MONITORING OF VERTICAL MOVEMENT IN A 5-STOREY WOOD FRAME BUILDING IN COSTAL BRITISH COLUMBIA

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ABSTRACT: The work described in this paper was initiated to provide better guidance on prediction of vertical movement during construction and commissioning to specifiers and designers of wood frame buildings over 4 storeys. This work was designed to assess the impact on movement of factors including construction materials and methods, wood moisture content, and loads. Displacement sensors were installed, with three lines at the northeast corner of Part A and three lines at the southwest corner of Part B. The paper provides results over a total monitoring period of 21 months for Part A and 17 months for Part B, starting when the roof was covered with sheathing and after two heating seasons of occupancy. It was found that framing in a wet season resulted in higher vertical movement (estimated at 34 mm in Part A) than framing in a relatively dry season (estimated at 17 mm in Part B). The use of Laminated Strand Lumber and I-joists for floor joists in this building appeared to greatly reduce vertical movement on each floor, compared with previously reported movement amounts measured from a 4-storey building using dimensional lumber floor joists.

KEYWORDS: Platform frame wood construction, Vertical movement, Wood shrinkage, Moisture content, Building settlement, Engineered wood floor joists

1 INTRODUCTION

Vertical movement over the height of wood frame buildings during construction and commissioning has become an important consideration in recent years with the increase of building height. In British Columbia (BC), wood-frame residential construction is permitted to be built up to 6 storeys as of April 6, 2009. In Quebec this was approved in July 2013. Differential movement caused by differences in movement between connected components, structural or non-structural, should be taken into consideration in order to ensure structural safety, serviceability, and building envelope integrity. Vertical movement of wood-frame walls is mostly caused by wood dimensional changes due to moisture content (MC) changes (shrinkage or swelling when the MC is below the fiber saturation point) as well as load-induced movement, such as building settlement resulting from simply closing of the gaps between elements, instant compression, and time-dependent deformation (creep). The shrinkage is mostly contributed by horizontal solid wood members since the contribution of vertical members can usually be ignored in design due to the negligible shrinkage in the longitudinal direction. Engineered wood products typically have improved dimensional stability compared with solid wood products.

FPInnovations started a vertical movement monitoring project in 2010 to help validate movement estimation methods and assess the impacts of climate, material use, and construction methods since very little data were available at that time. The field monitoring of a 4-storey building in BC showed considerable contributions to vertical movement from the increase in load resulting from installation of exterior and interior finishes and occupancy. The relative contributions of moisture content change and loads were then determined by loading and measuring vertical movement of two wood-frame structures under laboratory controlled moisture and load conditions. This paper describes and discusses the monitoring of vertical movement in a 5-storey wood frame building in Costal BC.

2 MATERIALS AND METHODS

The building is a large “U”-shaped building with a total of 150 units. It had two parts, Part A (the eastern part) and Part B (the western part), separated by a fire wall. The construction of the two parts was very similar, except that they were built in different seasons. Part A was mostly completed from February to August 2011; the major

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structure of Part B was built from June to November 2011. As a result of the typical climate in Coastal BC, the rain exposure during the construction of Part B was much lower compared with that of Part A.

Different from conventional stick-built construction methods typically used for low-rise wood-frame buildings, this project utilized a high level of prefabrication, such as prefabricated wall panels and roof trusses and engineered wood products. It used “S-Dry” Douglas-fir dimensional lumber for bottom and top plates, “S-Dry” SPF wall studs, laminated strand lumber (LSL) rim joists and I-joists (with an actual depth of 9.25”, OSB as the web and laminated veneer lumber (LVL) as the flange). The wall panels were prefabricated and shipped to the site before installation.

It was decided to monitor the movement at two diagonal corners of the building, in Part A and B, respectively. Three lines of displacement sensors were installed at the northeast corner of Part A in June 2011, after the roof sheathing was installed, to monitor and compare the movement at a shear wall of the hallway, an interior partition wall, and an exterior wall. For each line, there were five sensors in total, monitoring the movement of each floor. Each sensor was wired individually to the data acquisition units located in the electric room on the first floor. In September 2011, another three lines were installed at the southwest corner of Part B, at similar locations. Movement data were downloaded approximately once a month.

The MC of wood products during construction was measured during each site visit using a portable capacitance-based moisture meter. The measurements were randomly conducted on sill/bottom plates, at bottom and chest height of studs, and usually over 20 spots for each measurement category. In addition, during the installation of displacement sensors, 11 resistance-based moisture pins, together with temperature sensors to calibrate moisture readings, were installed at several locations on the first floor of Part A, at both bottom plates and chest height of studs close to the displacement sensors. They were used to monitor the local wood MC starting from when the roof sheathing was installed, and compare with the MC results generated from the portable meter for the overlapped short period of the construction.

3 RESULTS

The results from monitoring this building were generally consistent with those from the previous monitoring of a 4-storey building. The major results included:

- When the building was framed in relatively wet seasons, the MCs of “S-Dry” SPF or Douglas-fir dimensional lumber mostly remained around 20% on average, or slightly below depending on detailed conditions, before the building was sheltered and heated. Space heating was necessary in order to efficiently reduce wood MC below 19% and avoid prolonging construction time to wait for sufficient natural drying to occur.
- When framing was finished in relatively dry seasons, most dimensional lumber stayed at MC levels considerably below 19%, even below 15%; no space heating was therefore needed before wall enclosure.
- Framing in a relatively wet season resulted in higher vertical movement amounts (in Part A) than framing in a relatively dry season (in Part B). With monitoring started when the building was covered with its roof sheathing, the total movement amount reached about 34 mm in Part A and about 17 mm in Part B, after the monitoring over a period of 21 months in Part A and 17 months in Part B, i.e. two heating seasons into occupancy.
- The vertical movement was dominated by downward movement in the entire process. However, “expansion”, instead of “shrinkage”, was detected in the first few months of monitoring of Part B, resulting from wood picking up moisture during construction.
- Compared with the previously reported results from monitoring a 4-storey building built with dimensional lumber floor joists, the use of LSL and I-joists in this building appeared to greatly reduce vertical movement amounts on each floor.
- Load appeared to be a factor for movement amounts, but probably at a lower order than MC. The effect of load resulted in higher amounts of vertical movement in interior walls, where there were much higher design loads, and there were higher movement amounts on the bottom floors. There was an indication of contributions from creep.

Overall it was found in this study that the use of engineered wood products can significantly reduce the vertical movement amounts. Mostly associated with the use of solid wood, the initial moisture condition was the most critical factor and the use of dry lumber significantly reduced vertical movement amounts. Therefore estimation of vertical movement amounts for wood-frame construction should take into consideration realistic moisture conditions of wood. These are mostly affected by factors such as wood MC on arrival, weather conditions during framing, and on-site protection methods. Framing in dry weather and good on-site protection can both reduce wood MC and consequently movement amounts, and may even eliminate the need for space heating and thereby reduce construction cost.