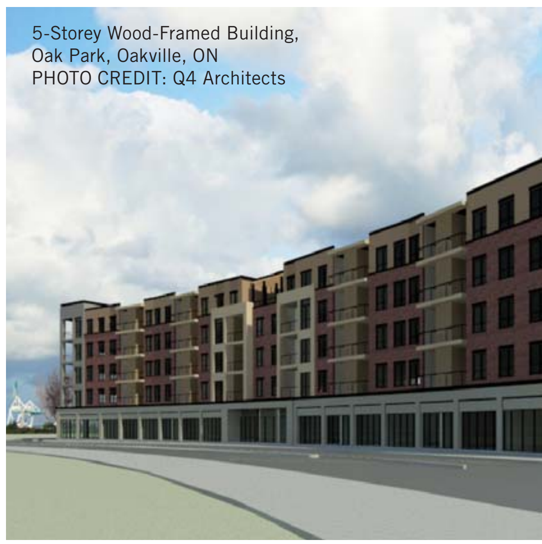
Structural Engineering Mid-rise Buildings

Engineers consider additional design and costing considerations for mid-rise wood-frame structures

Michael Baldinelli



5-Storey Wood-Framed Building, Oak Park, Oakville, ON
PHOTO CREDIT: Q4 Architects

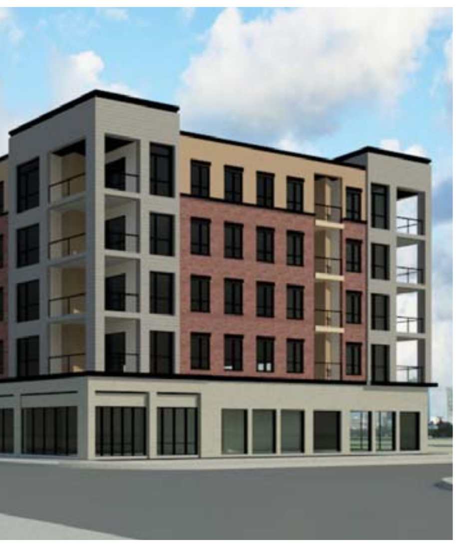
Lightweight wood-framed (LWWF) construction has gained significant popularity over the past decade as a sustainable, cost-effective solution for low-rise multi-level buildings. More recently, the push has been to extend the use of LWWF to mid-rise construction for increased density on urban or rural projects. In 2009, British Columbia amended the building code to allow five- and six-storey residential wood-framed buildings, and in September of 2014, the Province of Ontario passed legislation to permit wood-framed buildings up to six storeys in the next Ontario Building Code amendment (effective January 1, 2015).

Clients have seized the opportunity to begin building taller with wood. Wood *WORKS!* Ontario, a program of the Canadian Wood Council, organized a visit to BC for design professionals interested in learning more about LWWF mid-rise design and construction. The tour included visits to several mid-rise wood buildings under construction, which aimed to highlight the structural design considerations, fire issues during construction, implications of wood shrinkage, and cost implications for five- and six-storey LWWF buildings.

When designing mid-rise LWWF structures, it is necessary to perform additional engineering analysis and design, which is typically not required for single-family housing and small buildings. The design must also account for material and labour costing. When designing a LWWF mid-rise building, structural engineers must account for:

a) All wind and seismic loading on the building.
b) Distribution of forces assuming both rigid and flexible floor diaphragms.
c) The overall building deflection and inter-storey drift at any location in the structure.
d) The relative stiffness of other building materials (concrete masonry units, cast in place concrete, steel cross braced frame, etc.).

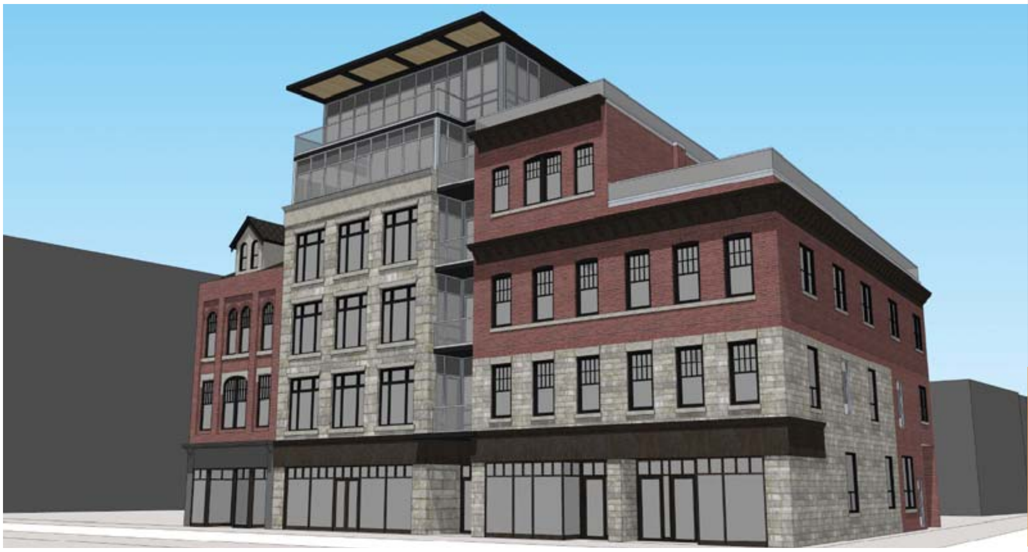
6-Storey Wood-Framed Building
PHOTO CREDIT: Strik Baldinelli Moniz



6-Storey Wood-Framed Building,
Templar Flats, Hamilton, ON
PHOTO CREDIT: Strik Baldinelli Moniz

e) The building's natural frequency and torsional sensitivity.
f) The cumulative effect of hold-down anchor slippage and nail slippage in deflection calculations.

The goal of the structural engineer is to select the most cost-efficient, code-compliant design to resist the gravity and lateral loads induced on the building. Our experience on five wood buildings in Ontario, Canada has found estimated construction cost savings of 10 to 15 per cent versus traditional design methods.


6-Storey Wood-Framed Building PHOTO CREDIT: Lintack Architects

Structural Design: Constraints and Observations

Over the past eight months, the design of three mid-rise buildings ranging from five to six storeys has been completed. The buildings will be located in Oakville, Hamilton and London, Ontario. Because of the different geographical locations, each building's performance and analysis differs depending on the seismic and wind loading values provided for each city. A brief summary of the findings and observations:

a) In Hamilton and Oakville (Golden Horseshoe Area), the seismic load cases governed the strength aspect of the design, while the wind load cases governed the overall building deflection analysis.
b) Both the rigid and flexible floor diaphragm force distribution needs to be analyzed for each building, with loads and deflections enveloped.
c) Earthquake drift infrequently governs the design, but often is high enough that the gypsum wall board cannot be relied upon to brace the studs on the lower stories (drift>hs/100).
d) Small (narrow) shear wall segments (ex. walls between exterior windows) are often governed by wind deflection (H/400) and inter-storey drift limits (h/40) resulting from seismic loads.
e) The weak link in a typical shear wall assembly (i.e. six levels of stacked shear walls) is the connection of the walls through the diaphragm, the cumulative shear load at floors one and two are extremely high requiring through bolts or other means to transfer loads.
f) The structural separation of the concrete block (stair shafts) from the wood structure greatly reduces the seismic loads on the building.
g) In most cases, a continuous tension rod system is required in both five and six-storey buildings to control building deflections.
h) For a wood structure bearing on a concrete podium, the concrete podium structure is to be designed for the capacity of the wall, not the load on the walls (in reference to lateral loads). In reference to the gravity loads, the actual true loads are to be considered on the podium structure.

Next Steps

It is often necessary to employ structural engineering software to accurately calculate building deflections, inter-story drift, overcapacity ratios, and a building's natural frequency and strength parameters. Software tools provide efficiency and confidence that the designs meet all CSA O86-14 and local building code requirements. A parametric study on building performance is scheduled to be completed by January 2016, in which an eight-storey LWWF building will be designed and parameters such as deflection, drift, shear load interaction at floor diaphragms, and other structural strength considerations will be reviewed and vetted. Research into a finite element method (FEM) for mid-rise LWWF design is beginning in conjunction with National Research Council Canada and Western University. Phase I of the research aims to create a FEM shell element that can properly model wood shear walls and floor diaphragms, taking into account nail slippage and hold-down elongation.

Michael Baldinelli is a principal with Strik Baldinelli Moniz, Civil and Structural Engineers. He has been involved in the design of 35+ commercial LWWF buildings in Ontario. His firm has won numerous awards for low-rise wood construction and in 2013 won Best Design for Multi-Level Wood Building by the Canadian Wood Council. Michael has recently lectured on behalf of Ontario Wood *WORKS!* on the Structural Design and Optimization of Multi-Level Wood Buildings. The firm has recently (2015) been awarded six mid-rise LWWF buildings ranging in size from four to six storeys. He can be reached at mike@sbmltd.ca or www.sbmltd.ca.