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NBC 2015 CHANGES – MIDRISE WOOD FRAME CONSTRUCTION BUILDING ENVELOPE (WALL) DESIGN CONSIDERATIONS

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1. Introduction

The NBC 2015 has extended the limit some building occupancies constructed of wood from four storeys to six storeys. This paper discusses design implictions of higher structures on the building enclosure, mostly pertaining to wall construction. The information in this paper is based on the Mid-rise Wood-Frame Construction Handbook, First edition, 2015, Chapter 8.

Taller buildings impose a higher demand on building enclosure components, and therefore both the design and durability of those components are very important when specifying materials.

Comparing a six-storey building to a four-storey building, the six-storey structure has higher wind loads on upper floors and more wetting potential on the lower floors, both during construction, and in operation. Properly designing for these two environmental conditions is key to ensuring a durably constructed building. However, there are additional challenges the wall assembly design must consider. One challenge is the higher loads on lower storey wood studs, often requiring more studs and less insulation, opposing the need to ensure energy efficient construction where more insulation and less studs are beneficial. Another challenge is that accessing above four storeys requires different (and more costly) techniques than typically used for four storeys and lower, and therefore using materials in the building enclosure that do not require frequent maintenance or repair is benefical. Finally, in the case of a typical platform-framed wood wall construction, differential movement between materials must also be considered to accommodate the invariable shrinkage of wood once it dries.

2. Wall design: wind | water | energy conservation | access to 5-6 | shrinkage

While there are no specific building envelope provisions pertaining to five- and six-storey buildings compared to four-storey ones, some typical envelope construction practices used in lower-storey structures may not be applicable to taller buildings. When designing a building height of five- or six- storeys, it’s important to recognize that:

1. Wind and interior (stack effect) pressures are greater as the buildings get higher, requiring stronger materials and assemblies to resist the higher loads. This means ensuring air barriers, weather barriers (also called water-resistive barriers and

sheathing membranes), cladding systems and cladding attachments, windows, and roofing are strong enough.

2. Wind-driven rain loads, just as wind pressures, are higher. Greater rain loads on the exterior walls require more attention to water management and drainage systems, particularly for the walls and windows. The possibility of longer construction periods for taller structures (and therefore longer exposure to the elements) means that protecting building materials during construction is important.

3. Gravity and seismic loads are often higher, resulting in increased structural framing in the exterior walls compared to lower structures, reducing the thermal resistance. Coordinating structural engineering requirements with building envelope needs is important to achieve efficient design.

4. The upper levels of five- and six-storey buildings are not accessible by ladder and therefore are not as easily maintained and repaired as lower height structures. Design and selection of materials and components should be durable and accessible to minimize maintenance requirements and costs.

5. The total shrinkage of the structure is greater, requiring enclosure materials and details that can accommodate movement. Cladding, insulation, and weather barrier all need to account for movement, as does the mechanical equipment. The greater total shrinkage of the structure is a result of not only the taller structure, but also the possibility of the higher moisture content in the wood due to prolonged exposure to moisture during construction.

3. Designing for higher wind

Wind loads acting on the upper wall components for a six-storey building are approximately 10% higher than that for a similar four-storey building. Accounting for the increased wind and rain loads typical of five- and six-storey buildings is critically important. Under-estimating the loads can result in a compromise of structural integrity (for example, inadequately fastened cladding systems), wet assemblies, or unacceptable air leakage levels.

Air barriers, weather barriers (sheathing membranes), cladding systems and cladding attachments, windows, and roofing must all be designed to accommodate the higher wind pressures associated with higher building heights.

The air-barrier system of the building enclosure acts as the main line of defence for controlling air leakage. Some non-adhered, sheet-type membranes on the outside of sheathing may be particularly vulnerable to high wind suction loads because there is a potential for the wind to tear the membranes around the fasteners or attachment materials. Care must be taken to ensure that adequate structural support is provided in the upper levels, particularly if there is a capillary break/gap between the air barrier and cladding. Adhered sheet membranes and liquid-applied membranes are gaining in popularity and do not have the same structural support issue.

Consideration must also be given to the cladding type and the attachment of the cladding through the air barrier, from the perspective of the barrier. For example, non-combustible cladding, such as masonry veneer, may increase the probability of tearing exterior air-barrier materials because brick relies on metal ties that produce localized penetrations of the barrier, and that produces concentrated loads at the ties. More evenly distributed loads can be achieved by using tightly spaced strapping to secure the membrane. Also, using more robust membranes with higher strength and tear resistance would be a wise choice to resist the higher loads. Self-adhered and liquid-applied membranes make the sheathing and membrane an integral, rigid air-barrier material.

4. Designing for more water

The higher wind loads on upper levels of five- and six-storey buildings means those storeys are exposed to more wind-driven rain than in low-rise structures. In low-rise buildings, wind-driven rain predominately wets upper roof edges and corners of buildings. On these low-height structures, overhangs can dramatically change wetting patterns–even small overhangs can greatly reduce rain deposition on exterior walls. However, the extra height of mid-rise buildings will mean more water impacts on the walls and windows during wind-driven rain events and accumulations as it runs down the building to grade level. Features such as drip flashings encourage surface water to drip away from the building, minimizing the impact of wetting on the components and materials below. Still, in many cases, there will be more water accumulating on the lower levels of walls and windows in six-storey buildings when compared with similar four-storey buildings. This accumulation of run-off should be considered in designing the water shedding surface features of the building enclosure.

The water-shedding surface is the outer surface of assemblies, interfaces, and details that deflect and/or drain the vast majority of the exterior water from the assembly. For wall assemblies, the water shedding surface is the cladding. The building code calls this the first plane of protection.

The water-resistive barrier is the surface farthest from the exterior that can accommodate moisture without incurring damage to interior finishes or materials within the assembly, and it is intended to prevent liquid water from travelling further to the interior. For many wall assemblies, the water-resistive barrier is the sheathing membrane in combination with flashing and sealants at penetrations. In exterior-insulated assemblies, this may be the surface of the insulation if it is taped and sealed, or it may be a sheathing membrane installed behind the insulation. In building code terminology, this would be the second plane of protection.

The amount of water that reaches the water-resistive barrier in an assembly depends on a variety of factors that are affected by the exterior environment as well as on the effectiveness of the water-shedding surface. In assemblies where the water-shedding surface and water-resistive barrier are distinct layers, the assembly has two lines of defence against water penetration. Even better control of water penetration can occur when two lines of defence are provided with a drainage space between them and when an air barrier is incorporated to control driving forces. Fundamentally, this is the definition of a rainscreen water-penetration control strategy. It is the rainscreen strategy that greatly improves the durability of all wall systems in locations of moderate to extreme rain exposure.

Designers of five- and six-storey buildings may want to consider more robust rainscreens with the following features:

- A rainscreen wall assembly that includes a continuous air-barrier system at the water-resistive barrier to improve the control of rainwater penetration.

- A ventilated rainscreen, with larger openings arranged to encourage air movement, rather than just a vented rainscreen with minimal openings at the perimeter of the cladding (for brick cladding, this typically means openings only at the bottom of the wall). Ventilated cavities will have an improved drying capability compared to vented cavities.

- Compartmentalizing the rainscreen, by blocking the cavity vertically (resisting horizontal flow) at building corners and possibly at some intermediate locations as well. Compartmentalizing can assist in moderating the pressure drop over the cladding. Compartmentalization efforts should never compromise drainage and ventilation capacity.

5. Energy Efficiency is still required regardless of the higher structural loads

Since taller structures accumulate more loads at the base (the accumulated gravity loads and seismic overturning loads at the base increase as the number of storeys increases), it is not uncommon to see large stud packs (five to eight or more studs) and tie-down rods to resist overturning forces, deeper and more closely spaced studs to resist gravity loads. All of this extra framing reduces the available cavity between framing and ultimately lowers the effective thermal insulation values in walls at lower levels. This means that insulating five- and six-storey structures in the way that low-rise structures are typically insulated may not be practical.

One solution is to use exterior insulation in order to adequately insulate the wall assemblies. Another solution is to mitigate the load on the exterior walls in order to facilitate more typical framing (for lower-rise structures) and therefore more insulation. This might be possible if the walls between units and corridor walls are designed to take the majority of the gravity and shear loads, allowing exterior walls to be framed with more typical stud spacing. This highlights the fact that it is important to coordinate the building enclosure design with the structural engineering requirements to achieve an efficient design.

A helpful tool in the design of thermal wall requirements is the Canadian Wood Council's Wall Thermal Design Calculator, available for free at www.cwc.ca/wtd. This tool makes it easy for designers to consider many wall types, compare them to nominal, total or effective thermal insulation requirements, and assess the durability of the wall assembly.

6. Designing for low maintenance

The upper levels of five- and six-storey buildings are of a height that ladder access is generally not possible. It therefore becomes necessary to consider access methods that are more common for high-rise buildings, such as suspended access equipment (swing-stages and bosun's chairs) or boom lifts to access upper levels for maintenance and repair. Structural considerations for such attachments to the building should be analysed in the design phase in order to minimize the costs of incorporating them.

The design, components and materials should be durable to minimize maintenance requirements and costs. The materials used must be able to take the higher wind pressures and the harsher rain loads described earlier. Compatibility of building enclosure membranes, adhesives, and sealants should be verified to reduce the probability of early replacement. Materials requiring regular maintenance and inspection should be located where they are accessible. If wood is used to enhance the exterior, choosing the best treatments (including coatings) available would mitigate the need for frequent re-treating.

7. Designing for shrinkage

Differential movement between materials is one of the challenging issues the building enclosure must be designed to deal with. This is especially true for taller structures with materials that respond differently to environmental conditions or where the materials are in different environmental conditions. A classic example is the shrinkage or "shortening" of wood framing as it dries in the enclosure compared to the slight expanding of brick cladding due to heat from the sun and wetting due to prolonged rain. Interfaces between different materials are required to accommodate this type of movement. For brick cladding, shelf angles that accommodate differential movement are essential. Expansion joints and slip flashings are key to accommodating movement at windows.

8. Conclusions

This paper provides very brief guidance to assist practitioners in designing energy-efficient and durable building enclosures of mid-rise wood-frame construction in the Canadian climates. It emphasizes the consideration of increased environmental loads, such as exposure to wind and rain, on a five- and six-storey building, compared to four-storey buildings and the major solutions for addressing these loads with robust building enclosure systems. Further information, including photos and illustrations, is found in Chapter 8 of the Mid-rise Wood-Frame Construction Handbook.

9. Literature

Mid-Rise Wood-Frame Construction Handbook, Chapter 8, Special Publication SP-57E, FPInnovations, 2015