DURABILITY BY DESIGN:

FOCUSSING ON MID-RISE WOOD CONSTRUCTION

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Summary

This paper describes general principles for durability by design in wood construction, and focuses on rain management and considerations of differential shrinkage for mid-rise wood construction. It also touches on general solutions to durability concerns caused by increasing levels of thermal insulation in building envelopes as required by new energy conservation regulations.

1. Rain Management

Buildings are expected to be safe, energy efficient, durable and to provide a comfortable and pleasant indoor environment. The accumulation of excessive moisture in the building envelope reduces a building's durability, compromises the structural integrity, and affects the quality of the indoor environment. Rain penetration is usually the major moisture source in coastal climates, which has led to extensive building failures in coastal British Columbia (Morrison Hershfield Limited 1996; Ricketts 1997) and some areas on the east coast. Similar building envelope failures have also been experienced in other countries such as the USA and New Zealand.

The experience from the BC problem led to guidelines for improved moisture management summarized as the four "Ds" (Hazleden and Morris 1999). These measures include deflection to reduce rain loads imposed on building envelopes, drainage by applying good building design and adequate water drainage system, drying capacity improvement by appropriate building assembly design, and using durable products such as naturally durable wood and preservative-treated wood products. Among these, the deflection and drainage perspectives are certainly the most important in order to reduce the moisture load on building envelopes. The survey of moisture problems in leaky condominiums did show that walls with wider overhangs and thus better deflection had fewer problems (Morrison Hershfield 1996; Ricketts 1997). Architects, at least those in British Columbia, have re-introduced overhangs and pitched roofs into many of their building designs, not only low-rise wood-frame buildings.

In terms of rain load, the actual driving rain load received by building façades is influenced not only by rain amounts, wind speed and droplet size, but also by the building geometry and design details, particularly the size of overhangs. The field monitoring work conducted in BC (RDH Building Engineering Limited 2007; Ge and Krpan 2009) found that: 1. the higher the height of the building, the higher the wind-driven rain loads; 2. the wider the roof overhang width, the lower the wind-driven rain which reaches walls. But up to now, there is very limited data on the amount of wind-driven rain impacting six- to ten-storey buildings and research has therefore been planned to fill the knowledge gaps.

In 1996, the City of Vancouver introduced a requirement for improved drainage through use of rainscreen walls incorporating a cavity and a secondary drainage plane behind the cladding. Based on climate chamber testing, Hazleden and Morris (2001) predicted that rainscreens should improve building envelope performance by increasing the drainage as well as the drying capacity of building envelopes. Field investigations conducted by RDH Building Engineering Group, confirmed that rain-screen walls constructed in the period from 1996 to 2006 had performed adequately in the west coastal climate (RDH Building Engineering Limited 2007). Later rain-screen requirements were added into the Part 9 of 2005 National Building Code for all areas of Canada with higher moisture loads. It may be introduced to the building code for all building types in British Columbia in 2012 to ensure durability performance with increased insulation levels in building envelopes under new energy regulations.

Coastal British Columbia has many fine examples of wood frame buildings 100 years old and more, and there is no reason that they cannot last another 100 years and longer if the owners continue the required maintenance. However these buildings were constructed with little or no insulation and poor air tightness, consequently, the building envelopes had very high drying capacity. They would not be built the same way today due to the need to conserve energy and reduce greenhouse gas emissions. Recent and upcoming regulatory changes in building energy efficiency certainly require extra amounts of attention to building envelope moisture management. High levels of insulation may bring with them an increased level of risk of moisture entrapment in building assemblies, as a result of reduced drying ability or increased vapour condensation. In most of Canada, the heating season predominates, and therefore the main concern is about moisture accumulation at exterior elements such as sheathing and siding associated with air exfiltration and high indoor humidity. For traditional or standard wood-frame assemblies using 2×4 or 2×6 dimension lumber with stud cavities insulated with fibreglass or other fibrous insulation, long-term practices and research have proved that they can perform satisfactorily in most climate zones in Canada (as well as other regions in the world) when sufficient attention is paid to airsealing and indoor humidity control to reduce the condensation potential, provide there is overall good moisture management, including rain penetration control (Sherwood 1983). However, under the new energy code requirements such as the 2011 National Energy Code for Buildings, which was recently published, such assemblies may not meet the high thermal resistance requirements without additional insulation in most of the cold climate zones in Canada or simply because of the mandatory requirements for “continuous insulation” in some climate zones. Therefore the existing wood-frame assemblies have to be modified to adapt to the new code requirements. For the modified assemblies, the moisture accumulation potential at exterior layers of walls and roofs may become higher due to the increased vapour condensation potential and the reduced drying ability. Both insulation and air sealing reduce the drying ability of assemblies since less heat or airflow will be available to dissipate moisture, when vapour condensation, rain penetration or other types of “wetting” occur in service. The assemblies may consequently become less forgiving of any wetting incidents. On the other hand, air leakage in well-insulated building envelope assemblies also increases the vapour condensation potential. As summarized by Wang (2011), in order to prevent wintertime vapour condensation in insulated building enclosure assemblies in heating dominated climates, measures should be taken to ensure air tightness and reduce air exfiltration, control indoor humidity, reduce outward vapour diffusion, and keep the assembly elements which are susceptible to deterioration as a result of moisture accumulation warm. In addition to vapor condensation prevention, other moisture management measures such as wind-driven rain control become more critically important for highly insulated assemblies (Straube 2011).

2. Considerations for Differential Movement

Wood-frame residential construction has been permitted to be built up to six storeys in the province of British Columbia as of April 6, 2009. This is a 50% increase in height from the four storeys allowed by the National Building Code of Canada. In building design and construction, 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 and serviceability. While the characteristics of wood-frame construction for mid-rise buildings do not change from low-rise construction, the consideration of differential movement becomes more important for taller buildings due to the cumulative effects of the additional, mostly horizontal, wood components. This is why differential movement was listed as one of the key issues to be addressed during the process of building code amendment in British Columbia to allow five- and six-storey wood construction (APEGBC and AIBC 2008).

Few building materials are immune from changes in size or shape when the environmental conditions change or when they are subjected to loading. Seismic, wind and snow loads are major sources of movement that have to be considered during the design phase. However, building envelope problems can also arise from the more subtle movements during construction caused by thermal expansion and contraction, moisture changes, deformation by structural loads, and closing up of manufacturing and assembling tolerances. For wood building materials, movement is primarily related to moisture loss or gain. In detail, it can be caused by shrinkage and swelling, instantaneous and time-dependent deformation (creep) under load, and settlement as a result of closing of gaps between wood elements with the increase in load. Thermal expansion does not cause significant dimensional changes of wood; however, it could be a major cause of movement of other materials used in wood construction, such as steel elements and masonry cladding.

Differential movement can occur where wood frame is connected to rigid components such as masonry cladding, concrete elevator shafts, mechanical services and plumbing, where kiln dried lumber and engineered wood products are used in parallel, or where connected wood elements are subjected to different environmental conditions. Movement per se is not an issue. It is always differential movement of materials and systems that is a concern and should be addressed in building design and construction. Most buildings are able to accommodate a small amount of differential movement. It is always important for designers to evaluate the differential movement amounts that may occur where it may have impact on building performance, and then provide appropriate design detailing. Movement occurs during construction and service life. For wood elements, the occurrence of shrinkage during construction usually results in less movement in building service. Therefore good construction sequencing and material handling can minimize the impact of differential movement on the building performance. For wood-frame buildings the failure to address differential movement during design and construction may show as cracks and nail pops in drywalls, back slopes of balcony decks and flashings, buckling or cracking of cladding, uneven floors, roof truss rises, and distortion of door and window openings.

Currently in the design communities in North America vertical movement of wood frame is usually estimated using shrinkage coefficient recommended by organizations such as the Canadian Wood Council that for transverse grain shrinkage, a rate of 0.2% per 1% change in MC be used for multi-story wood frame design (CWC 2005; Breyer *et al.* 2003). The American Softwood Lumber Standard recommends using an average shrinkage coefficient of 1% per each 4% drop in MC, i.e. 0.25% per 1% change in MC for cross sections of most softwood (American Softwood Lumber Standard 2005). The differential movement in wood-frame construction has recently been reviewed (Wang and Ni 2010), and the accurateness of such composite shrinkage coefficients are being validated by FPInnovations through field measurement of vertical movement in wood-frame buildings. The process of wood-frame construction has also been monitored to assess the impact of wood moisture content, loads, construction sequence etc. on movement behavior of wood frame construction.

3. References

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