Quantifying the impacts of moisture content and load on vertical movement in a simulated bottom floor of 6 storey wood frame buildings under controlled boundary conditions

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Introduction

- Multi-storey wood-frame construction is gaining popularity as an affordable and economical option to meet the demands for high density housing. As the boundaries of wood-frame construction are being pushed to greater levels, the need for better understanding of wood shrinkage and differential movement becomes paramount.

Figure 1. Small scale simulated wall/floor assembly under construction

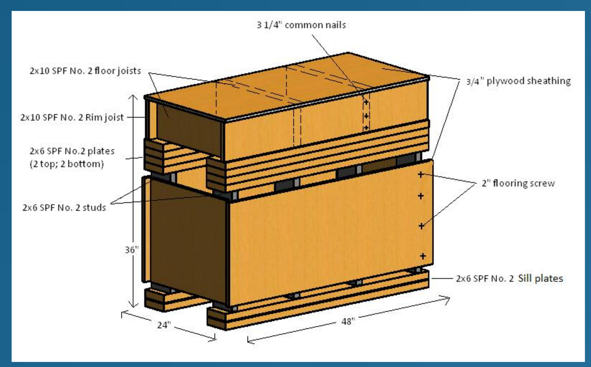

Figure 2. Construction schematic of small-scale wall/floor structures

Purpose of study

- This project is a small part of a research project being conducted by FPInnovations focussing on addressing the shrinkage and differential movement issue in mid-rise wood frame construction.
- The goal of this project was to conduct short term laboratory testing of two small-scale wood-frame structures in order to help quantify the effects of moisture content changes and loads on vertical movement under controlled boundary conditions.
- To estimate contributions of wood shrinkage, structural settlement, elastic compression and creep on vertical movement in wood-frame construction.

Figure 3. Sample blocks for assessing wood shrinkage coefficients being conditioned in a high humidity conditioning chamber

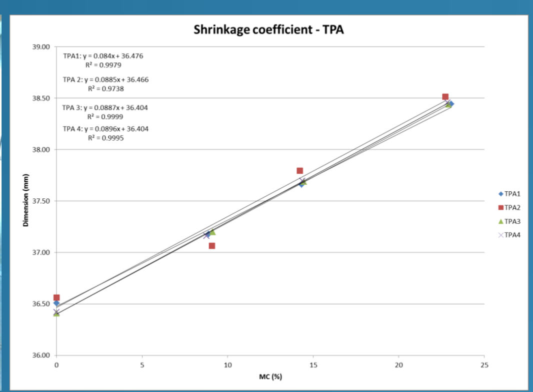

Figure 4. Example shrinkage coefficient calculated for a top plate, by plotting dimensional changes vs. MC

Methodology

- Two small scale simulated bottom floor assemblies were built identical to one another (using end matched material and complying with current building codes and construction techniques).
- Assemblies were conditioned to ≈ 20% MC over a 7 week period.
- Assemblies were instrumented with moisture pins and vertical displacement gauges.
- Upon removing assemblies from the conditioning chamber, a load was applied to structure 1, while structure 2 remained unloaded.
- Vertical displacement was monitored in both assemblies as they reached equilibrium moisture content under the climatic conditions of the FPInnovations Laboratory.
- The second phase of the research project is to apply the same amount of load to the second assembly and monitor displacement due to load while under constant moisture content.

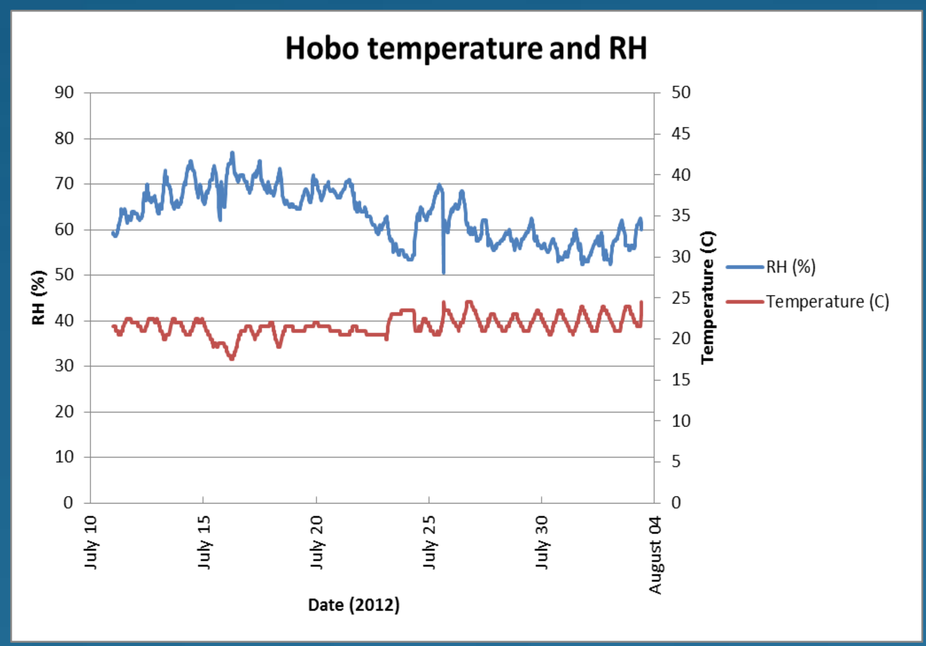

Figure 5. Temperature (°C) and RH (%) of the FPInnovations laboratory during 4 weeks of testing

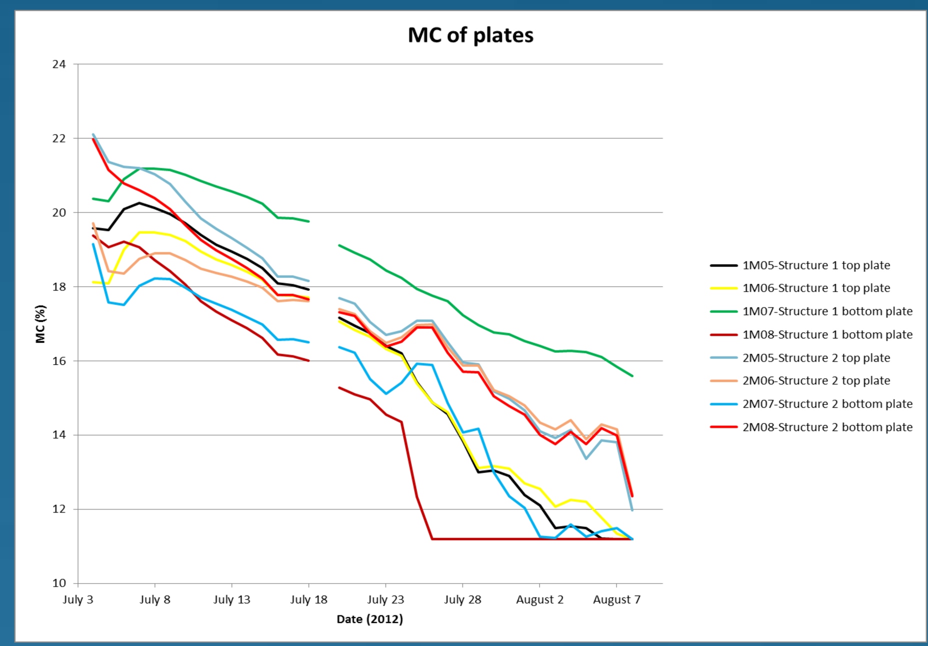

Figure 6. Plot showing change in MC of the top and bottom plates of both structures as they approached EMC in the laboratory

Results

- During the 4 week testing period in the FPInnovations laboratory, the temperature remained between 20 and 25 °C and the RH fluctuated between 55 and 75%.
- The MC of the wood dropped from approximately 20% to 12%. EMC had not been reached at the time of writing this report.
- Full height vertical displacement (including sill plates, studs, top/bottom plates and joists) varied significantly between the loaded and unloaded structures. Structure 1 (with applied load) experienced an average of 12.5 mm displacement while structure 2 (without applied load) averaged 3.5 mm displacement.

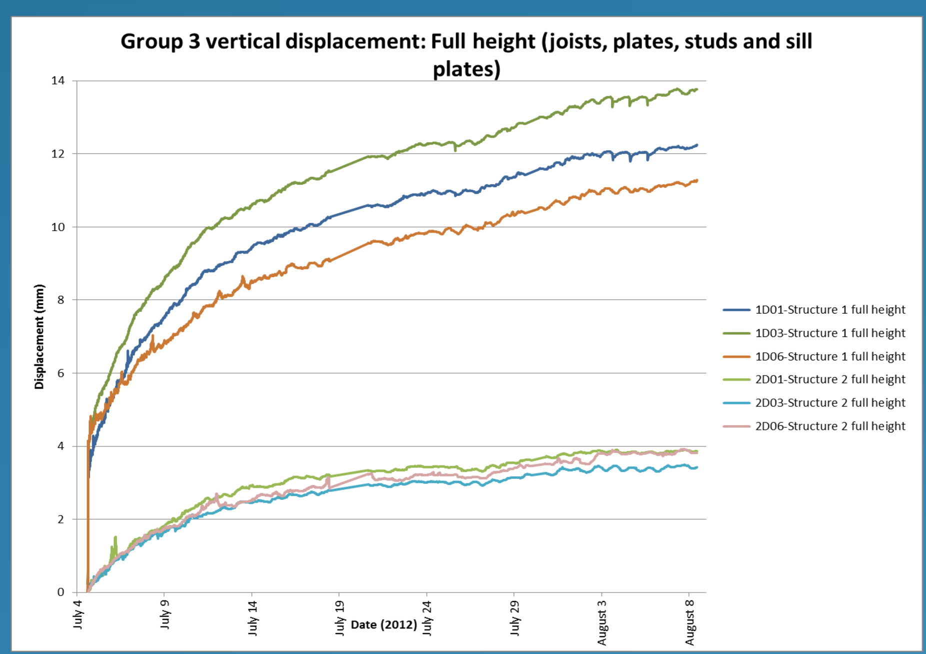

Figure 7. Full height vertical displacement of both structures after 4 weeks of monitoring. Structure 1 was monitored under an applied load, while structure 2 remained unloaded

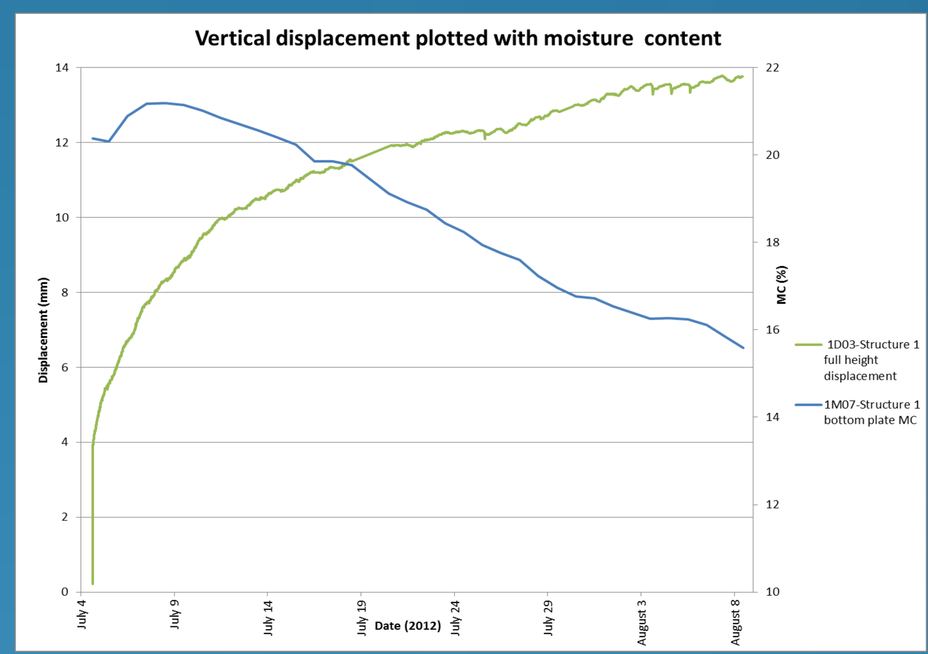

Figure 8. Graph showing full height vertical displacement and change in MC of the bottom plates of structure 1 over the 4 week testing period

Instrumentation

- Moisture pins and displacement sensors were installed to monitor vertical displacement as wood members approached equilibrium moisture content.
- 12 moisture pins and 8 (1") linear displacement sensors were installed on each structure.
- Data was collected by 3 wireless data acquisition units (WiDAQ) per structure .

Figure 9. WiDAQs mounted on structure 2

Figure 10. Displacement sensors and MC pins mounted on structure 1

Figure 11. Load cell used to determine the load being applied by the lever arm system

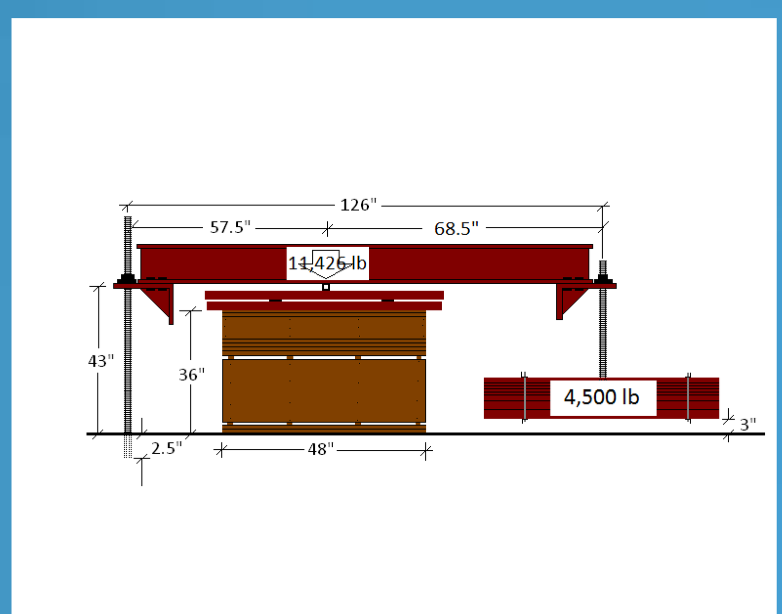

Figure 12. A lever arm system, with 4,500 lbs hung ≈ 70" from the fulcrum, generating ≈ 11,500 lbs of weight on the structure (originally designed by Conroy Lum and Paul Symons from FPInnovations)

Figure 13. Structure 1 and 2 during testing in the FPInnovations laboratory . Load applied to structure 1, while load awaits to be applied to structure 2

Conclusions

- The impact of load on vertical displacement is noticeable, provided the load is significant enough to cause bedding-in and/or elastic deformation.
- Calculations show that the expected displacement due to elastic deformation is trivial.
- Displacement observed immediately upon loading shows up to 25% of total displacement is due to bedding –in.
- Shrinkage accounted for at a minimum of 75% of the observed vertical displacement.
- Understanding differential vertical displacement and means to reduce and accommodate differential movement is critically important to design and build durable, robust, and sustainable mid-rise wood-frame buildings.

Summary of expected shrinkage vs. measured displacement

	Displacement sensors averaged	MC pins averaged	Description	Average ΔMC (%)	Expected shrinkage (mm)	Observed bedding in/elastic comp. (mm)	Measured displacement (mm)
Structure 1	1D01/1D03/1D06	All MC pins	Full height, top of rim joists to floor	9	8.7	4.0	12.4
	1D02/1D04	1M01/1M02/1M03/1M04 1M05/1M06/1M07/1M08	Top half - Joists and top/bottom plates	8	6.1	2.0	10.1
	1D05/1D08	1M09/1M10	Bottom sill plates only	8	1.3	0.75	1.4
Structure 2	1D01/1D03/1D06	All MC pins	Full height, top of rim joists to floor	9	8.8	NA	3.7
	1D02/1D04/1D07	2M01/2M03/2M04/2M02/ 2M05/2M06/2M07/2M08	Top half - Joists and top/bottom plates	10	7.5	NA	2.8
	1D05/1D08	2M09/2M10	Bottom sill plates only	6	1.1	NA	-0.1

Results summary table showing that calculated expected shrinkage (using shrinkage coefficients) combined with observed immediate bedding-in/elastic compression is comparable to total measured displacement for Structure 1 with load.

Future work

- As this is the first phase of a larger research project at FPInnovations, the second phase will involve loading the second structure once it has reached EMC to better quantify the effects of load on bedding in and elastic deformation.
- Other avenues of work could involve similar experiments using engineered lumber such as glulam or engineered I-joists.
- The ongoing field measurements of vertical movement will continue.

Acknowledgements

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