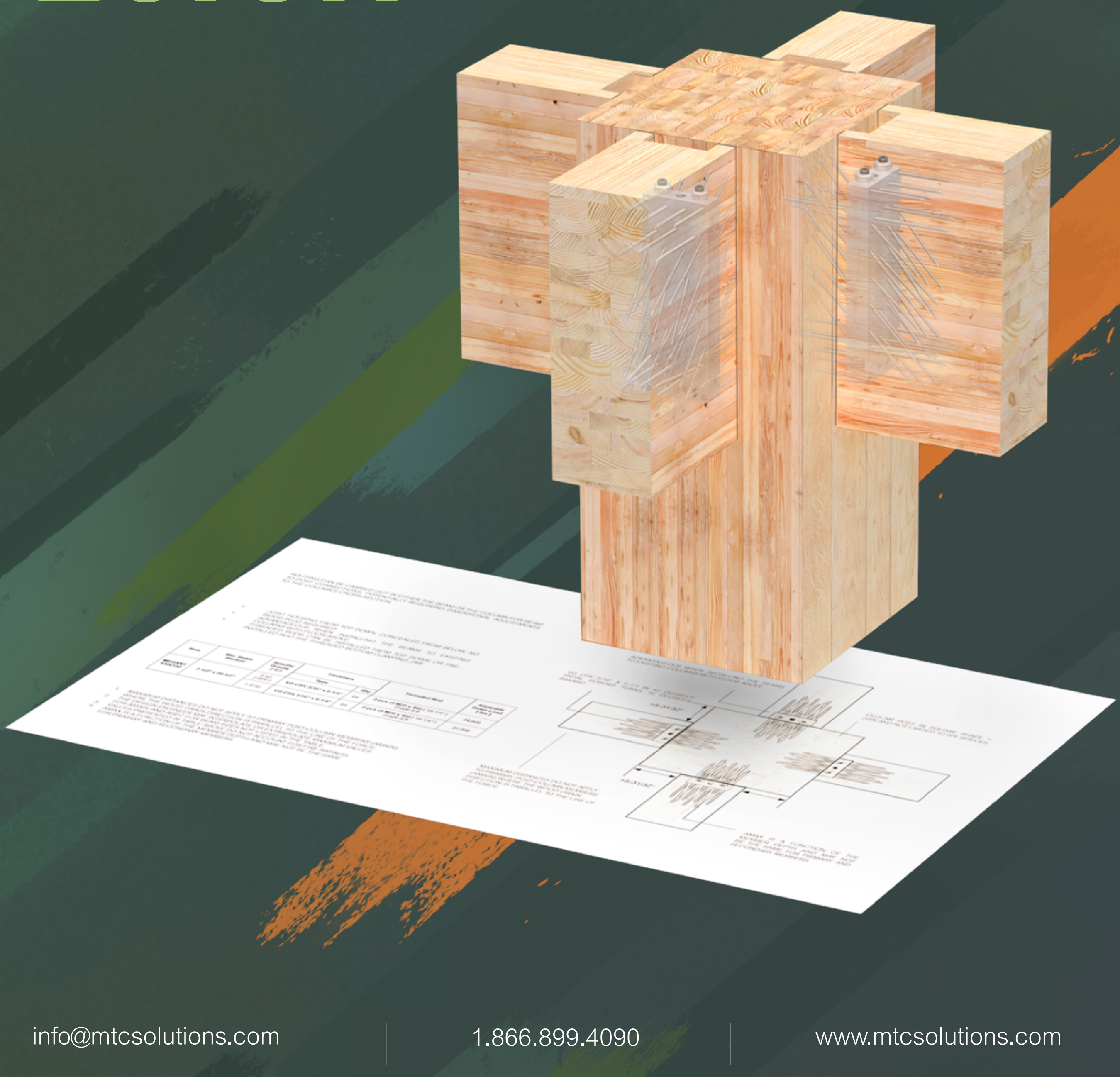
WHITE PAPER

MTC SOLUTIONS

STANDARD BAY FIRE DESIGN



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INTRODUCTION

Chemeketa Agricultural Complex - Salem, Oregon
Photo Courtesy of Swinerton

The evolution of building codes in the US and other jurisdictions worldwide, demonstrated by the 2021 release of the International Building Code (IBC-21), reflects an obvious trend towards the adaptation of taller combustible construction [1]. This shift is evidenced by continual adjustments in fire-rating standards, aimed at ensuring safety and strengthening public confidence. These evolving requirements push designers to specify wider beams to accommodate the prescribed increases in char-layer thickness through wood covers for connections, as outlined in the American Wood Council's 2021 Technical Report No. 10 (TR-10-2021). Consequently, designers are confronted with the challenge of acquiring beam hangers that align with the demands of their structural connections. A crucial fire safety consideration is the avoidance of connecting exposed glued-laminated timber (glulam) and cross-laminated timber (CLT) elements with non-protected steel systems, as steel strength significantly decreases under elevated fire-induced temperatures. Given the necessity of employing steel or other metallic elements for connections in the mass timber industry, implementing a char layer through a wood cover emerges as the only viable alternative. With the combination of structural loads in connections, increasingly stringent fire requirements, and the inherent anisotropic behavior of wood, designers must prioritize connection design early in the process to develop cost-effective solutions in line with architectural criteria.

Post-and-beam grid layouts topped by structural panels made from CLT, nail-laminated timber (NLT), dowel-laminated timber (DLT), or mass plywood (MP) currently represent the most common structural framing system for both commercial and residential mass timber buildings in North America. These panels generally transfer design loads to connection points, situated typically between beams and girders or between girders and posts.

Designing standardized, cost-effective connections for load transfer in mass timber requires detailed research, development, and testing. Unlike conventional building materials such as steel and concrete, mass timber is experiencing a developmental phase in the 21st century. Timber elements can be upsized to provide a sacrificial char layer in response to potential fire exposure. Alternatively, protective elements like gypsum boards can be applied around the member to achieve the required fire-resistance rating (FRR). When designing a post-and-beam grid bay with glulam, designers typically determine element sizes based on strength, serviceability, and FRR requirements.

One significant challenge in fire protection design involves the detailing and placement of connectors. It is a common practice among designers to initially select member sizes before detailing the actual connections or defining the connectors. Both the TR-10-2021 and the 2021 Fire Design Specification for Wood Construction mandate the inclusion of a sacrificial wood cover around the perimeter of a connector [2, 3]. While this is crucial for achieving the desired FRR, it poses constraints on available space for placing an appropriate beam hanger. Unfortunately, this aspect is often overlooked in the preliminary sizing of beams and columns. Designers should prioritize selecting a beam-hanger system with the appropriate capacity before moving on to designing the timber members. This approach allows for the optimization of member cross-sections to accommodate the chosen connector, ensuring a sufficient fire rating while also avoiding potential high costs associated with late-stage redesigns. This white paper presents a practical approach that places emphasis on early consideration of connection design in the process of designing a mass timber post-and-beam structure.

The following outlines a step-by-step procedure of this approach:

Step 1: Establish the loading and building grid pattern.
Step 2: Determine the FRR requirements.
Step 3: Select the beam hanger.
Step 4: Detail the connections in the timber member.
Step 5: Reassess the timber member sizing.

Step 1: Establish the Loading and Building Grid Pattern

Prior to finalizing a post-and-beam layout, a critical decision revolves around selecting the structural timber floor panel for the building. Structural panels, such as CLT, NLT, MP, and DLT panels, come with distinct material properties that impose specific limitations on bay layout, considering strength and serviceability limit states that must be observed. Timber manufacturers offer standardized material sizes tailored to accommodate typical transportation limitations, such as truck bed dimensions. Reducing waste, particularly in the form of off-cuts in panels made from standard stock materials is an important consideration for manufacturers. Early collaboration with timber suppliers, in conjunction with a comprehensive understanding of manufacturing limitations, supply chain constraints, and the mechanical properties of specific panel materials, can substantially contribute to the project's economics. Ultimately, the selected grid pattern and bay size will dictate connection loading and, therefore, directly influence the selected structural beam layout and design. Once the initial round of iterations is complete and the preliminary grid pattern is established, designers can proceed with designing the connections.

Step 2: Determine the FRR Requirements

Designers evaluate the fire resistance criteria for their buildings based on the specific occupancy type. The IBC-21 provides guidance on selecting the appropriate building type, factoring in considerations such as height and area, which directly influence the FRR of connections. In cases where FRR requirements are absent, connections may remain exposed without the need for additional fire protection measures. However, as buildings rise in height, so do the FRR demands. Designers should be aware of these evolving requirements and their implications for fire protection of connections. Currently, a 2-hour FRR is a common standard for connections. To achieve fire ratings in connections, designers typically employ two primary approaches. The first involves the application of protective, non-combustible materials to the surface of the timber around the connection. Alternatively, a combustible, sacrificial char layer can be created around the connection (Figure 1). In most cases, this is accomplished by housing the connector within a dapped-out or routed-out cavity. The cavity and connector are shielded by the surrounding sacrificial wood material. This is commonly achieved by oversizing the cross-section of the members (Figure 2). Utilizing renewable, combustible, and natural wood to protect metallic connection elements from fire also imparts a clean, natural, and aesthetically appealing architectural finish.

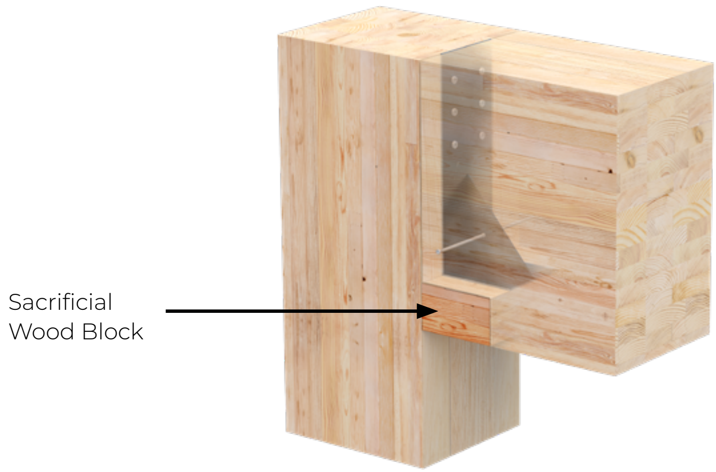


Figure 1. Example of a Beam Connection with Extra Wood Material for Wood Cover

The current guidelines for FRR connection design, as outlined in the TR-10-2021, distinguish between two major connection categories: bonded and unbonded. Specifically, bonded connections can achieve a 2-hour FRR with a minimum 3.01”-thick sacrificial char layer surrounding the connection elements. In contrast, unbonded connections require a minimum char-layer thickness of 5.20” to attain the same rating. The categorization of connections as “bonded” and “unbonded” depends on the condition of the gap between the two connected elements, such as the side face of the post and the end of the beam in a post-to-beam structure. Connections with gaps filled with fire caulking, intumescent tape, or wood glue bond are generally classified as bonded connections.

Figure 2. Example of a Concealed Fire-Rated Connection with a MEGANT Connector

Step 3: Select the Beam Hanger

After establishing the grid pattern and FRR requirements, the next step involves selecting the beam-hanger system. Delaying such decision can lead to complications, as standard beam hanger sizes may not align with the selected cross-sections. Likewise, opting for a custom-designed post-to-beam connector may present challenges or incur higher costs in satisfying all structural detailing constraints, particularly with regards to fire rating. Custom connections, such as bearing beam hangers, may be difficult to design for high-loading scenarios without addressing unknowns in the form of accurate deformation and stiffness. Additionally, bearing hangers are difficult to fully conceal for FRR requirements. Therefore, it is important to prioritize the selection of the connector system immediately after finalizing the sizing of the timber members.

In the event of a fire, beams are generally exposed on three sides, with the top side protected by floor assemblies. This three-sided exposure pattern prompts designers to lean towards wider and shallower beam members, resulting in a squarer cross-section. Neglecting to consider the FRR requirements for the connection at an early stage may thus pose challenges in sourcing connectors capable of transmitting the required loads while accommodating this squarer cross-section in adherence to the FRR standard. The fire design of connections, frequently considered the most challenging aspect in timber structures, is likely to dictate the overall fire resistance of the structure. The above highlights the significance of selecting a suitable beam-hanger system prior to finalizing beam geometry. This approach enables the designer to simply choose a connector that fulfills the load requirements and can also accommodate the FRR at this stage.

Optimizing grid patterns in line with established mass timber manufacturing standards and best practices allows designers to leverage standardized products, including pre-engineered beam hangers. Certain pre-engineered beam-hanger systems not only meet both design capacity and FRR requirements but also fit within the members' cross-sections with sufficient installation tolerances. Notably, a key advantage of pre-engineered beam hangers lies in the predetermined minimum required beam section, given the fasteners' minimum spacings, edge distances, and end distances. Additionally, some pre-engineered connectors, including the MEGANT and RICON S VS, are fire-tested under conditions specified in ASTM E119.

WHY BEAM HANGERS?

Beam hangers, such as the RICON S VS and MEGANT (see Figure 3 and Figure 4), are pre-engineered systems that have undergone rigorous testing to validate their capacity to withstand specified structural loads. This process involved multiple iterations of product development, ensuring the elimination of inefficiencies and the proper design of materials for load resistance. Moreover, their streamlined drop-in installation and factory installation capabilities reduce on-site labor while expediting the construction process.

Recognized for their precisely engineered shape and test-verified load ratings, the RICON S VS and MEGANT beam-hanger systems stand out as an ideal solution for fire-rated post-and-beam connections. Adhering to ASTM E119 test standards, these connectors have attained a certified 1-hour FRR under a specified design load. This rating has been accomplished through the incorporation of a sacrificial wood char layer, as illustrated in Figure 5.

The MTC Solutions Beam Hangers Design Guide provides all relevant information concerning the beam-hanger systems, including their capacities and geometry requirements. Implementing these tested solutions can help ensure predictable connection behaviors, affording a higher level of control over design uncertainties, which ultimately results in reduced project costs and environmental impact.

Figure 3. RICON S VS Connector

Figure 4. MEGANT Connector

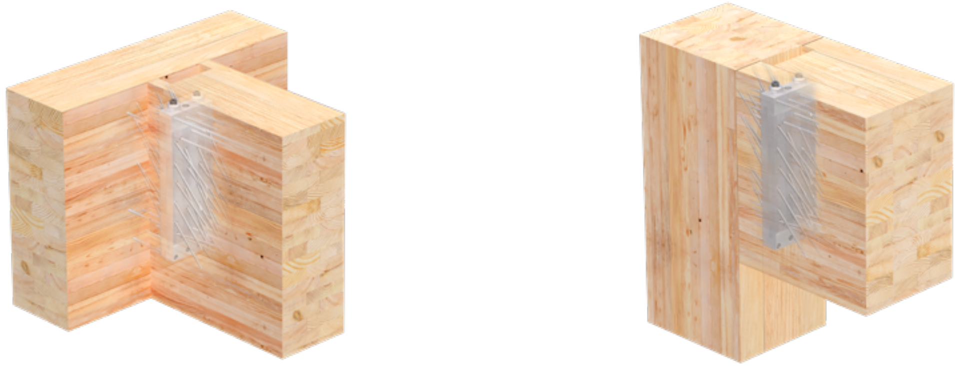


Figure 5. Examples of Concealed Beam-to-Girder and Beam-to-Post Connections

Step 4: Detail the Connections in the Timber Member

Concealing connectors within the timber element offers an economical method of achieving the desired FRR for the connection. Detailing the geometry of the connector housing constitutes a crucial step in the design process of mass timber connections, which is directly affected by the selected connector.

To achieve the required fire rating with a minimal wood-cover thickness, a fire sealant or intumescent tape is typically applied to the timber surrounding the beam hanger. Current practice often entails the application of fire caulking, even when no gap is anticipated between the connecting interfaces. Designers commonly grapple with a variety of detailing challenges. Prominent examples include providing appropriate fire sealant recommendations, mitigating potential screw collisions within the members when connecting from multiple faces into a given girder, and navigating spatial constraints for placing the connector itself. The following section will explain housing considerations and their impact on connection detailing in the beam, girder, and column members when using the MEGANT and RICON S VS connectors.

4.1 Beam-to-Girder Connections

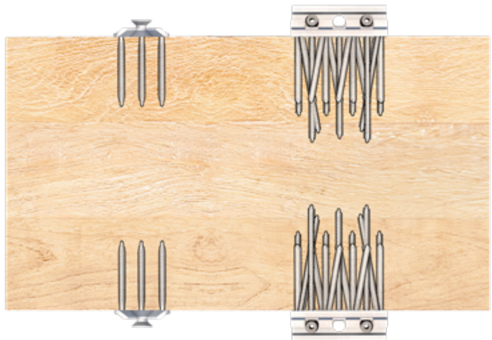
The RICON S VS and MEGANT connectors offer versatile configurations for connection housings, affording designers the flexibility to address the constraints of connection engineering. For beam-to-girder connections, beam hangers can be housed within either the beam or the girder. Figure 6 visually illustrates typical beams equipped with and without end housing for drop-in installation. The RICON S VS is depicted on the left, and the MEGANT on the right. The routing depth of the housing is instrumental in meeting the project's tolerance requirements and achieving the appropriate beam end-to-post face gap width required for the FRR.

Additionally, housing can be incorporated into the girder member. While this approach eliminates the need for wooden plugs at the beam end, it may necessitate considerations for reduction in the respective cross-section due to material removal for the housing. Furthermore, when housings are provided on each face of the girder, addressing screw collision concerns becomes imperative, as depicted in Figure 7.

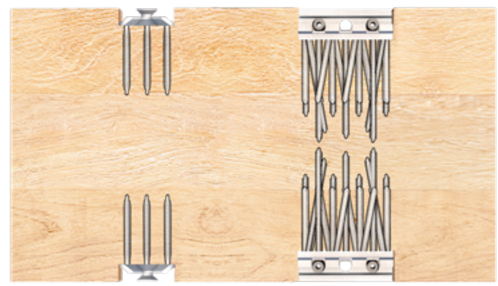
(a) Routing in the Beam

(b) Routing in the Girder

Figure 6. Top View of a Typical Beam Girder Connection



(a) With Housing



(b) Without Housing

Figure 7. Top View of a Typical Girder Beam

4.2. Beam-to-Post Connections

Routing can be carried out in either the beam or the column for beam-to-post connections, potentially requiring dimensional adjustments to the column's cross-section. In situations where connectors are housed in the end grain of the girder beam, a through housing with a wood plug is required for the drop-in installation of the MEGANT connector. On the other hand, the RICON S VS connector does not require a through housing but rather a housing open from the bottom face of the beam. As shown in Figure 8, the connector is face-mounted to the column. The use of through housings in the beam end for post-and-beam connections does introduce the need for installing wood plugs, incurring additional labor and costs in most cases. Therefore, it is recommended to use housings cut into columns and end face-mounted connectors for typical post-and-beam connections (see Figure 9).

When column members are anticipated to receive beam members from multiple directions, potential screw collisions must be verified in the design stage. Additionally, in tall timber buildings, the necessity for post-to-post connections may give rise to interference with the selected post-and-beam connector. Alongside these considerations, the imperative of accounting for the FRR for the connection nodes, including post-to-post and post-to-beam connecting elements, highlights the importance of early and proper detailing and selection of connector systems.

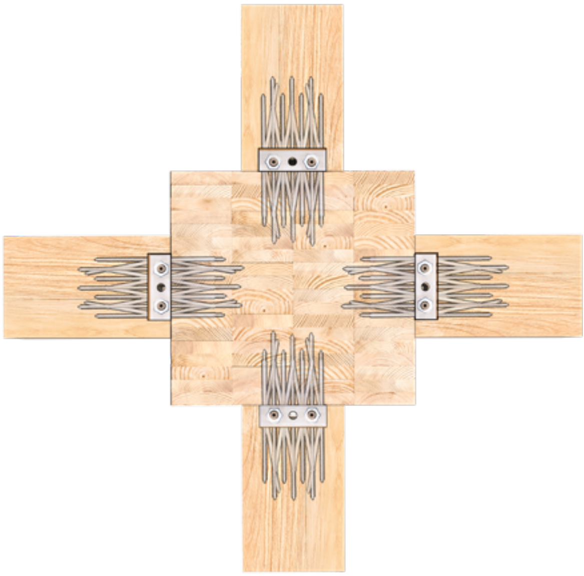


Figure 8. Top View of Column Connectors with Routing in a Girder

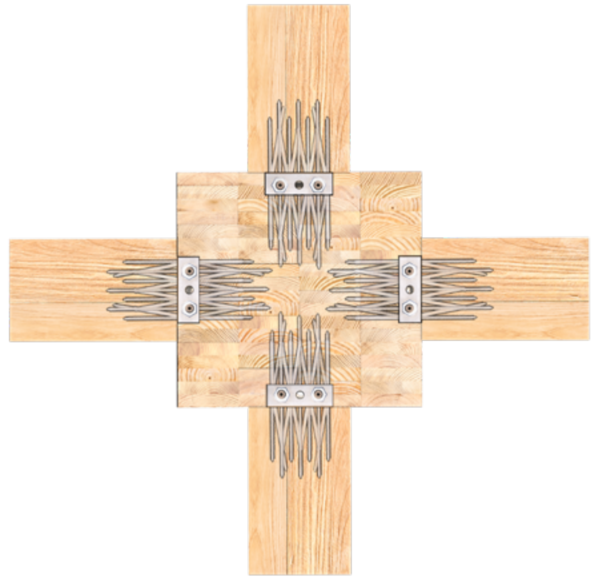


Figure 9. Top View of Column Connectors with Routing in a Column

Step 5: Reassess the Timber Member Sizing

In Step 5 of this guide, timber member sizing is reassessed following the establishment of connections and the FRR based on the selected beam-and-post grid patterns. The designer must confirm the proper design criteria for serviceability and strength.

Choosing the beam hanger before finalizing timber member sizing ensures an optimized cross-section for the selected connector. This approach aligns with the practical guidance provided in this document, emphasizing fitting beam cross-sections to the connectors rather than adapting connectors to inappropriate beam sizes, thus avoiding costly late-stage alternations.

CONCLUSION

This document provides a five-step approach for selecting a beam-hanger system for a post-and-beam mass timber structure. The iterative nature of this method emphasizes the need for considering various factors to achieve the desired capacity, detailing, and FRR. It is beneficial to consider the design of the beam-hanger system prior to finalizing the structural elements. Initiating the design iteration with the connector system can prevent challenging design adjustments later in the process.

Designers are encouraged to carefully choose and collaborate with their connection supplier from the outset of the design phase. This approach ensures a thorough evaluation of all available connection solutions, leading to the selection of the most optimized solution. The MTC Solutions Design Guides and Technical Support Team serve as valuable resources that can simplify the design process.

CHEMEKETA AGRICULTURAL COMPLEX

Salem, Oregon

Photo Courtesy of Timberlab

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