Technical Evaluation Report
TER 1409-01
EStud Structural Insulated Wall Stud

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Product:
EStud Structural Insulated Wall Stud

Issue Date:
May 13, 2016
Revision Date:
June 13, 2019
Subject to Renewal:
July 1, 2020
1 PRODUCT EVALUATED

1.1 EStud Structural Insulated Wall Stud

2 APPLICABLE CODES AND STANDARDS

2.1 Codes

2.1.1 IBC—12, 15, 18: International Building Code®

2.1.2 IRC—12, 15, 18: International Residential Code®

2.2 Standards and Referenced Documents

2.2.1 ANSI/AWC NDS: National Design Specification (NDS) for Wood Construction

2.2.2 ASCE/SEI 7: Minimum Design Loads and Associated Criteria for Buildings and Other Structures

2.2.3 ASTM A653: Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

2.2.4 ASTM C578: Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation

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1 Building codes require data from valid research reports be obtained from approved sources. An approved agency, which is an approved source, is defined as "an established and recognized agency that is regularly engaged in furnishing product certification where such agency has been approved..." Being approved, defined as "acceptable to the building official," is accomplished via accreditation using ISO/IEC 17065 evaluation procedures meeting code requirements of independence, adequate equipment, and experienced personnel. DrJ is an ISO/IEC 17065 ANSI-Accredited Product Certification Body – Accreditation #1131.

Through ANSI accreditation, DrJ certification can be used to obtain product approval in any country that is an IAF MLA Signatory and covered by an IAF MLA Evaluation per the Purpose of the MLA – "certified once, accepted everywhere." Manufacturers can go to jurisdictions in any IAF MLA Signatory Country and have their products readily approved by authorities having jurisdiction using DrJ’s ANSI accreditation.

For more information on any of these topics or our mission, product evaluation policies, product approval process, and engineering law, see drjcertification.org.

2 Unless otherwise noted, all references in this TER are from the 2018 version of the codes and the standards referenced therein (e.g., ASCE 7, NDS, ASTM). This material, design, or method of construction also complies with the 2000-2015 versions of the referenced codes and the standards referenced therein. As required by code, where this TER is not approved, the building official shall respond in writing stating the reasons this TER was not approved. For any variations in state and local codes, see Section 8.

3 All terms defined in the applicable building codes are italicized.
2.2.5 ASTM D198: Standard Test Methods of Static Tests of Lumber in Structural Sizes
2.2.6 ASTM E72: Standard Test Methods of Conducting Strength Tests of Panels for Building Construction
2.2.7 TPI 1: National Design Standard for Metal-plate-connected Wood Truss Construction

3 PERFORMANCE EVALUATION

3.1 ESTud was evaluated to determine its applicability for use as an alternative material where nominal 2x4 solid sawn lumber is specified in accordance with the IBC and IRC.
3.2 ESTud testing and analysis was conducted to determine its compression, flexural strengths, and flexural stiffness.
3.3 ESTud was examined for the following:
   3.3.1 Use as an alternative material to that described in IBC Chapter 23, in particular, compliance with requirements for the design and construction of wood-based products as described in Section 2302.1 for allowable stress design (ASD) and load and resistance factor design (LRFD).
   3.3.2 Compliance with IBC Section 2308 and Section 2304 and IRC Chapter 6 for conventional light-frame construction applications.
   3.3.3 Use as an alternative material and method of construction in compliance with IBC Section 104.11 and IRC Section R104.11.
3.4 When used in an application that exceeds the limits of IBC Section 2308 or IRC Section R301, an engineered design shall be submitted in accordance with IRC Section R301.1.3 and this TER.
3.5 Any code compliance issues not specifically addressed in this section are outside the scope of this TER.
3.6 Any engineering evaluation conducted for this TER was performed on the dates provided in this TER and within DrJ’s professional scope of work.

4 PRODUCT DESCRIPTION AND MATERIALS

4.1 The product evaluated in this TER is shown in Figure 1.

![Figure 1. 8' ESTud Construction Detail and Specifications](image)

**Figure 1. 8' ESTud Construction Detail and Specifications**

4.2 ESTuds are made from a minimum of No. 2 Spruce Pine Fir (SPF) lumber and 2" (50.8 mm) extruded polystyrene (XPS) insulation.
   4.2.1 Any lumber species can be used, as long as the design values of the lumber are equal to or greater than No. 2 SPF.
   4.2.2 The lumber is ripped length-wise into 1.75"-wide (44.5 mm) members, and the XPS insulation is placed between sections of cut lumber.
   4.2.3 After ripping, the lumber is re-graded to a minimum of #2 grade of the given species.

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4 2015 IBC Section 2301.2
4.2.4 Lumber re-grading shall be performed by an American Lumber Standards Committee (ALSC) approved grading agency.

4.3 The XPS insulation is manufactured in accordance with ASTM C578 prior to EStud manufacture and is adhered to each section of the stud with a heat-resistant adhesive.

4.4 The adhesive used in the manufacturing process is a proprietary adhesive formulated specifically for bonding XPS insulation to wood surfaces.

4.5 Illinois Tool Works Building Components Group (ITWBCG), a.k.a. Alpine, 5” x 5”, 20 gauge (36 mil) metal connector plates or equivalent are used to tie the stud assembly together with the lumber acting as tension and compression chords (Figure 1 and Figure 2).

4.5.1 Three (3) metal connector plates are installed on each wide face of the assembly (total 6 plates); one plate is placed at each end, and one is located in the center of the EStud length.

4.5.2 The plates at the ends are located 1” (25.4 mm) from the end of the EStud.

4.5.3 Plates shall be ITW wave plates or equivalent.

4.5.4 For top and bottom plate material, 2’ x 5” metal connector plates are located 1” from each end and 12” on center along the plate material length.

4.6 Materials

4.6.1 Lumber:

4.6.1.1 Grade: No. 2 SPF

4.6.1.2 Thickness: 1½” (38.1 mm)

4.6.1.3 Width: 1¾” (44.5 mm)

4.6.1.4 Lengths: 8’, 9’, and 10’ (2.44 m, 2.74 m, and 3.05 m) nominal

4.6.2 XPS Insulation:

4.6.2.1 The XPS insulation is manufactured in accordance with ASTM C578.

4.6.3 Metal Connector Plates:

4.6.3.1 Metal connector plates used in EStud are manufactured in accordance TPI 1 Chapter 4.

4.6.3.2 Metal connector plates shall be made of 20 gauge (36 mil) ASTM A653, SS Grade 40 structural steel.

4.7 Metal connector plates shall have a minimum G60 galvanized coating (0.0005” thickness on each side).
5 APPLICATIONS

5.1 Prescriptive Provisions

5.1.1 EStud is an alternative to solid sawn lumber for wall structural members.

5.1.1.1 EStud is an acceptable replacement to nominal 2x4 solid sawn lumber in accordance with IBC Section 2308 and IRC Section R602.

5.1.2 XPS insulation is in accordance with IBC Chapter 26, Section 2603.2, 2603.3, and 2603.4 and IRC Section R316, specifically Section R316.2, R316.3, and R316.4.

5.1.3 Metal connector plates used are per TPI 1 Chapter 4, Section 4.3.3 and 4.3.4.

5.1.4 Cutting, Notching, and Boring:

5.1.4.1 Cross cutting EStuds is permitted. Where EStuds are cross cut such that a metal connector plate is not within 3” (76.2 mm) of the EStud end, one of the following shall be done:

5.1.4.1.1 The EStud chords must be nailed to another framing member.

5.1.4.1.2 A metal connector plate shall be field applied to connect the EStud chords, as shown in Figure 1.

5.1.4.2 Notches in structural members (chords or plates) are not permitted.

5.1.4.3 Holes may only be bored in the XPS insulation of EStud and shall not exceed 2" (50.8 mm) in diameter.

5.1.4.4 Holes shall not be bored in metal connector plates.

5.1.5 EStud used as structural members of a wall shall be fastened as specified in Table 1.

<table>
<thead>
<tr>
<th>Application</th>
<th>Number &amp; Type of Fastener</th>
<th>Fastener Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling Joists to Plate (toe nail)</td>
<td>4 (2 1/2&quot; × 0.113&quot;)</td>
<td>2 toe nails into each chord</td>
</tr>
<tr>
<td>Rafter or Roof Truss to Plate (toe nail)</td>
<td>4 (3&quot; × 0.128&quot;)</td>
<td>2 toe nails into each chord</td>
</tr>
<tr>
<td>Built-up Studs (face nail)</td>
<td>(3&quot; × 0.128&quot;)</td>
<td>1 nail into each chord at 16&quot; o.c.</td>
</tr>
<tr>
<td>Abutting Studs at Intersecting Wall Corners (face nail)</td>
<td>(3 1/4&quot; × 0.131&quot;)</td>
<td>1 nail into each chord at 12&quot; o.c.</td>
</tr>
<tr>
<td>Double Studs (face nail)</td>
<td>(3&quot; × 0.128&quot;)</td>
<td>1 nail into each chord at 16&quot; o.c.</td>
</tr>
<tr>
<td>Double Top Plates (face nail)</td>
<td>(3&quot; × 0.128&quot;)</td>
<td>1 nail into each chord at 12&quot; o.c.</td>
</tr>
<tr>
<td>Double Top Plates, Minimum 24&quot; Offset of End Joints, Face Nail in Lapped Area</td>
<td>18 (3&quot; × 0.128&quot;)</td>
<td>9 nails into each chord</td>
</tr>
<tr>
<td>Stud to Plate (toe nail)</td>
<td>4 (2 1/2&quot; × 0.113&quot;)</td>
<td>2 toe nails into each chord</td>
</tr>
<tr>
<td>Top or Sole Plate to Stud (end nail)</td>
<td>2 (3 1/2&quot; × 0.162&quot;) or 4 (3&quot; × 0.128&quot;)</td>
<td>1 nails into each chord or 2 nails into each chord</td>
</tr>
<tr>
<td>Top Plates, Laps at Corners &amp; Intersections (face nail)</td>
<td>4 (3&quot; × 0.128&quot;)</td>
<td>2 nails into each chord</td>
</tr>
</tbody>
</table>

SI: 1" = 25.4 mm

1. Where a rafter is fastened to an adjacent parallel ceiling joist in accordance with this schedule, provide two (2) toe nails on one (1) side of the rafter and toe nails from the ceiling joist to top plate in accordance with this schedule. The toe nail on the opposite side of the rafter shall not be required.

2. For all connections, care must be taken to avoid splitting of EStud chords.

5.1.6 EStud may be used as a top plate in accordance with IRC Section R602.3.2 and the following:

5.1.6.1 Top plate design shall include 2" x 5" metal plates spaced every 12" (305 mm) o.c., starting no more than 12" (305 mm) from each end of the board to allow the top plates to be cut to custom lengths in the field, while maintaining a metal plate within 12" (305 mm) of each end.
5.1.6.2 Fasteners for EStud connections shall be evenly distributed in each EStud chord (e.g., top plate to stud connections shall have one fastener installed in each EStud chord).

5.1.6.3 Double top plates must be used on all walls.

5.1.7 Use as jack, trimmer, and cripple studs is acceptable, provided at least two (2) metal connector plates are attached on each side of the stud, no less than 1" (25.4 mm) from the ends.

5.1.7.1 If cut in the field to accommodate sizing, EStud must be fastened to a double stud through its face with, at a minimum, 10d (3" x 0.128") nails 16" (610 mm) o.c. into each chord.

5.1.7.2 When used as a jack stud, EStud must be fastened to a king stud.

5.1.7.3 When used as a cripple stud, one (1) nail must be driven through the window sill plate into each end of the EStud structural members.

5.1.8 Structural sheathing shall be installed on one side of the wall and minimum ½" (12.7 mm) gypsum wallboard (GWB), or equivalent, on the other side of the wall fastened in accordance with the applicable building code. Sheathing attached to only one side of the wall is not permitted.

5.1.9 Trusses and rafters having a maximum reaction of 2,789 lbs. may be placed anywhere on walls with double EStud top plates.

5.1.9.1 For cases where a higher reaction needs to be supported, use of built-up studs fastened in accordance with Table 1 is permitted with a limit of 2,789 lbs. per ply (e.g., 5,578 lbs. per 2-ply built-up stud). In this case, the built-up stud shall be located directly under the applied load.

5.1.9.2 Walls with nominal 2x6 lumber top plates shall be in accordance with IRC Section R602.3.2.

5.2 Engineering Design

5.2.1 The design provisions for wood construction noted in IBC Section 2301.2 and IRC Section R301.1.3 apply to EStud for allowable stress design (ASD), unless otherwise noted in this TER.

5.2.2 Material Properties:

5.2.2.1 Reference design values for EStud are specified in Table 2.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fb</td>
<td>875 psi</td>
</tr>
<tr>
<td>Fc</td>
<td>1,150 psi</td>
</tr>
<tr>
<td>Ft</td>
<td>450 psi</td>
</tr>
<tr>
<td>Fc⊥</td>
<td>425 psi</td>
</tr>
<tr>
<td>EI</td>
<td>8,400,000 lb-in²</td>
</tr>
<tr>
<td>EImin</td>
<td>3,100,000 lb-in²</td>
</tr>
</tbody>
</table>

5.2.2.2 Reference design values for EStud shall be multiplied by the applicable adjustment factors specified in NDS Section 4.3.

5.2.3 Design for Axial Loads:

5.2.3.1 The maximum allowable compression load for EStud is specified in Table 3.

5.2.3.2 The maximum allowable compression load is based on perpendicular-to-grain crushing of SPF top and bottom plates.

5.2.3.3 The allowable axial compression for EStud can be calculated using the provisions of NDS Section 3.6 and 3.7.

5.2.3.4 For computing the column stability factor, the critical bucking design value, $F_{CE}$, shall be computed using the formula:
\[ F_{cE} = \frac{\pi^2 E I_{\text{min}}}{A (\ell_c)^2} \]

Where:

\( A \) = total cross-sectional area of EStud (wood only) = \( 2 \times 1.5" \times 1.75" = 5.25 \text{ in}^2 \)
(for SI: \( 2 \times 38.1 \text{ mm} \times 44.5 \text{ mm} = 3391 \text{ mm}^2 \))

### Table 3. EStud Maximum Allowable Compression

<table>
<thead>
<tr>
<th>EStud Length (ft)</th>
<th>Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 10 )</td>
<td>( 2789 )</td>
</tr>
</tbody>
</table>

Sl: \( 1" = 25.4 \text{ mm}, 1 \text{ lb} = 4.45 \text{ N} \)

#### 5.2.4 Design for Bending:

5.2.4.1 EStud resists bending using tension and compression stresses in the chord members and bending in the chord member on the side of the EStud to which the loads are applied.

5.2.4.2 The axial stresses in each member can be computed using the following equation:

\[ f_a = \frac{M}{0.5 \cdot A \cdot d_{\text{eff}}} \]

Where:

\( M \) = bending moment applied to EStud (lb-in)
\( A \) = cross-sectional area of EStud chord = \( 1.5" \times 1.75" = 2.625 \text{ in}^2 \)
(for SI: \( 38.1 \text{ mm} \times 44.5 \text{ mm} = 1695 \text{ mm}^2 \))
\( d_{\text{eff}} \) = distance from center-to-center of EStud members = \( 3.75" (95.3 \text{ mm}) \)

5.2.4.3 The bending stress in the member on the side of the EStud to which the loads are applied shall be calculated using NDS Section 3.3 as follows:

\[ f_b = \frac{6M}{bd^2} \]

Where:

\( M \) = moment due to bending of the EStud member between metal connector plates = \( \frac{\omega \ell^2}{12} \)
\( \ell \) = center-to-center spacing of metal connector plates
\( b \) = width of EStud members = \( 1.5" (38.1 \text{ mm}) \)
\( d \) = depth of EStud members = \( 1.75" (44.5 \text{ mm}) \)

5.2.4.4 The combined axial and bending stresses in EStud members shall be checked in accordance with NDS Section 3.9.

#### 5.2.5 Design for Combined Bending and Axial Loads:

5.2.5.1 Stresses due to axial loading of EStud shall be added to the axial stress due to bending and checked in accordance with NDS Section 3.9.

5.2.5.2 Allowable axial load values for EStud subject to ASD wind pressures are specified in Table 4.

5.2.5.3 Example design calculations for EStud subject to combined bending and axial loads can be found in Appendix A.
### Table 4. Allowable Axial Loads & Deflection Ratio for ASD Wind Loading

<table>
<thead>
<tr>
<th>Stud Spacing (in)</th>
<th>Wall Height (ft)</th>
<th>Allowable Axial Load, lb (Deflection Ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ASD Wind Pressure (psf)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>2789 (L/1948)</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>2160 (L/1352)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1622 (L/976)</td>
</tr>
<tr>
<td>16</td>
<td>8</td>
<td>2764 (L/1461)</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>2035 (L/1014)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1482 (L/732)</td>
</tr>
<tr>
<td>24</td>
<td>8</td>
<td>2484 (L/974)</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>1732 (L/676)</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1152 (L/488)</td>
</tr>
</tbody>
</table>

SI: 1" = 25.4 mm, 1 lb = 4.45 N, 1 psf = 0.0479 kN/m²

5.2.6 For applications outside of the scope of the applicable code, consult the manufacturer’s installation instructions or a registered design professional.

5.3 Where the application exceeds the limitations set forth herein, design shall be permitted in accordance with accepted engineering procedures, experience, and technical judgment.

6 INSTALLATION

6.1 Installation shall comply with the applicable code, the approved construction documents, this TER, the manufacturer’s installation instructions, NDS, and otherwise standard framing practices as applied to solid-sawn lumber. In the event of a conflict between the manufacturer’s installation instructions and this TER, the more restrictive shall govern.

6.2 Installation Procedure

6.2.1 EStud is pre-assembled and designed to be used as a direct replacement of nominal 2x4 (38 mm x 89 mm) solid sawn lumber as wall studs and top plates.

6.2.2 Install EStud in the same manner as solid sawn lumber, except as noted herein.

6.2.2.1 For IBC Section 2308 and the IRC, install in accordance with the provisions therein, except as noted in this TER.

6.2.2.2 For engineered design, walls shall be designed in accordance with the IBC and the referenced standards therein using the material properties and design limitations as noted in Section 5.

6.3 Design of connections using EStud shall be in accordance with NDS.
7 TEST ENGINEERING SUBSTANTIATING DATA

7.1 Flexural Capacity of the EStud; Richard DeVries, Ph.D., P.E.; Milwaukee School of Engineering
7.3 Cyclic Tests of WSP Shear Walls with EStud Framing, by SBCRI under contract with Qualtim, Inc.
7.4 Compressive Load Testing of EStuds, by SBCRI under contract with Qualtim, Inc.
7.5 Bending Tests of EStuds, by SBCRI under contract with Qualtim, Inc.
7.6 Bending Tests of EStud Top Plates, by SBCRI under contract with Qualtim, Inc.
7.7 Some information contained herein is the result of testing and/or data analysis by other sources which conform to IBC Section 1703 and relevant professional engineering law. DrJ relies on accurate data from these sources to perform engineering analysis. DrJ has reviewed and found the data provided by other professional sources to be credible.
7.8 Where appropriate, DrJ’s analysis is based on design values that have been codified into law through codes and standards (e.g., IBC, IRC, NDS®, and SDPWS). This includes review of code provisions and any related test data that aids in comparative analysis or provides support for equivalency to an intended end-use application. Where the accuracy of design values provided herein is reliant upon the published properties of commodity materials (e.g., lumber, steel, and concrete), DrJ relies upon the grade mark, stamp, and/or design values provided by raw material suppliers to be accurate and conforming to the mechanical properties defined in the relevant material standard.

8 FINDINGS

8.1 EStud insulated wall studs installed as framing members in walls, as described in this TER, are compliant with the codes listed in Section 2 and are approved for use as an alternative to nominal 2x4 (38 mm x 89 mm) solid sawn lumber.
8.2 IBC Section 104.11 (IRC Section R104.11 and IFC Section 104.9 are similar) states:

104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, not less than the equivalent of that prescribed in this code…Where the alternative material, design or method of construction is not approved, the building official shall respond in writing, stating the reasons the alternative was not approved.

8.3 This product has been evaluated in the context of the codes listed in Section 2 and is compliant with all known state and local building codes. Where there are known variations in state or local codes applicable to this evaluation, they are listed here.
8.3.1 No known variations

9 CONDITIONS OF USE

9.1 The manufacturer's published installation instructions shall be available at the jobsite at all times during installation.
9.2 EStud is a suitable alternative to 2x4 sawn lumber as permitted by the codes listed in Section 2 subject to the following conditions:
   9.2.1 Metal connector plates must not be removed.
      9.2.1.1 If metal connector plates are missing upon arrival, not applied correctly from the distributor, or fall off during installation, the stud shall be replaced.
   9.2.2 EStud may not be used as a bottom plate where fixture to a sill plate and anchor bolts is required.
9.2.3 EStud may not be used as a stud pack where hold-downs are required for engineered design.

9.2.4 The maximum wall height for EStud is 10' (3.05 m).

9.2.5 Increases for duration of load shall be in accordance with the limitations of the applicable building code for sawn lumber.

9.3 Creep factors applicable to sawn lumber may be applied to this product, in accordance with the applicable building code.

9.4 Where required by the building official, also known as the authority having jurisdiction (AHJ) in which the project is to be constructed, this TER and the installation instructions shall be submitted at the time of permit application.

9.5 Any generally accepted engineering calculations needed to show compliance with this TER shall be submitted to the AHJ for review and approval.

9.6 Design loads shall be determined in accordance with the building code adopted by the jurisdiction in which the project is to be constructed and/or by the Building Designer (e.g., owner or registered design professional).

9.7 At a minimum, this product shall be installed per Section 6 of this TER.

9.8 This product is manufactured under a third-party quality control program in accordance with IBC Section 104.4 and 110.4 and IRC Section R104.4 and R109.2.

9.9 The actual design, suitability, and use of this TER, for any particular building, is the responsibility of the owner or the owner's authorized agent. Therefore, the TER shall be reviewed for code compliance by the building official for acceptance.

9.10 The use of this TER is dependent on the manufacturer’s in-plant QC, the ISO/IEC 17020 third-party quality assurance program and procedures, proper installation per the manufacturer’s instructions, the building official’s inspection, and any other code requirements that may apply to demonstrate and verify compliance with the applicable building code.

10 IDENTIFICATION

10.1 The product(s) listed in Section 1.1 are identified by a label on the board or packaging material bearing the manufacturer’s name, product name, TER number, and other information to confirm code compliance.

10.2 Additional technical information can be found at lbwilkens@hotmail.com.

11 REVIEW SCHEDULE

11.1 This TER is subject to periodic review and revision. For the most recent version of this TER, visit drjcertification.org.

11.2 For information on the current status of this TER, contact DrJ Certification.
APPENDIX A

ESTUD Example Calculations

Material Properties of ESTUD:

The ESTUD uses SPF lumber graded as No. 2.

\[ F_c := 1150 \text{ psi} \quad F_b := 875 \text{ psi} \quad F_t := 450 \text{ psi} \]

\[ C_{fc} := 1.15 \quad C_{fb} := 1.5 \quad C_{ft} := 1.5 \]

\[ F_{c,\text{perp}} := 425 \text{ psi} \]

\[ EI := 8400000 \text{ lbf} \cdot \text{in}^2 \]

\[ EI_{\text{min}} := 3100000 \text{ lbf} \cdot \text{in}^2 \]

Section Properties of ESTUD:

\[ d_1 := 1.75 \text{ in} \quad \text{Wide face dimension.} \]

\[ d_2 := 1.5 \text{ in} \quad \text{Narrow face dimension.} \]

\[ d_{ef} := 3.75 \text{ in} \quad \text{Moment arm between members.} \]

\[ A := d_1 \cdot d_2 \cdot 2 = 5.25 \text{ in}^2 \quad \text{Area of ESTUD.} \]

\[ l_1 := 92.625 \text{ in} \quad \text{Height of ESTUD.} \]

\[ l_3 := \frac{l_1 - 7 \text{ in}}{2} = 42.813 \text{ in} \quad \text{On center spacing of truss plates.} \]

Calculate allowable stresses for the ESTUD:

\[ C_D := 1.6 \]

\[ C_r := 1.5 \]

\[ C_b := \frac{d_2 + 0.375 \text{ in}}{d_2} = 1.25 \]

\[ F' := F_t \cdot C_D \cdot C_{ft} = 1080 \text{ psi} \]

\[ F'_b := F_b \cdot C_D \cdot C_{fb} \cdot C_r = 3150 \text{ psi} \]

\[ F_{c,\text{atw}} := F_c \cdot C_{fc} \cdot C_D = 2116 \text{ psi} \]
\[ c := 0.8 \quad \text{Constant for sawn lumber.} \]

\[ K := 1.0 \quad \text{Buckling effective length factor for pinned-pinned column.} \]

\[ F_{cE} := \frac{\pi^2 EI_{\text{min}}}{A (K \cdot l_1)^2} = 679 \text{ psi} \]

The equation for the Euler buckling stress given in NDS Section 3.7.1 is rearranged to show the term \( EI \).

\[ C_p := \frac{1 + \left( \frac{F_{cE}}{F_{c,\text{star}}} \right)}{2 \cdot c} \sqrt{1 + \left( \frac{F_{cE}}{F_{c,\text{star}}} \right)^2} - \frac{\left( \frac{F_{cE}}{F_{c,\text{star}}} \right)}{c} = 0.296 \]

\[ F'_c := F_{c,\text{star}} \cdot C_p = 627 \text{ psi} \]

**Combined Axial and Wind Loads on ESTud:**

\[ p := 30 \text{ psf} \quad \text{Wind pressures on wall. For combined axial and bending checks, MWFRS wind loads may be used. For checking bending stresses independent of axial stresses, C&C wind loads shall be used.} \]

\[ \text{Spacing}_{\text{studs}} := 16 \text{ in} \]

\[ S := \frac{d_2 \cdot d_1^2}{6} = 0.766 \text{ in}^3 \]

\[ w := 0.75 \cdot p \cdot \text{Spacing}_{\text{studs}} = 30 \text{ plf} \]

\[ M_{\text{mem}} := \frac{w \cdot l_3^2}{12} = 382 \text{ lbf \cdot in} \]

\[ f_b := \frac{M_{\text{mem}}}{S} = 499 \text{ psi} \]

\[ M_{\text{stud}} := \frac{w \cdot l_1^2}{8} = 2681 \text{ lbf \cdot in} \]

For bending of the entire ESTud, the equation for a beam pinned at each end is used.

\[ f_{a,\text{bend}} := \frac{M_{\text{stud}}}{\frac{A}{2} \cdot d_{\text{eff}}} = 272 \text{ psi} \]

\[ P := 951 \text{ lbf} \quad \text{Axial load on the ESTud is selected to result in a CSI of 1.0.} \]
\[ P_{c_{\text{perp}}} := F_{c_{\text{perp}}} \cdot C_b \cdot A = 2789 \text{ lbf} \quad > \quad P = 951 \text{ lbf} \]

\[ f_{a_{\text{comp}}} := \frac{P}{A} = 181 \text{ psi} \]

For positive wind pressures:

\[ f_c := f_{a_{\text{bend}}} + f_{a_{\text{comp}}} = 454 \text{ psi} \quad < \quad F_{c_E} = 679 \text{ psi} \quad \text{and} \quad < \quad F_c' = 627 \text{ psi} \quad \text{OK} \]

\[ \left( \frac{f_c}{F_c'} \right)^2 + \frac{f_b}{F_b' \left( 1 - \frac{f_c}{F_{cE}} \right)} = 1.00 \quad \text{OK} \]

\[ f_{c_{\text{in}}} := f_{a_{\text{comp}}} - f_{a_{\text{bend}}} = -91 \text{ psi} \quad < \quad F_{t'} = 1080 \text{ psi} \quad \text{OK} \]

For negative wind pressures:

\[ f_t := f_{a_{\text{comp}}} - f_{a_{\text{bend}}} = -91 \text{ psi} \quad < \quad F_{t'} = 1080 \text{ psi} \quad \text{OK} \]

\[ \frac{f_t}{F_{t'}} + \frac{f_b}{F_{b'}} = 0.07 \quad < \quad 1.00 \quad \text{OK} \]

\[ f_c := f_{a_{\text{comp}}} + f_{a_{\text{bend}}} = 454 \text{ psi} \quad < \quad F_{c_E} = 679 \text{ psi} \quad \text{and} \quad < \quad F_c' = 627 \text{ psi} \quad \text{OK} \]

Check Deflection Limit for EStud:

\[ \Delta := \frac{5 \left( \frac{w}{0.75} \right) \cdot l_1^4}{384 \cdot EI} = 0.38 \text{ in} \]

\[ \frac{l_1}{\Delta} = 244 \quad > \quad 240 \quad \text{OK} \quad \text{(for gypsum board wall finish)} \]

Summary of Design Calculations for EStud:

The EStud has an axial load capacity of 951 lbs for an 8' tall wall with a wind pressure of 30 psf.