Standard Connections, Issue 1: Gravity

Connection design variability is often considered to be a significant cost driver for mass timber projects, yet designers often lack clear guidance on what standard solutions could look like. The purpose of this document is to provide the construction industry with standardized detailing practices that cover a wide range of connections commonly found in mass timber buildings in Canada. These details can be adapted across multiple projects with various design teams and suppliers. The focus is on providing high-capacity, simple installation, and overall cost-effectiveness for timber connections.

Six details are presented based on typical beam, column, and wall connections. This document also outlines the design focus areas that were prioritized during detail development. Lastly, a checklist is provided for detailers to ensure that all priorities are considered. Companion 3D versions of these details can downloaded here.

Bright Photography, courtesy of naturallywood.com

Design Focus Areas

These standard connections were developed by carefully considering all stakeholder priorities, resulting in a balanced and cost-effective approach. These general focus areas can be adapted for unique conditions as well.

Structural Design

Splitting: Tension perpendicular to grain commonly occurs with tension-side notches, openings, and pre-engineered hangers. Splitting cracks can propagate suddenly and unexpectedly if not detailed adequately. These occurrences should either be avoided or adequately reinforced. Torsion and cross-grain bending should also be avoided as they can lead to tension perpendicular to grain.

Figure 1. Reinforcement screws being installed in the shop
Photo Credit Agency Media, courtesy of naturallywood.com

Drift Compatibility: These connections are intended for gravity loads only. However, designers must carefully consider drift compatibility between gravity and lateral systems if large lateral deformations are expected. Common strategies include providing gaps, oversized or slotted holes, and other means of allowing for joint rotation.

Fabrication

Machining: The ability and efficiency of CNC work has changed the cost profile for mass timber connections. The details provided seek to find a balance between CNC and hardware costs for most projects. Specific situations may have different supplier constraints.

Hardware: A comparison between custom and pre-engineered hardware may change on a detail-by-detail basis. Even though off-the-shelf pieces can be more accessible, they may not provide sufficient site flexibility needed for the project. For example, a custom hanger may provide larger placement tolerances at a concrete interface compared to a dovetail hanger.

Installation

Tolerances: Dissimilar materials are often installed to different tolerances. Thus, it is critical to accommodate this variation at member interfaces. Both members and connections need to be designed with field modifications in mind to provide the most flexibility.

Figure 2. Beam installation between column and a concrete wall
Photo Credit Jason Harding, courtesy of naturallywood.com

Field Scope: It is advisable that the majority of connection labour be completed at the shop in a controlled environment to keep installation at a fast pace. However, field work such as cutting and welding may provide the additional on-site flexibility needed for complex connections. These scopes should be clearly delineated.

Durability

Service Conditions: Although temporary wetting is likely to occur during construction, these connections are intended for dry service conditions only. It is critical to ensure that moisture is not trapped in the connection, and that water can freely run off.

Shrinkage: Changes in ambient conditions can result in moisture-induced dimensional changes. These movements should occur without restriction. Trying to restrain these changes may result in induced stresses at the connection and checking on the surface of the wood.

Fire Performance

All connections described in this document can be exposed or concealed. When exposed, it is important to minimize the gaps between elements to avoid the risk of an accelerated char contraction. Additional fire-stopping may be required to mitigate this risk with large gaps.

Detailing Checklist

This non-exhaustive checklist aims to provide general recommendations to ensure that the connections are developed with all different needs in mind:

Structural Design

- ☐ Load path is well defined and uses wood efficiently
- ☐ Tension perpendicular to grain is avoided, or reinforcement is provided to mitigate the risk of splitting
- ☐ Joint can accommodate the lateral seismic deformations expected without premature failures
- ☐ Connector placement meets structural, fire, tolerance, and aesthetic requirements

Fabrication

- ☐ Hardware specifications are readily available
- ☐ Connection is achievable with standard machinery available to the supplier
- ☐ Machining on multiple faces of the same member is only specified where required
- ☐ There are no significant lead times associated with the hardware specified
- ☐ Hardware specification is standardized across project details
- ☐ Fastener pre-drilling is specified where required
- ☐ Labour-intensive activities can be performed at the shop
- ☐ Inclined washers are provided to avoid inclined countersunk holes on steel plates

Installation

- ☐ Connection installation does not dictate erection sequencing
- ☐ Temporary supports can be avoided during installation
- ☐ Connectors can be used as a lifting point for erection whenever appropriate
- ☐ Interfaces between dissimilar materials have adequate tolerances
- ☐ Field- and shop-installation scopes are clearly defined

Durability

- ☐ Connection prevents trapped moisture
- ☐ The member is free to undergo moisture-induced movements without induced stress in both temporary and permanent conditions
- ☐ Steel is adequately protected to avoid rusting and staining the wood

Fire Performance

- ☐ All steel is adequately concealed or treated for fire exposure
- ☐ Fire-stopping is specified for larger gaps and openings
- ☐ No intumescent paint or specialized coatings are required for fire performance
- ☐ The fire resistance of exposed wood has been considered through an engineering approach in order to maintain sufficient structural capacity in a fire event

Industry Contributors

Details were developed in a workshop in collaboration with the following attendees:

ASPECT Structural Engineers

BC Institute of Technology

DIALOG Design

EQUILIBRIUM Consulting

ETRO Construction

Fast+Epp

Francl Architecture

Fraserwood Industries

Glotman Simpson

ISL Engineering and Land Services

Kalesnikoff Mass Timber

MTC Solutions

PUBLIC Architecture

Rothoblaas

Seagate Mass Timber

Simpson Strong-Tie

Spearhead

StructureCraft

Western Archrib

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BEAM-BEAM FLUSH CONNECTION

PRE-ENGINEERED DOVETAIL HANGER FOR A CONCEALED CONNECTION BETWEEN TWO ORTHOGONAL WOOD MEMBERS

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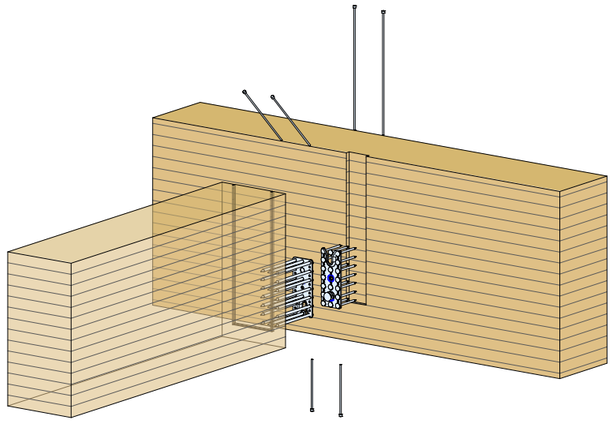


DESIGN RECOMMENDATIONS

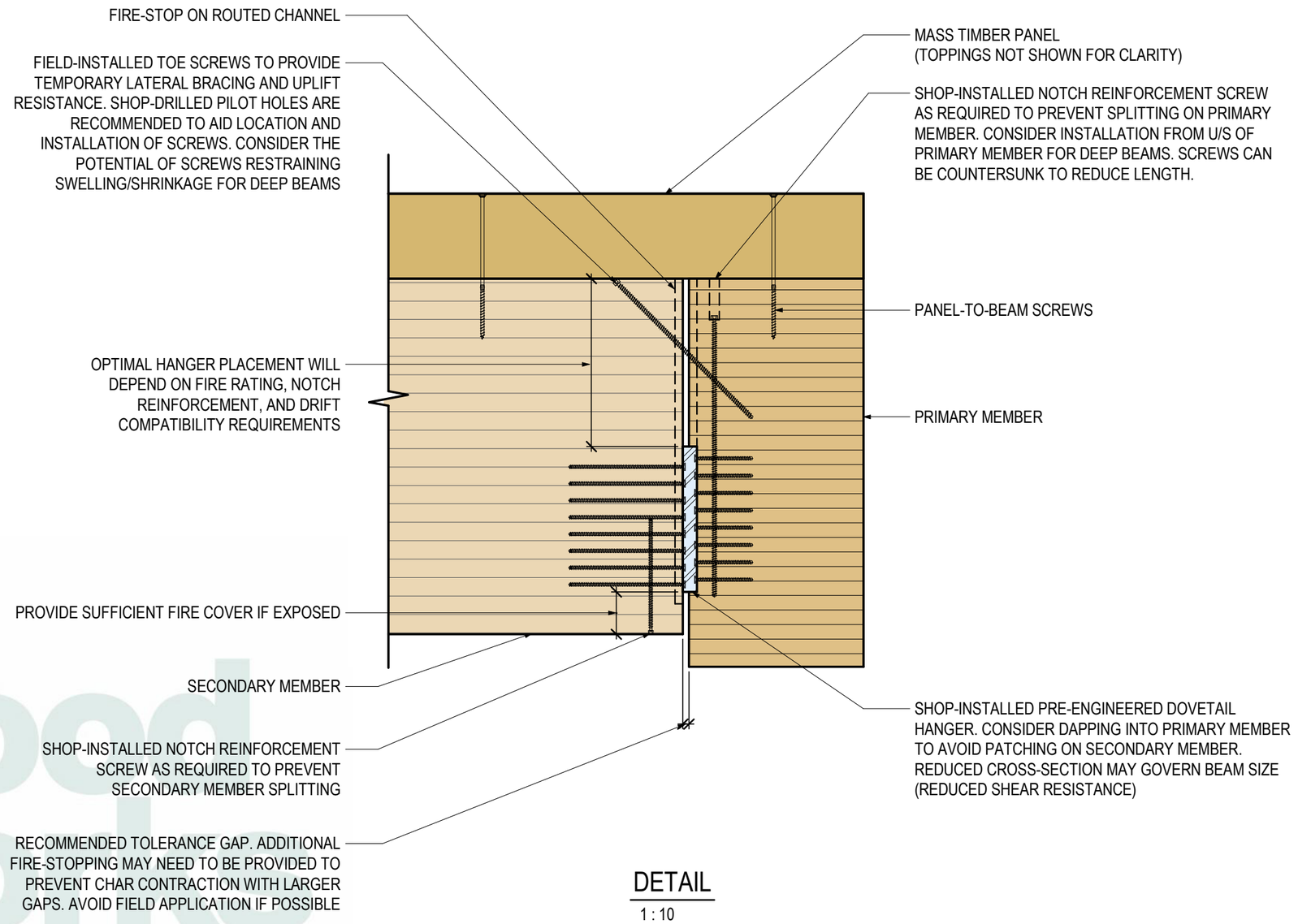
1. CONSULT WITH HARDWARE SUPPLIER FOR HANGER RESISTANCES COMPLIANT WITH CSA O86 (LATEST EDITION).
2. SKEWED MEMBERS MAY REDUCE THE RESISTANCE OF THE HANGER. CONSULT WITH HARDWARE SUPPLIER FOR SPECIFICS.
3. IT IS RECOMMENDED TO PROVIDE ALTERNATIVE PATHS TO RESIST AXIAL, LATERAL, AND TORSIONAL LOADS AS MOST HANGERS ARE DESIGNED AS SHEAR (VERTICAL) ONLY CONNECTORS. CONSULT WITH HARDWARE SUPPLIER FOR SPECIFICS.

INSTALLATION

1. HOUSING ON SECONDARY MEMBER CAN BE A COST-EFFECTIVE OPTION FOR ENCAPSULATED CONNECTIONS WHERE PATCHING IS NOT REQUIRED.
2. TOP-DOWN BEAM INSTALLATION IS PREFERRED.
3. REINFORCEMENT SCREWS CAN BE CHALLENGING TO INSTALL DUE TO THEIR LENGTH AND TIGHT TOLERANCES REQUIRED TO NEST IN BETWEEN HANGER SCREWS.
4. PRE-ENGINEERED HANGERS CAN HAVE TIGHT INSTALLATION TOLERANCES COMPARED TO TYPICAL ERECTION ALLOWANCES.

DURABILITY

1. UNPROTECTED STEEL IS PRONE TO RUSTING AND STAINING THE WOOD IF EXPOSED TO MOISTURE DURING CONSTRUCTION.
2. DETAIL IS INTENDED FOR DRY SERVICE CONDITIONS ONLY.



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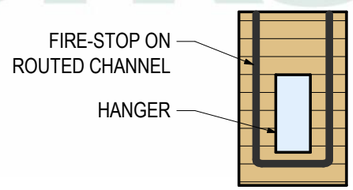

SECONDARY MEMBER

PURLIN-GIRDER DROP CONNECTION

EXPOSED BEARING CONNECTION BETWEEN TWO WOOD MEMBERS

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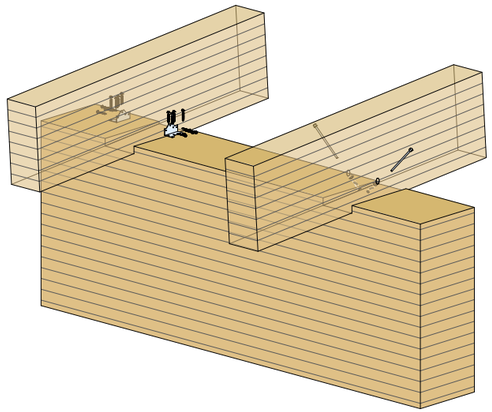


DESIGN RECOMMENDATIONS

1. SLOPED PURLINS MAY EXPERIENCE BI-AXIAL BENDING IF NO BLOCKING IS PROVIDED.

2. IT IS RECOMMENDED CONNECT TOP OF COLUMNS DIRECTLY TO THE DIAPHRAGM, OR PLACE PURLINS/BLOCKING ABOVE COLUMN-TO-BEAM JOINTS TO BRACE THE COLUMNS OUT-OF-PLANE.

INSTALLATION

1. CONSIDER THE TEMPORARY LATERAL AND TORSIONAL STABILITY OF PURLINS BEFORE THE POSITIVE CONNECTION IS INSTALLED (FRAMING CLIPS OR SCREWS). TEMPORARY ASSEMBLY SCREWS MAY BE REQUIRED.

DURABILITY

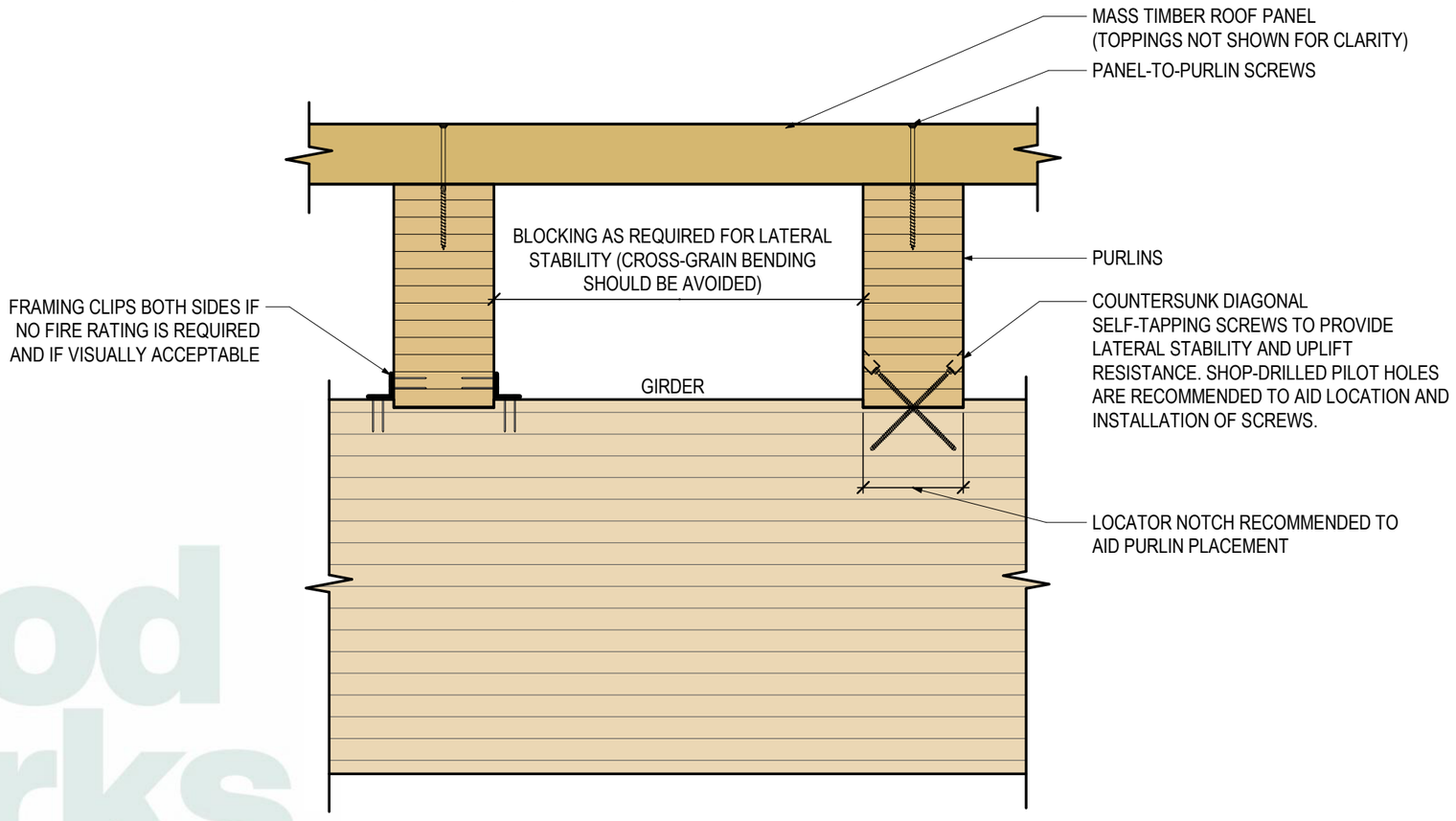
1. UNPROTECTED STEEL IS PRONE TO RUSTING AND STAINING THE WOOD IF EXPOSED TO MOISTURE DURING CONSTRUCTION.

2. DROP CONNECTIONS ARE MORE SUSCEPTIBLE TO SHRINKAGE DUE TO INCREASED DEPTH OF FRAMING. CUMULATIVE SHRINKAGE FROM PANEL, PURLINS, AND GIRDERS SHOULD BE ACCOUNTED FOR THE DETAILING OF ARCHITECTURAL COMPONENTS.

3. DETAIL IS INTENDED FOR DRY SERVICE CONDITIONS ONLY.

OPTION A: FRAMING CLIPS (NO FIRE RATING)

OPTION B: DIAGONAL SCREWS



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BEAM-COLUMN FACE-MOUNTED CONNECTION

PRE-ENGINEERED DOVETAIL HANGER FOR A CONCEALED CONNECTION BETWEEN A WOOD BEAM AND A WOOD COLUMN

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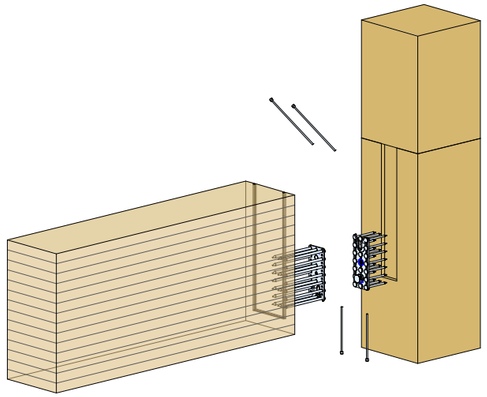


DESIGN RECOMMENDATIONS

1. CONSULT WITH HARDWARE SUPPLIER FOR HANGER RESISTANCES COMPLIANT WITH CSA O86 (LATEST EDITION).

2. IT IS RECOMMENDED TO PROVIDE ALTERNATIVE PATHS TO RESIST AXIAL, LATERAL, AND TORSIONAL LOADS AS MOST HANGERS ARE DESIGNED AS SHEAR (VERTICAL) ONLY CONNECTORS.

3. FACE-MOUNTED HANGERS MAY INDUCE ECCENTRIC LOADING ON THE COLUMN (SHEAR AND MOMENT).

INSTALLATION

1. HOUSING ON SECONDARY MEMBER CAN BE MORE COST-EFFECTIVE FOR ENCAPSULATED CONNECTIONS WHERE PATCHING IS NOT REQUIRED.

2. TOP-DOWN BEAM INSTALLATION IS PREFERRED.

3. REINFORCEMENT SCREWS CAN PRESENT SIGNIFICANT INSTALLATION CHALLENGES DUE TO LENGTH AND TIGHT TOLERANCES REQUIRED TO NEST IN BETWEEN HANGER SCREWS.

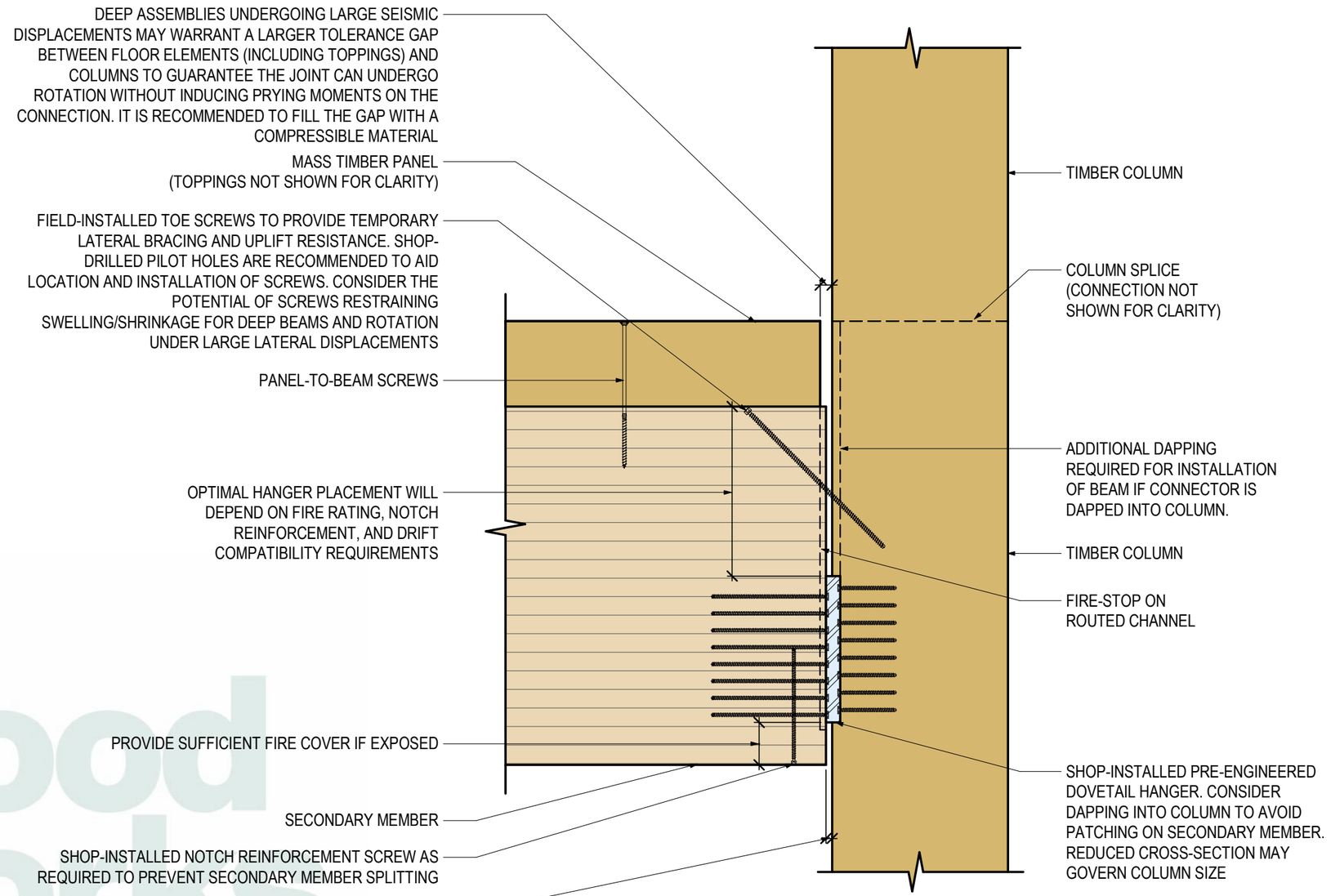
4. THERE ARE POTENTIAL SCREW CLASHES IF HANGERS ARE INSTALLED ON BOTH SIDES OF THE COLUMN. HANGERS CAN BE OFFSET IF A CLASH IS PRESENT.

5. COLUMN PLACEMENT IS CRITICAL TO BE ABLE TO MEET TIGHT TOLERANCES REQUIRED BY MOST PRE-ENGINEERED HANGERS.

DURABILITY

1. UNPROTECTED STEEL IS PRONE TO RUSTING AND STAINING THE WOOD IF EXPOSED TO MOISTURE DURING CONSTRUCTION.

2. DETAIL IS INTENDED FOR DRY SERVICE CONDITIONS ONLY.



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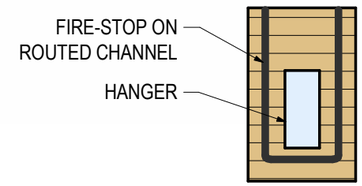

SECONDARY MEMBER

BEAM-RC WALL FACE-MOUNTED CONNECTION

CUSTOM KNIFE PLATE HANGER FOR A CONCEALED CONNECTION BETWEEN A WOOD BEAM AND A CONCRETE WALL

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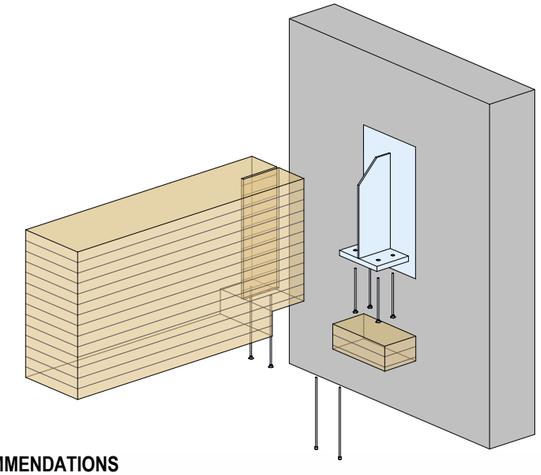


DESIGN RECOMMENDATIONS

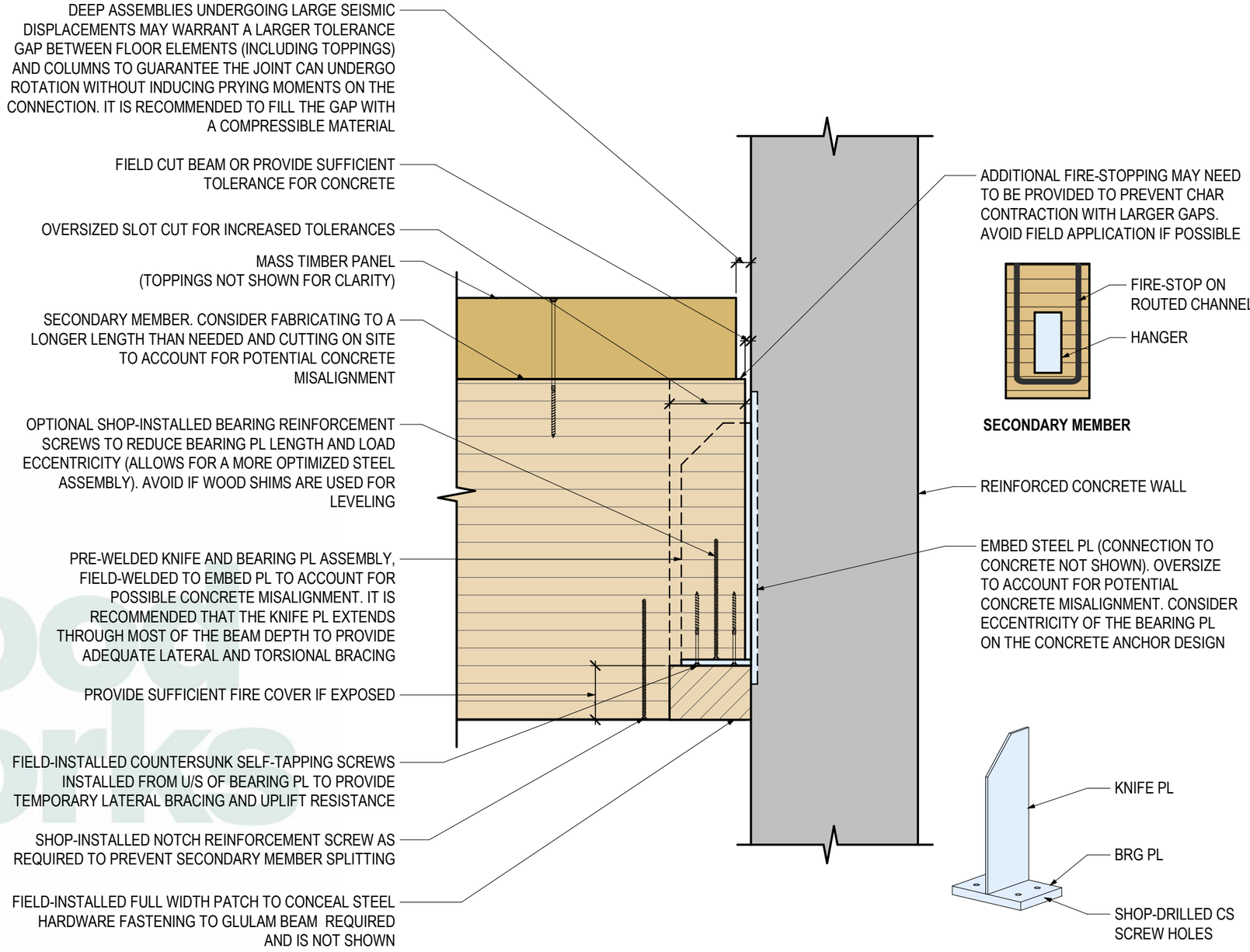
1. FACE-MOUNTED HANGERS MAY INDUCE ECCENTRIC LOADING ON THE WALL (SHEAR AND MOMENT).
2. A DOUBLE KNIFE PL ASSEMBLY MAY BE MORE EFFICIENT FOR WIDER BEAMS AS IT MINIMIZES THE THICKNESS OF THE BEARING PLATE.
3. BUCKET HANGER CAN BE A COST-EFFECTIVE OPTION FOR ENCAPSULATED CONNECTIONS.
4. AVOID WELDED CONNECTORS WITH LOW TOLERANCE SUCH AS PRE-ENGINEERED DOVETAIL HANGERS.

INSTALLATION

1. TOP-DOWN BEAM INSTALLATION IS PREFERRED.
2. CAST-IN PLACE ANCHORS ARE PREFERRED TO AVOID POTENTIAL CLASHES BETWEEN POST-INSTALLED ANCHORS AND WALL REINFORCEMENT.

DURABILITY

1. UNPROTECTED STEEL IS PRONE TO RUSTING AND STAINING THE WOOD IF EXPOSED TO MOISTURE DURING CONSTRUCTION.
2. DETAIL IS INTENDED FOR DRY SERVICE CONDITIONS ONLY.



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BEAM-STEEL COLUMN FACE-MOUNTED CONNECTION

CUSTOM KNIFE PLATE HANGER FOR A CONCEALED CONNECTION BETWEEN A WOOD BEAM AND A STEEL COLUMN

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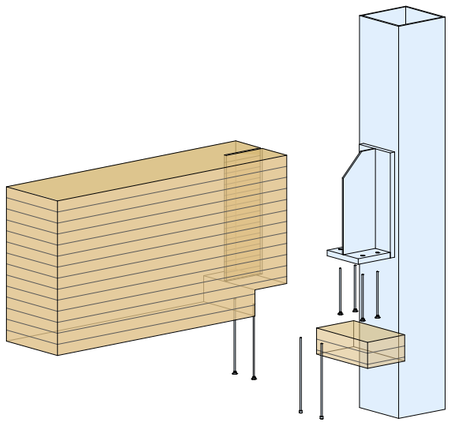


DESIGN RECOMMENDATIONS

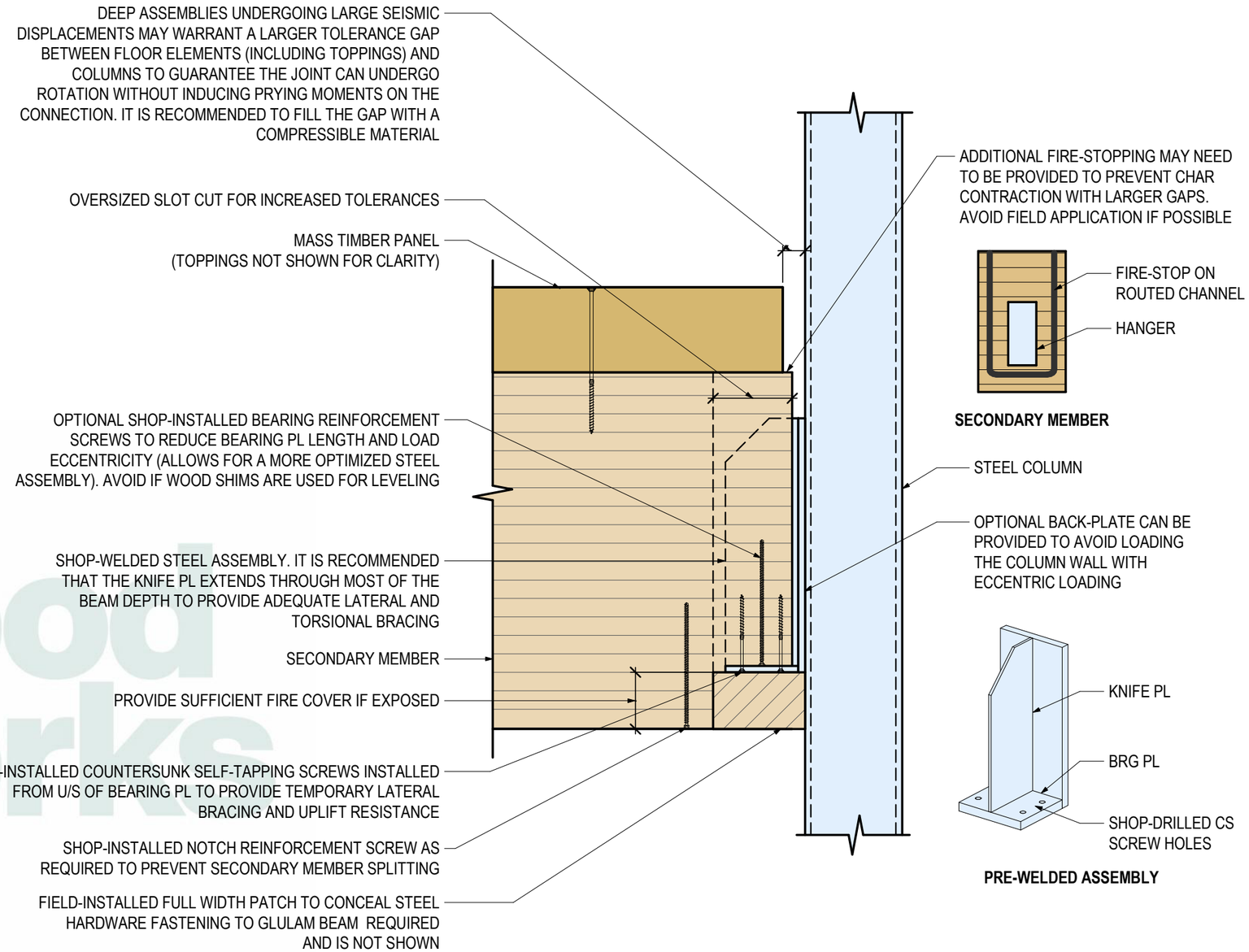
1. FACE-MOUNTED HANGERS MAY INDUCE ECCENTRIC LOADING ON THE COLUMN (SHEAR AND MOMENT).
2. A DOUBLE KNIFE PL ASSEMBLY MAY BE MORE EFFICIENT FOR WIDER BEAMS AS IT MINIMIZES THE THICKNESS OF THE BEARING PLATE.
3. BUCKET HANGER CAN BE A COST-EFFECTIVE OPTION FOR ENCAPSULATED CONNECTIONS.
4. AVOID WELDED CONNECTORS WITH LOW TOLERANCE SUCH AS PRE-ENGINEERED DOVETAIL HANGERS.

INSTALLATION

1. TOP-DOWN BEAM INSTALLATION IS PREFERRED.

DURABILITY

1. UNPROTECTED STEEL IS PRONE TO RUSTING AND STAINING THE WOOD IF EXPOSED TO MOISTURE DURING CONSTRUCTION.
2. DETAIL IS INTENDED FOR DRY SERVICE CONDITIONS ONLY.



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COLUMN CONNECTIONS

CUSTOM SPLICE CONNECTION BETWEEN TWO WOOD COLUMNS
CUSTOM BASE CONNECTION BETWEEN WOOD COLUMN AND FND

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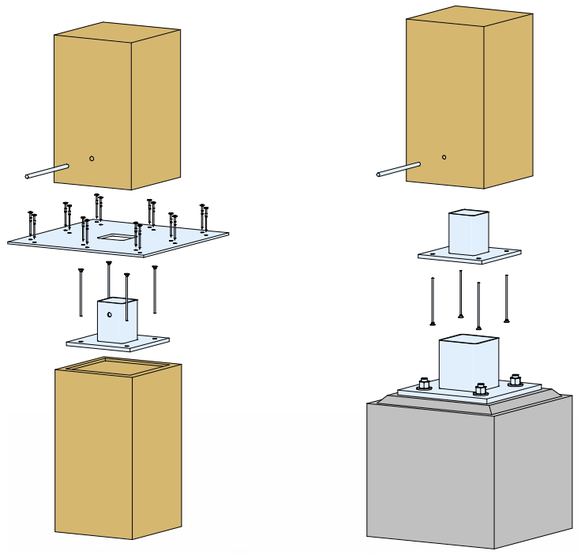


DESIGN RECOMMENDATIONS

1. COLUMN CONNECTIONS SHOULD BE DESIGNED TO PROVIDE LATERAL BRACING FOR THE COLUMN AS WELL AS POSITIVE CONNECTION FOR UPLIFT.

2. ENSURE THE COLUMN IS LATERALLY BRACED ON BOTH ENDS THROUGH A DIRECT CONNECTION TO THE DIAPHRAGM OR AN ALTERNATIVE LOAD PATH.

INSTALLATION

1. TEMPORARY BRACING MAY BE REQUIRED BEFORE CONNECTION TO THE DIAPHRAGM IS INSTALLED.

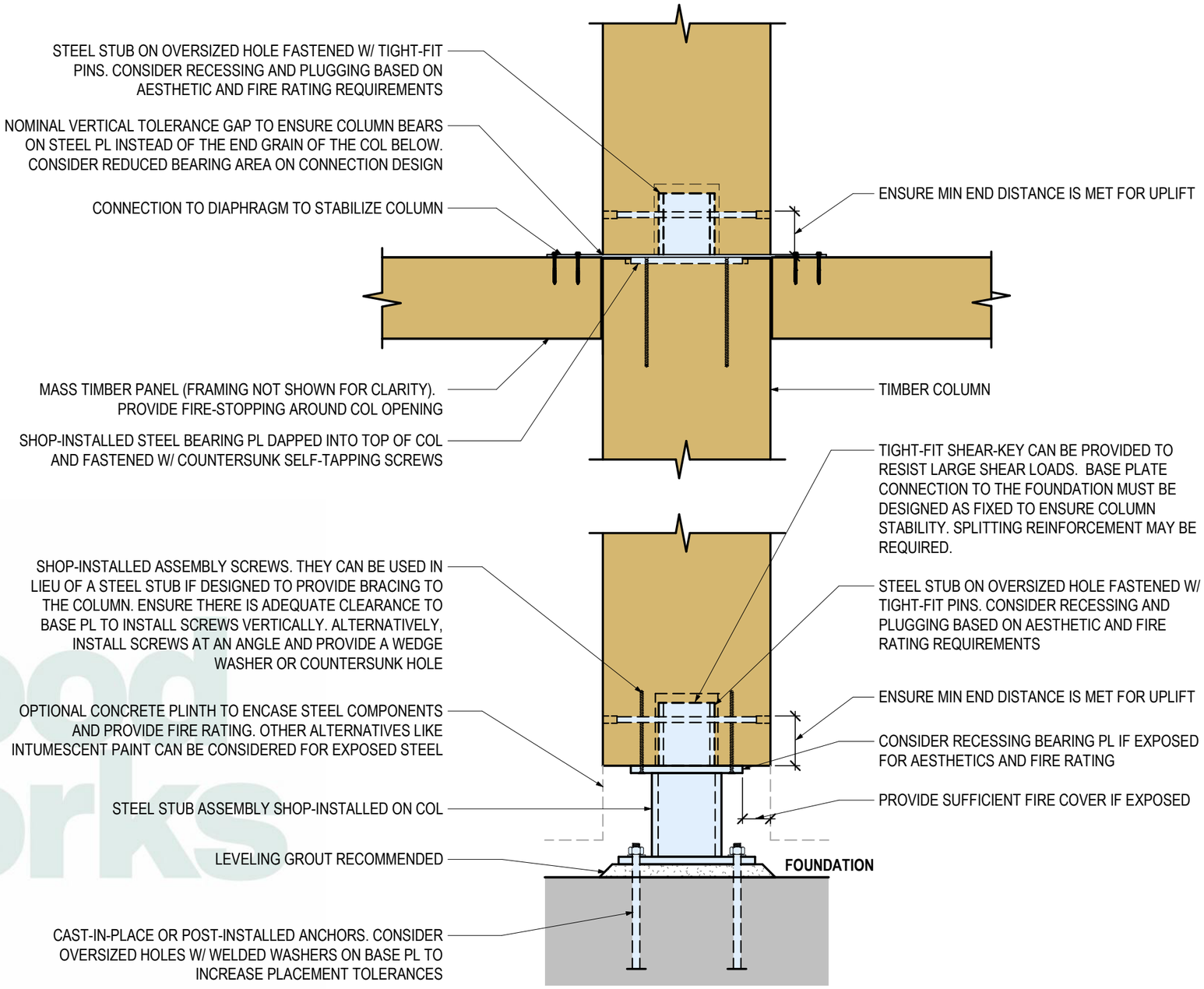
2. STEEL ASSEMBLY CAN BE USED TO LIFT THE COLUMN INTO PLACE. ENSURE SCREWS OR OTHER ANCHORS ARE DESIGNED ACCORDINGLY.

DURABILITY

1. UNPROTECTED STEEL IS PRONE TO RUSTING AND STAINING THE WOOD IF EXPOSED TO MOISTURE DURING CONSTRUCTION.

2. IT IS RECOMMEND TO KEEP COLUMN ENDS ELEVATED TO ENSURE MOISTURE ON THE FLOOR IS NOT ABSORBED THROUGH THE END-GRAIN.

3. DETAIL IS INTENDED FOR DRY SERVICE CONDITIONS ONLY.



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