Elastic and ductile design of multi-storey cross-lam massive wooden buildings under seismic actions

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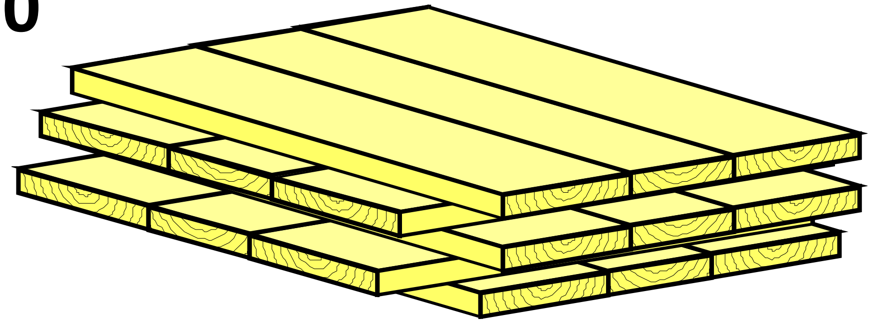
Outline

- **Introduction** on crosslam buildings and seismic design
- **Provisions to ensure ductile failure** mechanisms
- **Evaluation of overstrength factors**
- **Case study building: elastic and nonlinear** (pushover) **analysis**
- **Influence of connection ductility on** the **seismic performance** of xlam buildings
- **Conclusions**

Crosslam Buildings

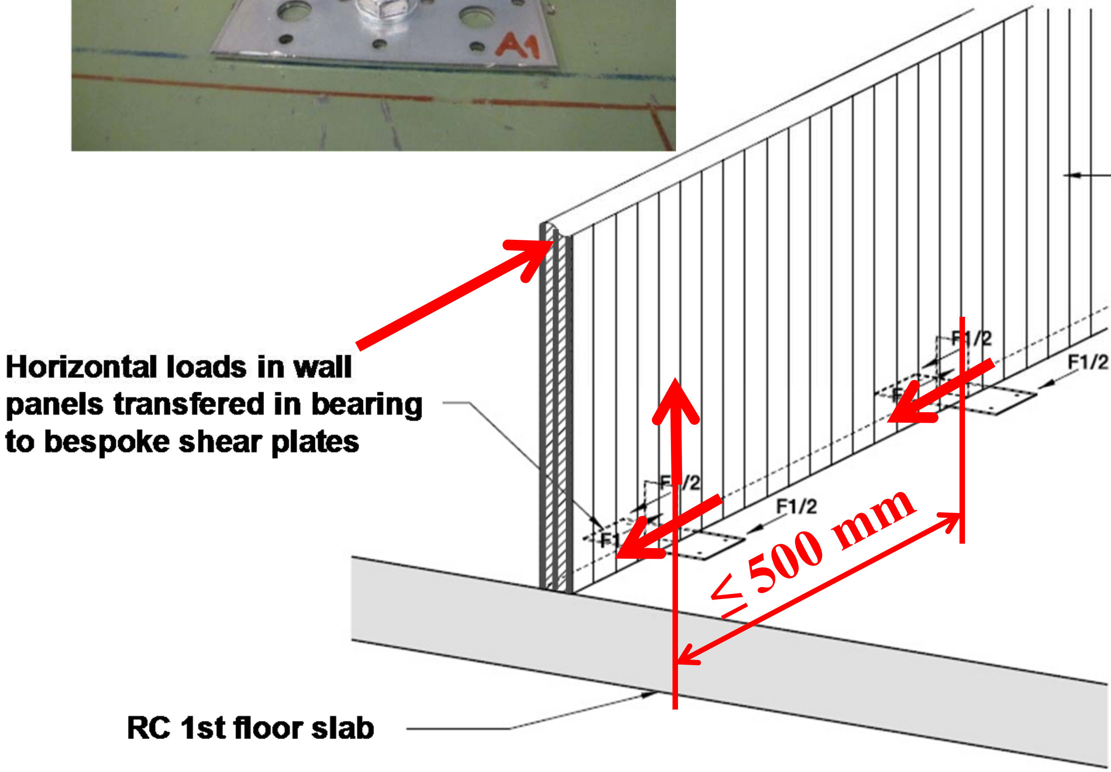
Cross-laminated panels: made of layers of boards, with the adjacent layers glued at 90°

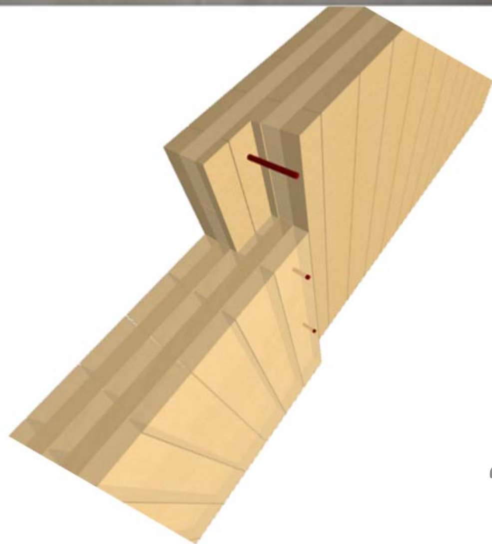


Structural details - Connections

Wall-foundation connections: using metal brackets with 10 ϕ6 mm nails (or screws)

Wall-to-wall connections: using ϕ8 mm screws @ 300 mm c/c





Seismic Design

Seismic design

Brittle structural **behaviour**: use **elastic design spectrum: Sd=Se**

↓

(Elastic) **design for full earthquake actions**

↓

Larger cross-sections required

Ductile structural **behaviour**: use **reduced design spectrum: Sd=Se/q, q=1.5-5**

↓

(Elastic or nonlinear) **design for reduced earthquake actions**

↓

Smaller cross-sections obtained, but....

↓

Need to use **Capacity Based Design**

Capacity based design

The **brittle members** (timber panels) must be **designed for the ovestrength of the ductile members** (connections):

$$E_d' = \gamma_{Rd} \cdot \gamma_{od} \cdot E_d$$

Strength demand in the **brittle member** to design for

Strength demand due to the **reduced elastic spectrum** Se/q

Overstrength factor $\gamma_{Rd} = \frac{F_{0.95}}{F_d}$

$\gamma_{od} = \frac{F_d}{E_d}$ **Overdesign factor**

Open questions:

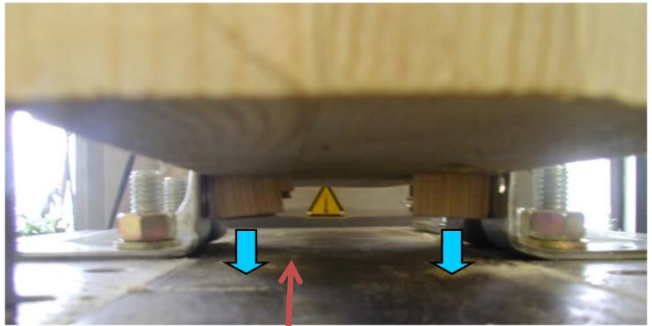
- **No overstrength value suggested by Eurocode 8 for timber** (for steel and r.c.: $\gamma_{Rd} = 1.1 - 1.3$; $\gamma_{Rd} = 2.0$ for timber in New Zealand Standard)

- **No specific provisions** for crosslam buildings **on how to achieve** a **ductile failure** mechanism

- **Lack of indications** on **how to model a crosslam building**, both for elastic and nonlinear (pushover) seismic analysis

- **No information on the effect of connection ductility on the seismic performance** of crosslam buildings

Choice of a ductile failure mechanism for multi-storey cross-lam buildings



- **Ductility** achieved **only in the connections**
- **Desirable failure mechanisms with nails / screws deforming** instead of rotating – more energy dissipation
- In bracket connectors loaded **in shear**, **longer nails** (60 mm) **provide higher strength and ductility**
- In bracket connectors loaded **in tension**, **longer nails** (60 mm) **prevent plug shear failure**