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

Horizontal loads in wall panels transferred in bearing to bespoke shear plates

RC 1st floor slab

≤ 500 mm
Seismic Design

Brittle structural behaviour: use elastic design spectrum: $S_d = S_e$

(Elastic) design for full earthquake actions

Larger cross-sections required

Ductile structural behaviour: use reduced design spectrum: $S_d = S_e/q$, $q=1.5-5$

(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 overstrength of the ductile members (connections):

\[ E_{d'} = \gamma_{Rd} \cdot \gamma_{od} \cdot E_d \]

Strength demand in the brittle member to design for

Overstrength factor

\[ \gamma_{Rd} = \frac{F_{0.95}}{F_d} \]

Overdesign factor

\[ \gamma_{od} = \frac{F_d}{E_d} \]

Strength demand due to the reduced elastic spectrum \( S_e/q \)
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