From Design to Construction, How to manage & minimize differential movement in Tall Mass Timber Structures?

*Presented by:*

+ Josephine Racine  
+ Specialist Engineer, EIT, Dipl. Ing.

*Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.*
What has been said...

+ Timber moves
+ Sources of movement
+ How to assess them
What we will see now...

+ What differential movement to consider?
  How much movement to account for?

+ Effective strategies to minimize and/or accommodate movement during design and construction

“Today’s message”
What differential movement to consider in Tall Mass Timber Structures?

+ Materials movement
+ Tall structures & cumulative effect
+ Not specific to timber
+ Differential movement to consider
What differential movement to consider in Tall Mass Timber Structures?

+ Non-Timber Structural Elements

Lateral System
What differential movement to consider in Tall Mass Timber Structures?
What differential movement to consider in Tall Mass Timber Structures?

+ Non-Structural Components
  - Interior Partitions
  - Exterior Cladding
  - Mechanical Equipment
  - Roof Drainage
What differential movement to consider in Tall Mass Timber Structures?

+ Between timber elements

\[ \Delta_t = \frac{PL}{AE} \]
How much movement to expect?

\[ \Delta \text{(TIMBER)} = \text{SHRINKAGE} + \text{ELASTIC SHORTENING} + \text{CREEP} + \text{JOINT SETTLEMENT} \]
How much movement to expect?

\[ \Delta_t = \frac{PL}{AE} \]
How much movement to expect?

Contribution from the sources of movement to the total estimated movement in timber columns

**Brock Commons – 17-storey**
- Service Dead Load Axial: 25%
- Service Reduced Live Load: 42%
- Shrinkage: 23%
- Creep and Joint Settlement Estimate: 10%

**INTRO – 8-storey**
- Service Dead Load Axial: 31%
- Service Reduced Live Load: 9%
- Shrinkage: 26%
- Creep and Joint Settlement Estimate: 34%
How much movement to expect?
How much movement to expect?

+ It is not practical to precisely predict the vertical movement of wood structures
+ However, it is possible to get a relatively good estimate
+ Get a lower and upper bound limit to better understand the range of movement

Structural Health Monitoring can help to better understand movement in Mass Timber Buildings
How much movement to expect?

source: CCBST, Moisture Performance and Vertical Movement Monitoring of Pre-Fabricated Cross Laminated Timber – Featured Case Study: UBC Tallwood House, G. Mustapha, K. Khondoker, J. Higgins
Moisture Measurements

6 sensors placed at different depth to capture moisture gradient through panel thickness
Moisture Measurements

During Fabrication and Transportation

During Construction

Figure 10. Analysis of Sample A During Transport

Figure 16. Year Long Moisture Performance

source: CCBST, Moisture Performance and Vertical Movement Monitoring of Pre-Fabricated Cross Laminated Timber –Featured Case Study: UBC Tallwood House, G. Mustapha, K. Khondoker, J. Higgins
Moisture Measurements

During occupancy:

- From 12%-18% MC to 8%-15% MC
  => 3.5% MC average variation

- Design assumptions:
  5% MC variation

source: Operational Performance of Cross Laminated Timber, Brock Commons TallWood House, September 2020
How much movement to expect?

During construction:
+ Disturbance due to shoring used to support outriggers during construction

<table>
<thead>
<tr>
<th>Floor</th>
<th>(inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2 (edge)</td>
<td>-0.055</td>
</tr>
<tr>
<td>L3 (edge)</td>
<td>-0.042</td>
</tr>
<tr>
<td>L3</td>
<td>-0.072</td>
</tr>
<tr>
<td>L4</td>
<td>-0.125</td>
</tr>
<tr>
<td>L5</td>
<td>-0.103</td>
</tr>
</tbody>
</table>

Displacement Measurements

During occupancy:

+ **Above Floor 7**
  0.01” to 0.04”

+ **Bottom Floors**
  0.08” to 0.16”

Estimated to result in 7/16” total cumulated displacement for an edge column after 2 years of in service

Source: Operational Performance of Cross Laminated Timber, Brock Commons Tailwood House, September 2020
How much movement to expect?

Difficult to validate design assumptions due to the multiple factors influencing movement

=> 7/8”, Estimation based on edge columns and overall results
Strategies to minimize and accommodate movement

+ Minimize

+ Accommodate
Strategies to minimize and/or accommodate movement

+ Minimize
  - Isolate perp-to-grain shrinkage & crushing
Strategies to minimize and/or accommodate movement

+ Minimize
  - Shimming
Strategies to minimize and/or accommodate movement

+ Minimize
  - Shimming
Strategies to minimize and/or accommodate movement

+ Minimize
  - Leveling nuts
Strategies to minimize and/or accommodate movement

+ Minimize
Strategies to minimize and/or accommodate movement

+ Accommodate
  - Between timber and concrete
Strategies to minimize and/or accommodate movement

+ Accommodate
  - Between timber and concrete
Strategies to minimize and/or accommodate movement

+ Accommodate

Protect non-structural components

- Deflection tracks at partition
- Control joints at cladding
- Flexible stack joints at vertical plumbing
Strategies to minimize and/or accommodate movement

+ Minimize

- Planning a fast timber erection
- Getting the envelope installed in tandem with the timber
- Setting an effective water management plan
Strategies to minimize and/or accommodate movement

+ Do not over shim
+ Estimated Movement vs On-Site Measurement
Conclusion

+ Critical to consider vertical movement in tall mass timber buildings

+ Negative impact can be avoided

+ Collaboration between design team and construction team

+ Accommodating vertical movement simply becomes another design criteria
Thank you!

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