Timber Design Guide 2019-16

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Prepared by:	Jim DeStefano, P.E., AIA, F.SEI		
Title:	Detailing Glulam Timber Connections		

Introduction

Figure 1 A glulam timber structure with traditional joinery and a CLT roof deck

Glued-laminated (glulam) timbers are commonly used in timber structures that require curved timbers or long spans. Designing and detailing glulam timber connections for substantial member forces and reactions can be challenging. Glulam timbers can be fabricated with traditional-style joinery, similar to a sawn timber frame; however, specialty glulam fabricators and erectors are often unaccustomed to this style of joinery and lack the skills to execute it successfully.

Figure 2 A glulam timber structure being erected by ironworkers

Because glulam timber connections often involve steel fasteners and connection hardware, it is not uncommon for glulam timber structures to be erected by a crew of ironworkers that are experienced at erecting structural steel.

The fundamental principles of designing glulam timber connections are the same as those for timber joinery – see *TFEC Technical Bulletin 2011-03 Rules of Timber Joinery*.

Fasteners and Hardware

The most versatile fastener used in glulam timber structures is the common bolt. Bolts are typically used in groups or clusters. Never use a single bolt in a connection where the bolt is the primary method of load transfer; always have at least two bolts to provide some redundancy. There is no advantage to using high-strength bolts, since the capacity of a bolted connection is usually controlled by stresses in the wood. Bolts are therefore typically ASTM A307, rather than the A325 or A490 bolts common in steel construction. Bolts should be galvanized to minimize the potential for staining of the timbers.

Split rings or shear plates are sometimes used in conjunction with bolts when a connection is highly loaded and fewer bolts are desired. The required spacing between bolts is somewhat larger when split rings or shear plates are employed. Split rings are used when the bolt passes through two or more timbers, and shear plates are used between a timber and a steel gusset plate.

In instances where bolts are impractical, lag screws were often used in the past. Self-tapping structural screws are becoming increasingly popular as a substitute for lag screws. Because self-tapping screws do not require precise predrilling of the timber, they are less dependent on the quality of site labor and therefore often preferable to lag screws. Screw spacings and edge distances should adhere strictly to manufacturer's recommendations; it is unconservative to use values intended for lag screws.

Figure 3 Connection hardware is shop fastened with timber rivets and field bolted. The beam reaction is resisted in bearing on the seat and the bolts are not taking load.

Timber rivets are well suited to connecting steel hardware to a glulam timber in the shop. Timber rivets are nail-like fasteners with flattened oval shanks and tapered heads. The wide dimension of the rivet shank should be oriented parallel to the grain of the timber. They are driven through round holes in thin steel plates, and the tapered rivet heads nest tightly in the drilled holes. The plate thickness should never exceed ¼".

Figure 4 Timber rivets

The *AWC National Design Specification for Wood Construction (NDS)* covers in great depth the design of bolts, split rings, shear plates, lag screws, and timber rivets. The web-based Connection Calculator at www.awc.org is an extremely handy tool for calculating the capacity of bolts and lag screws.

Connection Details

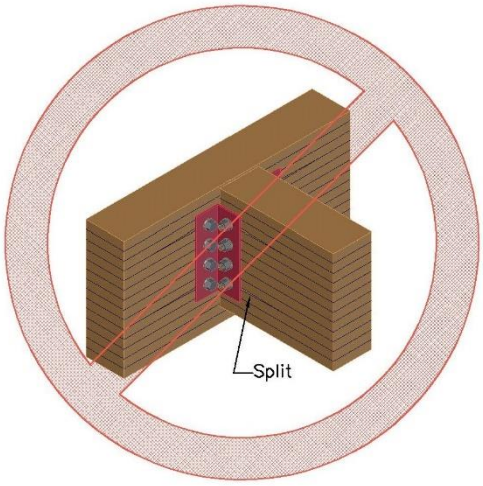

Figure 5 Bolted double angle connection

It is not unusual for glulam timber connections to emulate common structural steel connections. For a variety of reasons, these details are ill suited to timber connections and often perform poorly. For instance, the bolted double angle connection shown in Figure 5 tends to restrain timber dimension changes associated with seasoning and will often cause the timbers to split.

Glulam timbers are fabricated from lumber that has been dried to a moisture content of approximately 15%. While exposed to the elements during construction, the moisture content can rise above 20%. Once in service, timbers in an interior environment will eventually dry to an equilibrium moisture content that is often between 6% and 10%. The dimension changes associated with these fluctuations in moisture content are in the range of 2% of the depth and width of the timber. That may not sound like much, but if the movement is restrained by steel connection hardware, the timber has no choice but to form a split.

A smarter choice is a stiffened seat connection, shown in Figure 6. Load is transferred in bearing on the seat plate, and the bolts are not resisting any structural loads. The bolts only serve to hold the joint together and are positioned close to the bearing seat so that they do not restrain dimension change movements. Since the bolts are not loaded, end distances less than 4D can be used.

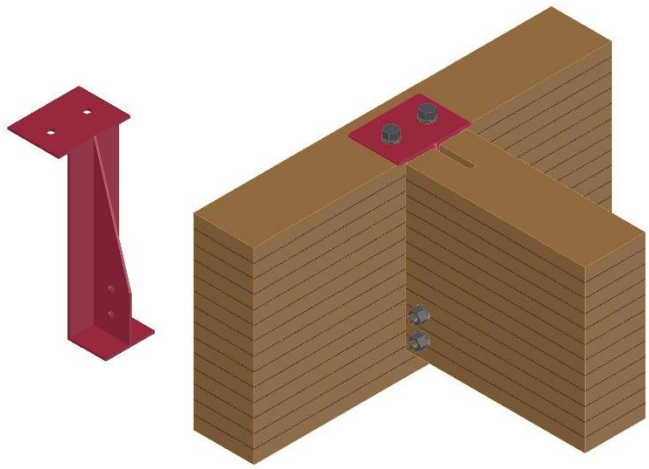

Figure 6 Stiffened seat connection

Similarly, the bolted gusset plate splice connection shown in Figure 7 will restrain dimension change movements and is prone to splitting of the timbers.

The stiffed seat splice shown in Figure 8 does not restrain dimension change movements and performs much better.

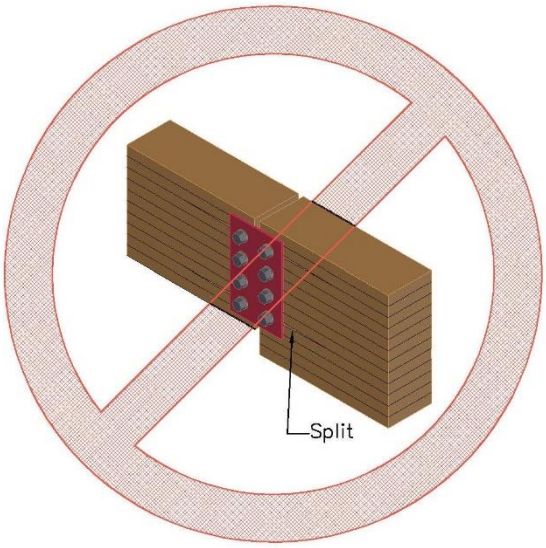

Figure 7 Bolted gusset plate splice

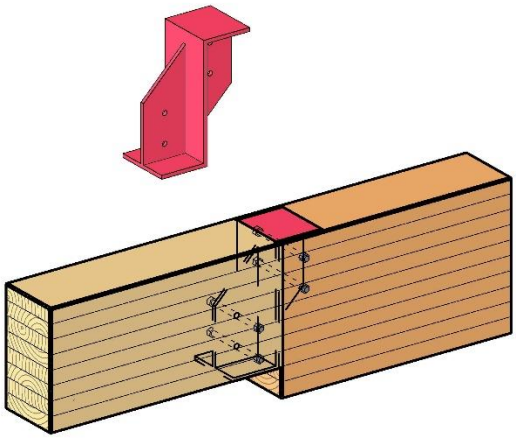

Figure 8 Stiffened seat splice

Durability

If the structure is exposed to the weather, special measures need to be taken in detailing connections.

Timbers need to be preservative treated if they are not a naturally decay-resistant wood species. All fasteners and connection hardware should be galvanized or stainless steel. Avoid proprietary concealed connection hardware that is made of aluminum since it is prone to galvanic corrosion when in contact with steel screws.

Figure 9 Timber in contact with exposed gusset plate is prone to decay

Figure 10 Rotted post base

Connection hardware needs to be detailed to prevent the accumulation of water and to permit the timber to dry after wetting. Exposed gusset plates tend to inhibit drying and should be avoided.

Post base details are critical. The end grain of a post should not be in direct contact with concrete, and the connection hardware should allow water to drain out. Base shoes that hold water should be avoided, and absolutely never bury a post base in the ground or in a concrete pour.

Wet service factors should be used when designing connections that will be exposed to the weather.

Figure 11 Elevated post base drains freely

Fire Resistance

Figure 12 Fire damaged timber structure

In general, mass timber structures exhibit good performance in fires. Evaluating the fire endurance of a structural timber is covered in *AWC Technical Report 10*.

Traditional mortise-and-tenon-style joinery also exhibits good fire performance. The same is not true of timber connections with exposed steel hardware and bolt heads. Steel conducts heat readily, resulting in elevated temperatures in the wood surrounding an exposed steel bolt or plate.

The best way to protect steel connection elements from fire is to embed them in wood with sufficient cover. Steel kerf plates positioned in the center of a timber are preferred over external gusset plates. Bolt heads can be countersunk and plugged with wood plugs that are at least as thick as the anticipated char depth.

Figure 13 Stiffened seat connections with the bottom of the seat plate exposed

The stiffened seat connections shown in Figure 13 have kerf plates that are protected, but the bottoms of the seat plates are exposed. The exposed steel can be protected with an intumescent coating. Since the bolts are not carrying load, in this instance it is not necessary to countersink and plug the bolt heads.

Intumescent coatings puff up when heated to create an insulating barrier. They should only be applied to exposed steel surfaces and should not be applied to steel surfaces that will be in contact with a timber.

Where timbers are not exposed to view, gypsum board can always be used for fire protection.

Pre-Engineered Metal Connectors

There are a variety of pre-engineered products on the market today for glulam connections. While it can be tempting to select a pre-engineered connection out of a catalog, it may not be the most cost-efficient or appropriate solution. It is incumbent upon the engineer to research the manufacturer's technical literature to verify that the product is suitable for the application and not rely on sales literature.

Figure 14 Pre-engineered galvanized steel connectors with a bearing seat and screws into the ends of the timbers

Some North American manufacturers publish code evaluation reports for their products that describe the performance characteristics and applicability of the product based on research and testing. These code evaluation reports are extremely helpful in determining if a particular product is suitable for the application. Unfortunately, many foreign companies do not have North American code evaluation reports for their products.

There are potential durability issues associated with some pre-engineered connections, particularly those that rely on dissimilar metals (for instance aluminum and steel) being in contact. Also, some connectors are fastened with screws into the end grain of a timber and the small diameter screws may have a limited corrosion life.

New products that do not have a long history of satisfactory performance should be evaluated thoroughly – buyer beware.