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Effects of Wood Shrinkage in Buildings

Please note

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Abstract

This Digest discusses the nature of wood shrinkage and its effect on the performance of certain building assemblies.

Characteristics of Shrinkage

Wood shrinks when it dries and swells when it becomes wet. These dimensional changes vary with the species and the orientation of the wood fibres. When wood dries from its green condition, little or no shrinkage occurs until the moisture content falls below the fibre saturation level. At this level, all free moisture has been released from the cell cavities, leaving only the cell walls saturated. The moisture content at which this condition is reached varies, but averages 30% (based on the ratio of the weight of water to the oven-dried weight of wood). As the cell walls continue to release moisture, the wood shrinks almost in direct proportion to its moisture loss. That is, for each percentage drop in moisture content, the wood shrinks by about 1/30 of its total potential shrinkage.

The moisture level of the wood will eventually reach equilibrium with that of the surrounding air This equilibrium moisture level depends principally on the relative humidity of the air. Air temperature has little effect on the equilibrium moisture level over its normal indoor range. Figure 1 shows the equilibrium moisture content of wood at various humidity levels and temperatures.

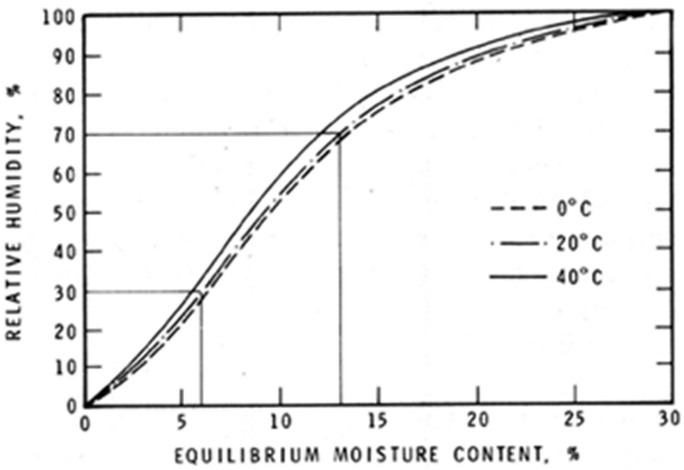

Figure 1. Moisture content of wood at various relative humidities

Wood shrinks (or swells) not only tangentially and radially, but longitudinally as well. Tangential shrinkage (concentric to the growth rings) is approximately twice the radial shrinkage (perpendicular to the growth rings). Shrinkage values for individual specimens of the same species can vary considerably, so computed values based on averages may be somewhat misleading. The average tangential shrinkage of spruce from the fibre saturation level to the oven-dried state is 7 to 8%, while the average radial shrinkage is about 4%.[1] The longitudinal shrinkage for most species over this moisture range, however, is only 0.1 to 0.2% for so-called "normal" specimens. This small value is usually ignored in design, sometimes with unfortunate consequences. Greater longitudinal shrinkage can occur if the wood is badly cross-grained or contains juvenile or compression wood. Juvenile wood comes from trees that grew rapidly during their early years. Compression wood, i.e. wood subjected to unusual compression stresses during its growth, usually results when trees grow on a slant. It also forms immediately below large branches, so that lumber with many knots may exhibit greater-than-normal longitudinal shrinkage.

Plywood has shrinkage characteristics similar to lumber in the longitudinal direction. This stability is due to the much higher modulus of elasticity of wood with the grain than across the grain. Alternating the direction of the grain in adjacent plies, therefore, stabilizes the plywood in both directions.

Waferboard benefits from a similar stabilizing effect because the individual wafers are randomly organized. If waferboard is soaked, however, the resulting increase in thickness can so weaken its internal bonds that it exhibits greater movement than would normal lumber.

The heartwood of freshly sawn lumber contains 30 to 100% moisture, depending on the species. The moisture content of the sapwood is usually much higher, from 100 to 200%. When exposed to air, lumber dries fairly rapidly in warmer weather to the fibre saturation level. It then dries at a decreasing rate until it is in equilibrium with the surrounding air The rate of drying slows as the air temperature drops.

Equilibrium moisture contents for wood stored under cover during the summer in most inland areas vary from 11 to 12%, while in the coastal areas they range from 14 to 16%. At these levels about half to two-thirds of the total potential shrinkage will have occurred. If lumber is installed in a building before the equilibrium level is reached, even less of its potential shrinkage will have taken place, increasing the risk of shrinkage-related problems. For this reason most building codes in Canada specify that the moisture content of framing lumber must not exceed 19% at the time of installation.

Wood in heated buildings can be subjected to a wide range of humidity levels over an annual cycle. Winter humidity levels of 20 to 30% are common in houses, and may be even lower in other occupancies such as offices that generate little or no moisture. During the summer, outdoor humidity levels average 60 to 70% in most inland areas. These differences cause the equilibrium moisture content of wood to vary from 6% in winter to 12% in summer assuming steady-state conditions are reached.

Effects on Metal Fasteners

Any shrinkage of the wood along the embedded length of metal fasteners causes their heads to rise above the wood surface while forcing the tips slightly deeper into the wood. The initial and final moisture contents of the wood, and the depth of fastener penetration, are the principal factors in determining the amount of outward movement, but subsequent seasonal cycles of moisture content changes can add to the initial movement.

Nails with annular grooves are generally affected less by shrinkage than plain shank nails because they require less penetration to achieve the same withdrawal resistance. Screw fasteners, which require even less penetration, are affected least.

Wood shrinkage can cause "nail popping" in dry. wall finishes. As the fasteners are eased out of the wood, a space is created between the drywall and its supports. Subsequent pressure on the drywall causes the fastener heads to push through the drywall cement covering them, resulting in nail popping.

The "nail popping" effect can also be observed in the ceiling, normally around the perimeter As the fasteners are pushed outward, the downward movement of the ceiling is resisted by the wall membrane, forcing the fasteners through the cement covering. Since the ceiling perimeter is normally supported by the wall membrane, the nails around the perimeter serve no essential purpose. This source of nail popping can be eliminated by not putting ceiling fasteners within 300 mm of the walls.

Shrinkage produces similar effects when fasteners in the subflooring or underlayment are covered by thin materials such as vinyl. The raised fastener heads may show on the finished floor as a pattern of tiny bumps. This problem can be reduced by recessing the fastener heads into the wood before the flooring is laid.

Other Common Shrinkage Effects

Since the greater shrinkage occurs across the grain, wood-strip flooring is particularly vulnerable to the effects of shrinkage and swelling. Thus, when flooring is installed, its moisture content should be as close as possible to the level it will attain in service.

Flooring used below ground level may be subjected to humidity that will raise its equilibrium moisture level significantly above its kiln-dried level. To avoid buckling, the flooring should be stored in a location that will allow it to reach the higher moisture level before it is laid. A clearance of 10 to 15 mm around the floor perimeter should be provided to allow for expansion.

Although conventional wood framing is reasonably tolerant of the effects of shrinkage, using unseasoned lumber can invite problems, particularly if construction proceeds rapidly and the lumber is enclosed before much of the potential shrinkage has occurred. This prevents corrective action being taken, such as using shims to compensate for the shrinkage effects. Differential shrinkage commonly occurs around windows and doors where the lintels shrink away from the supporting jack studs. It also occurs where metal joist hangers support unseasoned wood joists around floor openings.

The manufacturing process of waferboard results in a final moisture content of about 2%, which is considerably below its moisture content in use. Accordingly, before it is installed, it should be allowed to reach a moisture content level close to that expected in service. If waferboard or plywood is used in locations subject to high moisture levels, such as wall and roof sheathing, a gap should be left between the sheets to reduce the possibility of buckling due to expansion.

Wood Truss Uplift

An increasingly common effect of wood shrinkage is the upward bowing of wood trusses in winter This causes cracks between the partitions and the ceiling of up to 20 mm in severe cases. Wood truss uplift is primarily caused by the differential longitudinal movement of the upper and lower chord members.

Air in a well-ventilated attic space contains approximately the same amount of moisture as the outside air In winter the relative humidity of the outside air is fairly high; consequently, the top chords and web members will absorb moisture until equilibrium is reached with the surrounding air. The higher moisture content causes the top chords to lengthen.

The lower chords, however experience a different phenomenon. Since in modern houses they are often covered with up to 300 mm of insulation, their average temperature in winter is closer to the indoor temperature. This causes the air spaces in the insulation adjacent to the wood to have a much lower relative humidity than the air adjacent to the top chords. As a result, the air spaces adjacent to the bottom chords absorb moisture from the wood until an equilibrium moisture level is reached. The moisture content in the lower chords may decrease to less than 10% during the coldest winter months, and cause the chords to shorten.[2] As the lower chords shrink and the top chords expand, the peaks of the trusses are forced upward. This forces web members attached near the peaks to pull the lower chords upward, which, in turn, causes cracks between the ceiling and the partitions. If the chord members contain compression or juvenile wood, the amount of movement can be significantly increased.[3]

Using unseasoned lumber may be a significant factor in truss uplift problems, particularly when the ceiling is installed before the moisture level of the trusses has been reduced to a reasonable level. Tests on roof trusses containing unseasoned juvenile wood have demonstrated that either upward or downward movement can occur as the wood dries, depending on whether the juvenile wood is located in the upper or lower chords.

A number of factors can influence the degree of uplift. Roof slope is one; the lower the slope, the greater the amount of arching for the same difference in moisture content between the upper and lower chords. The amount of insulation is another factor; the more insulation, the greater the difference in moisture content between the upper and lower chords. Differential shrinkage resulting from the lower moisture content of the partition framing in winter compared with the exterior wall framing, can also contribute to the separation of the ceiling membrane from the partition.

Thermal contraction, in the winter months, of the top chord relative to the bottom chord is insufficient to counteract arching caused by moisture changes. The weight of the roof assembly and the snow load, in most cases, only partially counteract truss uplift.

Even if seasoned lumber is used, roof truss uplift may not be avoidable without changing the present system of construction so that the top and bottom chords are exposed to the same environmental conditions. Because of the costs and adjustments this would entail, it seems more practical to modify the current system to allow the wood trusses to bow upwards without causing damage to the interior finish.

This can be achieved 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.[4] The ceiling membrane can be coupled to the partition by special clips or corner beads nailed to the tops of the partitions so that the ceiling membrane is forced to flex, rather than tear away from the partition, as the truss moves upward (Figure 2).

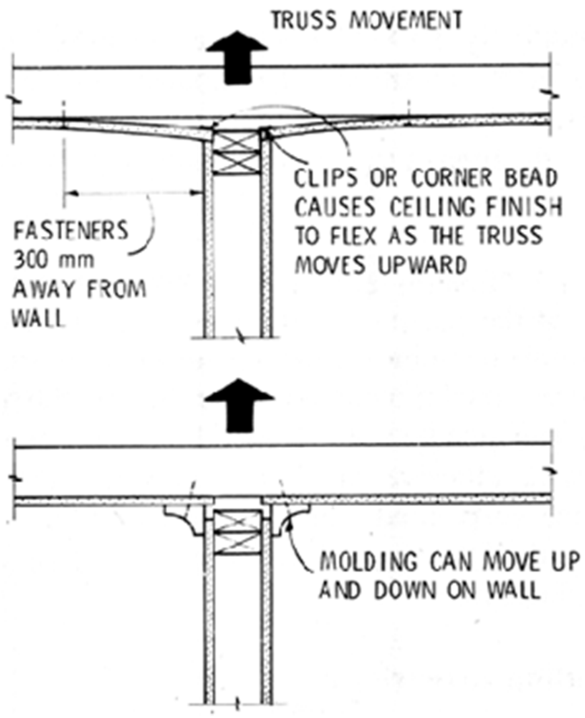

Figure 2. Masking the effects of upward bowing

Alternatively, 19 x 140 mm boards can be nailed to the tops of the partitions. The boards must be fitted between the trusses where the partitions are at right angles to the trusses (unless the ceiling is supported by furring strips).

If such "floating corners" have not been provided, damage at the partition can be masked by installing cove moldings fastened to the ceiling supports only. This permits the molding to slide up and down the wall with the seasonal movement of the trusses. Suspended ceilings can also be used. It may be necessary to seal cracks with adhesive tape before installing the molding or the suspended ceiling, to prevent air leakage into the attic if the vapour barrier has been damaged by the arching effect.

Concluding Remarks

Wood shrinkage can cause many problems, from nail popping to truss uplift. using lumber whose moisture content does not exceed 19% should significantly reduce the incidence of most of these problems. It is possible to allow for truss uplift by using floating corners that will permit the ceiling to flex without tearing away from partitions. If floating corners are not used, corrective action is normally limited to concealing the damage by means of moldings or suspended ceilings.

References

1. Wood handbook: wood used as an engineering material. U.S. Dept. of Agriculture, Forest Products Laboratory, Forest Service Handbook No. 72, Washington D.C., 1974.
2. Onysko, D.M., Bellosillo, S.B., and Aplin, E.N. Seasonal uplift of roof trusses: a progress report. Forintek Canada Corporation, Ottawa, 1980.
3. Gorman, Thomas M. Juvenile wood as a cause of seasonal arching in trusses. Forest Products Journal, Vol. 35, No. 11/12, Nov./Dec. 1985.
4. Special bulletin report on roof truss uplift. Prepared for the Technical Research Committee, Housing and Urban Development Association of Canada, Toronto, 1980