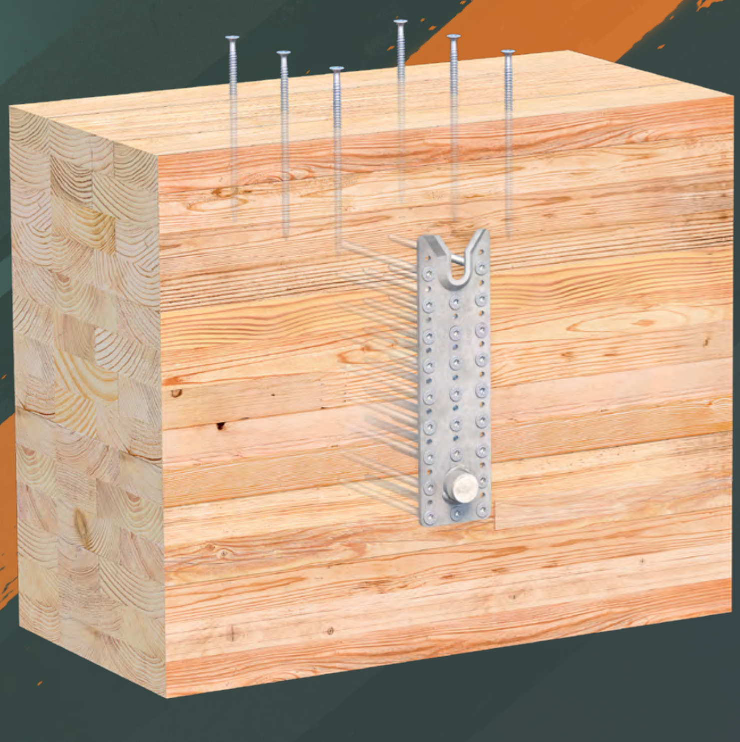
WHITE PAPER

PRACTICAL CONSIDERATIONS FOR THE DETAILING OF BEAM HANGERS



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ABSTRACT

Beam hangers are robust, long-lasting, and safe options for connecting mass timber elements. This white paper focuses on parameters that should be prioritized when designing and detailing beam hanger connections. Techniques to minimize supplemental reinforcement, relevant brittle wood failure modes to consider, and tips for efficient design are discussed.

The primary purpose of this document is to help designers reduce the need for reinforcement and simplify connection detailing. Brittle failure mechanisms that should be considered, particularly for connections and assemblies that involve multiple fasteners, are presented. Additionally, best practice recommendations for the location of self-tapping screws and beam hangers in timber members are included. Placement of the beam hanger merits careful consideration, as it can influence the requirement for additional reinforcement and the connections' fire resistance. Guidance on installing reinforcing screws, preventing fastener collision, and maximizing fastener efficiency is also provided.

INTRODUCTION

Beam hangers are a simple, adaptable, pre-engineered solution that can be used for connecting mass timber elements. While their primary function is to transmit downward loads, certain models are capable of transmitting axial tension loads along the framing.

The most common connections made with beam hangers include joists to girders, girders to columns, and beams framing directly into bearing walls. These connections all consist of a primary (supporting) member and a secondary (supported) member.

Much of the North American mass timber market consists of structures with post-and-beam framing. This type of construction, while efficient, limits the number of redundant load paths. Accordingly, highly-loaded connections must be carefully designed to ensure desired performance. Beam hangers provide an efficient solution for transferring higher loads, while offering a range of added benefits, including:

- Using building information modeling techniques allows for an optimized material delivery sequencing process, which, combined with the option to pre-install the beam hanger in a controlled workshop environment results in faster installation times;
- Installation versatility in various configurations (sloped and/or skewed), as the beam hangers only require two parallel faces for connections;
- Aesthetically pleasing options, including fully concealed installation;
- Optimized solutions for differing fire resistance requirements;
- Installation versatility into multiple materials, allowing for connections to be created between mass timber elements and building elements made from steel or concrete; and
- The ease of using a tested product with a specified load range and ready-to-use drawings.

This white paper focuses on considerations for detailing beam hangers, helping designers understand how to minimize the need for supplemental reinforcement. Topics for discussion also include brittle wood failure modes that are not addressed in depth in the National Design Specification for Wood Construction (NDS), and the behavior of mass timber connections that can influence splitting. Common situations requiring reinforcement are discussed, as well as key parameters to prioritize when designing and detailing beam hanger connections. This article primarily examines connection assemblies containing a single beam hanger; however, provisions for using two beam hangers in the same connection assembly for additional capacity can be found in the MTC Solutions Beam Hangers Design Guide.

Wood Failure Modes Perpendicular-to-Grain

Wood is orthotropic with capacity that varies depending on the direction of the load applied relative to its grain direction. Its highest strength is realized when loaded in bending or axially parallel-to-grain. Conversely, when loaded in tension perpendicular-to-grain (i.e., cross-grain tension), wood exhibits limited capacity, with brittle failure modes in these applications.

One limitation of the NDS is that the fastener provisions focus on single-fastener behavior and do not include extensive guidance for designers to account for the brittle failure modes resulting from local stresses in groups of fasteners. Engineers should consider brittle failure modes when designing and detailing any multi-fastener connections, as well as assemblies such as beam hangers, bolted knife plates, and custom products using multiple fasteners. There are many brittle failure modes, both parallel and perpendicular-to-grain; however, for the purpose of this paper, two perpendicular-to-grain failure modes are considered: tension-induced splitting in the side of primary members, and beam-end fracture.

Perpendicular-to-grain tension-induced splitting in the side of primary (supporting) members, as shown in Figure 1. These connections may require reinforcement depending upon the relative height of the beam hanger within the primary member.

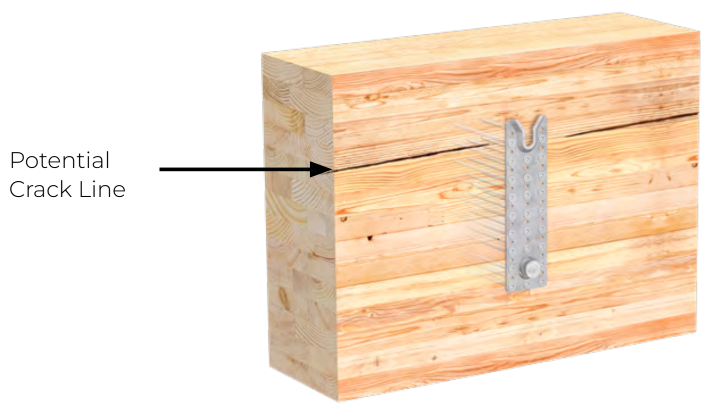


Figure 1. Primary Member with Perpendicular-to-Grain Splitting

Beam-end fracture induced by cross-grain tension. These connections may require additional reinforcement to prevent stress concentrations from initiating a crack at the location of a virtual or physical notch, as shown in Figures 2 and 3 respectively.

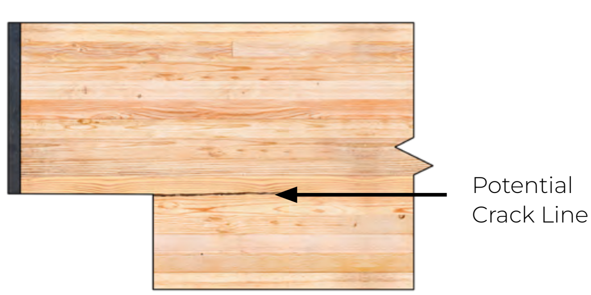


Figure 2. Member With a Physical Notch

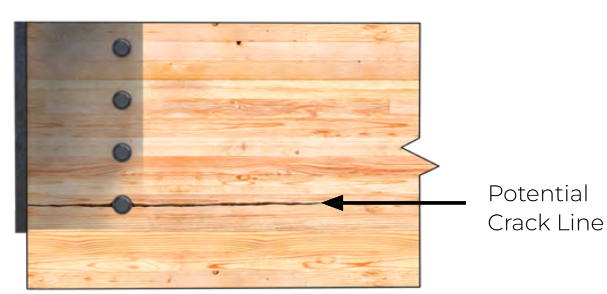


Figure 3. Member With "Virtual Notch" Created by Knife Plate Connection

In general, locating the beam hanger at the appropriate height relative to the depth of the connected framing can avoid the need for additional reinforcement. Current best practices suggest that supplementary reinforcement is required in the primary members when the uppermost fasteners of the connection is penetrating bellow the top 30% of the girder depth (Figure 4(a)). Conversely, when installed in the end of a secondary member, the beam hanger should be installed as low as possible (Figure 4(b)).[1,2,3]

(a) (b)

Figure 4. (a) Beam Hanger Without Reinforcement
(b) Beam Hanger With Reinforcement

The drawback of placing the beam hanger higher in the secondary member is that the screws engage higher up in the cross-section of the member and are assumed to behave like an angle bracket, creating a "virtual notch" that potentially gives rise to a stress concentration at the corner of the notch. Designers should be aware that this phenomenon occurs with any type of connector that engages the secondary member in this fashion, including beam hangers, bolted knife plates, and custom products.

REINFORCEMENT OF BEAM HANGERS

Given that the two brittle failure modes presented earlier are highly correlated with the location of the connector relative to the beam depth, placement is critical to consider. In situations where physical requirements dictate connector placements other than the product specifications, the failure mode may change, necessitating reinforcement to achieve the desired capacity. When wood members require reinforcement, fully threaded self-tapping screws (STSs) are a common solution. Their threads provide a continuous mechanical connection along their length. This feature makes STSs an efficient option as they can be easily shop- or field-installed perpendicular to the wood surface, or at an incline.

Designers are advised to reinforce the primary member instead of the secondary member. There are multiple reasons that primary-member reinforcement is preferred, including:

- When examining equations used to calculate design forces in reinforcing screws for notched members, the primary member carries load more effectively and impacts the required capacity of reinforcement. In short, it is a more efficient use of fasteners to reinforce the primary member;[4]
- Placing the screws closer to the shear plane in the primary member is more efficient, the restrictive end-distance geometry requirements that apply to secondary-member reinforcement are not applicable to primary-member reinforcement;
- There are typically fewer installation issues due to reduced potential for screw collision. Deviation during installation primarily occurs cross-grain. In secondary members, this can lead to either collision with the beam hanger hardware or the reinforcing screw protruding from the edge of the beam;
- There is typically more room to place a row of reinforcing screws in the primary member on either side of the connector, whereas the geometries of the secondary member adjacent to each side of the beam hanger present limitations to installation.

Current timber engineering best practices recommend reinforcing areas with potential stress concentrations, such as the origin of a notch or, in the case of a beam-end hanger connection, the lowermost row of screws. Any reinforcing fasteners should be positioned as close as possible to the point of stress initiation, while ensuring compliance with the minimum end-distance, edge-distance, and spacing requirements. There is a limited distribution length of the tensile stresses perpendicular-to-grain outside the corner of a notch.

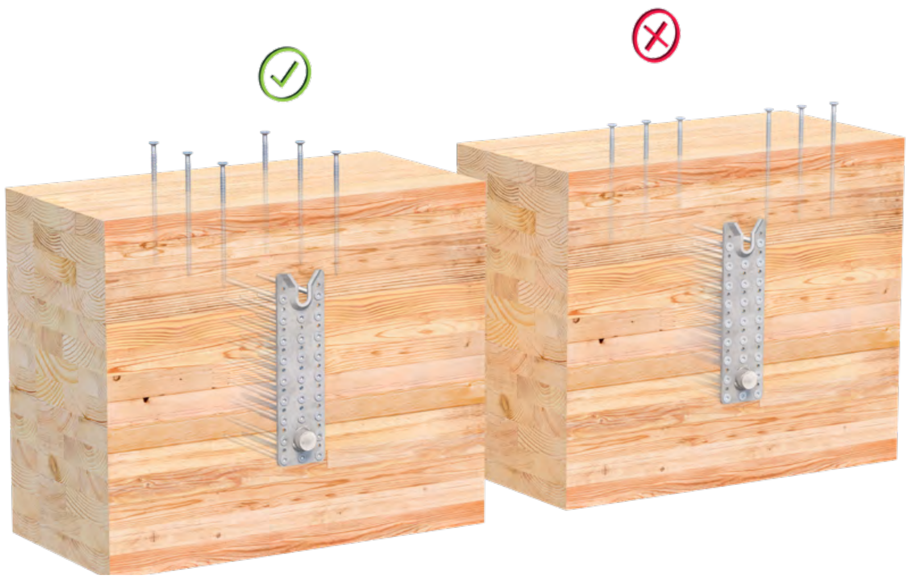
The distance between the reinforcement and the connector should be minimized to enable the perpendicular-to-grain tensile forces to be effectively transferred to the reinforcement, while still allowing adequate room to prevent fastener collision or protrusion from the edge of the member. The ability of a fully threaded STS to carry this load can be verified by checking its withdrawal capacity when inserted perpendicular-to-grain against the anticipated crack initiation force.

Other considerations may require the beam hanger to be mounted higher in the secondary member. When a beam hanger is detailed to accommodate drift due to lateral loads, it is better to mount the connector close to the center of the secondary member. Fire-resistance requirements may demand additional wood cover to protect the connection for the specified duration, which would also necessitate a higher beam hanger position in the secondary member.

In addition, the NDS provisions that determine shear capacity for bending members notched at the end are based on the square of the ratio of the depth of the notched and unnotched portions of the member. An added benefit of reinforcing a notched beam end is that in accordance with the NDS and CSA O86, the effects of the virtual notch can be neglected. The full depth of the beam is permitted to be used in shear resistance calculations, providing increased capacity and enhanced resistance to brittle failure modes.

Reinforcement Placement Considerations

Multiple rows of fasteners may not distribute loads evenly, potentially leading to stress concentrations in the row of fasteners closest to the stress initiation (see Figure 5). Installing the screws in a single row promotes even load sharing among the fasteners. Consequently, only one row of fasteners should be used for reinforcement. MTC Solutions recommends that no more than three screws should be placed in a row on each side of the primary member, and that the secondary member should be limited to a row of two reinforcing screws on each side of the beam hanger.



(a) (b)

Figure 5. Primary Member Reinforcement with (a) Optimal Placement and (b) Inefficient Placement for Load Sharing.

To avoid fastener collision, reinforcing screws should be installed on the outer side of the beam hanger, rather than within the connector assembly (see Figure 6). If two beam hangers are used, the screws in the secondary beams should be installed to either side of the beam hanger, and ideally, between them.

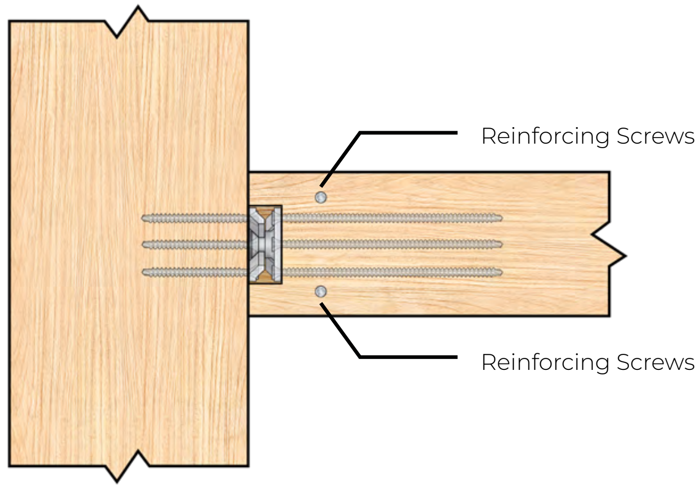


Figure 6. Top View Showing Reinforcement Placement Outside of Beam Hanger Assembly

Connections should be detailed with sufficient clearance to minimize congestion and prevent fastener collision during installation. The final placement and installation tolerances of both the beam hanger fasteners and any necessary reinforcing fasteners need to be considered. For MTC Solutions' fully threaded screws used with beam hangers, geometry requirements can be found in the MTC Solutions' Beam Hangers Design Guide.

Installation Considerations

The Beam Hangers Design Guide provides information on proper positioning and installation of beam hangers, but designers should always ensure that there is adequate space for tool positioning to facilitate proper installation. Predrilling a pilot hole for steel-to-wood connections is an effective means of ensuring centering and alignment to prevent head protrusion or uneven bearing. Practical limitations should be carefully considered when specifying predrilling for long fasteners, including available drill bit lengths.

The product specifications should always be consulted during design. Research conducted by MTC Solutions[5] indicates that near-edge installation of STSs loaded in withdrawal should not be directly correlated to guidelines of lag screws, as STSs loaded in withdrawal in near-edge applications are seemingly more prone to splitting failure modes, even with predrilled holes. Screws installed near the edge of a member may be angled slightly inward (by approximately 5°) to mitigate the risk of deviating during installation and protruding from the side of the beam.

CONCLUSIONS

Beam hangers are not explicitly detailed in North American design standards. As a result, specifiers are strongly advised to pay careful attention to the manufacturer's specifications for proper design and installation. These specifications provide efficient solutions for load transfer and fast installation. They can also be adapted to accommodate the demands of project design and construction sites. Recommendations for designers to consider when using beam hangers are summarized below:

Recommendations		*Reasoning*
Only install a single row of reinforcing screws parallel to the face of the beam hanger;	⟶	Forces are not evenly distributed across multiple rows of fasteners;
When reinforcement is required for a beam hanger connection, it is best practice to prioritize placement of the secondary member to avoid reinforcement, helping isolate reinforcement only to the primary member;	⟶	More efficient design and more space for reinforcement in the primary member;
Ensure fastener spacing meets manufacturer's guidelines;	⟶	Helps prevent fastener collision and wood splitting;
Reinforcing fasteners near beam edges may be angled slightly inward (by ~5°) if geometry can be accommodated;	⟶	Minimizes risk of fastener deviation out of the side of the beam during installation;
Pilot holes should be drilled as close to the full length of the fastener as possible.	⟶	Facilitates a proper penetration path for fasteners and reduces risk of fastener collision.

For more information and design guidance, please contact our Technical Support Team.

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[2] Schickhofer, G., 2006. Holzbau Nachweisführen für Konstruktionen aus Holz. Institut für Holzbau & Holztechnologie Technische Universität Graz.

[3] Annex 7 of European Technical Assessment ETA-15/0667

[4] Annex 4 of European Technical Assessment ETA-11/0190

[5] "Screw Withdrawal Resistance in Near-Edge Applications", https://mtcsolutions.com/resources/white-papers/screw-withdrawal-resistance-in-near-edge-applications/

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