



VERTICAL MOVEMENT IN WOOD PLATFORM FRAME STRUCTURES:

Design and Detailing Solutions

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Acknowledgements

The publication was developed by FPInnovations and Canadian Wood Council based on design and construction practice and relevant research. This publication would not have been possible without financial support of Forestry Innovation Investment of Province of British Columbia.

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INTRODUCTION

It is important for designers to identify locations where potential differential movement could affect structural integrity and serviceability.

Most buildings are designed to accommodate a certain range of movement. In design, it is important for designers to identify locations where potential differential movement could affect structural integrity and serviceability, predict the amount of differential movement and develop proper detailing to accommodate it. To allow non-structural materials to be appropriately constructed, estimate of anticipated differential movement should be provided in the design drawings.

Simply specifying wood materials with lower MC at time of delivery does not guarantee that the wood will not get wet on construction sites and will deliver lower shrinkage amounts as anticipated. It is therefore important to ensure that wood does not experience unexpected wetting during storage, transportation and construction. Good construction sequencing also plays an important role in reducing wetting, the consequent wood shrinkage and other moisture-related issues.

Existing documents such as the APEGBC Technical and Practice Bulletin on 5- and 6-Storey Wood Frame Residential Building Projects, the Best Practice Guide published by the Canadian Mortgage and Housing Corporation (CMHC), the Building Enclosure Design Guide – Wood Frame Multi-Unit Residential Buildings published by the BC Housing- Homeowner Protection Office (HPO) provide general design guidance on how to reduce and accommodate differential movement in platform frame construction.

Design solutions for building movement

Based on the APEGBC Technical and Practice Bulletin on 5- and 6-Storey Wood Frame Residential Building Projects, the following good practice are recommended:

1. Lumber produced to the “19% maximum moisture content” specification ($MC \leq 19\%$), such as those marked “S-Dry” or “KD”, should be used for wood frame construction regardless of its height. For buildings exceeding 4 storeys, except upper two floors in which floor joists can be made of wood products with $MC \leq 19\%$, floor joists of lower floors should be constructed of wood products with $MC \leq 12\%$.
2. For a wood frame building, elements within a floor system or in closely adjacent systems should be built of wood products having similar shrinkage amounts unless details are provided to accommodate differential movement between the adjacent elements.
3. Allowance should be provide for restraints to vertical movement such as:
 - blocking through floors;
 - steel connectors;
 - steel columns or beams;
 - concrete block, masonry or concrete walls or columns; and
 - exterior or interior finish materials that restrain or oppose the shrinkage of wood frames, such as brick cladding.
4. Allowance should be provide for mixed structural systems:
 - wood frame construction built adjacent to vertical structural or non-structural elements of steel, concrete, masonry construction;
 - wood framing members adjacent to multi-storey columns of wood or other materials.

The following information summarizes design solutions for critical locations based on a literature review conducted by FPIinnovations.

Masonry Cladding

It is widely recognized that one of the most challenging issues in construction is the differential movement between the wood frame and exterior masonry cladding for multi-storey wood-frame buildings. The rigid and brittle nature of masonry products does not allow it to accommodate a lot of differential movement. Contrary to wood components which usually shrink under protected environment, masonry cladding may increase slightly in size over its service life. Therefore the total amount of differential movement between them is the sum of the shrinkage of the wood and the expansion of the masonry cladding. There are many types of masonry products and they may have different movement characteristics. For estimation of masonry cladding expansion, it is recommended to obtain the expansion coefficients from manufacturers. Commonly used masonry claddings, have expansion ranging from 0.7-1.0 mm/m per 100°C .

While there is no published height limit for stacked masonry cladding supported on foundations, masonry cladding height up to 3 storeys for wood-frame construction is usually used by the construction industry. Significant differential movement may occur within such a height if the wood frame does not reach EMC at the time of cladding installation. It is essential that all interfaces between the wood frame and the brick cladding are detailed to allow for differential movement, particularly at windows, doors, parapets or any other features extending from wood frames over to the plane of brick.

To accommodate the shrinkage at window sills, sill flashings can be detailed in two pieces as slip flashings, and the sill plates should be installed with sufficient slopes in order to retain positive slopes after the movement has occurred (see Figure 1). In addition, wall ties shall also be able to accommodate differential movement as well as the transfer of horizontal forces.

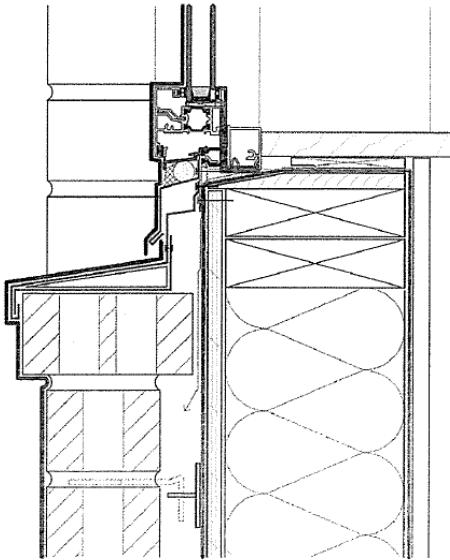


Figure 1: Schematic construction detail at window sill to accommodate different movement

To limit the amount of differential movement between framing members and masonry cladding, it is desirable to compartmentalize the cladding and limit the cumulative movement in each storey. Masonry veneers can be supported by shelf angles in conjunction with expansion joints at each floor level. To prevent damage to masonry veneers, the deflection of the supporting elements should be limited to L/480, unless special attention is paid to vertical movement joints in the masonry to prevent brick from cracking. Note that there could be concerns about bolting steel shelf angles at each floor plate as it may pose additional building science challenges related to the increased thermal conduction and concealed condensation. For large wall openings such as windows, loose lintel angles which incorporate local compression joints between the angle and the opening will help accommodate the differential movement, as shown in Figure 2.

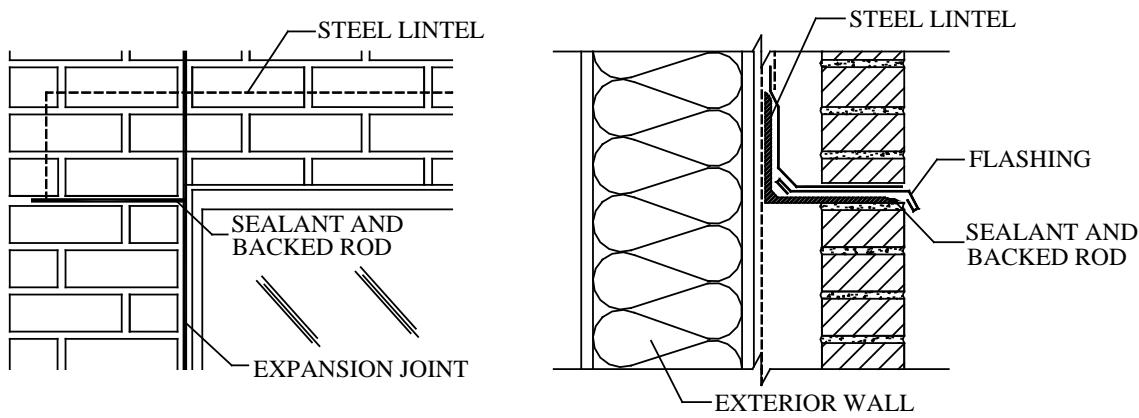


Figure 2: Loose lintel angles above large openings

Connections to Stairwells and Elevator Shafts Constructed of Concrete or Masonry Block

Attention should be paid to interfaces between concrete or masonry stairwells/ elevator shafts and the surrounding wood members. This can be addressed by framing the wood floor in such a way that it is entirely independent of the concrete stairwells/elevator shafts. Vertical slotted connections can be used to connect the concrete stairwells/elevator shafts to the wood frames to accommodate the differential movement where wood framed structure needs to be tied to the concrete stairwells/elevator shafts.

For taller wood frame buildings, detailing connections between wood frame walls and masonry walls may be difficult. In many applications, including elevator shafts, wood frame walls may be used in lieu of masonry or concrete walls provided that they meet the requirements of the Building Code. If elevator shafts are built with wood frames, elevator stopping levels should be adjusted periodically as the structure shrinks.

Balconies or Walkways Supported by Columns

On taller wood framed buildings, balconies may be cantilevered. This is usually accomplished by connecting the balcony joists parallel to the floor joists, so that the impact of accumulative movement on individual balcony slopes is minimized. With cantilevered balconies, consideration should be paid to the deflection of the interior floor joists, particularly if the interior floors are topped with concrete or gypsum based toppings. The deflection of the interior joists could lift the end of the balcony joists. The balcony joists should be installed so that there is sufficient slope away from the building after the deflection of the interior joists has occurred.

In low rise multi-family wood-frame buildings balconies may be supported on exterior posts. To prevent deterioration problems, it is necessary that the balcony be sloped to provide drainage. The exterior posts need to be designed to accommodate the expected accumulated wood shrinkage at that location and to ensure that the slope is adequate to provide drainage. If steel posts are used, the posts should be designed to be progressively shorter with the longest post between the grade level and the 2nd storey and the shortest post between the top two storeys. If wood posts are used differential shrinkage between the wood wall framing and wood posts would also have to be considered (refer to uneven shrinkage at end of joists – below).

Seismic Ties and Hold-Down Anchors

When metal straps and hold-downs anchors are used, loose connections may occur when the framing members shrink or settle. This could undermine the performance of shearwalls and consequently the performance of the wood-frame buildings under lateral loads due to wind and earthquakes. With loose connections, excessive deformation may occur under lateral loads, resulting undesirable storey drift. This is especially critical for five- and six-storey wood-frame buildings, as meeting the maximum lateral drift limits may become the controlling factor for lateral load design. It is recommended that hold-downs with shrinkage compensators be used in the hold-down systems to accommodate shrinkage in taller buildings. Where large uplift force is expected, continuous rod system with shrinkage compensators extending from the foundation to the top of the structure should be used to provide the load capacity and overturning resistance. Examples are shown in Figure 3.

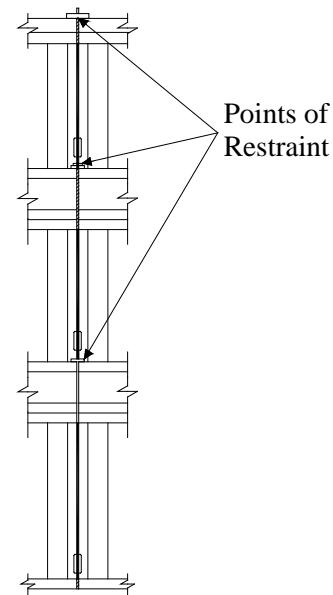


Figure 3: Continuous steel rod hold-down systems

(<http://www.strongtie.com/products/ats/skip/uplift.asp>)

Mechanical Devices and Plumbing

Ideally all the building services such as plumbing, mechanical, electrical services should be carried out after the wood framing has had adequate time to dry and settle. This is particularly important for tall buildings such as five- and six-storey wood-frame buildings. These services and related connections should also be designed and installed to allow for movement, particularly horizontal connections at floor levels. For example, water lines into units can use flexible pipes, and hard drainage pipes should have enough horizontal run with adequate slopes to accommodate some vertical movement. Contractors are generally able to accommodate differential shrinkage, provided that the movement amount to be anticipated is provided.

Uneven shrinkage at end of joists

Similar to the connections with stairwells and elevator shafts, if a floor joist is supported by a wood frame wall on one end and by a masonry block on the other, differential movement between the two ends may occur. To ensure uniform shrinkage at both ends, a sill beam which is designed to provide an equal amount of shrinkage as interior beam could be used on the concrete block, as shown in Figure 4.

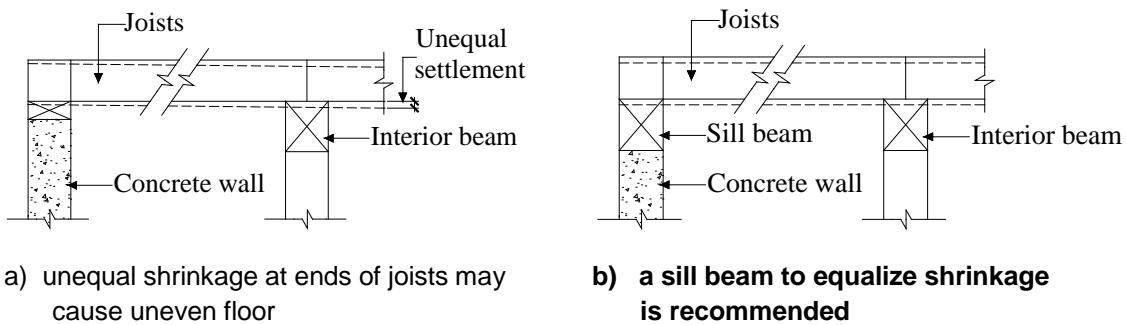


Figure 4: Uneven shrinkage at ends of joists

Similarly, differential movement between ends of the joists may occur in split level floors if the upper floor joists sit on top of the lower floor joist. In this case, it is recommended to support the upper floor joists on short vertical studs running through the lower floor joists to the wall plate below. This results in a uniform shrinkage for both floors, as shown in Figure 5 [6].

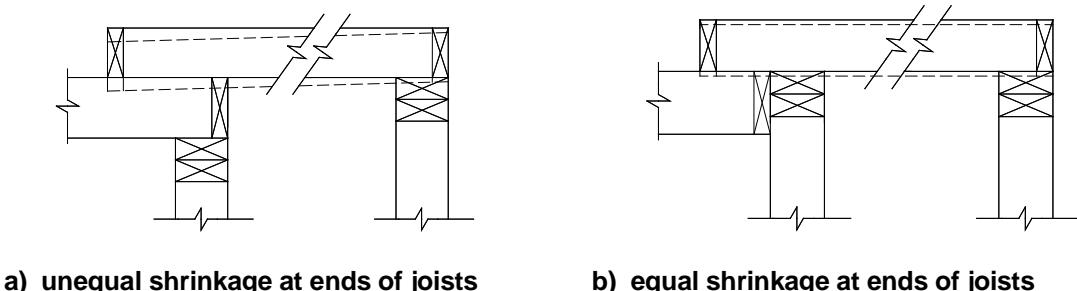


Figure 5: Split level floor

Connection Detailing

In a well-ventilated roof space, the temperature differences and the consequent RH differences between the top and the lower chords of the roof truss may cause lower chords to shrink and top chords to expand in winter [7]. This will force the peaks of the trusses upward and consequently causes cracks between the ceiling and the partitions.

This can be prevented by eliminating ceiling fasteners within 300 mm of the partitions, and by coupling the ceiling to the partitions at their juncture so that the trusses can move upwards without breaking the joint between the partition and ceiling. The ceiling members can be coupled to the partition by special clips or corner beads nailed to the tops of the partitions (Figure 6), so that when the truss moves upwards, the ceiling membrane is forced to flex, rather than tear away from the partition.

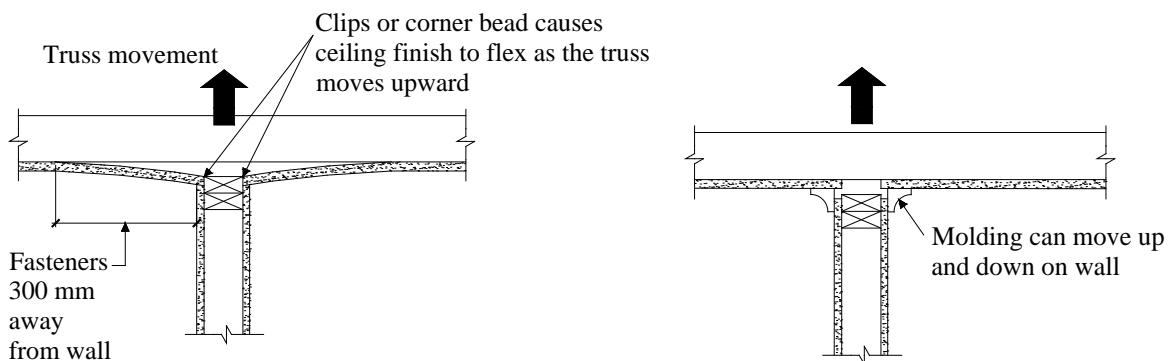


Figure 6: Mask the effect of upward bowing

If floor lumber joists are bottom supported by hangers that are then side-mounted so that the tops of the joist are initially flush with the top of the Glulam beam, the joists may shrink more than the beam due to the usually lower MC of Glulam, leaving the tops of the joist below the top of the supporting beam. This could result in a bulge in the finish floor. This can be prevented by providing design details so that the top of the joists is slightly higher than the top of the Glulam beam at construction, as shown in Figure 7 [6]. The difference in shrinkage of the two materials should be estimated in order to provide design details.

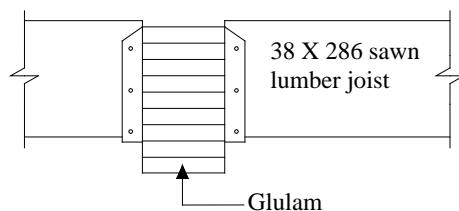
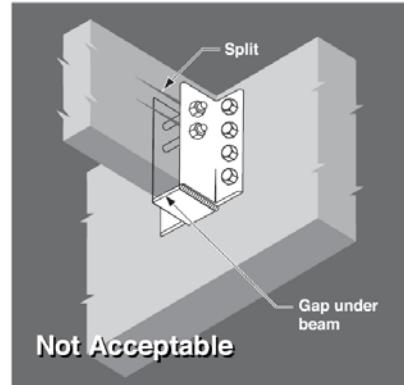


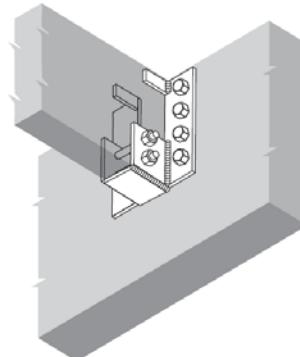
Figure 7: Lumber joist to Glulam beam connection

In the design of timber connections, attention should be paid to proper detailing of metal connections to avoid splitting of wood members due to dimensional movement. If a connection does not allow wood to move, tension stresses perpendicular to grain may develop and cause timber to split. Examples of poor detailing practice and suggestions for improvement are shown in Figure 8 below:

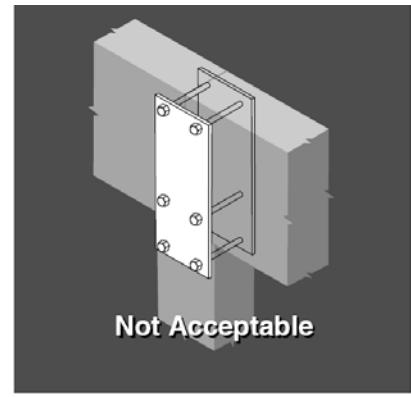
Deep beam hangers that have fasteners installed in the side plates towards the top of the supported beam may promote splits at the fastener group should the wood member shrink and lift from the bottom of the beam hanger because of the support provided by the fastener group.



Provide a lower side plate connection for the supported beam, and if the top of the beam is not laterally restrained by other means such as decking or sheathing, keeper plates or separate clip angles without a fastener should be used.



When connecting deep beams to columns, it is important to avoid details where the distance from the top of the column to the uppermost bolt location is more than 300mm.



The recommended arrangement provides for a separate plate with slotted holes to keep the top of the beams aligned.

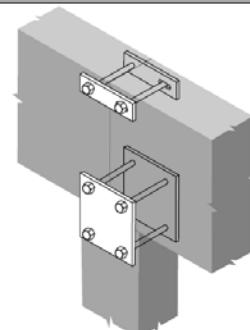


Figure 8: Detailing of metal connections to avoid splitting of wood members

Recommendations on material handling and construction sequencing

To ensure that wood does not experience unexpected wetting during storage, transportation and construction, outdoor storage of wood products on construction site should be minimized. Materials should be delivered just in time for installation in order to prevent potential wetting. Products such as "S-Dry" lumber are usually covered with wraps when they arrive on construction site. Plans should be made in advance to minimize on-site wetting. Lumber bundles should be kept under shelter, or in well drained and ventilated area. Dunnage should be used to keep wood off the ground. The wraps should be kept on the bundles until the lumber is ready to use. It should be re-covered with waterproof tarps if the original wrapping is damaged. Also be aware that lumber wraps or tarps may also trap moisture and slow down drying if water is allowed to get into the bundles.

Wood-based composites and engineered products usually require more attention during storage and handling. Most of them are manufactured at a low MC with more end grains and other surfaces exposed during manufacturing. They may therefore be more susceptible to moisture uptake than lumber during wetting incidents. Factory finishing with special coatings and sealers can often provide temporary protection. But these products may also trap moisture and slow down drying if water gets into the wood. In addition, all engineered and prefabricated products such as glulam and roof trusses require special care during storage and transportation to prevent any structural damage.

Good construction sequencing also plays an important role in reducing wetting and other moisture-related issues. Once framing is started, make sure to install roof sheathing and membrane, and wall sheathing membrane as quickly as the construction allows. The use of prefabricated panels and roofs can greatly improve construction efficiency. Wet construction such as concrete topping pouring should be completed at early stages. Wood products under protected conditions can dry out naturally when it is well ventilated and the humidity level of the air is not too high, and sufficient time should be provided for the dry to occur. Walls and roofs should not be enclosed unless the framing materials have dried to an acceptable level of moisture. In cold and damp climate, the use of space heating can efficiently dry wood and improves construction efficiency. Rigid services and other connected components, such as hard pipes, elevator shaft, and masonry cladding, should be installed as late as the construction allows, to maximize the building settlement. Additional measures should also be taken to accommodate any differential movement that may occur, particularly at high floor levels.

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