Detailing Timber Connections

Dimensional Change Considerations

By: Jim DeStefano, P.E.

Timber structural elements change dimension with changes in moisture content. When timber is harvested from the forest, the wood is green with a moisture content well above the Fiber Saturation Point (FSP). As the timber seasons and dries, it does not experience any change in dimension until the moisture content falls below the FSP. For Douglas Fir the FSP is approximately 28%. When the moisture content of the timber falls below the FSP, its dimensions will shrink. Eventually the moisture content in the timber will come into equilibrium with the humidity level in the atmosphere. As the relative humidity fluctuates with the seasons, timbers will continually swell and shrink.

Timber is not an isotropic material and consequently its dimension change will vary with grain orientation. If a specimen of Douglas Fir is dried from the FSP to an oven dry condition, the longitudinal dimension change will be approximately 0.1%, the radial dimension change (perpendicular to growth rings) will be approximately 4% and the tangential dimension change (parallel with growth rings) will be approximately 8%.

Dimension changes must be considered in the detailing of timber connections. For practical purposes, longitudinal dimension change can be neglected, but if a connection restrains radial and tangential dimension change, the connection could fail.

Glulam Connections

Glued laminated timbers (glulams) are fabricated from kiln dried lumber that has been dried to a moisture content of approximately 19%. This reduces, but does not eliminate, dimension change of the timbers. Glulam timbers are usually connected with bolts or other metal fasteners and steel hardware.

Figure 1 illustrates a poorly detailed glulam beam to girder connection. The connection utilizes bolts loaded in shear with steel connection angles. This connection is very similar to a structural steel connection. The connection angles and bolts restrain vertical dimension change of the timbers, resulting in splitting of both the beam and girder.

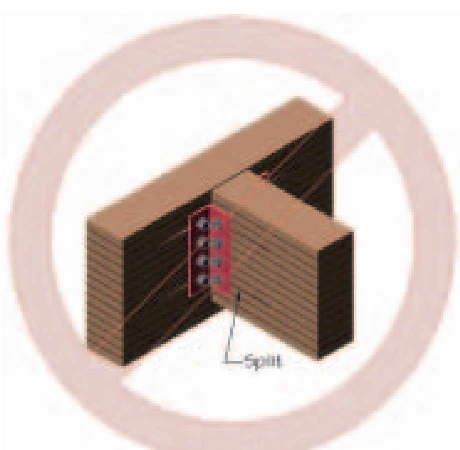

Figure 1

Figure 2 illustrates a preferred glulam beam to girder connection. The beam reaction is transferred to the steel connection hardware in bearing rather than relying on bolts acting in shear. The bolts are only needed to hold the connection together and to resist secondary longitudinal forces. The bolts in the beam are positioned near the bottom of the beam to prevent restraint of vertical dimension change. If the bolts had been inadvertently positioned near the top of the beam, the bottom of the beam would lift off of its bearing seat when the timber shrinks.

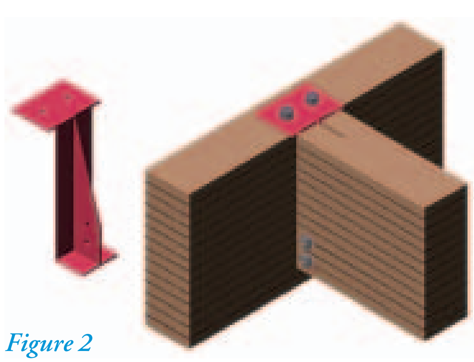

Figure 2

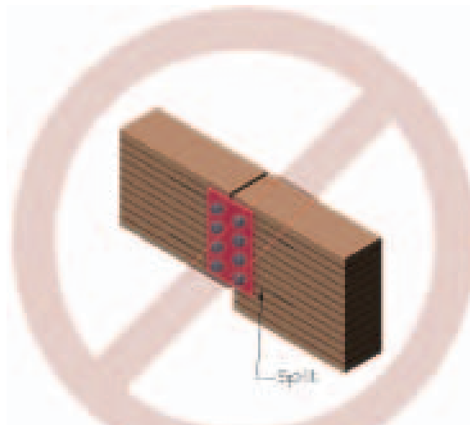

Figure 3

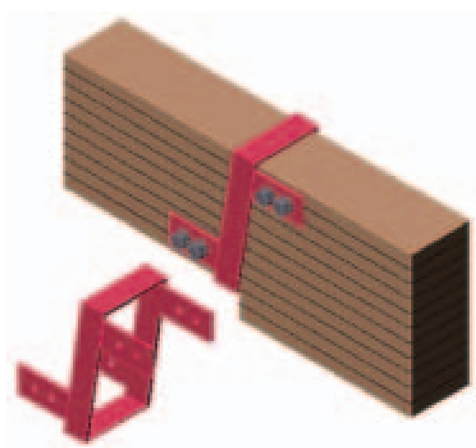

Figure 4

Figure 3 illustrates a poorly detailed cantilever beam connection. The bolts are loaded in shear and the steel side plates restrain vertical dimension change of the timbers.

Figure 4 illustrates a preferred cantilever beam connection detail. The vertical reaction is transferred in bearing rather than utilizing bolts in shear. The bolts are positioned near the top of the supporting beam and near the bottom of the supported beam so as not to restrain vertical dimension change.

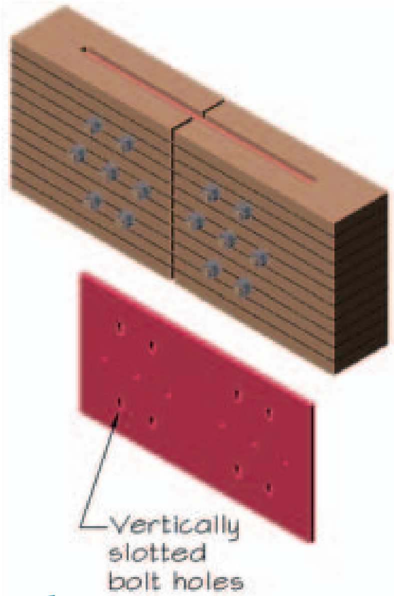

Figure 5

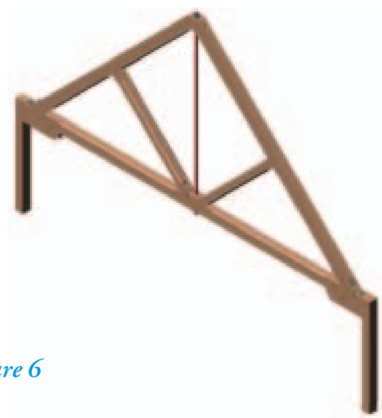

Figure 6

Figure 7

Figure 5 illustrates a properly detailed tension connection. This connection would be used to splice the bottom chord of a truss that is loaded in tension. A steel splice plate is positioned in a kerf cut into the ends of the timbers. Vertical slotted bolt holes are used for the upper and lower rows of bolts. Round bolt holes are only used for the middle row of bolts that must transfer any vertical shear forces.

Timber Trusses

Timber trusses are sometimes fabricated utilizing steel rods for tension members. *Figure 6* illustrates such a truss. This type of construction was very common in the late nineteenth century. Today timber trusses are often used for architecturally exposed roof structures.

If green timbers are used in the truss, the steel tension rods and connection bolts will become loose when the timbers dry and shrink. When the tension rods become loose, the truss will behave as if the rod does not exist. Often the truss will deflect significantly before the tension rod is engaged. It is not uncommon for diagonal truss members to fall out of the truss when the rods go slack. *Figure 7* is a photo of a roof truss in a nineteenth century structure located in New Haven, Connecticut. When the ceiling was removed for renovations to the building, several of the truss members were

Alternatives to Unseasoned (Green) Timbers

Dimension change movements of timber structures can be reduced if seasoned timbers are used. There are a variety of technologies available for seasoning timber.

Air-Drying – Timbers are stacked in a shed with wood spacers (stickers) that allow air to circulate around the timbers. A sealer is applied to the end grain to minimize checking. It can take several years to season large timbers by air-drying. Few people have the time or patience to season timbers in this manner.

Kiln Drying – Timbers are stacked with stickers in an insulated structure. Hot air is circulated around the timbers with fans. The temperature and humidity of the air is controlled to minimize uneven drying of the timbers. If the outside surface of the wood is allowed to dry too rapidly, it can result in a defect known as "case hardening." If the end of the timber dries too rapidly, it can result in excessive checking. Kiln drying is more effective with dimension lumber than with large timbers.

Radio Frequency Vacuum (RFV) Drying – This is a relatively new and promising technology. Timbers are stacked without stickers in a pressure vessel. Air is evacuated from the vessel with a vacuum pump. The timbers are bombarded with radio frequency waves similar to microwaves that vaporize the water within the wood (water boils at 90 degrees F in a vacuum). The timbers are dried evenly and rapidly with very little distortion or checking. RFV is most commonly used to dry Douglas Fir and Red Oak timbers. Not all wood species can be successfully dried by RFV. In certain species such as White Oak, the cell structure of the wood does not allow water vapor to escape rapidly and a defect known as honeycombing results.

Forest Salvage – Also known as "standing dead wood" are timbers that are milled from trees that had died years before they were harvested. Often trees that have been killed in a forest fire or by other natural causes are left standing for several years before loggers have an opportunity to harvest them. The wood will have an opportunity to season while it is still standing in the forest. The quality and moisture content of standing dead wood is highly variable.

Recycled / Remilled – Timbers are salvaged from older structures that are slated for demolition. Bolts, nails, and other metal items are removed from the timbers before the timbers are run through a sawmill. The recycled timbers are very stable and resemble new timbers except for scars left from metal fasteners and a subtle patina. The supply of recycled timbers in specific sizes is limited.

Timbers will experience some deformations such as warping and twisting during drying. Often rough sawn timbers are subjected to the seasoning operations. The timbers are resawn and surface planed to final dimension after seasoning found to have fallen away from their truss. The vertical tension rods were all slack.

If seasoned timbers cannot be utilized for roof trusses, a maintenance plan is needed. Tension rods and connection bolts must be tightened as the timbers season. Connections should be detailed so that all bolts are accessible for tightening in the completed structure. Annual tightening of tension rods and bolts is needed for the first 5 years. This can result in some serious logistical problems in an occupied building.

Mortise and Tenon Joints

Timber frame construction with traditional style mortise and tenon joints has experienced a resurgence in popularity over the past several years. Timber framers refer to connections as joints. The timber frames are usually constructed of unseasoned timbers and the joints are held together with hardwood pegs.

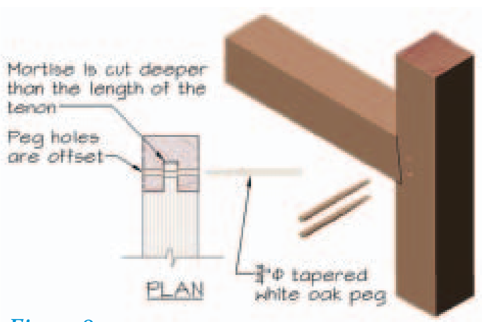

Figure 8

Figure 8 illustrates a typical timber beam to post joint. The vertical reaction is transferred in bearing on a shoulder cut into the post. The wood pegs are relied on to hold the joint together, not to transfer loads.

The mortise in the post must be cut deeper than the length of the tenon on the beam otherwise the joint would be pushed apart when the post shrinks.

The peg holes are offset approximately 1/8" between the beam tenon and the post. When a tapered hardwood peg is driven into the offset holes, the joint is pulled tight. An axial prestress force is introduced into the joint. As the timber post seasons and shrinks, the pegs will keep the joint tight. This process of offsetting the peg holes is referred to as "draw boring."

Conclusion

Dimension change must be considered when detailing timber connections. Failure to allow for shrinkage and swelling of timbers is the most common cause of failed connections.▪

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