**INTERNATIONAL ASSOCIATION OF PLUMBING AND MECHANICAL OFFICIALS**

**UNIFORM EVALUATION SERVICES**

**EVALUATION CRITERIA FOR**

**LRFD Resistance Values for Proprietary Wood Connections Using Wood Screws**

**EC 036-2019**

**(Proposed \_\_\_\_\_\_\_\_\_ 2019)**

1. **INTRODUCTION**
   1. **Background:** The currently accepted practice in the United States for designing connections for wood construction is to comply with the National Design Specification for Wood Construction (ANSI/AWC NDS), published by the American Wood Council. There are two general methods for design within the ANSI/AWC NDS: Allowable Stress Design (ASD) and Load and Resistance Factor Design (LRFD).

ASD design values for common connections are tabulated in the ANSI/AWC NDS for use as referenced. Alternatively, ASD values may be determined using the Yield Limit Equations in the ANSI/AWC NDS. Once the appropriate design values are known, adjustment factors common to ASD and LRFD are applied as appropriate for the type of loading, the condition of the wood, the connection geometry, and the environment to which the connection will be subjected in use.

Two options are provided in the ANSI/AWC NDS for determination of reference values for LRFD design. The first option relies on a Format Conversion Factor to convert the ASD design values tabulated in the ANSI/AWC NDS, or calculated in accordance with the Yield Limit Equations, to LRFD design values. A Resistance Factor, and Time Effect Factor rather than the ASD Load Duration Factor, are then applied before the other adjustment factors common to ASD and LRFD. Where increased connection values are sought, an alternative method is provided in the ANSI/AWC NDS. This method relies on testing to determine LRFD design values. The ANSI/AWC NDS provides for the use of ASTM D5457 to determine the extent of this testing. ASTM D5457 provides methods to determine the Reference Resistance, which then is used with the Resistance Factor and Time Effect Factor, and finally the other factors common to ASD and LRFD to determine connection values.

Annex A1 to ASTM D5457 provides the sampling, testing, and analysis requirements for the use of this alternative procedure, which shall be used in conjunction with testing procedures appropriate for the connection situation. Testing procedures for connections involving screws in wood are provided in ASTM D1761 for common wood connections using mechanical fasteners, including those involving fasteners subject to withdrawal and lateral loading, connected timber joints, and plate connectors in tension loading. For similar connection geometries that are outside the scope of ASTM D1761, appropriate testing procedures shall be proposed as part of the testing plan required to be submitted for approval.

* 1. **Purpose:** The intent of this criteria is to outline procedures for recognition of LRFD resistance values for wood-to-wood connections, and steel-side-plate-to-wood connections using the Reliability Normalization Factor in ASTM D5457. The Reliability Normalization Factor is used to establish the reference resistance to achieve a Target Reliability Index for connections. The Target Reliability Index is defined and explained in Section 4.2 of this criteria. The purpose is to establish methods of evaluation for self-tapping wood screws to be recognized in an Evaluation Report reviewed and issued by an independent evaluation service agency under the 2018, 2015, and 2012 International Building Code (IBC) and the 2018, 2015, and 2012 International Residential Code (IRC). The bases for recognition are IBC Section 104.11 and IRC Section R104.11.
  2. **Scope:** This evaluation criteria applies to self-tapping wood screws used for connections between lumber members, engineered wood members, and steel to wood-based members (where the main member is wood-based). The evaluation criteria focus on determining LRFD tensile, shear, bending yield, withdrawal, head pull-through and dowel bearing resistance strengths.
  3. **Definitions:** Terms not defined in this criteria shall have the code definition, the standard definition, or the ordinary accepted definition for the context for which they are intended.
     1. **Evaluation Service Agency:** Organization evaluating building products or finished construction for conformance to applicable codes and standards and publishing report or listing documents summarizing conclusions. The agency shall be accredited for the applicable product scope in accordance with ISO/IEC Standard 17065. The agency’s accreditation shall be issued by an accreditation body conforming to ISO/IEC 17011 and that is a signatory of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA) or another approved agency.
     2. **Self-tapping wood screws:** Threaded fasteners or screws that cut threads into the receiving materials with or without a predrilled hole. The screws considered in this Evaluation Criteria may have dimensions different than the ones specified in ANSI B18.2.1 or ANSI B18.6.4.

1. **REFERENCED STANDARDS**

Referenced standards shall be applied consistently with the specific edition of the code(s) for which the Evaluation Report is prepared unless otherwise approved by UES.

# International Code Council

* 2018, 2015, and 2012 International Building Code (IBC)
* 2018, 2015, and 2012 International Residential Code (IRC)

# American Wood Council

* ANSI/AWC National Design Specification for Wood Construction (ANSI/AWC NDS),
* AWC Technical Report 12, General Dowel Equations for Calculating Lateral Connection Values

# European Norms UNI EN

* UNI EN 1995-1-1, Eurocode 5 : Design of Timber Structures.

# American Society for Testing and Materials, ASTM International.

* ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products
* ASTM D1037, Standard Test Methods for Evaluation Properties of Wood-base Fibre and Particle Panel Materials
* ASTM D1761, Test Method for Mechanical Fasteners in Wood.
* ASTM D2395, Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials
* ASTM D2915, Standard practice for Evaluating Allowable Properties for Grades of Structural Lumber
* ASTM D4442, Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials
* ASTM D4444, Standard Test Method for Laboratory Standardization and Calibration of Hand-Held Moisture Meters
* ASTM D5457, Standard Specification for Computing Reference Resistance of Wood-Based Material and Structural Connections for Load and Resistance Factor Design.
* ASTM D 5764, Standard Test Method for Evaluating Dowel-Bearing Strength of Wood and Wood-Based Products.
* ASTM E105, Standard Practice for Probability Sampling of Materials
* ASTM F1575, Standard Test Method for Determining Bending Yield Moment of Nails

# American Society of Mechanical Engineers.

* ANSI/ASME Standard B18.2.1, Square and Hex Bolts and Screws (Inch Series), American Society of Mechanical Engineers. Standard B18.6.1, Wood Screws (Inch Series)

# American Iron and Steel Institute

* AISI S904, Standard Test Methods for Determining the Tensile and Shear Strengths of Screws.
* AISI S100, North American Specification for the Design of Cold-Formed Steel Structural Members.

# American Institute of Steel Construction

* AISC 360, Specification for Structural Steel Buildings

# Aerospace Industries Association (AIA/NAS)

* NASM1312-20, Fastener Test Methods, Method 20, Single Shear

# International Organization for Standardization (ISO/IEC)

* ISO/IEC 17020 Conformity assessment — Requirements for the operation of various types of bodies performing inspection
* ISO/IEC 17065 Conformity assessment — Requirements for bodies certifying products, processes and services

1. **BASIC INFORMATION:**

The following information and data shall be submitted for review and evaluation for recognition of self-tapping wood screws in an evaluation report:

* 1. **Product Description:**
     1. Description of each fastener, including brand name, fastener grade, and manufacturer’s catalog number. The fastener description shall include materials and fastener dimensions - the nominal fastener diameter, total length, thread size, thread pitch; and description of the head and drill point. The description shall include reference to the standard by which the fasteners are qualified, where applicable. Details shall include product drawings that describe dimensions and tolerances for each unique part of the fastener, including drill point and adjacent threads, load-bearing portion of the thread shank, fastener drive head, unthreaded shank, head, etc. The details shall be specific as to the requirements for each part of the fastener. Where the fasteners are treated for corrosion resistance, the type or method shall be described.
     2. The product description shall include a detailed description of the intended connection geometry. The connection geometry for each fastener to be recognized shall include fastener angle-of-installation in relation to the wood grain, embedment length, and fastened member physical and material descriptions.
     3. A description of the fastener manufacturing methods shall be included. Specifications of the raw materials and of the final products, including all aspects that affect the fastener performance, including chemical composition, steel specifications including bending yield strength, Fyb, mechanical properties, cold forming, heat treatment, and coating.
  2. **Installation Instructions:** Manufacturer’s published installation instructions shall be submitted, including applicable installation requirements and limitations. The installation details shall reflect the installation details used to prepare the samples within the submitted test report. Installation instructions shall include required tools, required tool operation, such as speed during installation, operator certification, drilling capacity, and other criteria as applicable to each fastener evaluated.
  3. **Packaging and Identification:** The method of packing and identifying the fasteners shall be reported. The identifying information on each box or package of fasteners shall include the brand name and model number, nominal fasteners size (number, fraction or decimal equivalent), nominal fastener embedment length (fraction or decimal equivalent), the evaluation report holder’s name, applicable evaluation serviced agency logo, and evaluation report number.

1. **TESTING**
   1. **Test Reports:** Test reports shall include descriptions of the product, product sample preparation, test assembly, and test procedures; test results, observations, and conclusions; measurement data and descriptions of the failures; and all information required by the test standards used.
   2. **Analysis:** Analysis framework of the test results shall be submitted to the evaluation service agency for review and approval prior to testing. The shape and the scale parameters of a two-parameter Weibull distribution shall be established to define the distribution of the connection resistance. The Normalization Factor derives from the Target Reliability index. The Target Reliability index is determined from the closed-form equation. The applicant shall test the connections in order to achieve the minimum required RM/Rn that will provide a Target Reliability Index equal to 4. Assuming wood samples will not reflect the full range of variability associated with end use conditions, a minimum level of COV equal to 14 percent shall be assigned. The Normalization Factor shall be computed at a live-to-dead load ratio of 1.5. Final presentation of results shall include the information required by A1.7 of ASTM D5457 Annex A1.
   3. **Testing Laboratories:** Laboratories shall be accredited as complying with ISO/IEC Standard 17025 for the testing conducted and reported (i.e. the laboratory’s scope of accreditation shall include ASTM D1761, ASTM A370, ASTM E105, ASTM D2915, or equivalent, as appropriate.) The laboratory’s accreditation shall be issued by an accreditation body conforming to ISO/IEC 17011 and that is a signatory of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). The type of testing covered in the test report shall be included in the scope of the laboratory’s accreditation. The laboratory’s accreditation certificate shall be provided.
   4. **Product Sampling:** The sampling shall be representative of the fasteners that are manufactured, and of the range of wood species with which the fasteners will be used. Reference design values may be interpolated between tested specific gravity values in accordance with Section 5.1 of this criteria. Tested specific gravity is allowed to vary ±10 percent from the nominal value. Manufacturing and material variability shall be accounted for in accordance with ASTM E105 and ASTM D2915. The test specimens shall be sampled or verified by an accredited inspection agency or testing laboratory. The product specifications shall be within the tolerance limits reported in the quality documentation and the relevant standards.
   5. **Dimension:** The relevant dimensions of the screws shall be measured according to the provisions of the applicable standard. The dimensions of the screws including the drill tip dimensions shall be documented in the test report.
   6. **Fastener tensile strength:** Tensile strength of the screws shall be determined for each fastener root diameter by testing according to Section 5.4.1 of this criteria. The tests shall be repeated for each fastener steel type.
   7. **Fastener shear strength:** Shear strength of the screws shall be determined for each fastener root diameter by testing according to Section 5.4.1 of this criteria. The tests shall be repeated for each fastener steel type.
   8. **Bending yield strength:** Bending yield strength of the screws shall be determined for each fastener root diameter by testing according to Section 5.4.2 of this criteria. The tests shall be repeated for each fastener steel type.
   9. **Withdrawal reference values:** Withdrawal reference values shall be determined by testing in accordance with to Section 5.5.1 of this criteria. The reference design value shall be divided by the length of the effective thread embedment, including the length of the tapered tip. The calculated reference withdrawal capacity, W, shall be computed using the equation in ANSI/AWC NDS Section 12.2. The recognized reference withdrawal capacity shall be the lower of the tested or calculated reference withdrawal capacities, unless the thread geometry of the tested fastener does not conform to ANSI/AWC NDS Appendix L, in which case the tested reference withdrawal capacity shall be used as the reference withdrawal capacity.
   10. **Dowel bearing strength values:** Dowel bearing strength reference values for use in determining calculated lateral resistance values in Section 4.11 of this criteria shall be determined by testing in accordance with Section 5.5.3 of this criteria. Alternatively, the reference dowel bearing strength values may be determined in accordance with Table 12.3.3 of the ANSI/AWC NDS.
   11. **Lateral resistance values:** The recognized reference lateral design values shall be calculated using the Yield Limit equations in ANSI/AWC NDS Section 12.3 and confirmed by testing. Dowel bending yield strength and dowel bearing strength for use in determining the calculated reference design values shall be determined by testing in accordance with Sections 4.8 and 4.10 of this criteria. Calculated lateral design values shall be confirmed by testing, as required in Section 5.5.4 of this criteria.
   12. **Head pull-through reference values**: Head pull-through reference values shall be determined by testing in accordance with Section 5.5.2 of this criteria. Reference values may also be determined in accordance to Section 12.2.5 of the ANSI/AWC NDS when the following requirements are met: the fastener heads are round and the underside of the head is flat, the wood member is sawn lumber or wood structural panel sheathing. For screws in connections with wood-based panels with a thickness below 0.472 inch, WH is limited to 85 lbf.

* 1. **Wood Material:** Reference wood characteristics may be derived for species identified in ANSI/AWC NDS Table 12.3.3A. Wooden elements used in test connections shall have a specific gravity determined on an oven-dry weight and volume basis equal to or lower than the ANSI/AWC NDS table values.
     1. **Moisture content:** Wood samples shall be conditioned to reach a moisture content of 10 to 14 percent when testing for dry in-service conditions. Fasteners qualified in accordance with this evaluation criteria are not certified to be used in service conditions with moisture content greater than 19 percent.
     2. **Structural composite lumber:** In order to recognize the fastener for installation in structural composite lumber (SCL), the fasteners shall be tested in both SCL and in sawn lumber. This is done for the purpose of comparison. The equivalent specific gravity of the SCL shall be equal to or greater than the measured specific gravity of the sawn lumber. If all tested fasteners installed in the SCL have reference design values that are at least 95 percent of those of the fasteners installed in the comparable sawn lumber, usage in SCLs with the same or higher equivalent specific gravity has been qualified. A minimum of five replicate assemblies for each SCL configuration shall be tested.
  2. **Wet Service Factor:** Fasteners qualified in accordance with this evaluation criteria are not permitted to be used in wet service conditions. Wet service factors CM shall not be used in conjunction with design values.
  3. **Edge, end, and spacing distances:** The minimum edge, end, and spacing distances for fasteners shall be derived from the lateral single shear values. Additional confirmatory tests may be performed to verify the edge, end, and spacing distances. Alternatively, minimum distances may be calculated in accordance with UNI EN 1995-1-1, Eurocode 5, but in no case shall minimum distances be less than the minimum values specified in the ANSI/AWC NDS.
     1. **Laterally loaded screws**: For structural timber members, minimum spacing and distances for screws in predrilled holes are given in EN 1995-1-1:2008 (Eurocode 5) Clause 8.3.1.2 and Table 8.2 as for nails in predrilled holes. The outer thread diameter d shall be considered. For screws in non-predrilled holes, minimum spacing and distances are given in EN 1995-1-1:2008 (Eurocode 5) Clause 8.3.1.2 and Table 8.2 as for nails in non-predrilled holes (Annex B). In no case shall the spacing, edge and end distances be less than the minimum values specified in ANSI/AWC NDS Table 12.5.1.
     2. **Axially loaded screws:** Minimum spacings and end and edge distances for axially loaded screws (see EN 1995-1-1:2008 figure 8.11 a) shall be taken from EN 1995-1-1:2008 Table 8.6, provided the timber thickness t >12d (Annex B). In no case shall the spacing, edge and end distances be less than the minimum values specified in ANSI/AWC NDS Table 12.5.1 or C12.1.5.7 for fasteners with shank diameters less than 0.250 inch.

1. **TESTING AND PERFORMANCE REQUIREMENTS**

Testing shall be performed using appropriate existing testing standards where possible. Adapting existing testing standards for alternate fastener geometries may be considered where appropriate. A two-parameter Weibull distribution shall be fit to the test result population in order to obtain the Reference Resistance (Rn), as described in ASTM D5457 Annex A1.4, and ASTM D2915. Final presentation of results shall include testing values achieved for these as required by Section A1.7 of ASTM D5457, Annex A1. The final results shall also include the Weibull distribution shape (α) and scale (η) as well as Coefficient of Variation (CVW) Reliability Normalization Factor (KR), Target Reliability Index (β=4) and Data Confidence Factor (Ω).

* 1. **Regression Analysis with respect to Specific Gravity:** Interpolation between tested specific gravity values with the support of best-fit regression functions may be used to estimate reference design values of connections. Interpolation using a best-fit regression function fitted to tests of connections can only be used if exclusively specific gravity is allowed to vary in the test series. A range of wood specific gravity shall be used for testing representing three specific gravities listed in ANSI/AWC NDS Table 12.3.3A. The average specific gravity for each range tested shall be within 10 percent of reference specific gravity values listed. For lateral load testing, a regression trend line shall pertain only to those tests exhibiting a common failure mode. Best fit functions shall be used to interpolate reference design values from regression analysis considering linear, polynomial, exponential, power, and logarithmic functions. Interpolation shall not be used for specific gravities outside the tested range. Reference design values for wood species which have a higher specific gravity than the tested range may be assumed to be equivalent to those of the highest specific gravity species tested. However, if specific gravity exceeds 0.50, specific testing shall be performed if predrilled holes meeting the requirements of ANSI/AWC NDS Section 12.1.5 are not used. Specific gravities exceeding 0.65 shall require specific testing.
  2. **LRFD and ASD Format Conversion:** The Reference Resistance values determined through testing are for use in Load and Resistance Factor Design (LRFD). LRFD design values shall be determined by applying the provisions of ANSI/AWC NDS Appendix N to the results of testing in accordance with ASTM D5457. The format conversion reference ASD resistance shall be computed by dividing the LRFD resistance by KF from ANSI/AWC NDS Table 2.3.5 and ASTM D5457.
  3. **Adjustment factors:** The Reference Resistance values for connections determined through testing shall be multiplied by all applicable adjustment factors shown in ANSI/AWC NDS Table 2.3.5. As explained in Section 11.2.3 of the ANSI/AWC NDS, adjustment factors from the ANSI/AWC NDS shall not be multiplied by the resulting reference design value if the reference design value of a tested connection is controlled by fastener tensile or shear strength or steel side plate metal strength rather than wood strength or fastener bending yield strength.
  4. **Fastener test methodology:** Design of fasteners shall be in accordance with Section 11.2.3 of the ANSI/AWC NDS. A minimum number of samples shall be tested in order to achieve a precision of 5 percent at a 95 percent confidence interval. In accordance with ASTM D2915, in no case shall the number of samples tested be less than 10. Fastener strength shall comply with Sections 5.4.1 and 5.4.2, and steel side plates shall be qualified in accordance with Section 5.4.3, of this criteria.
     1. **Fastener Shear and Tensile Strength:** LRFD values for shear and tensile strength shall be determined for the fasteners in accordance with AISI S100, from testing in accordance with AISI S904. Shear strength testing shall be conducted in accordance with AISI S904 Section 4.3, Single Shear Test; tensile strength testing shall be conducted in accordance with AISI S904 Section 4.1, Tensile Test. The LRFD values shall be computed from the test results in accordance with Section K2.1.1 of AISI S100. The LRFD shear and tensile strength values shall be used in the failure mode comparisons in Sections 7.9 and 7.10 of this criteria.
     2. **Fastener Bending Yield Strength:** Fasteners shall be tested for Bending Yield Strength in accordance with ASTM F1575. The bending yield strength shall be defined by the section at the root diameter of the fastener. The load deformation curve shall be used to determine the 5 percent offset yield load, which shall be used to calculate the bending yield strength of the fastener.
     3. **Side Plates:** Steel side plates in connections shall comply with Section 11.2.3 of the ANSI/AWC NDS. The tensile strength of the steel plate shall be tested with samples of the same steel sheet or plate used in the connection, or by mill certification. Base-metal thickness shall be determined by measuring the steel side plate thickness. Tensile strength testing shall be done according to ASTM A370.
  5. **Connection test methodology:** Connection testing shall be performed in accordance with ASTM D1761 for withdrawal and lateral load resistance, ASTM D1037 for head pull-through resistance, ASTM D5764 for dowel bearing strength, or other procedures as appropriate in accordance with the approved testing plan. Analysis shall be performed in accordance with ASTM D5457. Recognition of design values for connections determined using Annex A1 to ASTM D5457 shall be limited to the connection configurations tested, however, recognition may be extended to similar connection configurations where justified, such as connections involving different sized members or equivalent fastener penetration depths. Thus, for connection configurations applicable to a range of fastener sizes used in a common connection configuration, a portion of the fastener sizes, including the largest, smallest, and a reasonable number in between, may be tested to determine a highly reliable relationship for the values of a given type of fastener in a particular connection configuration. Once the relationship is determined, a reasonable number of samples of the untested fastener sizes shall be tested to verify the predicted relationship.

In the immediate vicinity of the location in which the fastener is driven, each wood member shall be free of knots, sloped grain and other growth characteristics that may affect the test results. A minimum number of samples shall be tested in order to achieve a precision of 5 percent at a 75 percent confidence interval, in accordance with ASTM D2915 and shall be a minimum of 30 unless noted otherwise. Test values for connections where the side member is a steel plate shall be adjusted to account for the measured or mill certified tensile strength and base metal thickness of the steel.

* + 1. **Withdrawal Load Resistance**: Withdrawal testing shall be conducted in accordance with ASTM D1761 Sections 1 to 12, “Nail, Staple or Screws Withdrawal Test” or as modified and provided for in the approved testing plan. The use of predrilled holes for the installation of the fastener shall be in accordance with the manufacturer’s instructions. Samples shall have equal embedded length, and the embedment length shall not exceed the thread length. Length of the tapered screw tip shall be considered in determining the effective embedment length. For fastener designs which are available with a variety of threaded lengths, withdrawal tests shall be performed for the minimum intended thread penetration. Testing shall also include either the longest intended thread embedment or a thread embedment where the fastener breaks before withdrawal.

Referring to ANSI/AWC NDS 12.2.1.2, in order to obtain a reference withdrawal design value, the results obtained in the test shall be divided by the length of thread penetration, pt, into a wood member, excluding the length of the tapered tip. This step is done to obtain a relationship between the embedment length and the withdrawal resistance.

For each diameter, Weibull statistical analysis shall be performed on the total number of samples including all thread lengths tested.

* + 1. **Head Pull-through** **Resistance:** Fasteners shall be tested for head pull-through by means of a test configuration where the fastener is installed in and is pulled through the side member. The test setup and procedure may be based on ASTM D1037 or as modified and provided for in the approved testing plan. In the case of samples available with a variety of screw heads, head pull-through tests shall be performed for each of the head types. If washers are used with the screws, these shall be included in the test program and tests shall be conducted both with and without washers. For fully threaded screws, the reference pull-through resistance shall be based only on the embedded threads in the wood side member, unless a washer is used.
    2. **Dowel Bearing Strength:** Fasteners shall be tested for dowel bearing strength in accordance with ASTM D5764 or as modified and provided for in the approved testing plan. Specimens shall consist of a single rectangular member with a fastener hole perpendicular to one face of the member and shall be evaluated for the resistance to embedding the fastener into the fastener hole, while ensuring not to bend the fastener. Sample size shall be estimated using procedures in ASTM D2915. A minimum number of 30 samples shall be tested. The test shall be performed both with the load direction parallel and perpendicular to the grain direction. The dowel bearing yield load is determined as the intersection of the load-deformation curve and a line which is an offset of the initial linear portion of the load-deformation curve by a deformation equal to 5 percent of the fastener diameter. The fastener dowel bearing strength is represented by the yield load obtained from the load-deformation curve divided by the fastener diameter and specimen thickness. The bearing strength shall be used in the Yield Limit Equations for connections as required in the ANSI/AWC NDS Section 12.3.1.
    3. **Lateral Load Resistance:** Calculated reference lateral design values shall be determined using the Yield Limit equations in ANSI/AWC NDS Section 12.3, and the dowel bending yield strength and dowel bearing strength determined in Sections 5.4.2 and 5.5.3 of this criteria. Confirmatory lateral load tests shall be performed in accordance with the testing plan, on samples representative of connection configurations for which recognition is sought. The minimum number of replicates tested per representative connection configuration shall be 10. Adjustments shall be made for steel side plate properties, as applicable. Where reference lateral design values are controlled by bending yield equations (wood strength or bending yield of fasteners), NDS adjustment factors shall be applied, as applicable.

1. **QUALITY CONTROL**
   1. The manufacturer’s quality management system shall comply with the evaluation service agency’s minimum requirements for quality management systems such as IAPMO ES-010. A complete description of the quality management system used in the factory to control the quality of the screws shall be provided to the evaluation service agency for review.
   2. Recognition shall require that a regimen of quality control testing be implemented at the manufacturing facility to confirm that the fasteners continue to qualify for ongoing recognition. The testing shall be carried-out by the manufacturer, and sampling and testing plans shall be submitted to the evaluation service agency for review and approval. The testing plan shall include acceptability parameters and a description of appropriate increased testing frequency and corrective action to be taken in the event the results fall short of the quality control target values.
   3. Inspections of manufacturing facilities are required for this product, by an agency accredited for the required tasks in accordance with ISO/IEC 17020 or ISO/IEC 17065. Initial third-party inspection frequency shall be twice yearly, and the frequency may be reduced to yearly if appropriate, based on a history of successful inspections without corrective actions.
2. **EVALUATION REPORT RECOGNITION**

Evaluation reports shall include the following information:

* 1. Basic product information, including technical description of the product and its intended use, description of connection geometry with images, and material properties. Recognition will be limited to configurations and conditions tested. Essential characteristics of the product and connection method, and criteria for assessing the performance of the product in relation those characteristics. Information described in Section 3.0 of this criteria.
  2. There shall a section providing the fastener dimensions.
  3. There shall be a section detailing the fastener capacities and a table providing bending yield strength, shear strength and tensile strength for each diameter tested. Strength values shall be determined in accordance with Sections 5.3.1 and 5.3.2 of this criteria.
  4. The method of connection design and analysis shall be explained in the report, with examples.
  5. There shall be a table providing reference values for withdrawal (W) determined in accordance with Section 5.4.1 of this criteria.
  6. There shall be a table providing head-pull through design reference values determined in accordance with Section 5.4.2 of this criteria. In cases where it can be demonstrated that a withdrawal values will always control the failure, the head pull-through design value table may be omitted from the evaluation report. If the product is not designed for head pull through purposes, head pull-through design value table may be omitted from the evaluation report.
  7. There shall be a section providing reference lateral design values (Z) for single shear plane. For each specific gravity considered, two tables shall be provided: one for wood-wood connections consisting of two members with identical specific gravity and another one for steel-wood connections. The reference values shall be determined in accordance with Section 5.4.3 of this criteria. If a product is intended to be used on solely wood-wood connections, the table related to steel-wood reference values may be omitted. If a product is intended to be used on solely steel-wood connections, the table related to wood-wood reference values may be omitted.
  8. There shall be a table providing minimum fastener end and edge distances and spacing, referring to Annex B of this criteria.
  9. It shall be stated that when a screw is loaded in tension, the design value is the least of:

1. Screw LRFD tensile strength (determined in accordance with Section 5.4.1 of this criteria),
2. Withdrawal reference value, W, adjusted by all applicable adjustment and reduction factors, and
3. Head pull-through reference value, WH, adjusted by all applicable adjustment and reduction factors.
   1. It shall be stated that when a screw is laterally loaded, the design value is the lesser of:
4. Screw LRFD shear strength (determined in accordance with Section 5.4.1 of this criteria), and
5. Reference lateral value, Z, adjusted by all applicable adjustment and reduction factors.
   1. Requirements concerning pre-drilling and pilot holes.
   2. Requirements concerning use of fasteners in wet service conditions (including exposure to moisture during construction).
   3. A limitation stating that use of the fasteners in shear walls and diaphragms is outside the scope of the report.
   4. Requirements for special inspection, in accordance with Chapter 17 of the IBC.

For configurations not covered by the tests, the designer shall calculate the connection strength according to Chapter 12 of the ANSI/AWC NDS, using mechanical properties of the fastener and the wood provided in the report. Connections with multiple shear planes shall be designed in accordance with Section 12.3.9 of the ANSI/AWC NDS. Design of connections having steel side plates shall comply with Section 11.2.3 of the ANSI/AWC NDS.

**ANNEX A**

**Lateral Connection Strength for Fasteners Installed at an Angle to the Grain**

This annex outlines the approach to evaluate the lateral strength of wood connections using fasteners installed at an angle to the grain. The objective is to test connections for orientations other than perpendicular and parallel to the grain. For example, the tests may be performed for fasteners installed at 60°, 45°, or 30°; the angle shall be in accordance with the recognition that is sought. Fasteners at an angle less than 90 degrees transfer loads through tension and shear combined; interaction diagrams may be provided to determine values at intermediate angles between those tested.

The analytical model for the lateral connection resistance for fasteners installed at an angle to the grain is described below. The lateral resistance is the lesser of: (a) inclined withdrawal resistance considered on Lef; (b) the tensile strength of the screw. The results of the tests shall be confirmatory of the results derived from the following calculation:

Where:

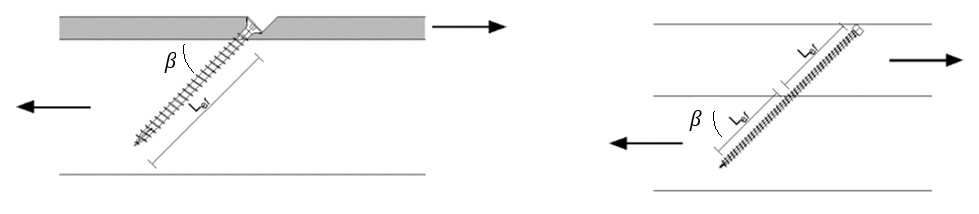
is the number of effective fasteners according to EN 1995-1-1:2008;

is the withdrawal resistance, considered on Lef;

is the tensile strength;

is the angle between the fastener axis and the connection plane;

μ is the tested kinetic friction coefficient between wood members or between wood and steel members



**Figure A 1** Inclined screw. Steel-Wood configuration on the left. Wood-Wood configuration on the right.

In the Steel-Wood configuration, Lef represents the thread length in the wood member.

In the Wood-Wood configuration, Lef represents the half thread length excluding tolerances for head, tip and shear plane.

Where:

is the shear plane tolerance, usually 0.4 inch

The test setup and an analysis proposal shall be submitted for review and approval to the evaluation service agency prior commencing of testing. The testing plan shall also include the type of fasteners intended to be evaluated, specific gravity and moisture content of the wood members, relevant dimensions and geometry of the test specimen, penetration of the fastener in wood, and direction of loading. The applicant shall indicate whether the evaluation methodology is applicable for single and/or multiple fasteners in the connection.

The testing methodology shall be fully described. The report shall describe the design methodology using descriptive details, equations and figures as needed. For each configuration, a minimum of three (3) replicas shall be tested. Every configuration shall be tested to verify the analytical model.

Edge and end spacing, and spacing of fasteners (if applicable), distances between rows (if applicable), dimensions, installation angle and amount of slip between wood members shall be described. Minimum distances and spacings shall be sufficient to prevent splitting of the wood. In case of steel-wood connections, the steel plate edge distance shall be minimum 1.5 times the diameter of the screw. Spacing of screws in steel-wood connections shall be minimum 5 times the diameter of the screw.

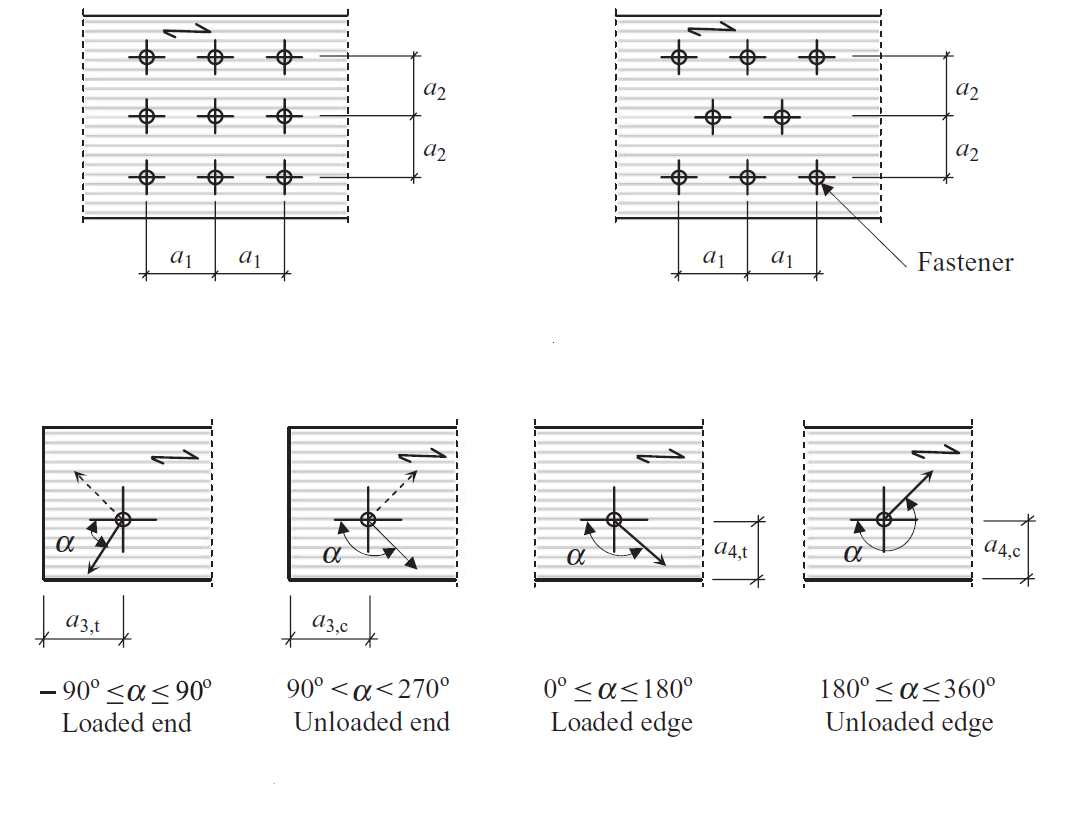
**ANNEX B**

The spacing, end, and edge distance recommendations in Table B1 are extracted from Eurocode 5. These minimum requirements for use with dowel-type fasteners have been developed from extensive testing programs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Spacing or distance** | **Angle α** | **Timber** **SG ≤0.42** | **Timber 0.42≤SG≤0.50** | **Predrilled hole** |
| Spacing a1  (parallel to grain) | 0°≤α≤360° | D≤5mm: (5+5IcosαI)D  D≥5mm: (5+7IcosαI)D | (7+8 IcosαI)D | (4+ IcosαI)D |
| Spacing a2  (perpendicular to grain) | 0°≤α≤360° | 5D | 7D | (3+ IsinαI)D |
| Distance a3,t  (loaded end) | -90°≤α≤90° | (10+5 cosα)D | (15+5 cosα)D | (7+5 cosα)D |
| Distance a3,c  (unloaded end) | -90°≤α≤270° | 10D | 15D | 7D |
| Distance a4,t  (loaded end) | 0°≤α≤180° | D≤5mm: (5+2 sinα)D D≥5mm: (5+5sinα)D | D≤5mm: (7+2 sinα)D  D≥5mm: (7+5sinα)D | D≤5mm: (3+2 sinα)D  D≥5mm: (3+4 sinα)D |
| Distance a4,c  (unloaded end) | 180°≤α≤360° | 5D | 7D | 3D |
|  | |  |  |  |

**Table B1** Minimum spacings and edge and end distances using screws for timber-to-timber connections.

The spacings and distances referred to in these tables are as shown in Figure B 1.



**Figure B1** Fastener spacings and distances.