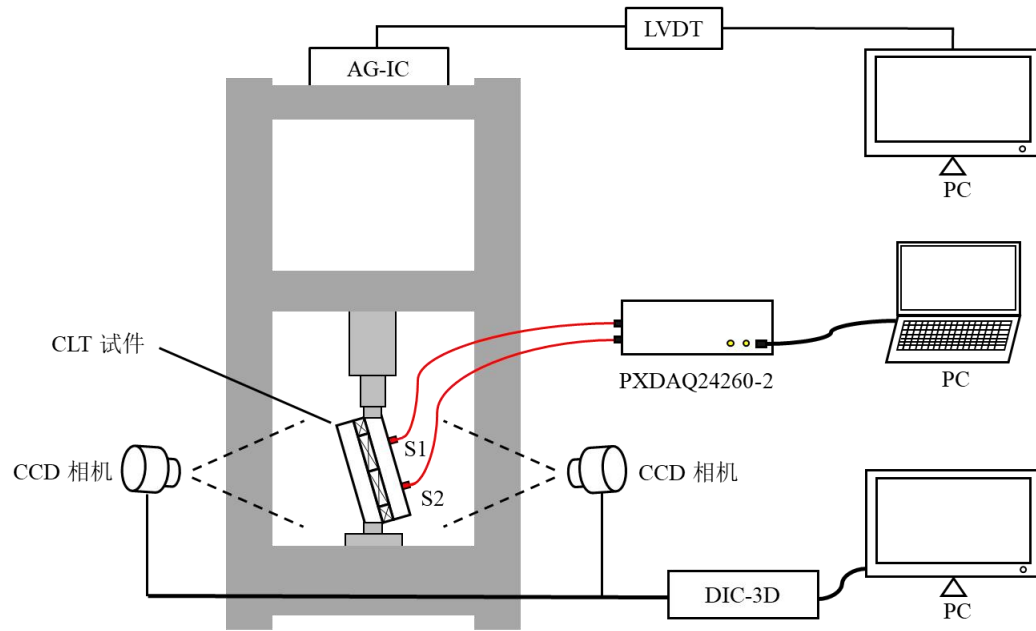


- The rolling shear of cross layer is the key performance of CLT under out-of-plane loading.
- Some weak zones in the radial-tangential (RT) section of wood, such as the earlywood/latewood boundary and wood rays, are easy to occur rolling shear failure.

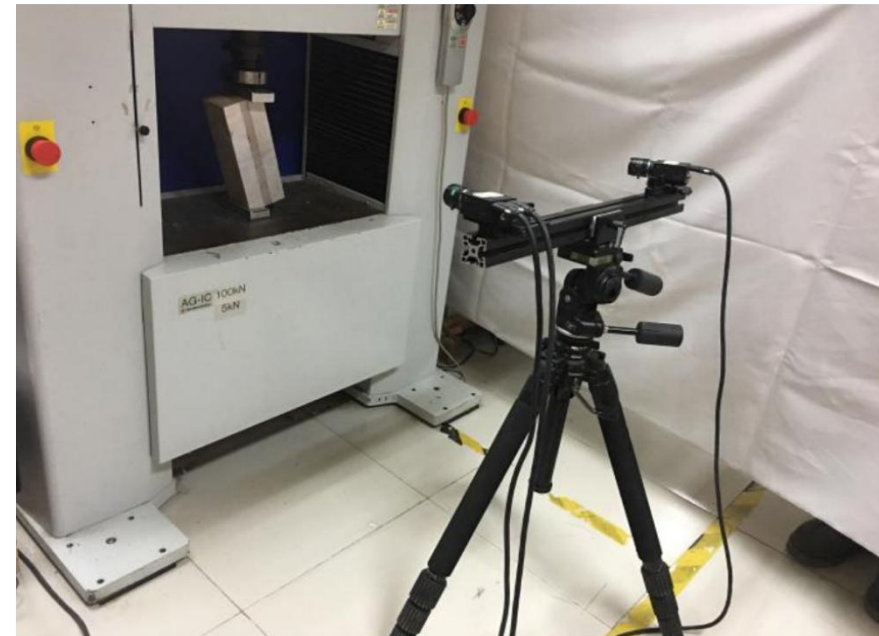
Rolling shear performance of domestic fast-growing poplar and bamboo

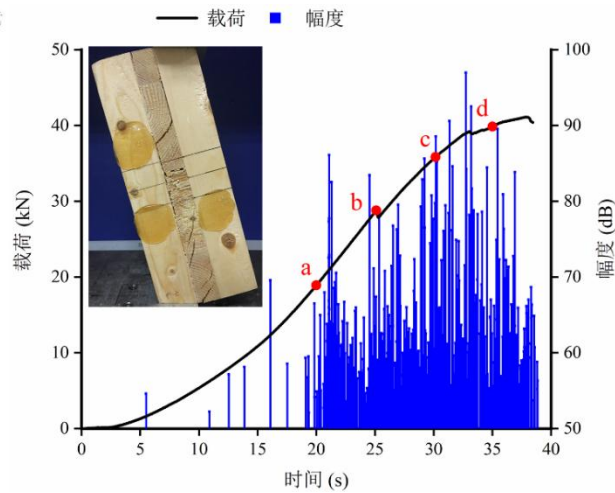
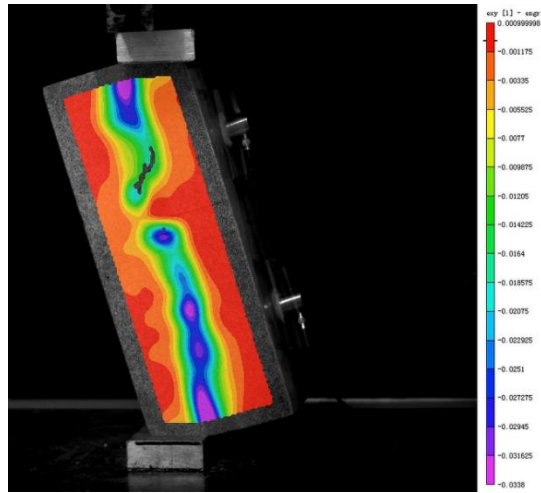


- The rolling shear performance of fast-growing poplar is superior to that of coniferous wood, such as spruce.
- The rolling shear performance of bamboo is 3 to 5 times those of spruce.
- Fast-growing poplar and bamboo are suitable for CLT cross layer materials.

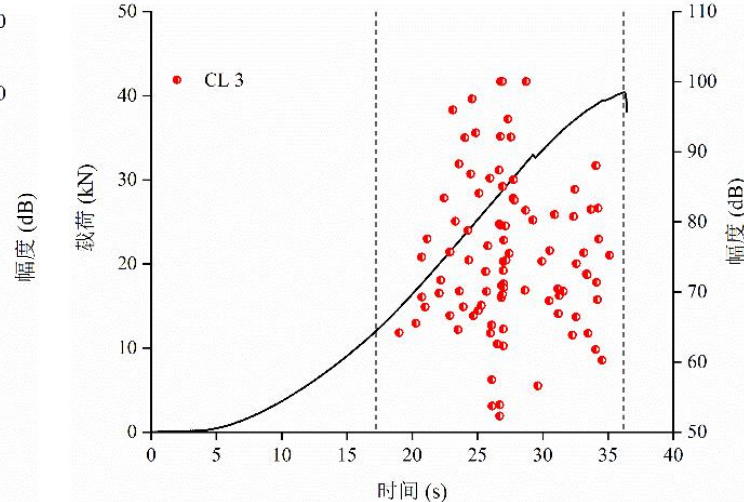
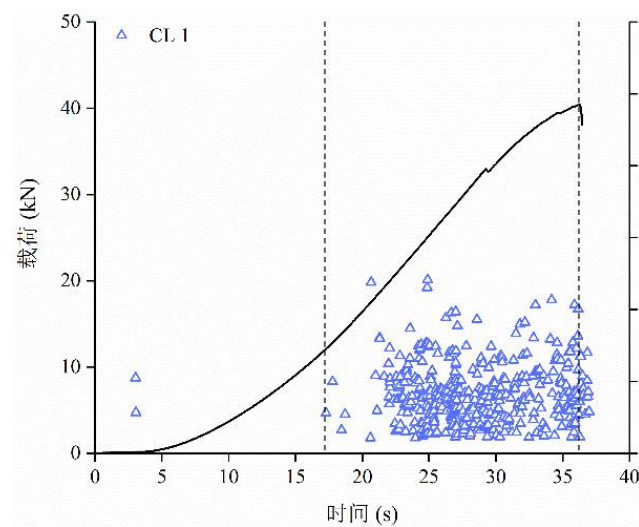
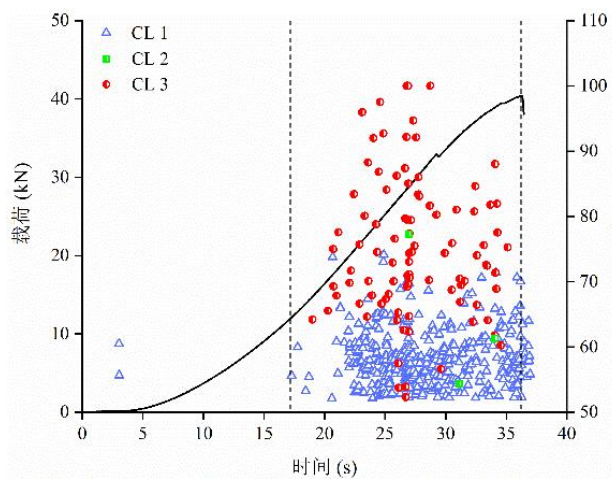


AE(Acoustic Emission) and DIC(Digital Image Correlation) technologies were employed in the rolling shear failure process of CLT

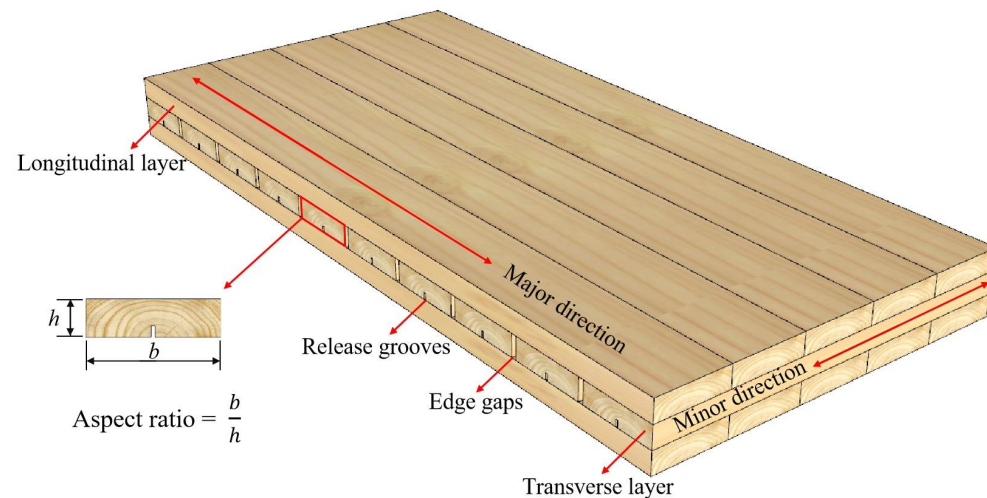




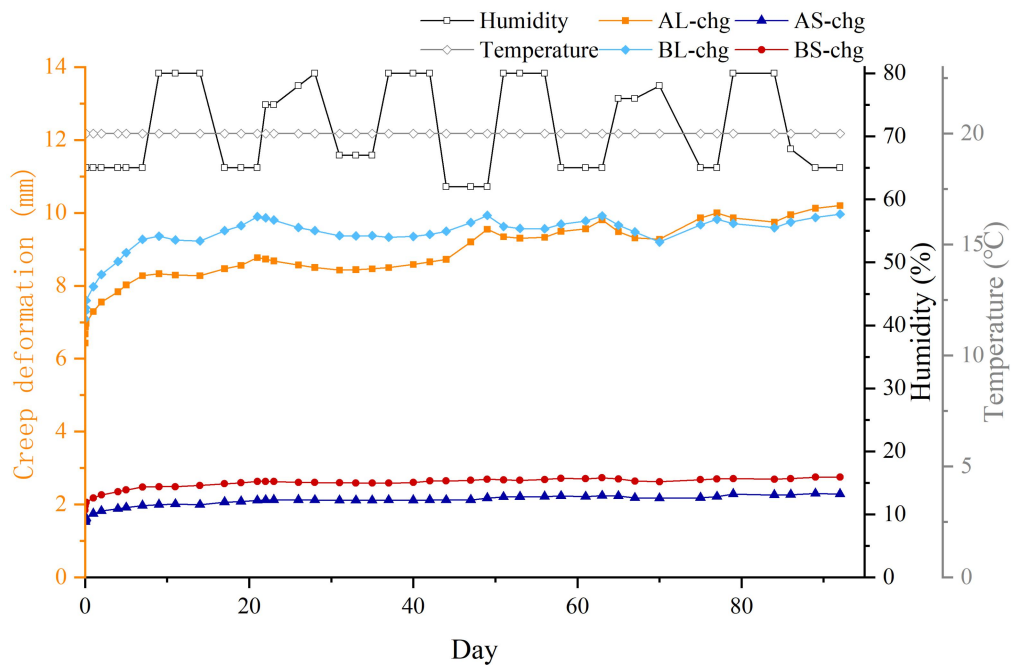
- DIC can accurately capture the cross layer deformation during rolling shear failure process.
- The main AE signals originate from the accumulation of internal damage in cross layer, and the extension and expansion of microcracks then generate secondary AE signals.



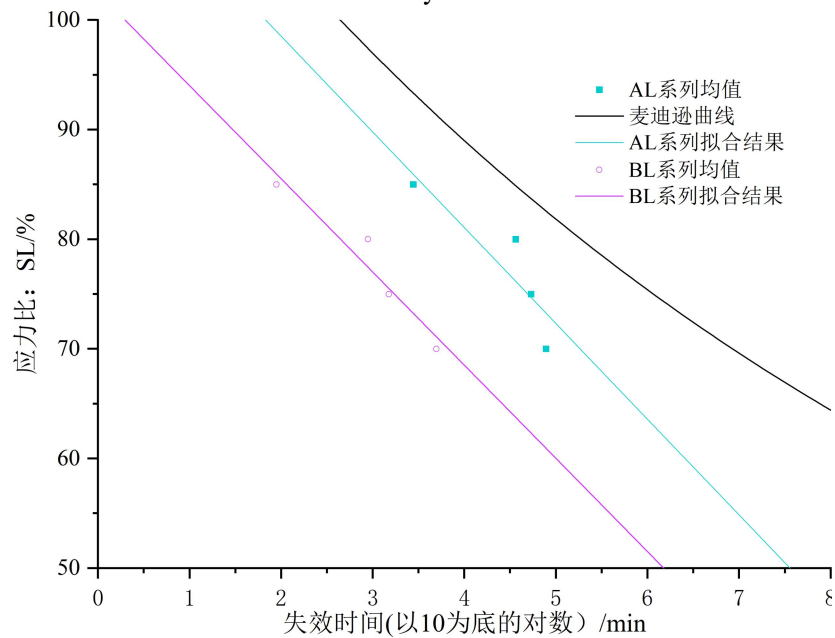
Creep and duration of load (DOL) of fast-growing Chinese Fir CLT



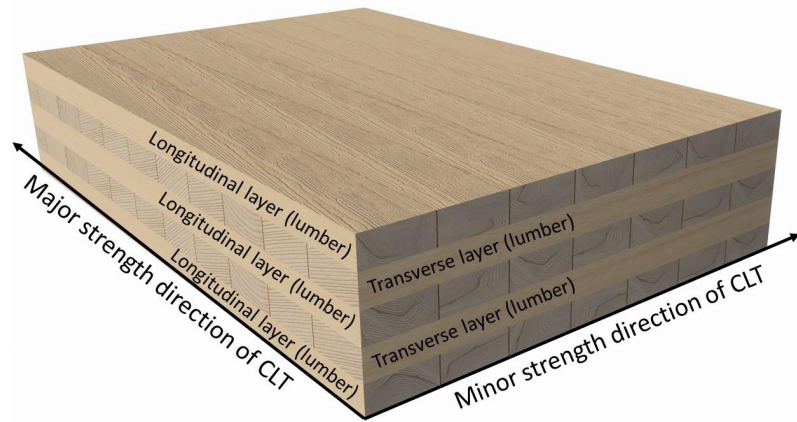
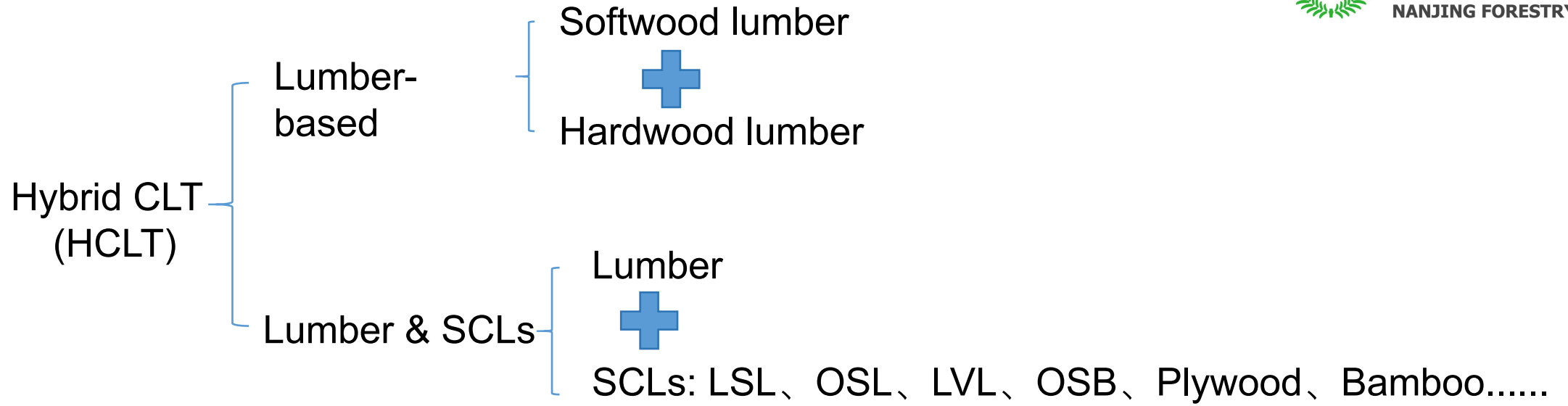
- For Chinese fir CLT specimens with different edge gap widths in cross layers, creep and DOL tests were conducted in normal and constant environment.
- The influence of the creep factor, DOL factor and structural characteristics of Chinese fir CLT on the long-term mechanical properties was determined.



Group	Width of edge gap /mm	Creep factor	DOL factor
AL	0	1.89	0.48
BL	6	1.69	0.42

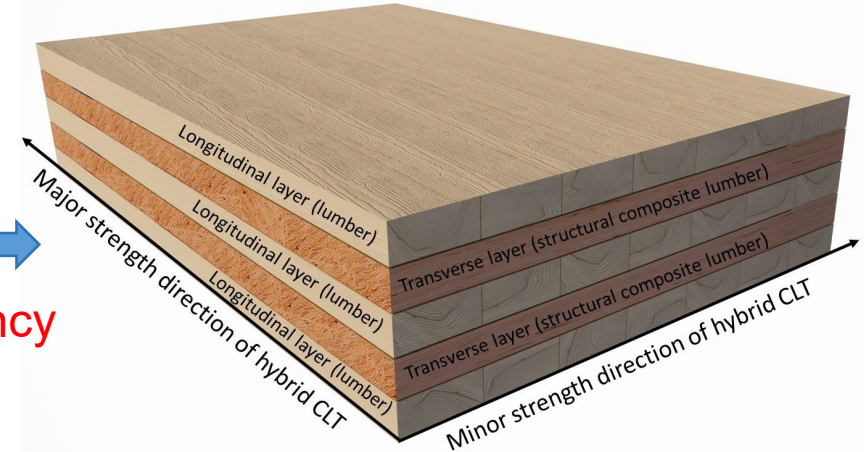


- The edge gap will reduce the creep deformation of CLT, but increase the influence of DOL effect.
- The creep factor of fast-growing Chinese fir CLT is lower than the standard requirement value, indicating good long-term mechanical properties.



(a) A generic CLT made of lumber only

Higher mechanical and connection properties
Higher production efficiency



(b) A hybrid CLT made of dimension lumber and structural composite lumber

Mechanical performances of cross-laminated timber-bamboo (CLTB)

- Using flattened bamboo as outermost layer and bamboo scrimber as cross layer to form CLTB.
- Evaluate the bending performance of CLTB by dynamic, static and theoretical formulas, etc.
- Optimize the layup structure of CLTB.



(a) 三层结构纯木 CLT 结构 CLT(WWW-CLT)



(b) 三层结构竹木复合 CLT 结构 CLT(WBW-CLT)

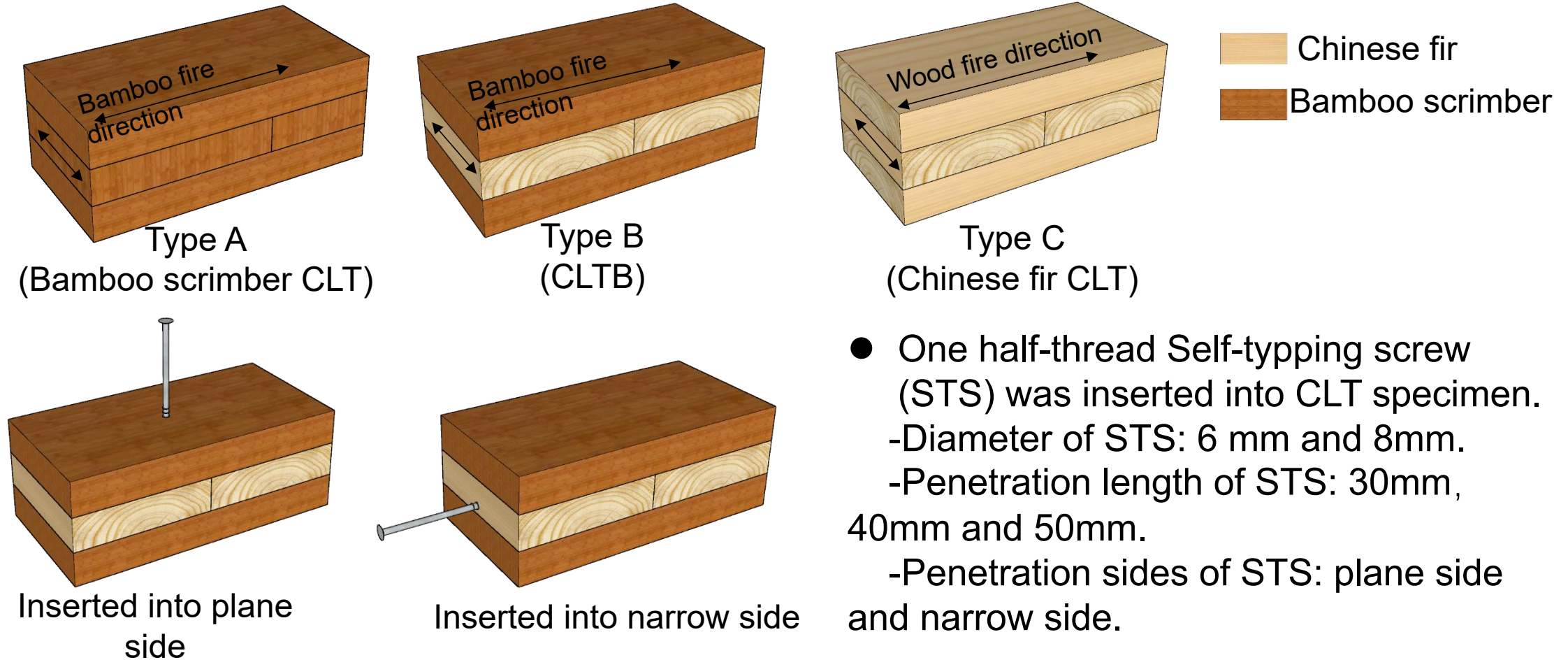


(c) 五层结构竹木复合 CLT 结构 CLT (BWBWB-CLT)

Group	MOE(MPa)	MOR(MPa)
WWW	9374	40.36
WBW	9742	32.55
BWBWB	11595	66.37

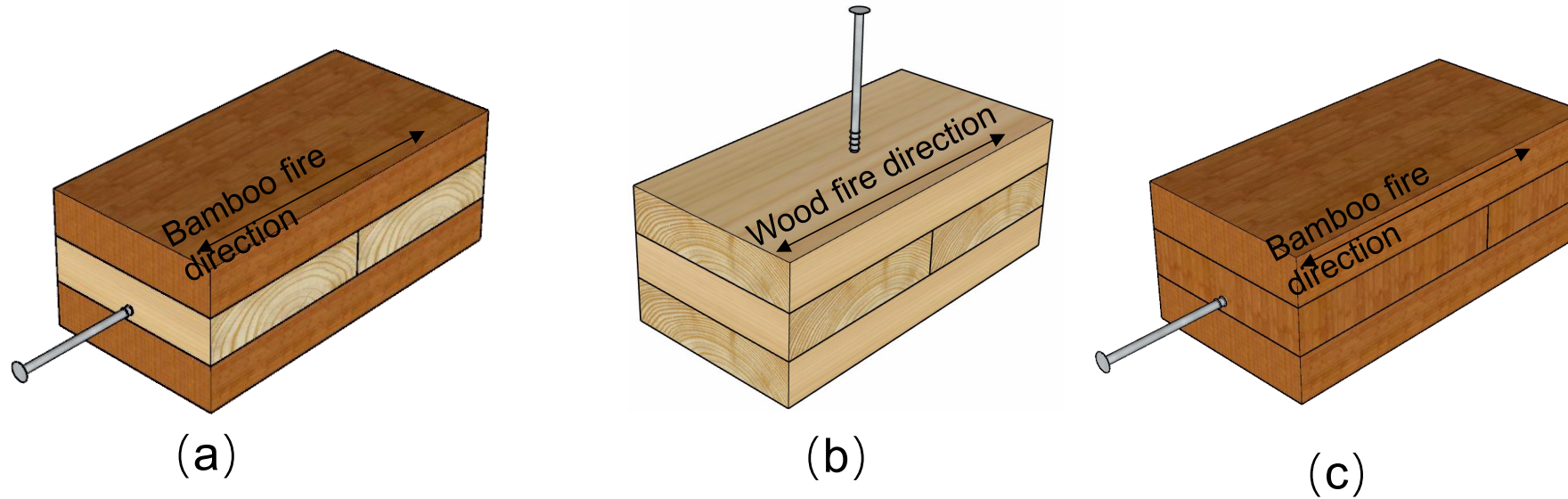
Withdrawal resistance for self-typing screw(STS) in CLTB

- Three types of CLTB made of Chinese fir lumber and bamboo scrimber.



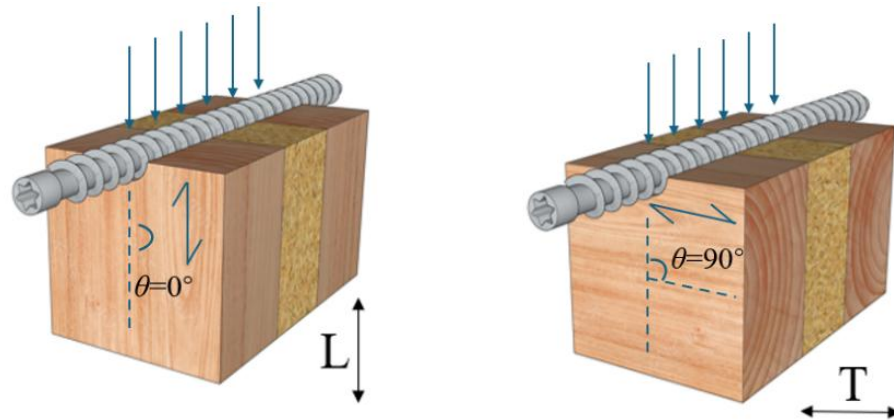
- One half-thread Self-typing screw (STS) was inserted into CLT specimen.
 - Diameter of STS: 6 mm and 8mm.
 - Penetration length of STS: 30mm, 40mm and 50mm.
 - Penetration sides of STS: plane side and narrow side.

Effects of penetration side on withdrawal resistance

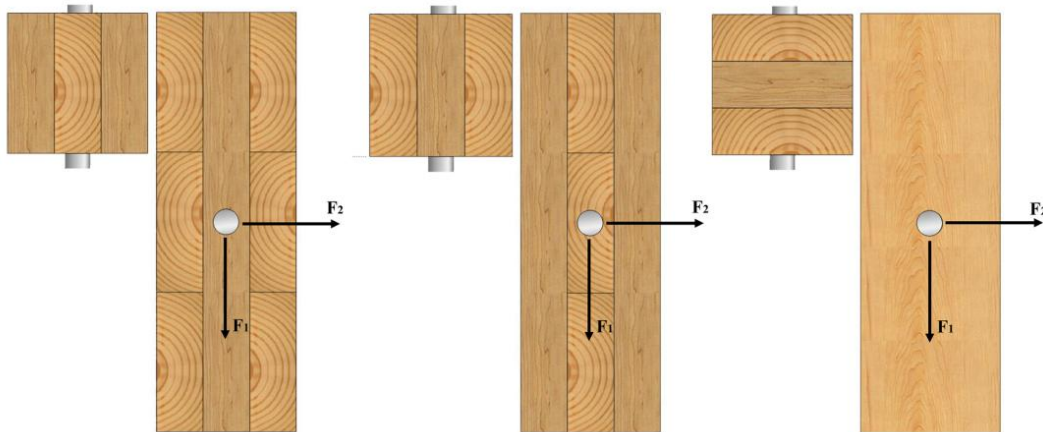


- When STS inserted into the narrow side or surface side, and penetrated the same type lamination, Figs. (a) and (b), their withdrawal resistance is similar.
- When STS inserted different type layer from narrow side, Figs. (a) and (c), their withdrawal resistance shows significant differences, with values of 4.11 kN and 14.76 kN, respectively.

Embedment performance of CLT and hybrid CLT (HCLT)



- Due to the orthogonal structure and the performance differences of different layers, the embedment capacity of CLT and HCLT is significantly different from that of timber or glulam. So the existing calculation formulas are not suit for CLT.
- The influences of the proportion of cross layer thickness, the embedment direction, and whether to consider cross layer on embedment capacity were studied, and new calculation formulas were established.



(a) Dowel installed in the narrow side (on edge), perpendicular to the grain
 (b) Dowel installed in the narrow side (on edge), parallel to the grain
 (c) Dowel installed in the plane side (on face), perpendicular to the grain

New formulas for embedment performance of CLT and HCLT

For CLT

$$f_{\theta,avg,Mod} = 336.4(0.45 - 0.02d)\rho_{12} \left(\frac{tt}{1.41 \cos^2 \theta + \sin^2 \theta} + \frac{(1-tt)}{1.41 \sin^2 \theta + \cos^2 \theta} \right)$$

(a) consider the proportion of cross layer thickness

For HCLT

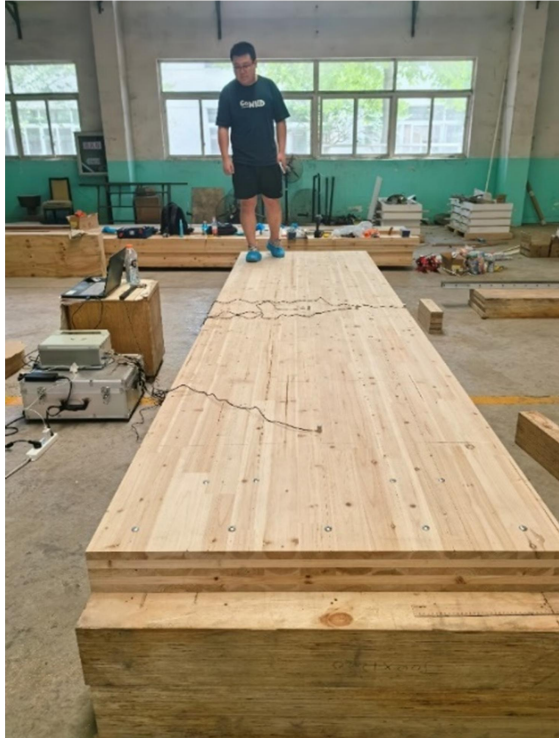
$$f_{h,mod-lower} = \frac{\sum_{i=1}^a t_{L,i} f_{h,L}}{\sum_{i=1}^a t_{L,i} + \sum_{j=1}^b t_{H,j}}$$

(b) ignore transverse layer contributions

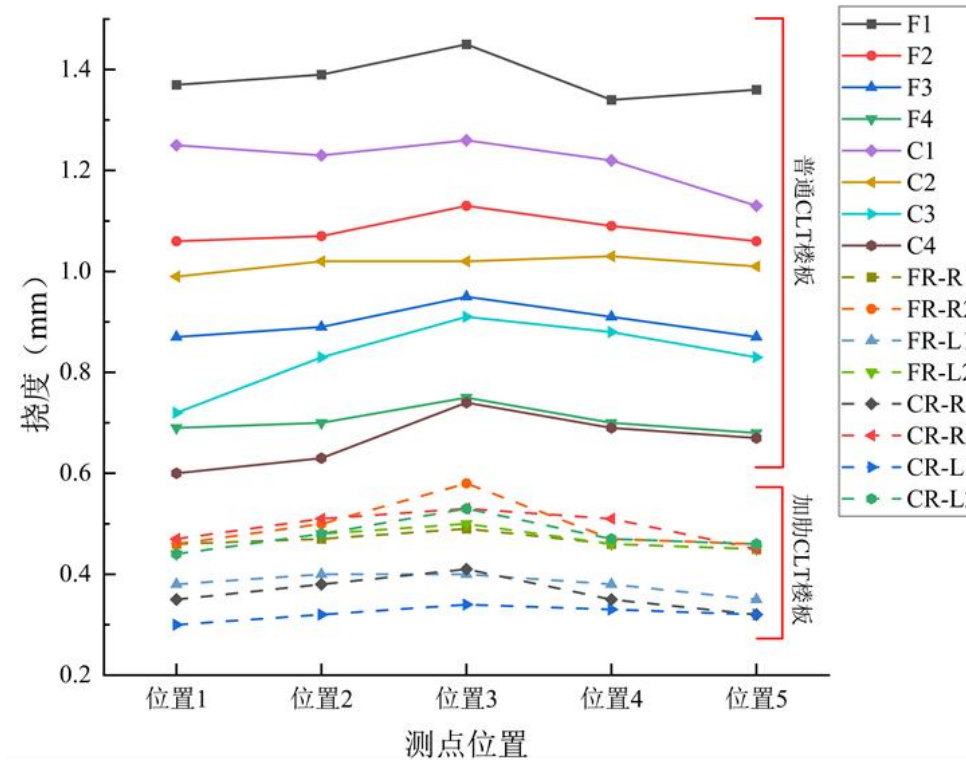
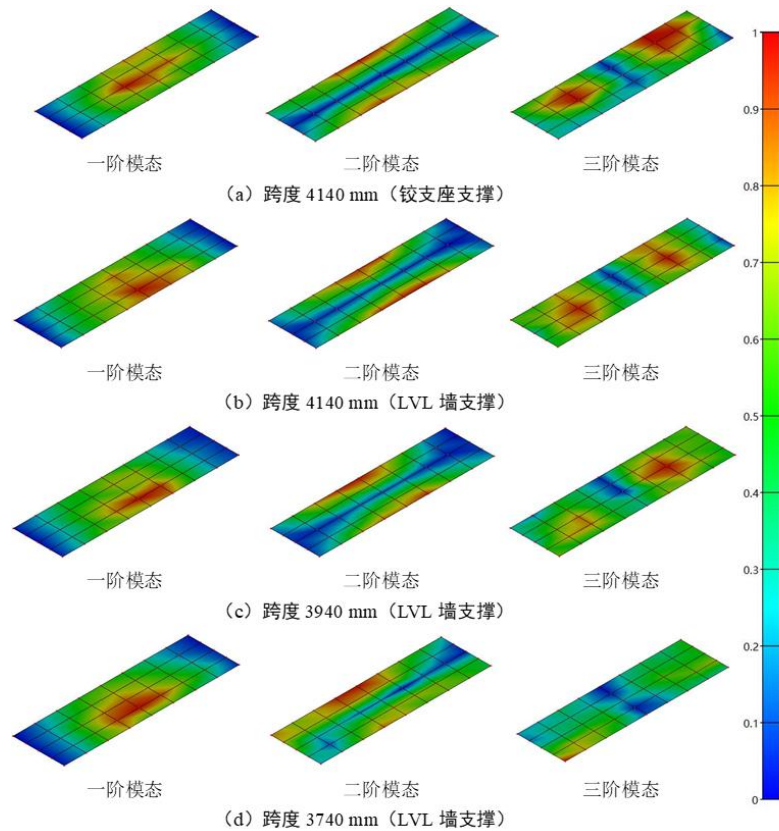
$$f_{h,mod-upper} = \frac{\sum_{i=1}^a t_{L,i} f_{h,L} + \sum_{j=1}^b t_{H,j} f_{h,H}}{\sum_{i=1}^a t_{L,i} + \sum_{j=1}^b t_{H,j}}$$

(c) consider transverse layer contributions

The human-induced vibration performances of CLT floor



- When the span of the CLT floor is relatively large, for example, greater than 6 m, the vibration performance of the floor plays a controlling role.
- The employed performances included concentrated load deflection, vibration mode, and subjective evaluation.



- Both generic CLT floor and ribbed CLT floor are classified as high-frequency structures.
- Vibration performances: ribbed CLT floor > HCLT floor > Chinese fir CLT floor.
- The boundary conditions, the span of floor, whether to add ribs and the structure of floor will affect the vibration performance.

End & Thank You

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