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Seismic Design of Hybrid Timber Building Systems

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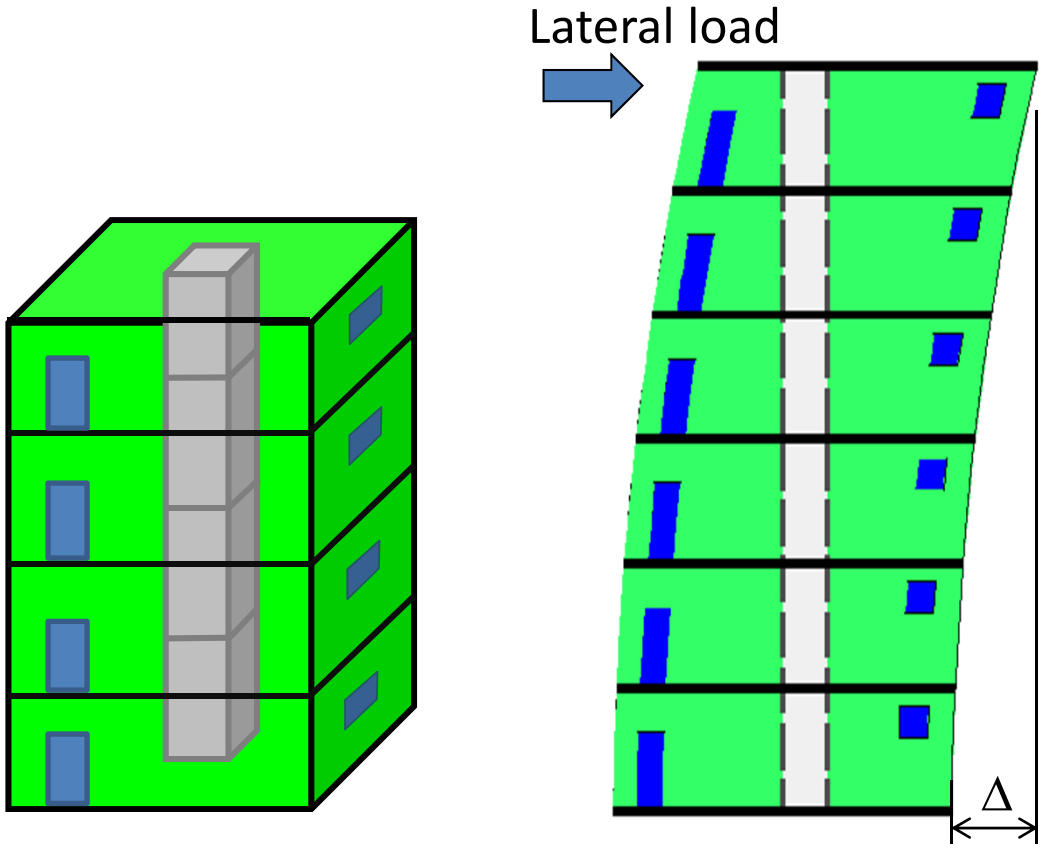
1. Introduction

- Why “Hybrid”?

➢ Solution to the mid-rise LWFBs

Develop a more economical design.



If the stiff core is connected to the timber system, then

$$\Delta' < \Delta$$

1. Introduction

- How “Hybrid”?

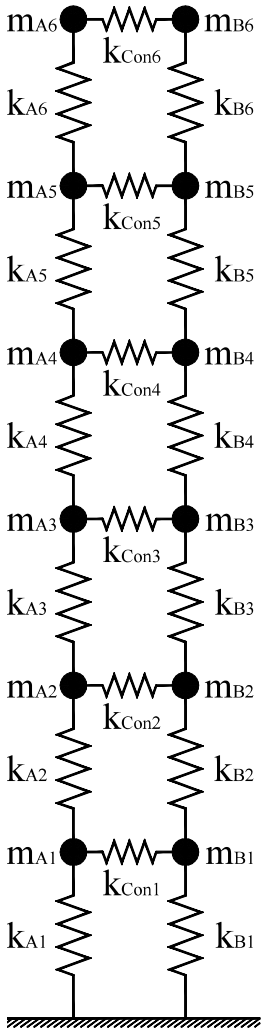
➢ Interaction among sub-systems and connections

How to predict the structural performance?

➢ Design principles of hybrid building systems

Using the lowest seismic modification factor could lead to an uneconomical design!

“Objectives”

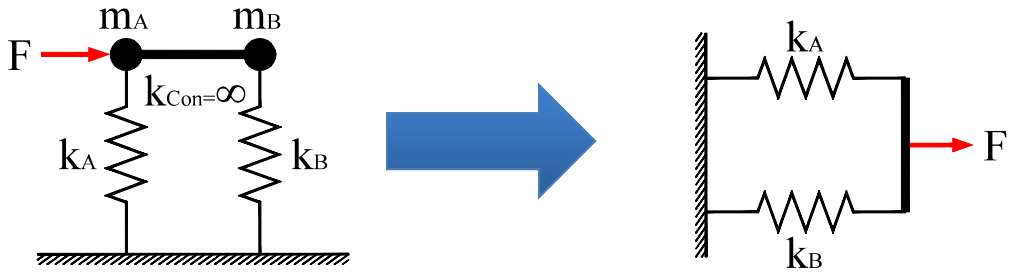


Hybrid system with two sub-systems

2. Design Principles of Hybrid Systems

- Single-Storey

(1) Rigid connection



the seismic design parameters can be estimated using

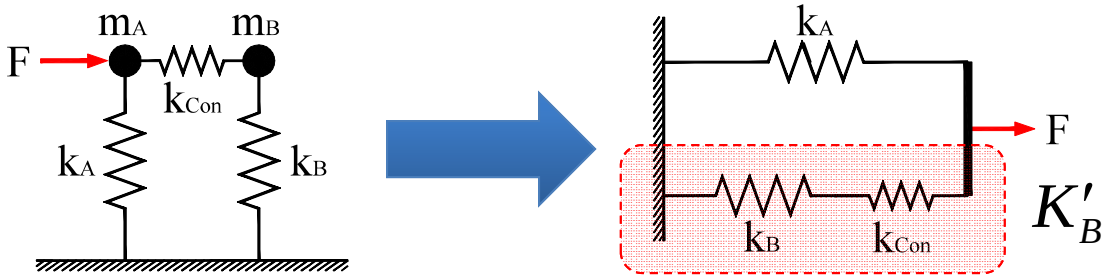
$$T_a = \sqrt{\alpha_A T_{aA}^2 + \alpha_B T_{aB}^2} \qquad \mu = \alpha_A \mu_A + \alpha_B \mu_B \qquad (\alpha_{Fi} \approx \alpha_{Ki} = \alpha_i)$$

$$R_d = \begin{cases} \mu & T_a > 0.5s \\ \sqrt{2\mu - 1} & 0.1 < T_a < 0.5s \\ 1 & T_a < 1/33s \end{cases} \qquad R_o = \alpha_A R_{oA} + \alpha_B R_{oB}$$

2. Design Principles of Hybrid Systems

- Single-Storey

(2) Semi-rigid connection

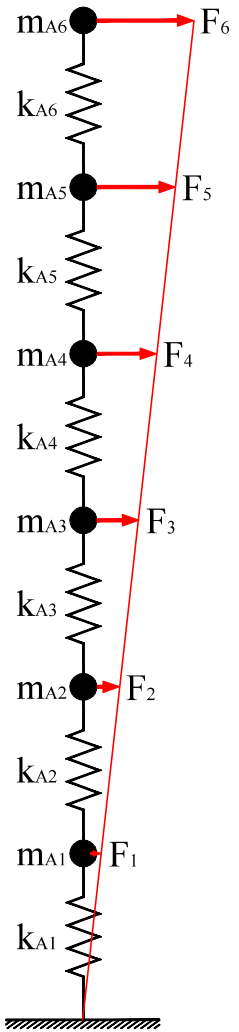


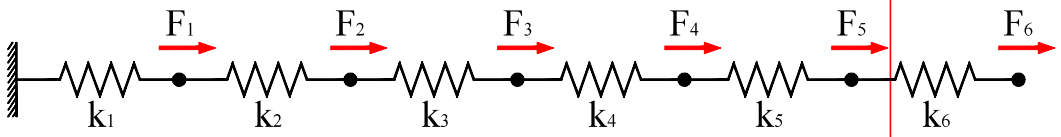
Ductile connection can increase the ductility of hybrid system but the connection system should not be stiffer and stronger than the sub-system B

→ structural contribution provided by sub-system B will be decreased

2. Design Principles of Hybrid Systems

- Multi-Storey





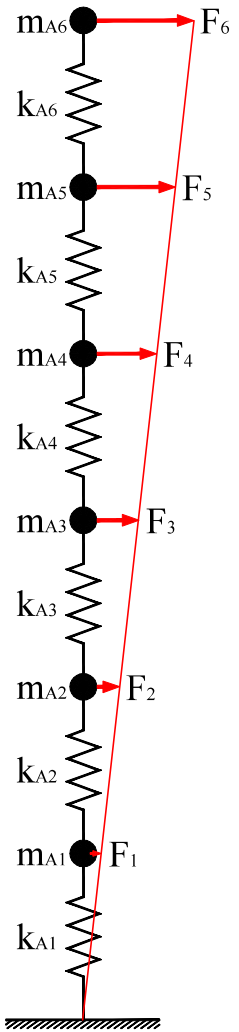
The system ductility ratio depends on which storey reaches its strength first.

Usually $\frac{V_1}{P_{y1}} = \max\left\{\frac{V_j}{P_{yj}}\right\}$, $\mu = \frac{\mu_1 + \sum_{j=2}^{n} \gamma_{1,j}\beta_{1,j}^{-1}}{1 + \sum_{j=2}^{n} \gamma_{1,j}\beta_{1,j}^{-1}} > \frac{\mu_1 + (n-1)}{n}$

where $V_i = \sum_{j=i}^{n} F_j$, $\gamma_{i,j} = \frac{V_j}{V_i}$, and $\beta_{i,j} = \frac{k_j}{k_i}$

2. Design Principles of Hybrid Systems

- Multi-Storey



However, only the inter-storey resistance and drift are of interest, so

$$R_o R_d = \min\{R_{oi} R_{di}\}$$

$$T_a = \sqrt{\min\{\alpha_{Long,i}\} T_{aLong}^2 + \max\{\alpha_{Short,i}\} T_{aShort}^2}$$

3. Validation

- Estimation of system ductility:

(a) Pushover analysis of 160 buildings including shear wall + portal frame;

(b) Reversed cyclic test of 6 shear walls sheathed with OSB or GWB alone or in combination.

- Estimation of seismic force modification factors:

(a) Nonlinear time history analysis of 27 buildings (shear wall + portal frame) under 22 pairs of earthquake actions with increasing intensity (CMR);

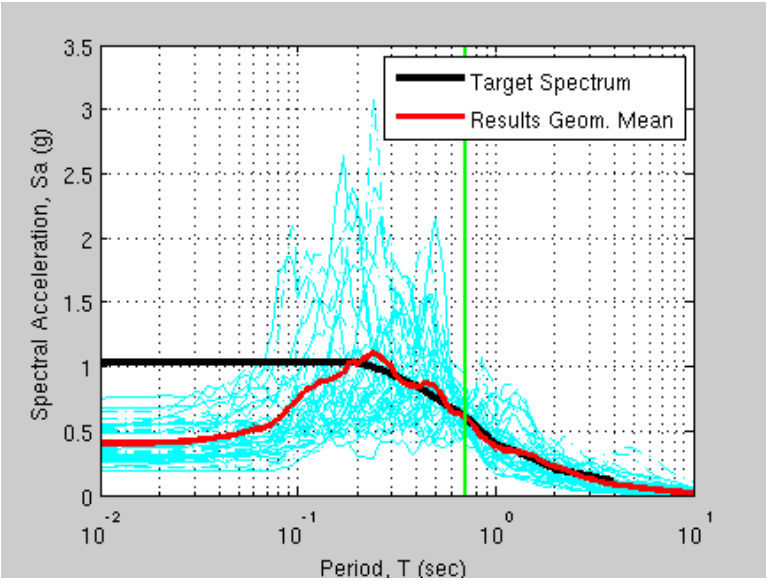
(b) Nonlinear time history analysis of 67 buildings (light wood frame + stiff core) under 2 seismic ground motions.

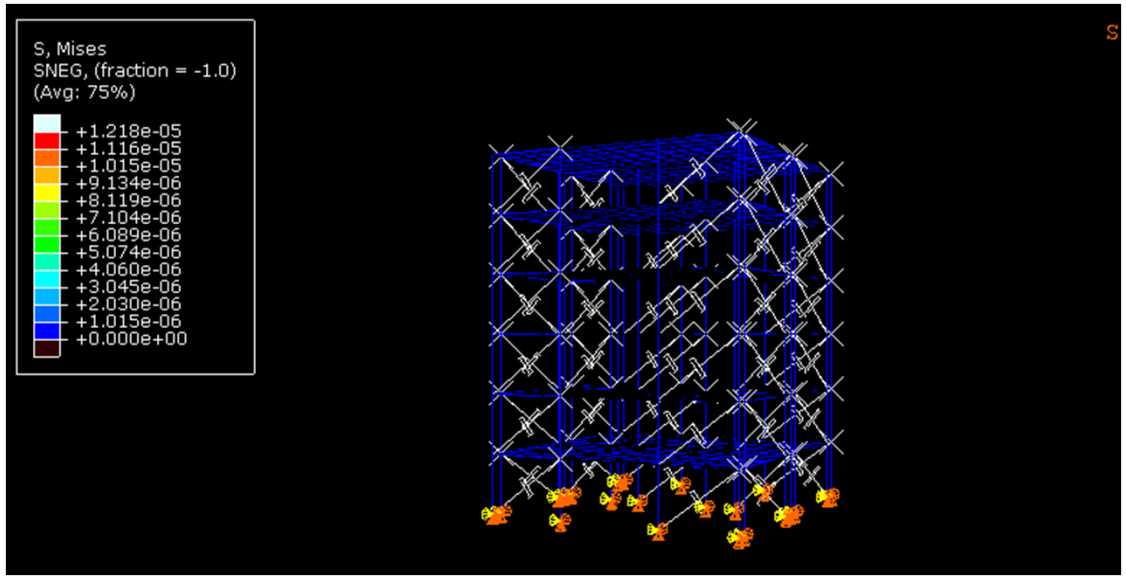
- Estimation of fundamental period:

Frequency analysis of 160 buildings (shear wall + portal frame) and 67 buildings (light wood frame + stiff core)

3. Validation

- Nine hybrid timber building were designed and analysed under 22 pairs of scaled earthquake





- The seismic response, in terms of inter-storey drift ratio and collapse margin ratio, of hybrid timber buildings was used to confirm that the proposed approach to estimate the system R_d factor of hybrid systems is appropriate.

Conclusions

- Ductile connection can improve the ductility of hybrid building systems, but the stiffness and strength of the whole system can be increased a little bit

- Sub-systems incorporate together efficiently using stiff and strong connection, the ductility, fundamental period, seismic force modification factors of the hybrid system can be estimated based on those of sub-systems along with the stiffness and strength ratios

- The principles of seismic design for hybrid buildings were proposed and validated.

The end!

Thank you for your attention!