Managing Shrinkage in Mid-rise and Tall Wood Buildings

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Wood is an ancient building material. Used by people for centuries, even millennia, it has proven its value time and time again. Building with wood allows for cost-effective, sustainable and code-compliant structures, even in seismically active parts of the world.

While multi-story wooden structures are anything but new, with temples and other buildings still in service after more than a thousand years, modern mid-rise construction has only recently experienced a renaissance. An increasing number of jurisdictions are now allowing six-story wood-frame buildings. Given the most recent interest in tall wood buildings, with various studies suggesting more than 30 stories is possible, the sky seems to be the limit and the race is on worldwide to push wooden structures to new heights.

One of the challenges designers and engineers face when designing mid-rise or tall wood buildings is shrinkage and, in hybrid buildings, differential shrinkage. The phenomenon of shrinkage is well understood on the material level, but needs to be taken into consideration when designing these large structures.

Wood is a hygroscopic and anisotropic material, which means wood is affected by the presence or absence of water and wood has properties that differ depending on the grain orientation. The compressive strength of wood parallel to the grain, for example, is different than the compressive strength perpendicular to the grain. Similarly, wood’s reaction to water, shrinkage in the case of water loss, is also dependent on grain. Axially, shrinkage is marginal and negligible in most cases; radially and tangentially, shrinkage is more pronounced.
The fiber saturation point (FSP) of wood is the point at which all free water in between the wood fibers and cells has dried out and water is only present in the cell walls and the cell lumen. In our common softwood lumber species, this relates to a moisture content of approximately 27 to 30 per cent. Shrinkage occurs in wood when it dries and loses water beyond its fiber saturation point (FSP) to oven dry (near zero water left). For commonly used construction materials (i.e. Douglas fir, spruce) shrinkage from green material to oven dry material is around four to five per cent in radial direction and about seven per cent in tangential direction, depending on actual wood species in the species mix. Drying wood from its harvested moisture content, which can actually be more than 100 per cent, to the FSP, does not cause any shrinkage in the wood as the cells are still saturated with water. At this stage, the weight of the material changes, but no volumetric change occurs. When drying wood further, the water stored in the cell lumen is usually removed first causing the cell to decrease in volume, or in other words, to shrink. If the wood is dried beyond that, it will cause water to be removed from the cell wall, which again causes the cell, and in turn the wood, to shrink further.

When considering shrinkage in building design, we usually do not look at the FSP and the oven dry moisture content of wood. Instead we are looking at the standard moisture content (MC) of our construction material which can be more than 19 per cent for “green” material, up to 19 per cent for dry lumber, about 12 to 15 per cent for glue-laminated timber and CLT, and as low as six to seven per cent for other engineered wood products including laminated veneer lumber (LVL), laminated strand lumber (LSL) and parallel strand lumber (PSL).
Another consideration is the equilibrium moisture content (EMC) that the wood structure will reach over time based on the relative humidity and temperature of its surroundings. In most structures, the EMC will be between eight and 12 per cent for the interior and can be as high as 15 per cent for the exterior in areas of high humidity and moderate temperatures. Managing shrinkage in mid-rise and tall wood buildings can be done in a variety of ways though strategies differ between types. Shrinkage in a conventionally framed building for example, would not be addressed in the same way that it would be in a solid wood structure made from CLT and glulam.

In conventionally framed buildings, the easiest way to manage shrinkage would be by balloon framing instead of the typical platform framing approach. Balloon framing, however, has some limitations and thus has been mostly replaced by platform framing. For platform framing, shrinkage can be managed by reducing the cumulative shrinkage through the use of engineered wood products with much lower moisture content like TJI or PSL floor joists and plates. Regardless of the product used to frame the individual floors and walls, the shrinkage of the entire building should be estimated and flashing details adopted accordingly. Furthermore, hold-down details need to be designed with shrinkage in mind to ensure hold-downs function as intended. The various manufacturers offering hold-down connectors and other fasteners have solutions on-hand and offer technical details on their respective products.

When considering tall wood structures, managing shrinkage is all the more important. The cumulative effect of shrinkage in these buildings, due to the larger cross sections and increased heights, has the potential to be more significant if not mitigated. Utilizing mass timber in the form of glulam, CLT, nailed systems or LVL (to name a few) helps diminish the overall amount of shrinkage. With plate-like mass timber elements like LVL and CLT panels available in considerable length, one way to control shrinkage is to actually apply balloon framing techniques for walls, continuing multiple stories with the floors in between supported on columns and ledgers as shown in Figures 1 and 2. As Figure 1 shows, the columns can be broken at every floor, but are stacked on top of each other end grain to end grain using steel spacers to allow for the thickness of the floor. As mentioned earlier, shrinkage in longitudinal direction is negligible and any shrinkage in the floor panels would not affect the overall building. An additional benefit of this detail is it takes advantage of the much higher compression parallel to grain strength of the wood by not bearing perpendicular to the grain on the floor elements.

Managing shrinkage in mid-rise and tall wood buildings, whether they are constructed by conventional wood framing methods or with mass timber elements, is not hard if the designer understands the material and details the building accordingly. Details to take into account range from building envelope considerations like flashings, to finishing details for drywall, to structural details and construction methods. Structural details like the stacked columns in Figure 1 and 2 are not new nor do they need to be reinvented; they have been used successfully in the past, like the detail shown in Figure 3 taken in the Steamworks Brewery building in Vancouver’s Gastown district, and can be used successfully today to build modern, mid-rise and tall timber buildings.

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