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

Presented by :

+ Josephine Racine

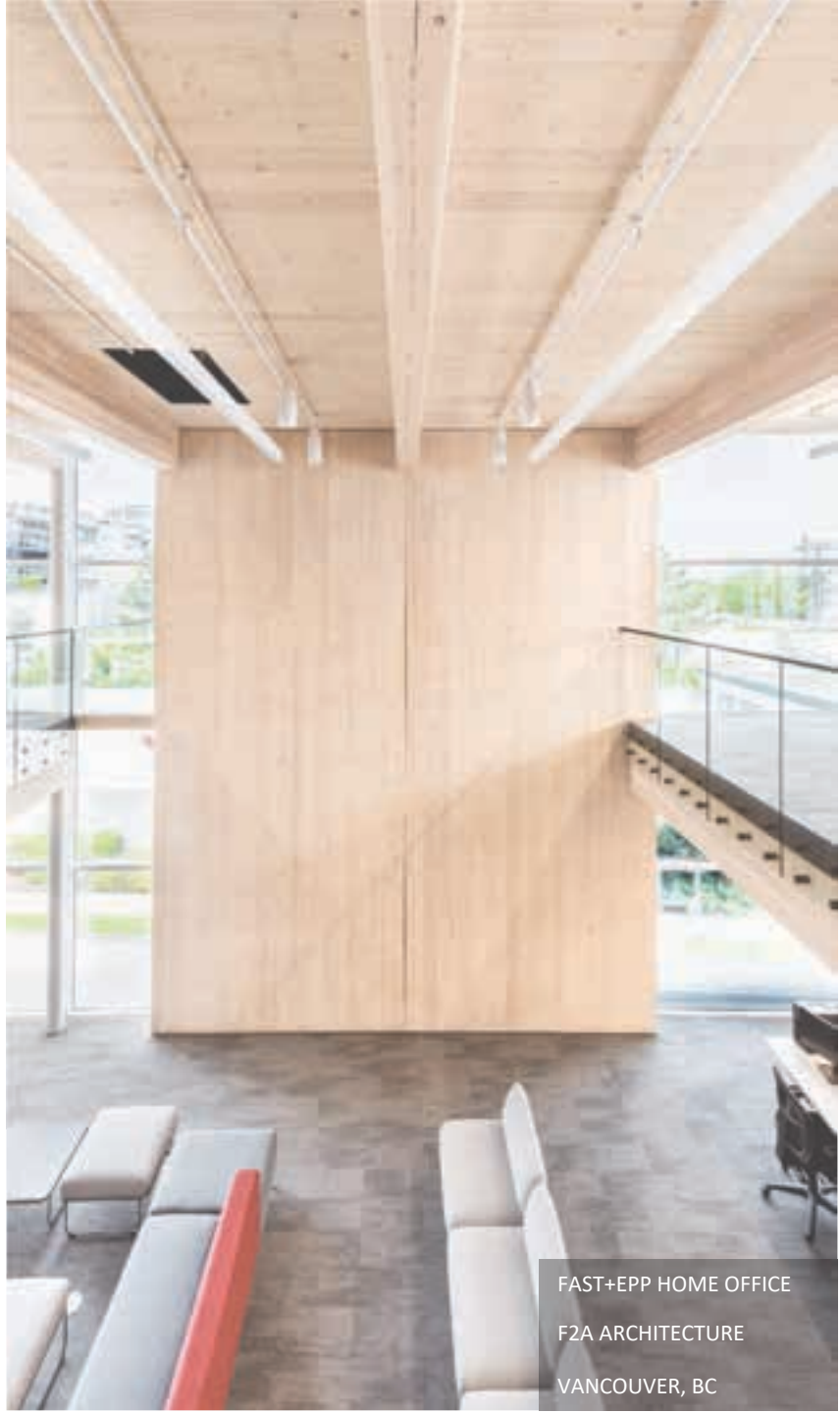
+ Specialist Engineer, EIT, Dipl. Ing.

Fast + Epp

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



FAST+EPP HOME OFFICE

F2A ARCHITECTURE

VANCOUVER, BC

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 ”

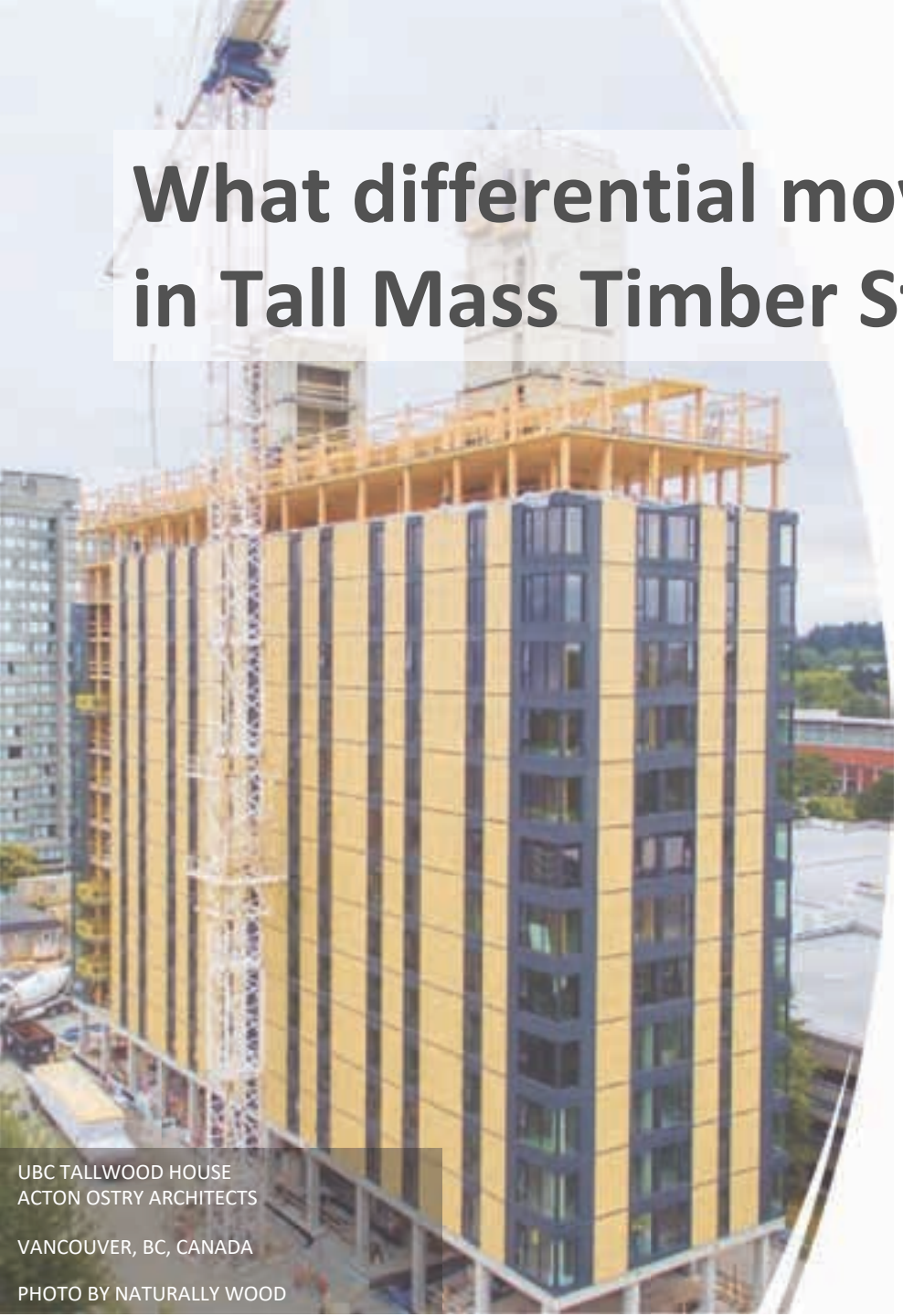
LIMBERLOST PLACE, GEORGE BROWN COLLEGE

MORIYAMA & TESHIMA ARCHITECTS AND ACTON OSTRY ARCHITECTS,

TORONTO, ON

IMAGE BY MORIYAMA & TESHIMA ARCHITECTS AND ACTON OSTRY ARCHITECTS

What differential movement to consider in Tall Mass Timber Structures?



UBC TALLWOOD HOUSE
ACTON OSTRY ARCHITECTS

VANCOUVER, BC, CANADA

PHOTO BY NATURALLY WOOD

- 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

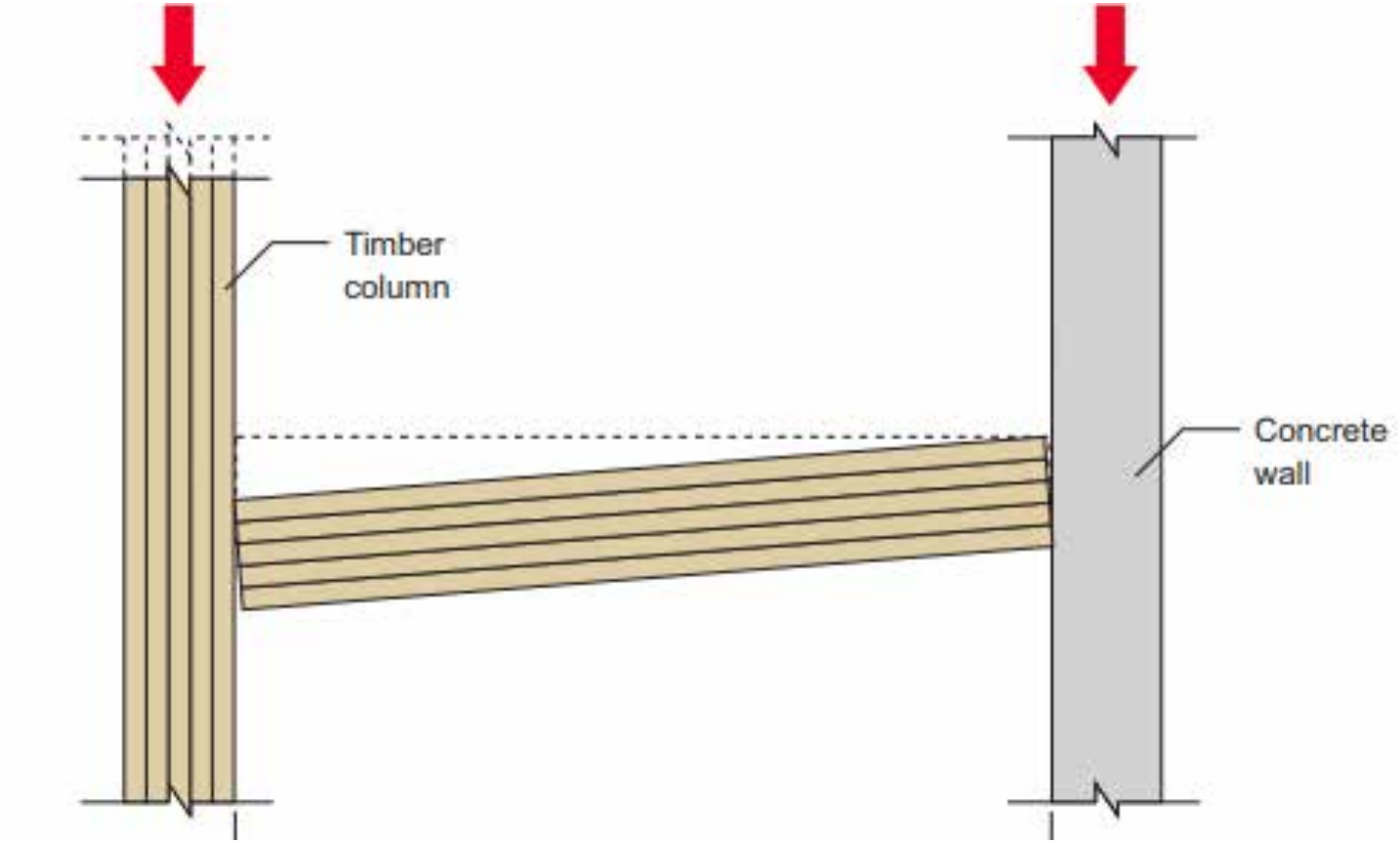
INTRO

HARTSHORNE PLUNKARD ARCHITECTURE

CLEVELAND, OH

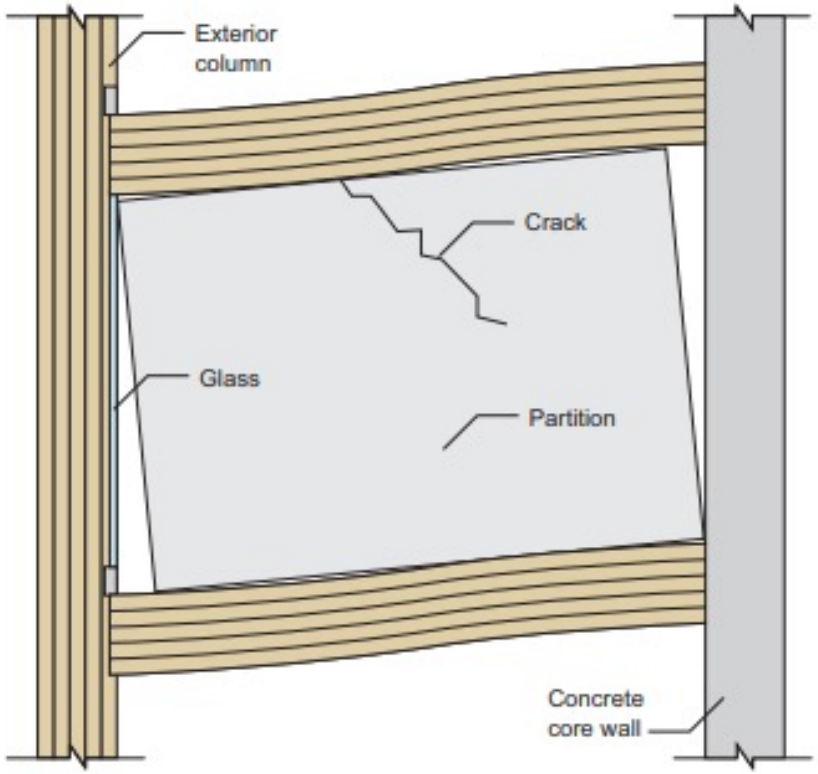
PHOTO BY SEAGATE

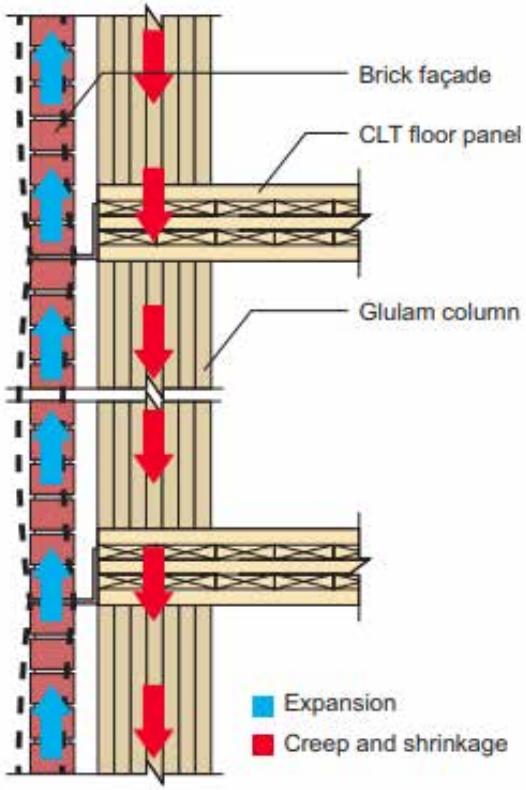
What differential movement to consider in Tall Mass Timber Structures?



What differential movement to consider in Tall Mass Timber Structures?

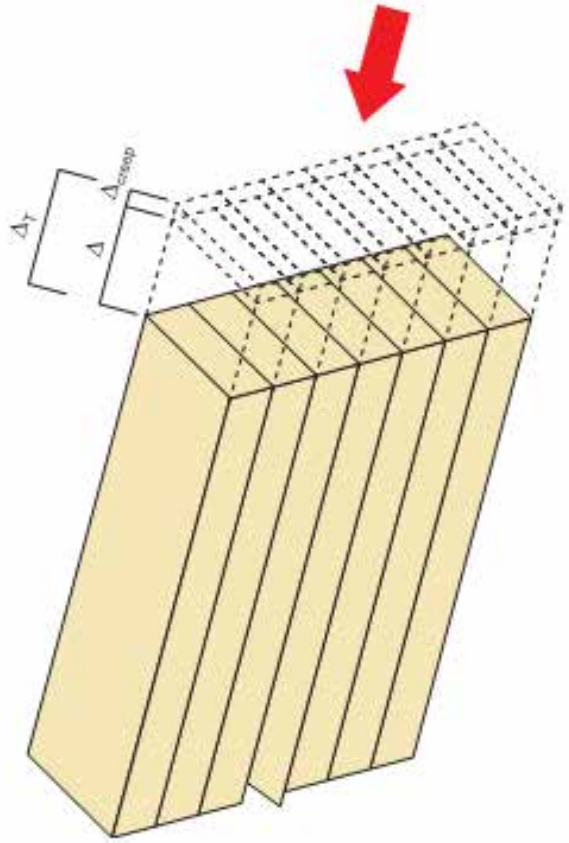
+ Non-Structural Components
  - Interior Partitions
  - Exterior Cladding
  - Mechanical Equipment
  - Roof Drainage





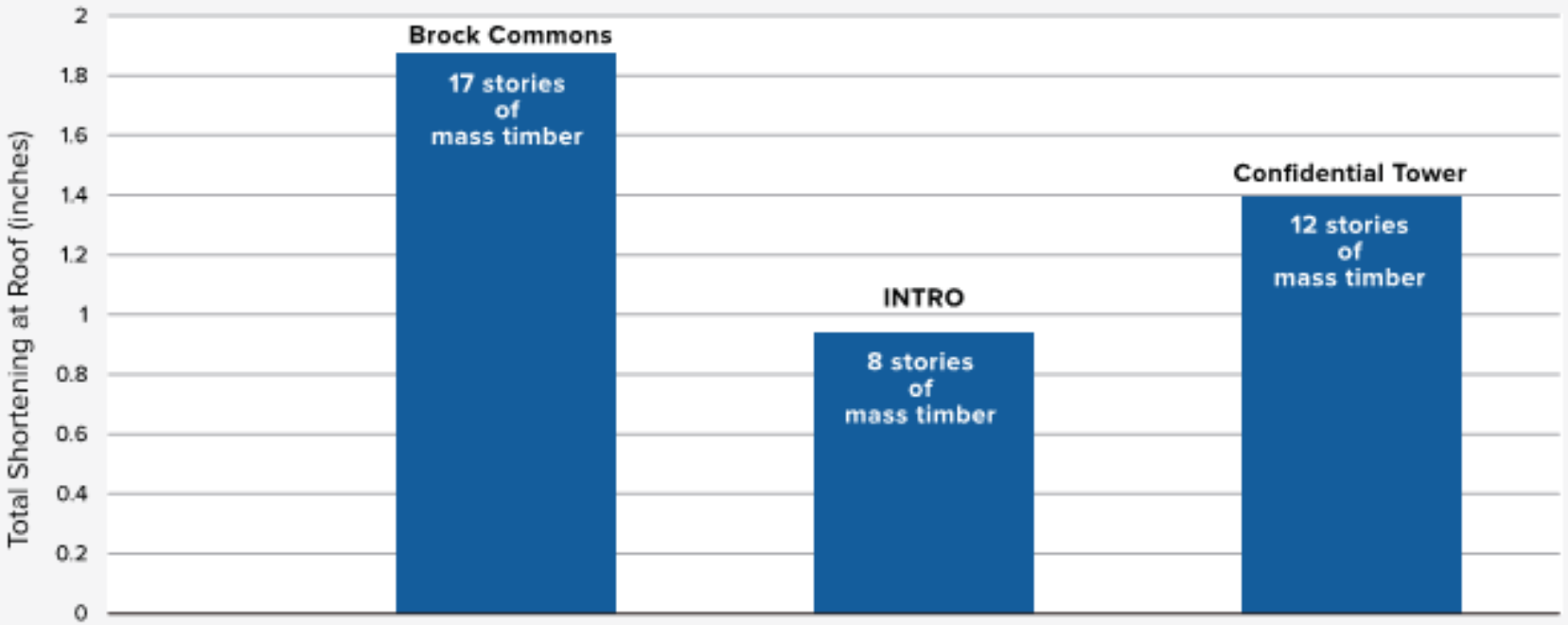
What differential movement to consider in Tall Mass Timber Structures?

+ Between timber elements



$$\Delta_t = PL/AE$$

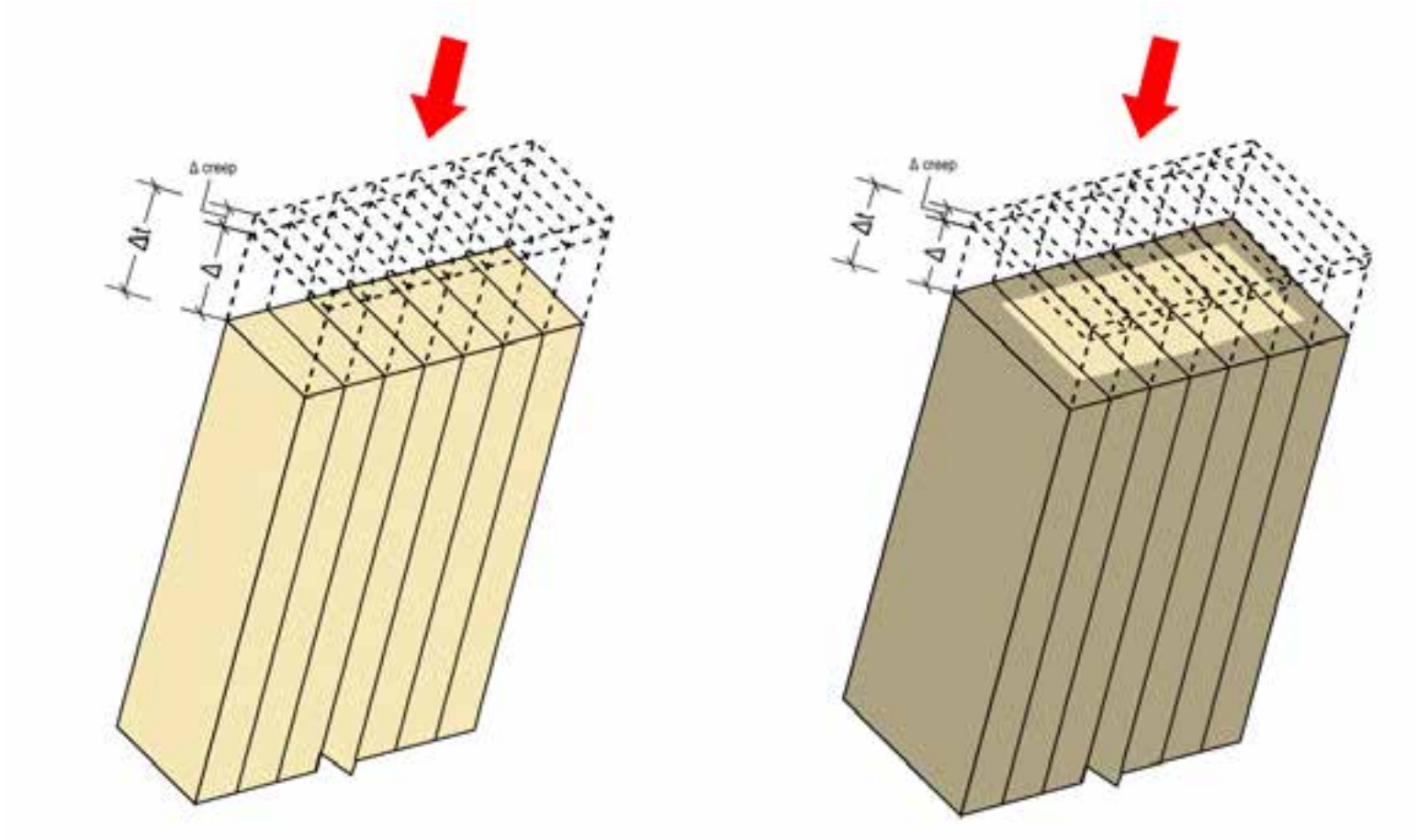
How much movement to expect?



FFR & Exposure	2 hrs - Fully encapsulated	2 hrs - Exposed	2 hrs - Partially encapsulated
Grid	13' x 9'	20' x 22' average	10' x 12'
Structural system	Point-supported CLT	CLT on glulam beams	
Main story height	9'-2"	11'-5"	9'-8"

$\Delta_{(TIMBER)}$ = SHRINKAGE + ELASTIC SHORTENING + CREEP + JOINT SETTLEMENT

How much movement to expect?

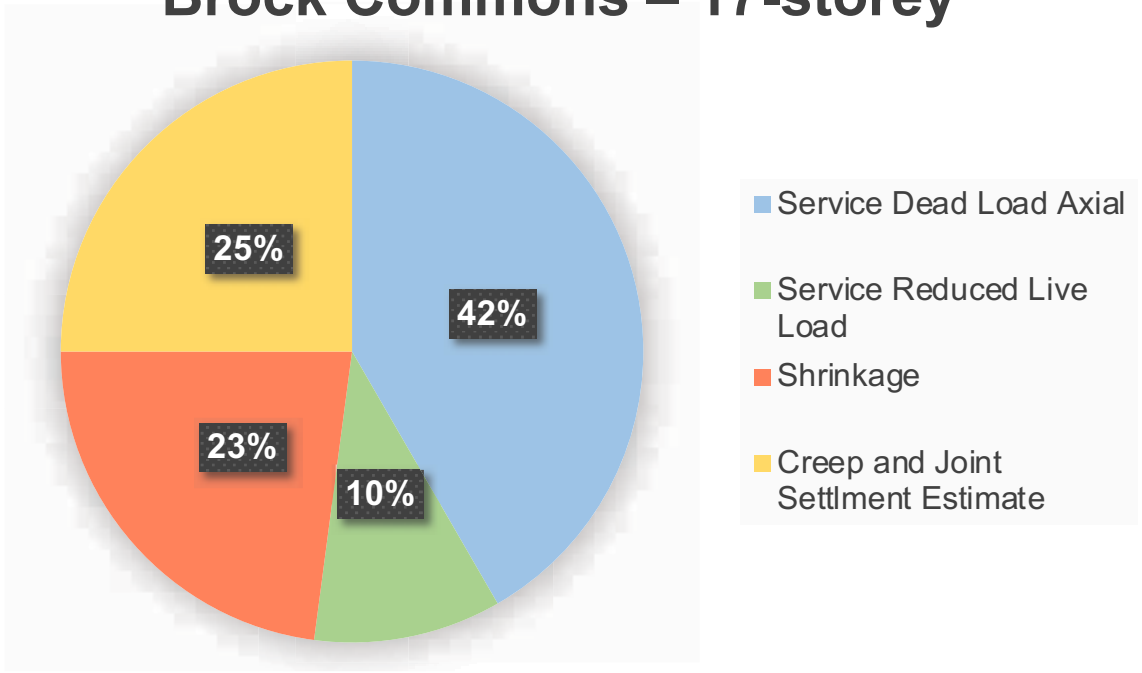


$$\Delta_t = PL/AE$$

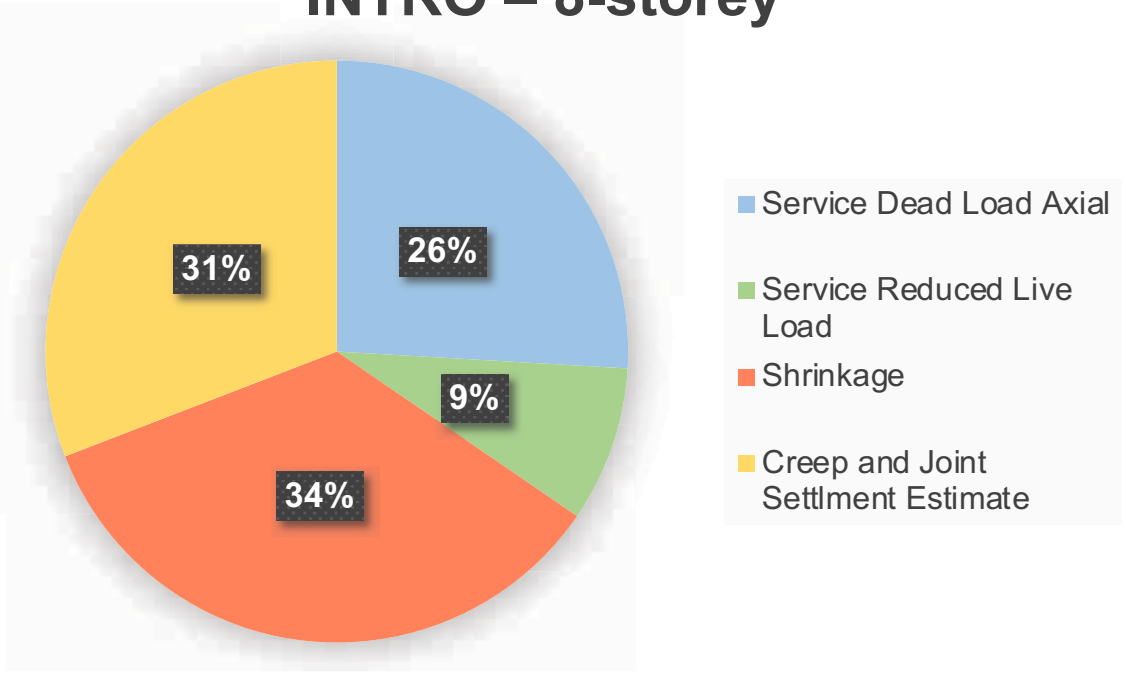
How much movement to expect?

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

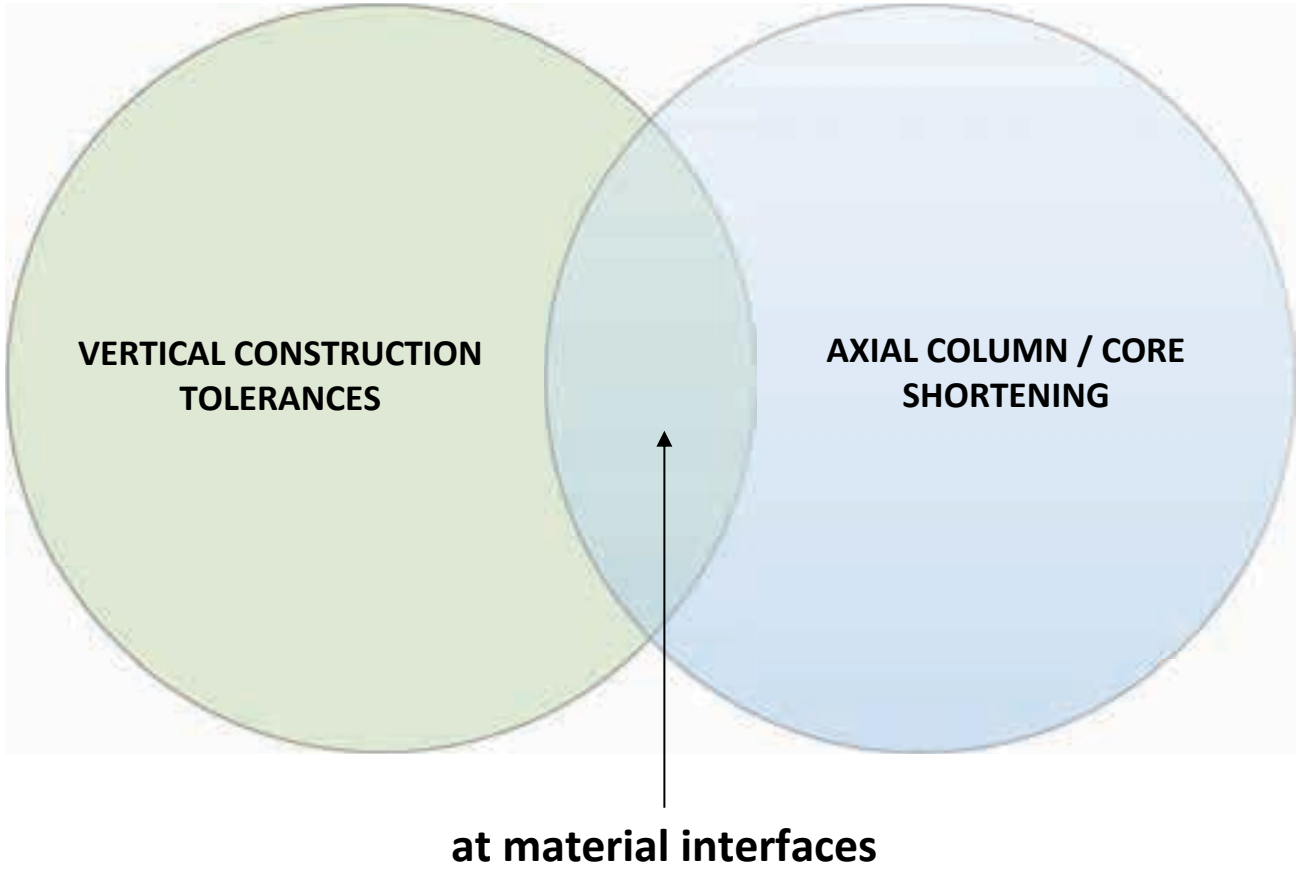
Brock Commons – 17-storey



INTRO – 8-storey



How much movement to expect?



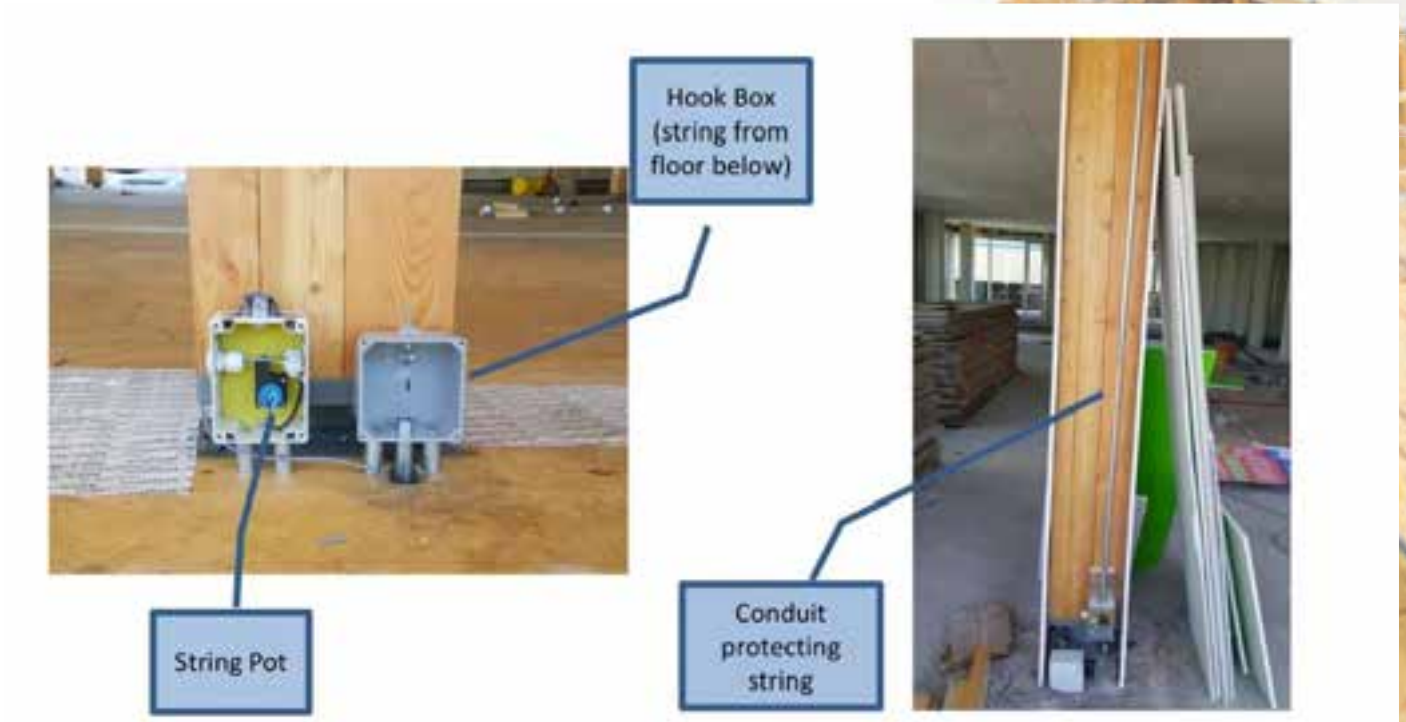
How much movement to expect?

- 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?



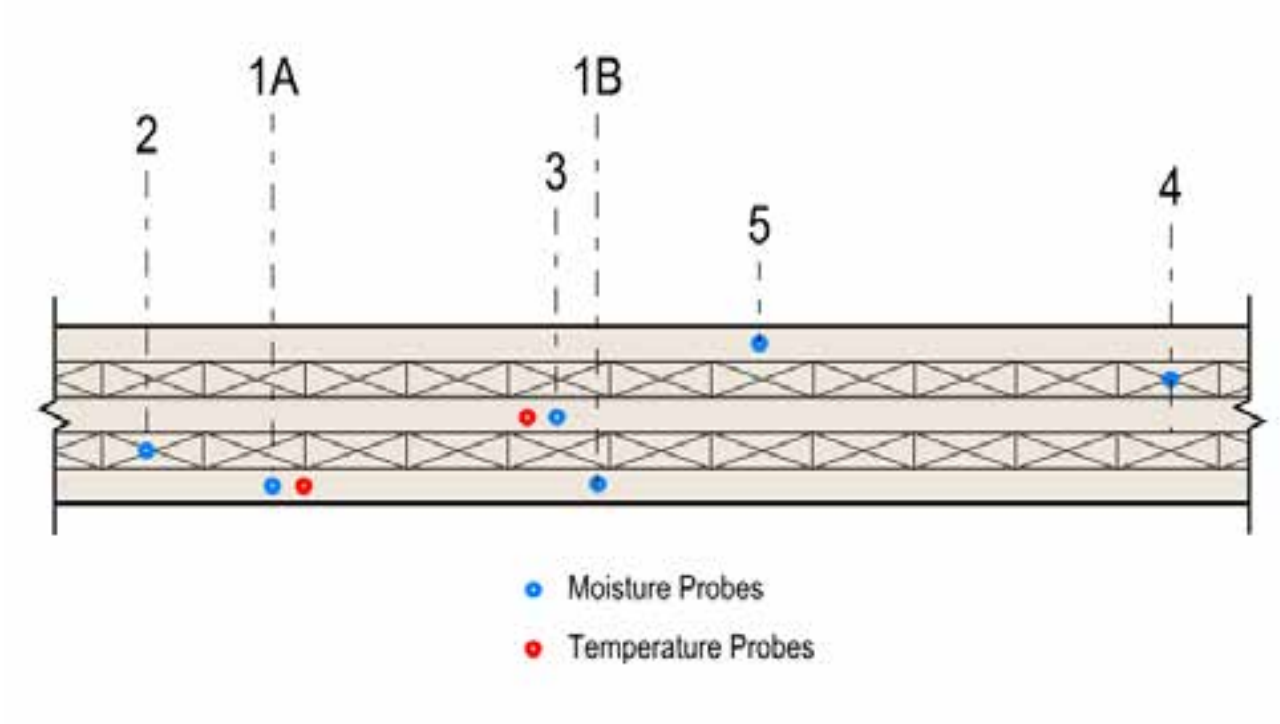
source: CCBST_Moisture Performance and Vertical Movement Monitoring of Pre-Fabricated Cross Laminated Timber –Featured Case Study: UBC Tallwood House, G. Mustapha, K. Khondoker, J. Higgins

UBC TALLWOOD HOUSE
ACTON OSTRY ARCHITECTS

VANCOUVER, BC, CANADA

PHOTO BY NATURALLY WOOD

Moisture Measurements



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

Moisture Measurements

During Fabrication and Transportation

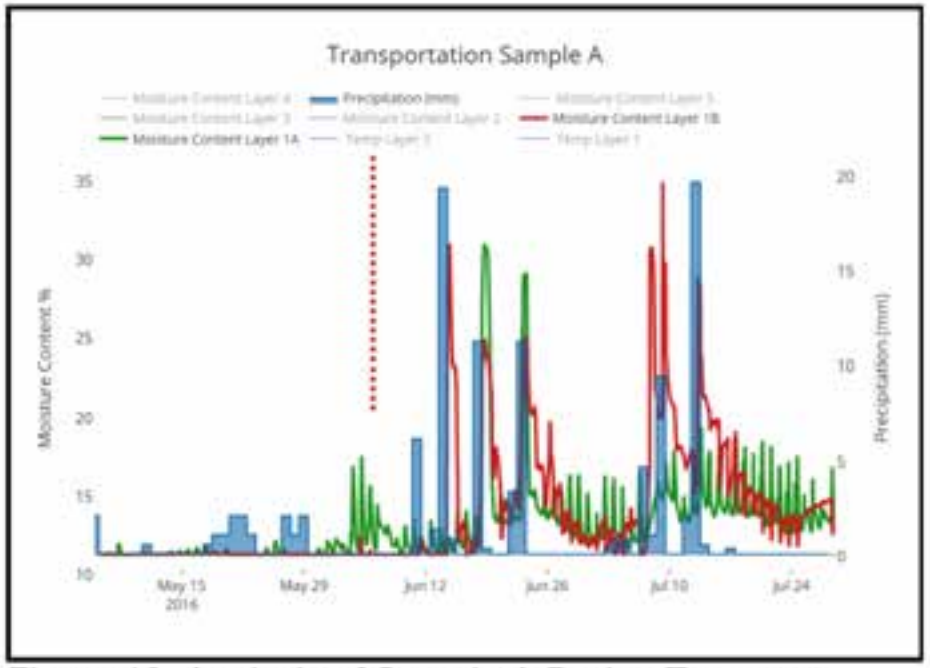


Figure 10. Analysis of Sample A During Transport

During Construction

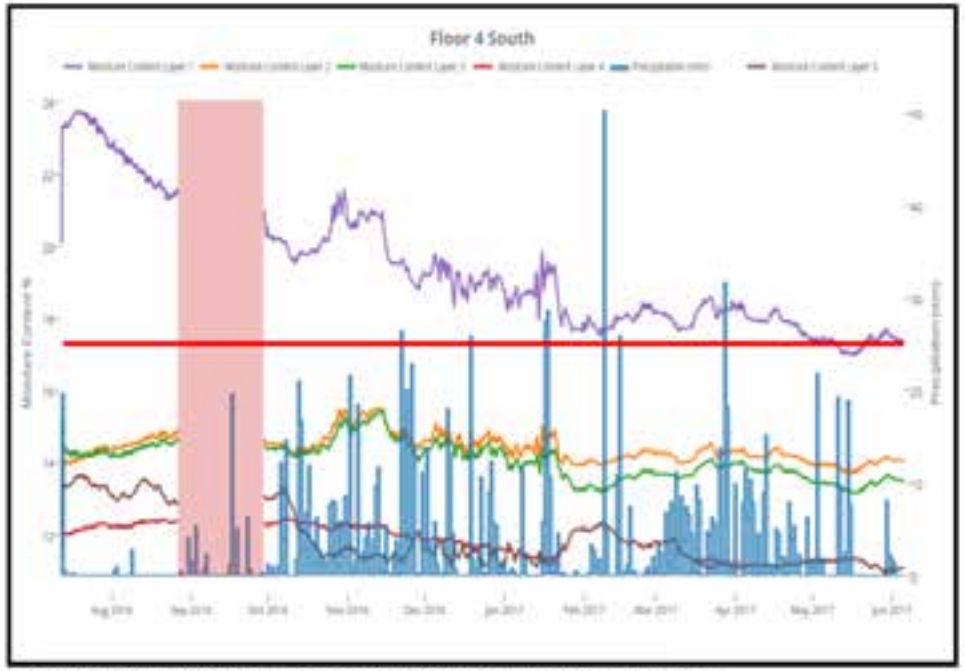
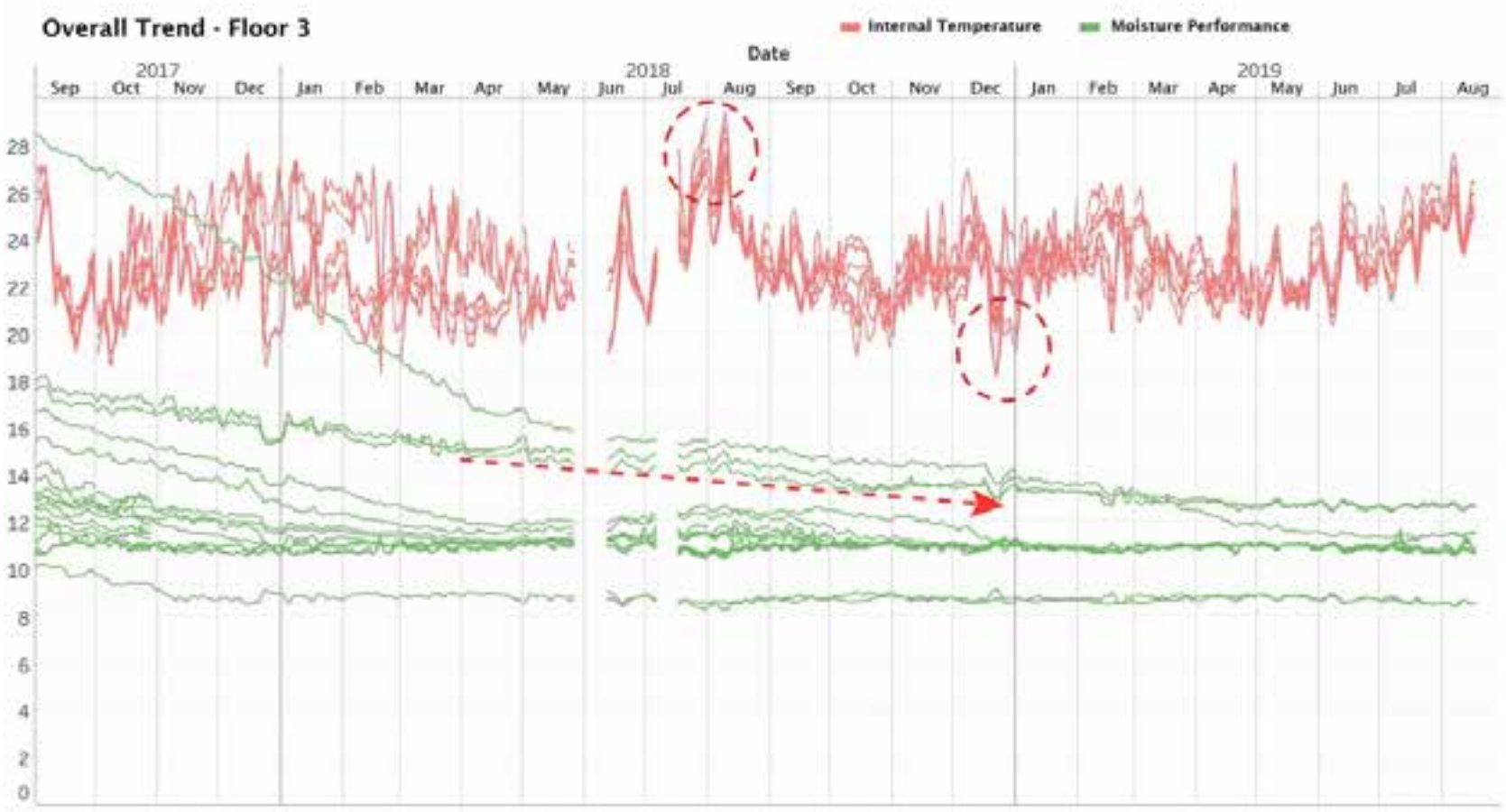


Figure 16. Year Long Moisture Performance

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



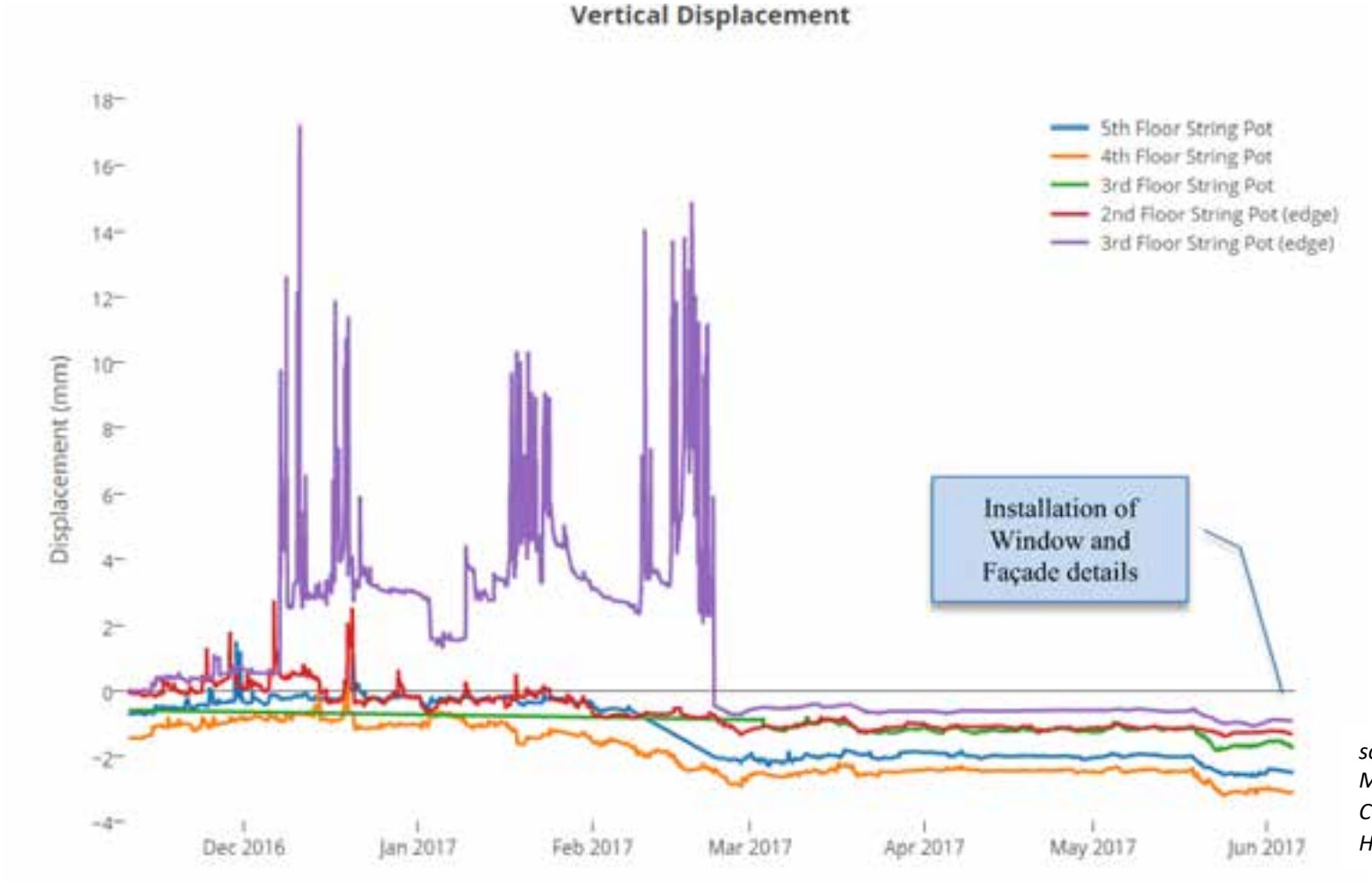
During occupancy :

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

+ Design assumptions :
  5% MC variation

source: Operational Performanceof Cross Laminated Timber, Brock Commons TallWood House, September 2020

How much movement to expect?



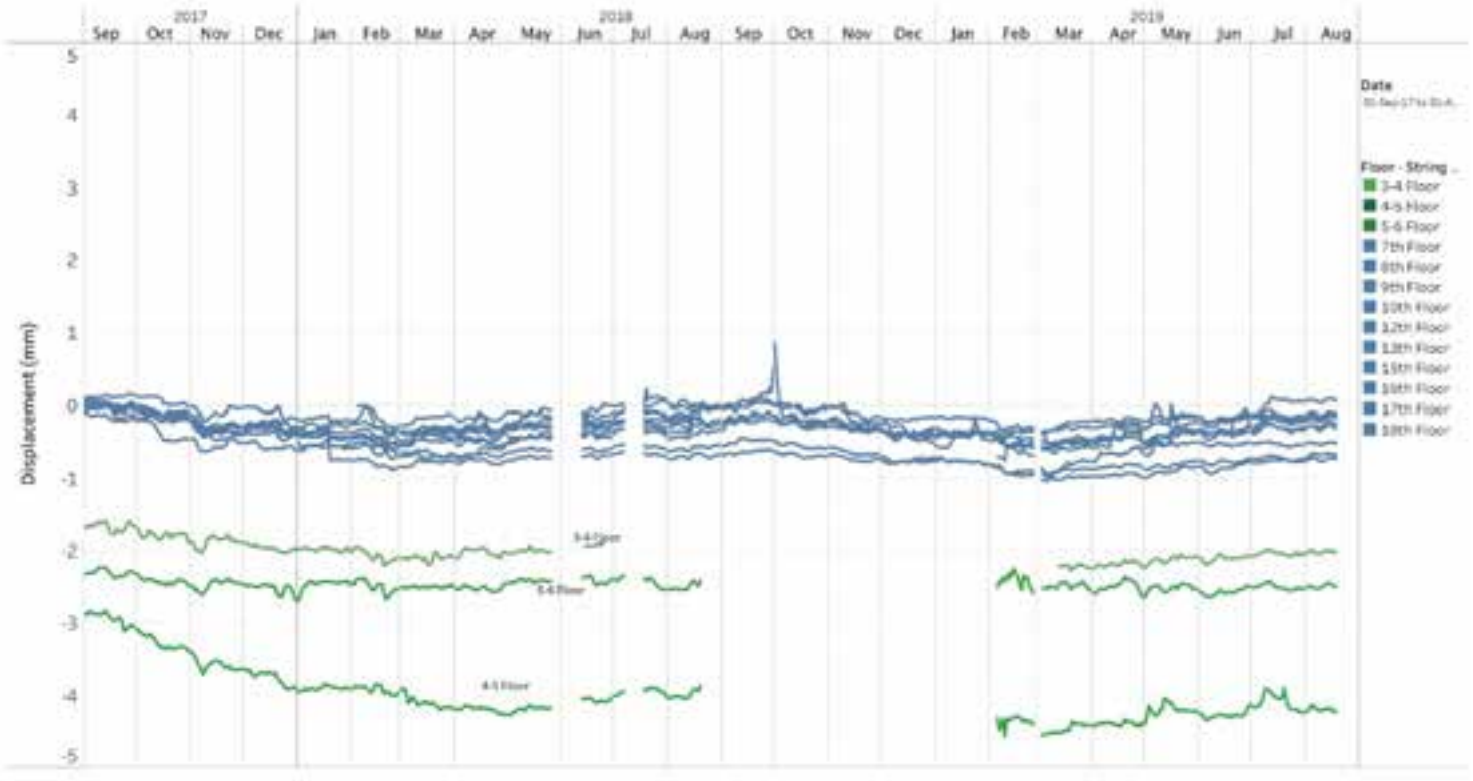
During construction :

\+ Disturbance due to shoring used to support outriggers during construction

Total Displacement June 2017	
Floor	(inches)
L2 (edge)	-0.055
L3 (edge)	-0.042
L3	-0.072
L4	-0.125
L5	-0.103

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

Displacement Measurements



source: Operational Performanceof Cross Laminated Timber, Brock Commons TallWood House, September 2020

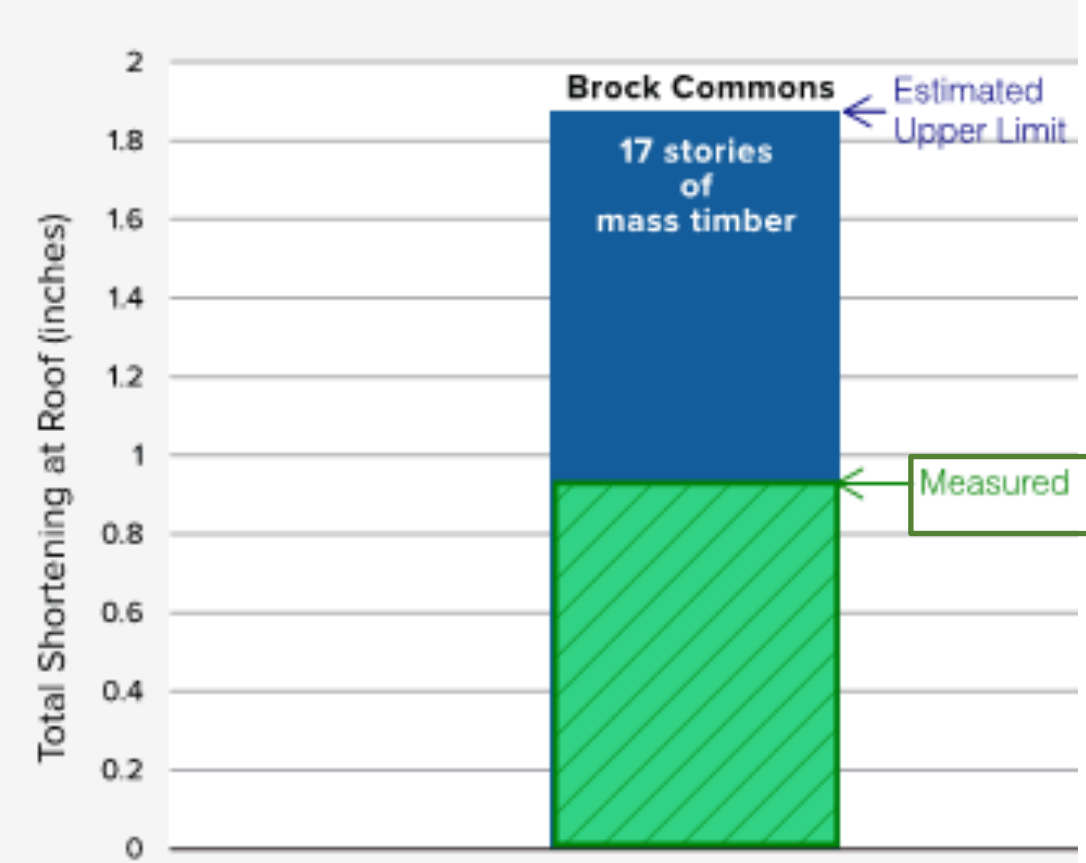
During occupancy :

+ **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

How much movement to expect?



=> 7/8'', Estimation based on edge columns and overall results

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

Strategies to minimize and accommodate movement

+ Minimize

+ Accommodate

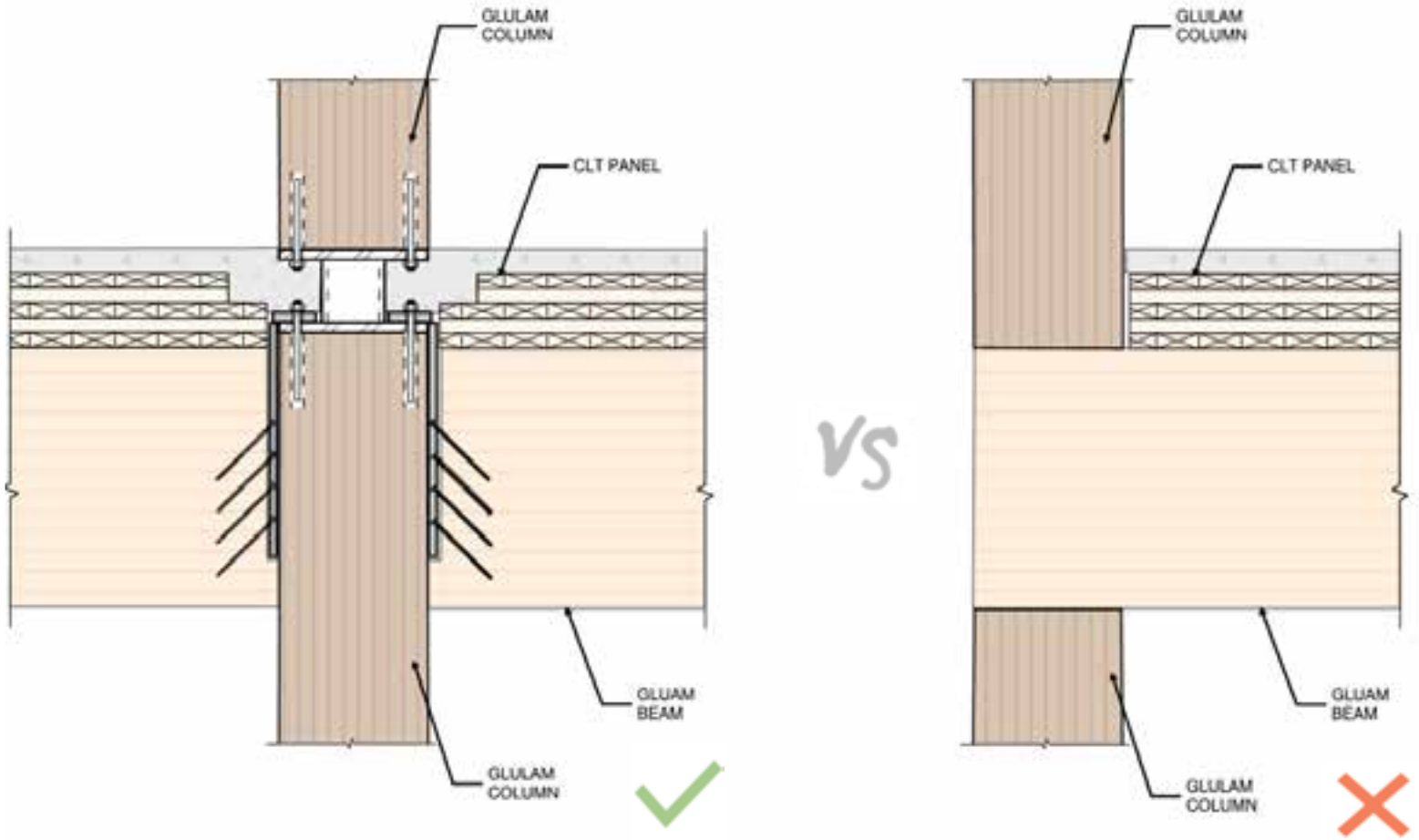
FAST+EPP HOME OFFICE

F2A ARCHITECTURE

VANCOUVER, BC

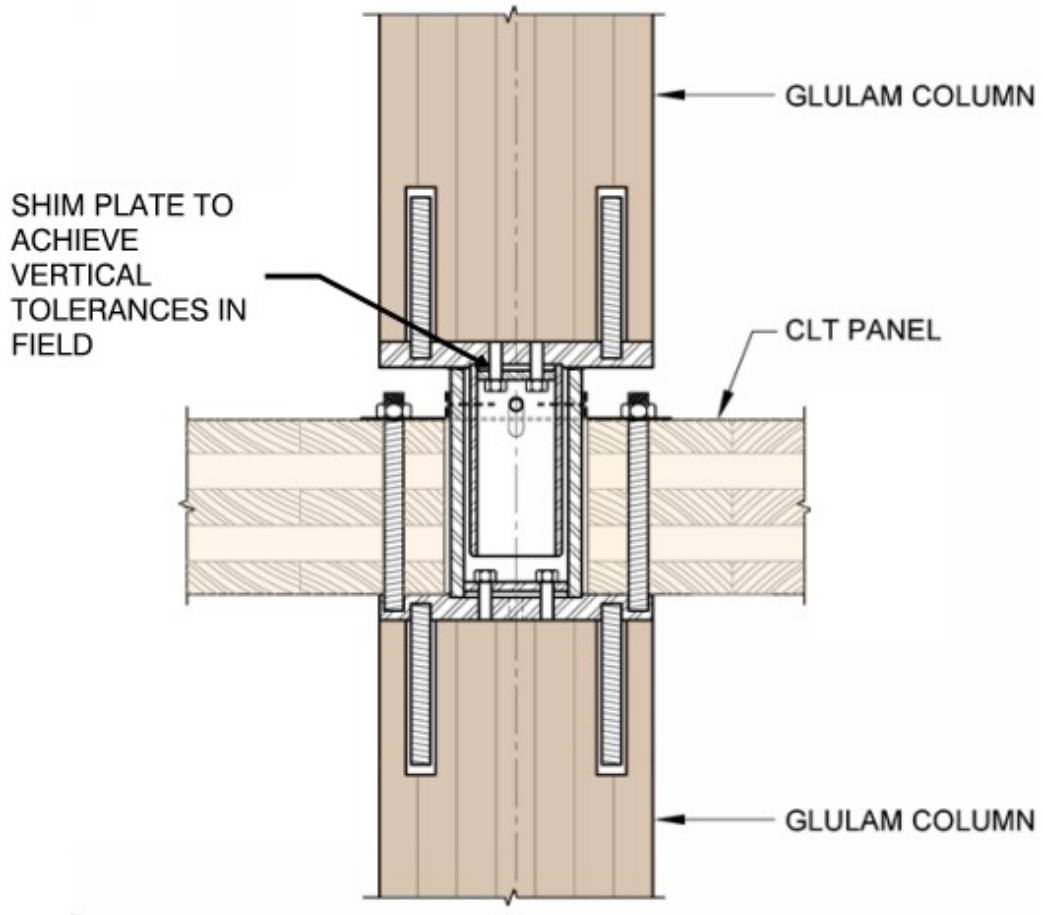
Strategies to minimize and/or accommodate movement

+ Minimize
    - Isolate perp-to-grain shrinkage & crushing



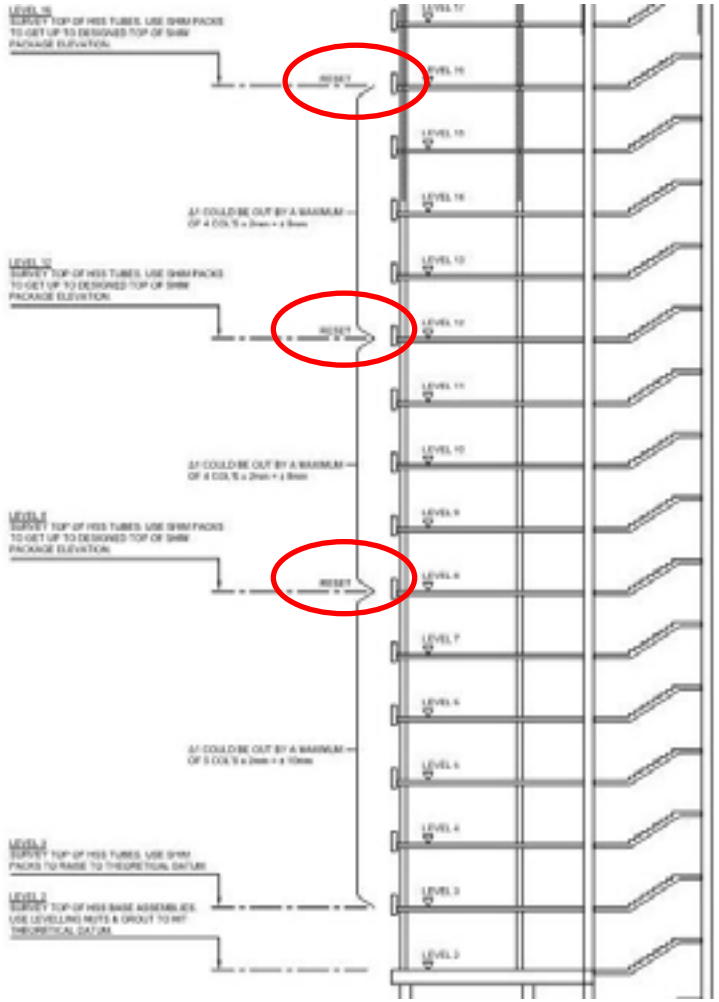
Strategies to minimize and/or accommodate movement

+ Minimize
    - Shimming



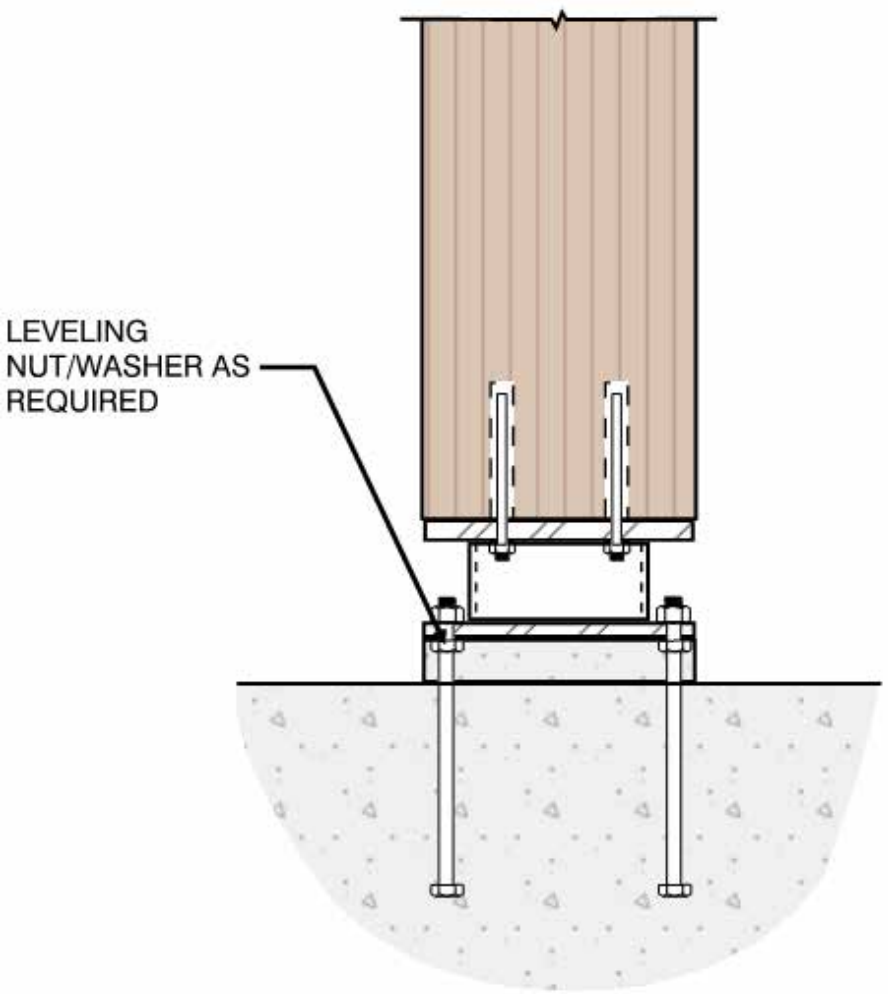
Strategies to minimize and/or accommodate movement

+ Minimize
    - Shimming



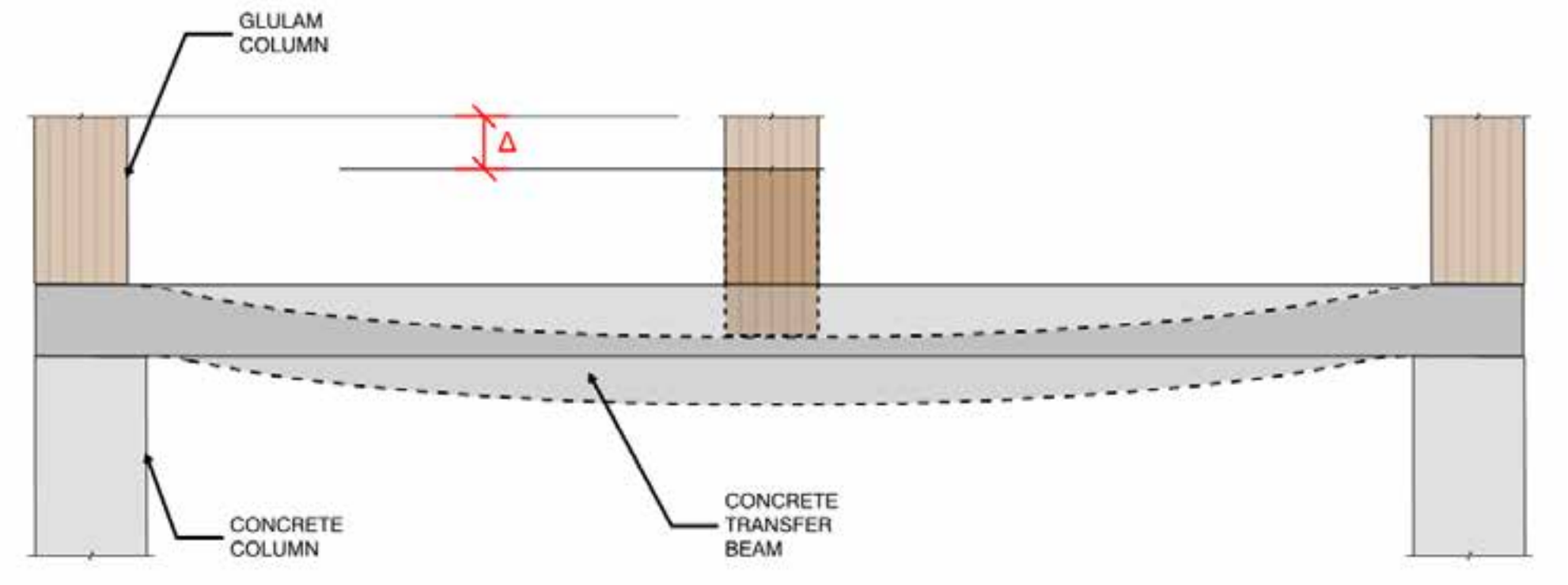
Strategies to minimize and/or accommodate movement

+ Minimize
    - Leveling nuts



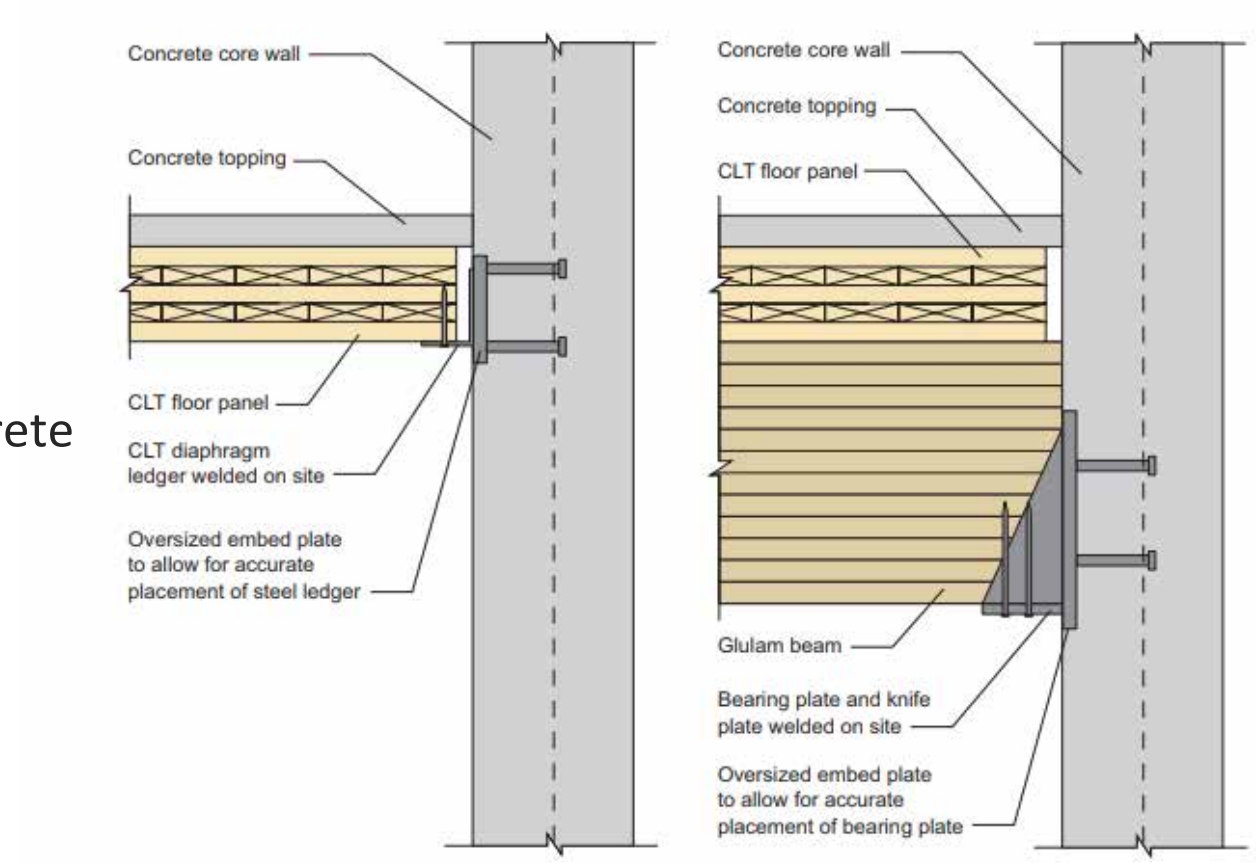
Strategies to minimize and/or accommodate movement

+ 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

CREDIT FOREFRONT STRUCTURAL ENGINEERS

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

UBC TALLWOOD HOUSE
ACTON OSTRY ARCHITECTS

VANCOUVER, BC, CANADA

PHOTO COURTESY OF SEAGATE STRUCTURES

Strategies to minimize and/or accommodate movement

- Do not over shim
- Estimated Movement *vs* On-Site Measurement

UBC TALLWOOD HOUSE
ACTON OSTRY ARCHITECTS

VANCOUVER, BC, CANADA

PHOTO COURTESY OF SEAGATE STRUCTURES

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 !

Copyright Materials

This presentation is protected by US and International Copyright laws. Reproduction, distribution, display and use of the presentation without written permission of the speaker is prohibited.

Funding provided in part by the Softwood Lumber Board

Disclaimer: The information in this presentation, including, without limitation, references to information contained in other publications or made available by other sources (collectively "information") should not be used or relied upon for any application without competent professional examination and verification of its accuracy, suitability, code compliance and applicability by a licensed engineer, architect or other professional. Neither the Wood Products Council nor its employees, consultants, nor any other individuals or entities who contributed to the information make any warranty, representative or guarantee, expressed or implied, that the information is suitable for any general or particular use, that it is compliant with applicable law, codes or ordinances, or that it is free from infringement of any patent(s), nor do they assume any legal liability or responsibility for the use, application of and/or reference to the information. Anyone making use of the information in any manner assumes all liability arising from such use.