Designation:D 5055–03 Designation: D5055 – 11

Standard Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists[1]

This standard is issued under the fixed designation D5055; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 *General*—This specification gives procedures for establishing, monitoring, and reevaluating structural capacities of prefabricated wood I-joists. Capacities considered are shear, reaction, moment, and stiffness. Procedures for establishing common details are given and certain design considerations specific to wood I-joists are itemized.

1.2 *Contents of the Standard*—An index and brief description of the main features of this specification are given in X1.1.1.

1.3 *Development of the Standard*—The development and intent of this specification is discussed in Appendix X1.

1.4

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in 6.1.1.5.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D198 Test Methods of Static Tests of Lumber in Structural Sizes

D245 Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber

D1990 Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens

D2559 Specification for Adhesives for Bonded Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions

D2915 Practice for Evaluating Allowable Properties for Grades of Structural Lumber Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products

D4761 Test Methods for Mechanical Properties of Lumber and Wood-Base Structural Material

D5457Specification for Computing the Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design 5456 Specification for Evaluation of Structural Composite Lumber Products

D5457 Specification for Computing Reference Resistance of Wood-Based Materials and Structural Connections for Load and Resistance Factor Design

D7247 Test Method for Evaluating the Shear Strength of Adhesive Bonds in Laminated Wood Products at Elevated Temperatures

D7480 Guide for Evaluating the Attributes of a Forest Management Plan

E4 Practices for Force Verification of Testing Machines

E529 Guide for Conducting Flexural Tests on Beams and Girders for Building Construction

E699 Criteria for Evaluation of Agencies Involved in Testing, Quality Assurance, and Evaluating Building Components in Accordance with Test Methods Promulgated by ASTM Committee E06

IEEE/ASTM-S1–10Practice for Evaluation of Agencies Involved in Testing, Quality Assurance, and Evaluating of Building Components

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

[1] This specification is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.02 on Lumber and Engineered Wood Products.

Current edition approved Oct. 1, 2003. Published December 2003. Originally approved in 1990. Last previous edition approved in 2002 as D 5055–02.

Current edition approved May 1, 2011. Published June 2011. Originally approved in 1990. Last previous edition approved in 2010 as D5055 – 10. DOI: 10.1520/D5055-11.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

2.2 ~~*Other Standards:*~~
~~U.S. Product Standard PS-1 Construction and Industrial Plywood~~U.S. Product Standards:[3]
~~U.S. Product Standard PS-2 Performance Standard for Wood-Based Structural-Use Panels[3]~~
PS-1 Structural Plywood
PS-2 Performance Standard for Wood-Based Structural-Use Panels
~~CSA O112.7Resorcinol and Phenol-Resorcinal Resin Adhesives~~ PS-20 American Softwood Lumber Standard
2.3 *Other Standards:*
~~CSA O151~~CSA O86 Engineering Design in Wood[4]
CSA Standards for Wood Adhesives O112 Series[4]
CSA O121 Douglas-fir Plywood[4]
CSA O141 Softwood Lumber[4]
CSA O151 Canadian Softwood Plywood[4]
~~CSA O325.0Construction Sheathing[4]~~
~~CSA O452Design Rated OSB[4]~~
~~Lumber Grading Rules Approved by American Lumber Standards Committee (ALSC) or Canadian Lumber Standards Accreditation Board (CLSAB)~~
CSA O325 Construction Sheathing[4]
CSA O437.0 OSB and Waferboard[4]
Lumber Grading Rules Approved by American Lumber Standards Committee (ALSC) or Canadian Lumber Standards Accreditation Board (CLSAB) [5]
SPS-1 Fingerjoined Structural Lumber[6]
SPS-4 Fingerjointed Flange Stock Lumber, 2001[6]

3. Terminology

3.1 *Definition:*

3.1.1 *prefabricated wood I-joist*—a structural member manufactured using sawn or structural composite lumber flanges and structural panel webs, bonded together with exterior exposure adhesives, forming an "I" cross-sectional shape. These members are primarily used as joists in floor and roof construction.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capacity (or structural capacity)*—the numeric result of certain calculations specified in this specification.

3.2.2 *design value*—the numeric value claimed by the manufacturer as appropriate for use in structural analysis.

NOTE 1—A brief discussion of this issue is found in X1.9.

3.2.3 *structural composite lumber*—a composite of wood elements (for example, wood strands, strips, veneer sheets, or a combination thereof), bonded with an exterior grade adhesive and intended for structural use in dry service conditions.

4. Design Considerations

4.1 *Design Value Adjustments*:

4.1.1 *Duration of Load*—~~P~~With the exception of reaction design values limited by compression perpendicular to grain, prefabricated wood I-joists shall be designed using the strength adjustment for load duration used in sawn lumber. This adjustment is determined in accordance with the section on Duration of Load Under Modification of Allowable Properties for Design Use in Practice ~~D 245~~D245.

4.1.2 *Repetitive Members*—The repetitive member factor for prefabricated I-joists shall be taken as 1.0.

NOTE 2—Committee D07 chose to reduce the repetitive member factor to unity primarily for purposes of design simplicity. A discussion of this decision is given in Appendix X1.

4.1.3 *Treatments*—Some pressure treatments affect material strength and the quality of prefabricated wood I-joists. Treated I-joists shall not be used without evaluation of such effects.

~~[3] Available from APA The Engineered Wood Association, P.O. Box 11700, Tacoma, WA 98411and PFS Research Foundation, 2402 Daniels Street, Madison, WI 53718.~~
[3] Available from APA—The Engineered Wood Association, 7011 South 19th Street, Tacoma, WA 98466, http://www.apawood.org; and TECO, 2902 Terra Court, Sun Prairie, WI 53590, http://www.tecotested.com.
~~[4] Available from Canadian Standards Association, 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3.~~
[4] Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, http://www.csa.ca.
~~[5] Available from American Lumber Standard Committee (ALSC), P.O. Box 210, Germantown, MD 20874. Canadian Lumber Standards Accreditation Board (CLSAB), 1055 W. Hastings St., Vancouver, BC, Canada V6E 2E9.~~
[5] Available from American Lumber Standard Committee (ALSC), P.O. Box 210, Germantown, MD 20874, http://www.alsc.org; and Canadian Lumber Standards Accreditation Board (CLSAB), 960 Quayside Drive, Suite 406, New Westminster, BC V3M 6G2, Canada, http://www.clsab.ca.
~~[6] National Lumber Grades Authority, SPS – 4 – 2001, Special Products Standard for Fingerjoined Flange Stock Lumber, 2001, New Westminster, BC, Canada.~~
[6] Available from National Lumber Grades Authority (NLGA), 302–960 Quayside Drive, New Westminster, BC V3M 6G2, Canada, http://www.nlga.org.

4.1.4 *Environment*—The capacities developed in this specification are applicable to joists used under dry conditions such as in most covered structures. Appropriate adjustments for uses in other environments shall be made.

4.2 *Shear Design*:

4.2.1 Neglecting loads within a distance from the support equal to the depth of the member shall not be permitted.

4.2.2 Adjustments to the shear design value near the support or at locations of continuity or where reinforcements are provided must be substantiated by independent testing to the general intended criteria for shear capacity herein.

5. Materials

5.1 ~~*Flange Stock*~~General—The following I-joist components meet the definition of a biobased product in accordance with 3.3.1 of Guide D7480:

~~5.1.1All flange material shall conform to the requirements of 6.3~~

5.1.1 Lumber flange materials complying with USDOC PS-20, CSA O141, NLGA SPS-1, or NLGA SPS-4.

~~5.1.2End joints in purchased flange stock are permitted provided such joints conform to the general intent and Section~~

5.1.2 Structural composite lumber flange materials complying with Specification D5456.

5.1.3 Web materials complying with USDOC PS-1, USDOC PS-2, CSA O121, CSA O151, CSA O325, or CSA O437.0.

5.2 *Flange Stock*:

5.2.1 All flange material shall conform to the requirements of 6.4. In addition, when the flange material is structural composite lumber, the following properties shall be determined in accordance with Specification D5456: modulus of elasticity (flat or edge, depending on flange orientation in the I-joist), compression (parallel and perpendicular to grain), and nail design values.

5.2.2 End joints in purchased flange stock are permitted provided such joints conform to the general intent and Section 10 of this specification.

~~5.2~~

5.3 *Web Material*—Panels shall conform to manufacturing or performance standards recognized by the applicable governing code. Examples are ~~U.S. Product Standard~~ PS-1 (or CSA O151~~,~~) and ~~U.S. Product Standard~~ PS-2 ~~or CSA O325.0.~~ (or CSA O325). In addition, all panels shall meet the equivalent of Exposure I requirements as specified in PS-1 or PS-2.

~~5.3~~5.4 *Adhesives*~~—Adhesives used to fabricate components as well as the finished products shall conform to the requirements in Specification D 2559D 2559 (CSA O112.7 in Canada) for use under exterior (wet-use) exposure conditions.~~ —Adhesives used to bond together components of the finished product shall conform to the requirements in Specification D2559 (or, in Canada, shall conform to an appropriate standard from the CSA Standards for Wood Adhesives, O112 Series, stipulated in CSA O86). In addition, adhesives used for web-to-web, web-to-flange, and flange-to-flange joints shall be qualified for heat durability performance in accordance with 5.4.3. Appendix X3 gives additional information and standards that shall be considered when qualifying adhesives and adhesive-bonded materials.

~~**6.**~~

NOTE 3—Heat durable performance implies that a bonded joint will exhibit similar material resistance to solid wood in an elevated temperature environment where the wood material surrounding the joint does not provide thermal protection.

5.4.1 Adhesives and binder systems used in the fabrication of Structural Composite Lumber products shall be evaluated in accordance with Specification D5456.

5.4.2 Adhesives and binder systems used in the fabrication of panel products used as a web shall be evaluated in accordance with PS-2 (or, in Canada, CSA O325) with the Exposure 1 classification.

5.4.3 *Adhesives*—Heat durability:

5.4.3.1 Adhesives used for web-to-web, web-to-flange, and flange-to-flange joints shall be qualified for heat durability performance through testing in accordance with Test Method D7247. The test temperature and heat exposure duration for specimens tested at elevated temperature (7.2 of Test Method D7247) shall meet the requirements of Items 1, 2, and 3 below.

(1) For the bonded specimens, the minimum target bondline temperature shall be 428°F (220°C). For the matched solid wood control specimens, the minimum target temperature at the shear plane shall be 428°F (220°C).

(2) The minimum target temperatures of Item 1 shall be maintained for a minimum of 10 min or until achieving a residual strength ratio for the solid wood control specimens of 30 ± 10 %, whichever is longer.

(3) Block shear testing shall be conducted immediately after removal from the oven such that the specimen bondline or shear plane temperature does not drop more than 9°F (5°C) after leaving the oven and prior to failure. This provision is satisfied when the time interval from the removal of the specimen from the oven to the failure of the block shear specimen does not exceed 60 s for each specimen tested and the room temperature of the test laboratory at the time of testing is not less than 60°F (15.5°C).

5.4.3.2 For adhesives tested in accordance with 5.4.3.1, the residual shear strength ratio for the bonded specimens, as calculated in accordance with Test Method D7247, shall be equal to or higher than the lower 95 % confidence interval on the mean residual shear strength ratio for the solid wood control specimens.

6. Qualification

6.1 *General*—This section describes procedures, both empirical and analytic, for initial qualification of the structural capacities of prefabricated wood I-joists. Qualification is required for certain common details of I-joist application since they often influence structural capacities. All capacities are to be reported with three significant digits. Any time significant changes in joist or application details, manufacturing processes or material specifications occur, qualification is required, as for a new manufacturer or product line.

6.1.1 *Testing*—Qualification tests shall be conducted or witnessed by a qualified agency as defined in 8.1. All test results are to be certified by the qualified agency.

6.1.1.1 *Sample Size*—The number of specimens specified in 6.2, 6.3, 6.4, and , 6.5, and 6.6 are minimums. The producer wishing to evaluate the validity of the sample size will find a procedure in 4.7 of Practice D 2915D2915.

6.1.1.2 *Test Specimens*—Materials and fabrication procedures of test specimens shall be as typical of intended production as can be obtained at the time of manufacturing qualification specimens. —Materials and fabrication procedures of test specimens shall be as typical of intended production as can be obtained at the time of manufacturing qualification specimens. Minimum specimen temperature at the time of test shall be 40°F (4°C). Specimens shall be tested at the as-received moisture content.

NOTE 3—It 4—It is desirable to conduct preliminary tests to aid the selection of representative specimens.

6.1.1.3 *Test Accuracy*—Tests in accordance with this specification are to be conducted in a machine or apparatus calibrated in accordance with Practices E 4E4except that the percentage error shall not exceed ±2.0.

6.1.1.4 *Test Methods*—Methods generally applicable to the full-section joist tests required herein are in Guide E 529E529, with the following exceptions: (*a1*) the methods are applicable to both qualification and quality control, and; (*b2*) load rate shall be as specified in the following sections, and;and (*c3*) delays between load increments are not required. Required tension and compression tests shall be substantially in accordance with Test Methods D 198D198 or Test Methods D 4761D4761 with load rates as specified in the following sections. All test report formats and content shall be in keeping with the intended use of the results and be agreed upon by all involved parties prior to the test.

6.1.1.5 *Test Safety*—All full-scale structural tests are potentially hazardous and appropriate safety precautions must be observed at all times. One particular concern is the potential for lateral buckling during full-section I-joist tests and appropriate lateral restraint must be maintained at all times.

6.2 *Shear Capacity Qualification* :

6.2.1 Initial capacity shall be established from either test results or calculations. The equations used for the calculation method shall be confirmed by a test program; the details of which are beyond the scope of this specification. Explanations of the statistics used in the analysis of test results, with an example, are given in Appendix X4.

6.2.2 Factors which influence shear capacity include web type, thickness, and grade; web to flange joint; joint type in web (machined, butted, glued or not, reinforced, etc.). Each combination of these web factors must be tested separately in accordance with 6.2.3, unless the critical combination in a proposed grouping is first established by test. Flange stiffness influences shear strength: if a range of flange sizes is to be used with a given combination of web factors, all sizes must be tested unless all values are to be based on tests with the smallest flange. When a range of species or grades of either sawn or composite lumber is to be grouped, preliminary tests shall be conducted to determine which is critical. Joists with structural composite lumber flanges, such as laminated veneer lumber (LVL), must be tested separately from joists with sawn lumber flanges.

6.2.3 For each web factor combination, a minimum of ten specimens shall be tested for each critical joist depth. Critical joist depths are minimum and maximum product depths with approximate 4-in. (102-mm) depth increments between. If the installation of specific reinforcement as defined in the manufacturer's literature is required at a certain depth to maintain product performance in the progression of a series of depths within a combination, the product must be tested at this depth plus the adjacent depth which does not require specific reinforcement.

6.2.4 Specimen length shall be that which usually produces failures in shear and shall not extend past each bearing support more than ¼ in. (6.4 mm). The bearing length shall be adequate to usually produce shear failure instead of a bearing failure but shall not exceed 4 in. (102 mm), unless justified. There shall be a minimum horizontal distance of 1½ times the joist depth between the face of the support and the edge of the load pad.

6.2.5 On one end of the specimen, a vertical web joint, if used, shall be located approximately 12 in. (305 mm) from the face of the support or ½ the distance between the support and the load pad.

6.2.6 The load shall be applied to the top flange either as a single point load at center span or as two point loads of equal distance from the center span. Load pads shall be of sufficient length to prevent local failure.

6.2.7 The load shall be applied at a uniform rate so that anticipated failure will occur in not less than 1 min.

6.2.8 Any required web reinforcements developed in 6.6.16.7.1 shall be installed at supports. When required to prevent failure at a load point, additional reinforcement shall be installed, provided such reinforcement is not wider than the load pad.

6.2.9Minimum specimen temperature at the time of test shall be 40°F (4°C).

6.2.10Ultimate 6.2.9 Ultimate load and mode of failure shall be recorded in addition to product and test setup descriptions. If any specimen fail in bending, the data shall be excluded. However, for purposes of evaluating shear capacity, bearing failure is considered a mode of shear failure. Appendix X5 discusses some of the modes of shear failure and offers a possible coding scheme.

6.2.110 The dead load of the specimen is to be included in the ultimate load calculation when specified by the producer.

6.2.126.2.11 The mean ultimate shear values shall show logical progression of strength as a function of depth. A linear regression analysis of the mean values shall have a coefficient of determination (r^2) of at least 0.9, or the specified tests of 6.2.3 must be repeated. If the second test set fails to meet the criteria, all depths which have been skipped must also be tested. (A check of the regression criteria is given in X4.4.5.)

6.2.1~~2~~1.1 Data from joist depths where failure is web buckling shall be excluded from the regression analysis, if: (~~a~~*1*) including the results causes failure to meet the criteria of ~~6.2.12~~6.2.11; or (~~b~~2) the producer determines the reduction in regression line slope is unacceptable. In either case, all depths greater than the shallowest excluded, shall be tested.

NOTE ~~4~~5—Depending on joist details and material, there will be some depth where web buckling appears as a mode of failure. Further increases in depth will result in consistent web buckling, and at some point ultimate strength will reduce compared to shallower joists.

6.2.1~~2~~1.2 When no more than three depths are to be qualified, the correlation is not necessary, but each depth must be tested.

6.2.1~~3~~2 The shear capacity of the product shall be limited to that calculated by taking into account sample size, test result variability, and reduction factors. Data from tests at different joist depths included in regression analysis are permitted to be combined to obtain a pooled estimate of variability.

~~6.2.13.1~~6.2.12.1 *Combining Data*—The regression equation from ~~6.2.12~~6.2.11 provides the expected mean shear strength (P_e) for depth (d_i):

$$P_e = A + Bd_i \tag{1}$$

where A and B are intercept and slope of the equation.

~~6.2.13.2~~6.2.12.2 Where too few depths are involved for correlation in ~~6.2.12~~6.2.11, when the tests fail the regression criteria, or where depths are excluded from the correlation, no combining is allowed and each such depth shall be evaluated separately.

~~6.2.13.3~~

6.2.12.3 The mean and standard deviation of the data from each depth tested are ($\bar{P}_i$) and (S_i). The coefficient of variation is:

$$v_i = S_i/\bar{P}_i \tag{2}$$

Let n_i be the number of tests for each depth (d_i) tested and included in the regression analysis. Then the coefficient of variation in the combined data sets is:

$$v = \sqrt{\frac{\Sigma[(n_i - 1)\, v_i^{\,2}]}{\Sigma n_i - J}} \tag{3}$$

Where J is the number of depths included in the regression analysis and the summation is from $i = 1$ to J.

~~6.2.13.4~~

6.2.12.4 *Shear Capacity*—The shear capacity is calculated as follows:

$$P_s = C\,(P_e - KvP_e)/2.37 \tag{4}$$

where:

K = factor for one-sided 95 % tolerance limit with 75 % confidence for a normal distribution. Values for this factor are given in Appendix X4, Eq X4.20, and Table ~~X4.3.~~ X4.3;

P_e = ultimate mean shear strength from Eq 1 or the mean of any depth in accordance with ~~6.2.13.2~~6.2.12.2~~,~~ ;

v = coefficient of variation of combined data from Eq 3 or, in accordance with ~~6.2.13.2~~6.2.12.2, from Eq 2 when any depth is evaluated ~~alone,~~ alone;

C = product of any appropriate special use reduction factors from Appendix X6~~, and~~ ; and

P_s = shear capacity.

~~6.2.13.5~~

6.2.12.5 When data are combined, the factor K is based on a sample size $N = \Sigma n_i - J$. When the criteria of ~~6.2.12~~6.2.11 are not met and for depths excluded from the regression analysis, then the allowable shear capacity is computed separately for each such depth and is:

$$P_s = C(\bar{P}_i - Kv_i\bar{P}_i)/2.37 \tag{5}$$

and the factor K is for a sample size of n_i. A discussion of the reduction factor (2.37) is given in Appendix X6.

~~6.3~~

6.3 *Reaction Capacity Qualification*—Reaction capacity shall be determined in accordance with Annex A1.

6.4 *Moment Capacity Qualification*~~—Moment capacity shall be determined either analytically from the characteristics of flange material or empirically from the results of I-joist bending tests. If the empirical method is used to determine moment capacity, one of the methods described in 6.3.3.4 or 6.3.3.5 shall be used.~~

~~6.3.1~~*—Moment capacity shall be determined either analytically from the characteristics of flange material (6.4.1) or empirically from the results of I-joist bending tests (6.4.3).*

6.4.1 *Analytical Method*:

6.3~~4~~.1.1 In this method, the I-joist moment capacity is determined as follows:

$$M_a = K_L F_a A_{net} y \tag{6}$$

where:

K_L = length adjustment factor, computed in accordance with ~~6.3.1.5~~6.4.1.5. The factor adjusts flange material F_a as a function of joist span and stress. Joist depth, tension test gage length, finger joint spacing, and material or joint variability are utilized in determining K_L~~.~~;
A_{net} = net area of one flange (excluding areas of all web material and ~~rout),~~ rout);
y = distance between flange centroids (with the rout ~~removed),~~removed); and
F_a = design flange axial stress, taken as the lower of flange tensile stress adjusted to the reference gage length or end joint tensile stress computed in accordance with ~~6.3.1.4~~6.4.1.4, or flange compressive stress computed in accordance with ~~6.3.1.6~~6.4.1.6.

NOTE ~~5—The~~ 6—The assessment of axial stress on the basis of average stress at a given cross section matches committee judgment and experimental evidence based on joists in which the thickness of an individual flange is less than approximately one sixth of the overall joist depth. For joists not meeting this criterion, additional consideration of extreme fiber stresses may be needed.

NOTE ~~6—The~~ 7—The information in this specification is not intended to be limited to the allowable stress design (ASD) format. Provided that appropriate scaling of design values is completed (from ASD to the limit states design (LSD) or load and resistance factor design (LRFD) format) in accordance with applicable standards.

~~6.3.1.2~~6.4.1.2 *Flange Material Types*—Flange materials fall into one of the following three categories:

~~*(a)*~~ *(1) Standard Lumber Grades; Standard Lengths*—Flanges utilizing nominal ~~8-ft (2.44-m)~~8-ft (2.44-m) and longer sawn lumber of a standard grade permitted by the governing code and graded under standards recognized by American Lumber Standards Committee (ALSC) or Canadian Lumber Standards Accreditation Board (CLSAB). The tabulated allowable tension value, F_t, is assumed to be based on a 12-ft (3.66-m) gage length. End joints, when used, shall be qualified in accordance with ~~6.4~~6.5.

~~*(b)*~~ *(2) Nonstandard Grades; Standard Lengths*—Flanges utilizing nominal 8-ft (2.44-m) and longer structural composite or sawn lumber, but not meeting the standard grade criteria of ~~6.3.1.2~~6.4.1.2 (~~*a*). Qualification testing and analysis shall be in accordance with 6.3.1.3 and 6.3.1.4. End joints, when used, shall be qualified in accordance with 6.4.~~ 1). Qualification testing and analysis shall be in accordance with 6.4.1.3 and 6.4.1.4. End joints, when used, shall be qualified in accordance with 6.5. Alternatively, a single end joint, when used, shall be permitted to be included within the gauge length of each flange specimen when tested in accordance with 6.4.1.3. To use this alternative method, the minimum end-joint spacing permitted in application and used to determine L_1 in 6.4.1.5 shall be the tested gauge length.

~~*(c)*~~ *(3) Any Grades; Short Lengths*—Flanges utilizing structural composite lumber or sawn lumber in lengths shorter than 8 ft (2.44 m) before end jointing. Qualification testing and analysis shall be in accordance with ~~6.3.1.3~~6.4.1.3 and ~~6.3.1.4~~6.4.1.4. Qualification specimens shall be used to establish a characteristic (that is, average) joint spacing as noted in Eq 7. Average joint spacing in individual flanges in the qualification sample shall not be less than 75 % of the established characteristic joint spacing. The characteristic joint spacing established during qualification shall be maintained in subsequent production.

$$L_J = L/N \tag{7}$$

where:
L_J = characteristic joint spacing,
L = total length of flange in the gage length for the qualification sample, and
N = total number of joints in the gage length for the qualification sample.

~~6.3.1.3~~
6.4.1.3 *Tension Tests*~~—For flange material conforming to 6.3.1.2, (*b*~~—For flange material conforming to 6.4.1.2 (*2*) or (~~*c*~~*3*), tension tests parallel to grain shall be conducted on a gage length (distance between grips) of not less than 8 ft (2.44 m) for sawn lumber and 3 ft (0.91 m) for structural composite lumber. When flanges utilize sawn lumber or structural composite lumber less than 8 ft long, the characteristic end joint spacing for the qualification sample shall comply with the provisions of ~~6.3.1.2~~6.4.1.2 (~~*c*~~*3*). Testing speed shall be in accordance with 28.3 of Test Methods ~~D 4761.~~D4761. The minimum sample size shall be 53. The flange material variability (coefficient of variation) and tension gage length shall be reported.

NOTE ~~7—SPS-4~~ 8—SPS-4 provides alternative methods which comply with the intent of characteristic joint spacing and minimum gage length provisions of ~~6.3~~6.4.

~~6.3.1.4~~6.4.1.4 *Capacity*—The tensile capacity shall be the lower 5 % tolerance limit with 75 % confidence, divided by 2.1. The lower 5 % tolerance limit shall be established with 75 % confidence using either parametric or nonparametric procedures; however, if parametric procedures are adopted, an appropriate analysis used to confirm the type of distribution must be presented. Minimal evidence that a distribution fits the data shall consist of a cumulative plot of the data with the chosen distribution superimposed on the data. The latter shall be either a curve as shown in Fig. X4.1 or a linearized plot as shown in Fig. X4.5.

~~6.3.1.5~~
6.4.1.5 The length adjustment factor K_L is the lesser of 1.0 or the value computed as follows:

$$K_L = K_S\,(L_1/L)^Z \leq 1.0 \tag{8}$$

where:

K_L = ~~length adjustment factor,~~ length adjustment factor;
K_S = stress distribution adjustment factor (adjusts design flange axial stress (F_a) from full-length constant stress (such as a tension test) to the reference stress condition = ~~1.15,~~ 1.15;
L_1 = gage length, (in.). For ~~6.3.1.2~~6.4.1.2 (~~a~~1) utilizing flange stress, L_1 ~~= 144 in. For 6.3.1.2~~ = 144 in. (3658 mm). For 6.4.1.2 (~~b~~2) utilizing flange stress, L_1 = distance between tension tester grips. For ~~6.3.1.2~~6.4.1.2 (~~c~~3) utilizing flange stress, L_1 = distance between tension tester grips. For ~~6.3.1.2~~6.4.1.2 (~~a~~1) and (~~b~~2) utilizing end joint stress, L_1 = minimum end joint spacing allowed in the ~~I-joist.~~ I-joist;
L = joist span = 18 times the joist depth ~~(in.),~~(in.); and
Z = exponent for Eq 8 in accordance with Table 1.

NOTE ~~8—K~~ 9—K_L is not intended for use as an adjustment factor for specific application lengths. It is a modifier for assigning design I-Joist moment capacity by depth. (See Eq ~~6.~~6.)

~~6.3.1.6~~6.4.1.6 Values for compression shall be established by testing the material in tension and assigning a value in compression such that:

$$F_{ci} = F_{ti}(F_c/F_t) \quad (9)$$

where:
F_t = closest assigned code value in tension for same species and size as tested ~~pieces,~~ pieces;
F_c = code assigned value in compression for same grade, species, and size as F_t ~~visual grades,~~ visual grades;
F_{ti} = tensile value as determined in ~~6.3.1.3~~6.4.1.3~~,~~; and
F_{ci} = allowable stress in compression.

If F_{ti} is larger than the highest value given in tables of visual grade lumber for the species, then the ratio of tension to compression shall be from tables for the nearest machine stress rated (MSR) lumber grade.

~~6.3.2~~

6.4.2 *Analytical Method Confirming Tests*:

6.3~~4~~.2.1 It is required that a minimum of ten I-joist specimens be tested at each of the extremes of flange size, allowable stress, and joist depth. This testing is not intended to substantiate the moment capacity determined in ~~6.3.1~~6.4.1, but is considered necessary for any new product to generally confirm the overall performance of the assembled components. This testing is also necessary to satisfy the requirements of ~~6.5~~6.6.

6.3~~4~~.2.2 Test setup and procedures shall conform to the requirements of ~~6.3.3~~6.4.3, except that loading may simulate uniform load with load points spaced no greater than 24 in. (610 mm) on center. In addition, the maximum permitted web hole specified in ~~6.3.3.2~~6.4.3.2 is optional.

~~6.3.2.3Any specimen failing at a calculated maximum moment of less than 2.1 times the calculated capacity indicates the possibility of errors in manufacturing, material selection, or calculation. The reason for such failures shall be carefully evaluated and further tests conducted as indicated.~~

~~6.3.3~~

6.4.2.3 Any specimen failing at a calculated maximum moment of less than 2.1 times the calculated capacity indicates the possibility of errors in manufacturing, material selection, or calculation. The reason for such failures shall be carefully evaluated and probable cause determined. Further testing shall be conducted as indicated in 6.4.2.4 and 6.4.2.5.

6.4.2.4 If the determined probable cause identified in 6.4.2.3 results in manufacturing or design changes of the product, retesting shall be conducted in accordance with 6.4.2.1.

6.4.2.5 If a probable cause is not found and the low result cannot be attributed to errors that can be corrected, further testing shall be conducted. A minimum of 10 additional samples for parametric analysis or 43 additional samples for nonparametric statistics shall be tested. The tested moment capacity shall be the lower 5 % tolerance limit with 75 % confidence divided by 2.1. To confirm the analytical method, the tested moment capacity shall be greater than or equal to the calculated moment capacity determined in 6.4.1.1.

TABLE 1 Exponent (*Z*) for Eq 8[A]

COV[B,C], %	Z
≤10	0.06
15	0.09
20	0.12
25	0.15
≥30	0.19

[A] Interpolation between tabular values is permitted.
[B] Coefficient of variation of the full data set based on a normal distribution, taken as not less than the higher COV attained from the tensile strength of flange material or end joints.
[C] Coefficient of variation for 6.3~~4~~.1.2(~~a~~1) material shall be 20 % for machine-graded lumber (including SPS-4 material) and 25 % for visually graded lumber.

NOTE 10—Although it is unlikely that in a ten-specimen confirming test of a controlled manufacturing process, a result below 2.1 times the calculated capacity will be encountered, it is statistically possible that such a specimen could appear. Increasing the sample size and applying parametric or nonparametric procedures to analyze the data will determine if changes to the analytical moment capacity are needed. (See commentary in X1.5.3.)

6.4.3 *Empirical Method*:

~~6.3.3.1~~

6.4.3.1 *Test Procedure*—Bending tests are to be conducted on a span of 17 to 21 times the joist depth. Two point loads are to be placed symmetrically about the center and the spacing between such load points shall be a minimum of one third of the span. Joists shall be reinforced under the load points when necessary to prevent local failure. Load rate shall be adjusted to produce failure in not less than 1 min. Maximum moment in the specimen and the location of failure shall be recorded.

NOTE ~~9—A~~ 11—A span to depth ratio of 18 is a frequent international practice.

~~6.3.3.2~~6.4.3.2 *Specimens Tested*—Specimens shall be typical of intended production. Each flange material, grade, dimension, species and supplier, combined with each web type, thickness and grade, shall be tested. Procedures for evaluating materials from each supplier shall be addressed in the manufacturing standard. One method of evaluation is shown in X1.1.1.8. When flanges contain end joints, such joints shall have been qualified in accordance with ~~6.4.1~~6.5.1, and all bending test specimens shall include at least one joint in the tension flange located between the load points. When holes are allowed in the web in accordance with ~~6.6~~6.7, the maximum permitted hole shall be located approximately at the center of the span. Sufficient bearing length or reinforcement, or both, shall be provided at supports to prevent bearing failures.

~~6.3.3.3~~

6.4.3.3 *Remanufactured Solid Sawn Flanges*—When flanges utilize remanufactured lumber, the specimens tested shall be typical of the specifications in the manufacturing standard in accordance with 9.1.1.1.

NOTE ~~10—It is strongly recommended that plant personnel performing regrading activities be trained by an agency under an accreditation program such as the American Lumber Standards Committee.~~

~~6.3.3.4*Sample Size and Analysis (Alternative 1—Testing to evaluate the web contribution to the joist moment capacity)*— The joist moment capacity shall not exceed the value calculated by multiplying the transformed joist section modulus (deducting the maximum anticipated hole size) and the flange tensile stress. The flange tensile stress shall be determined in accordance with 6.3.1. For qualification, a minimum of 28 specimens in each tested depth shall be tested at joist depth intervals no greater than 4 in. (102 mm). Moment capacity shall be the lower 5% tolerance limit with 75% confidence, divided by 2.1. Nonparametric statistics shall be used to determine the tolerance limit and confidence unless justification is presented for using parametric procedures. The moment capacity of I-joist depths not tested shall show logical progression as a function of the transformed joist section modulus between values assigned at the nearest depths tested to either side.~~

~~6.3.3.5*Sample Size and Analysis (Alternative 2—Testing to evaluate joist moment capacity based on full scale bending tests)*~~ 12—It is strongly recommended that plant personnel performing regrading activities be trained by an agency under an accreditation program such as the ALSC.

6.4.3.4 *Sample Size and Analysis*—For qualification, a minimum of 28 specimens are required in each tested depth. Testing shall be at joist depth intervals no greater than 3 in. (76 mm), with a minimum of four depths tested, including the minimum and maximum joist depths. The mean ultimate moment capacities shall show logical progression as a function of the depth squared. A linear regression analysis of the mean values shall have a coefficient of determination (r^2) of at least 0.9. If the manufacturer produces less than 4 depths, 53 specimens of each depth shall be tested, but the requirement for a coefficient of determination shall not apply. Moment capacity shall be based on the lower 5 % tolerance limit with 75 % confidence, divided by 2.1. Nonparametric statistics shall be used to determine the tolerance limit and confidence unless justification is presented for using parametric procedures. Joist depths not tested shall be assigned capacities based on a logical progression of the depth squared between values assigned at the nearest depths tested to either side.

~~6.4~~

6.5 *End Joint Qualification*:

~~6.4.1~~

6.5.1 *Standards*—Adhesives used in joints shall conform to the requirements of ~~5.3~~5.4.

~~6.4.2~~

6.5.2 *Testing*—Tension tests parallel to grain, on full-section joints, shall be conducted on a gage length (distance between grips) of not less than 2 ft (0.61 m). Testing speed shall be in accordance with 28.3 of Test Methods ~~D 4761.~~D4761. The minimum sample size shall be 53. The design stress shall be determined from ~~6.3.1.4~~6.4.1.4. End joint variability (coefficient of variation) shall be reported.

~~6.4.3~~

6.5.3 *Requirements*—Joints in any flange material shall conform to this specification, with particular reference to Section 10 when applicable.

~~6.5~~

6.6 *Stiffness Capacity and Creep*:

~~6.5.1~~

6.6.1 *Tests*—The tests of ~~6.3.2~~6.4.2 or the first ten tests at the extremes of depth in accordance with ~~6.3.3~~6.4.3 shall be used to confirm stiffness capacity and evaluate creep characteristics. Center span deflection measurements shall be recorded at a minimum of four increments to 1½ times expected moment capacity at time of qualification.

6.5.2
6.6.2 *Stiffness Capacity*—Any formula which accurately predicts the effects of both bending and shear deformation is permitted to be used. The equation must be adjusted when the mean of the ratios of test deflections at moment capacity load (determined from a least square line fitted through the data points), to predicted deflection is more than $1.0 + S/\sqrt{N}$, where S is the standard deviation of the ratios of test to predicted deflections and N is the total number of deflection tests conducted.

NOTE 113—Usually, a required adjustment will be applied only to the flange modulus of elasticity (MOE) used in the equation. For stiffness-limited applications of I-joists, the largest percentage of deflection is typically attributed to bending, and because of the section geometry, the principle elastic modulus is that of the flange material. Therefore, here and in Sections 9 and 11, emphasis is placed on the flange modulus of elasticity (MOE).

6.5.2.1, *emphasis is placed on the flange MOE.*
6.6.2.1 *Elastic Properties*—Mean values are to be used in the deflection equation (a1) when flange modulus of elasticity cannot be obtained from tables of recognized values, it shall be obtained from tests of the flange material used to establish moment capacity in accordance with 6.3.16.4.1;; or (b2) when moment capacity is determined in accordance with 6.3.36.4.3, the flange MOE shall be obtained from tables of recognized values or tests of the flange material. (c3) Elastic properties of the web material shall be obtained from the appropriate standard.

6.5.3
6.6.3 *Creep*—Two of the I-joist specimens shall be loaded to 20 % of their moment capacity and center-span deflection readings taken. For purposes of this test, 20 % is assumed to be typical basic dead load (BDL). The specimen shall then be loaded to 1½ times the moment capacity for 1 h and deflection readings taken. The specimen shall be unloaded to BDL and deflection readings shall be taken after 15 min. The specimens must recover an average of 90 % of the total deflection from BDL to the end of the 1-h load period.

6.6
6.7 *Details of End Use*:
6.6.1
6.7.1 The intent of this section is to define common application details. In addition to the following minimum considerations, other details which affect application performance shall be investigated (for example, minimum nail spacing to avoid splitting).

6.6.2*Bearing Length Qualification Tests*— Tests shall be conducted to determine recommended bearing lengths. The tests shall establish:
6.6.2.1The minimum bearing lengths without web reinforcement that will develop ultimate shear capacity.
6.6.2.2The minimum bearing lengths with specified web reinforcement that will develop ultimate shear capacity.
6.6.2.3Any special requirements at interior supports of multi-span joists.
6.6.2.4A minimum of five tests shall be conducted for each of the three conditions. Special details must be qualified with additional test specimens. Reinforcing materials shall be specified including size, fit, tolerance, and connections.

6.6.3
6.7.2 *Web Openings*:
6.6.3.1Holes6.7.2.1 Holes which remove a significant portion of the web will reduce shear strength at that section of the I-joist. Tests are to define such reductions for varying size and shape openings so that in application, openings can be located at sections subjected to appropriate shear levels. A minimum of five specimens of at least three depths encompassing the product range shall be tested for each depth/opening combination. Test specimens and setup are permitted to be the same as specified in 6.2 with an opening located between support and load points and centered on a web joint, when web joints exist in the product.
6.6.3.2Maximum6.7.2.2 Maximum size hole which can be located anywhere in the web, shall be specified by the manufacturer and supported by data.
6.6.3.3Spacing6.7.2.3 Spacing of allowed multiple holes must be verified by test.
6.6.46.7.3 *Special Details*—Depending on joist configuration, concentrated loads require local reinforcement. Loads supported by connection to the web or applied to the bottom flange require special consideration and appropriate details. These and other special conditions of application require appropriate evaluation and testing to ensure the safety provisions of this specification are maintained.

7. Design Values

7.1 *Design Value Limited*—Design values are determined from the analysis and capacities as specified in this specification. In no case shall a design value exceed the capacity determined in Sections 6 or 11. (See definitions of capacity and design value in 3.23.1.1.)

7.2 *Design Value*—It is the responsibility of the I-joist producer to determine design values. Judgment is required particularly when assessing design values from qualification tests. Design values shall consider potential low-line lot capacities to avoid marginal application performance or uneconomical reject rates in the quality assurance program.

8. Independent Inspection

8.1 A qualified agency shall be employed by the manufacturer for the purpose of monitoring the quality assurance production process on a random unannounced basis. The qualified independent agency shall establish (or approve) and maintain procedures for quality assurance.

8.2 A qualified agency is defined as one that:

8.2.1 Has trained technical personnel to verify that the grading, measurement, species, construction, shaping, bonding, workmanship, and other characteristics of the products as determined by inspection, sampling, and testing comply with all applicable requirements specified herein;

8.2.2 Has procedures to be followed by its personnel in performance of the inspection and testing; and

8.2.3 Has no financial interest in, or is not financially dependent upon, any single company manufacturing the product being inspected or tested; and is not owned, operated, or controlled by any such company.

9. In-House Quality Assurance

9.1 *Manufacturing Standard*:

9.1.1 A manufacturing standard shall be written and maintained for each product and each production facility and shall be the basis for the qualified agency's specific inspection at that location. As a minimum, it shall include the following:

9.1.1.1 Material specifications, including incoming inspection and acceptance requirements, and specifications for regrading flange stock when applicable,

9.1.1.2 Process controls for each operation in production of the product,

9.1.1.3 Quality control, inspection and testing procedures, and frequencies, and

9.1.1.4 Finished product identification, handling, protection, and shipping requirements.

9.1.1.5 When applicable, the minimum permitted flange joint spacing shall be specified.

9.2 *Inspection Personnel*—All in-house persons responsible for quality control shall demonstrate to the satisfaction of the qualified agency that they have adequate knowledge of the manufacturing process, of the inspection and test procedures used to control the process, of the operation and calibration of the recording and test equipment used, and of the maintenance and interpretation of quality control records.

9.3 *Record Keeping*—All pertinent records shall be maintained on a current basis and be available for review by both in-house and qualified agency inspection personnel. As a minimum, such records shall include:

9.3.1 All inspection reports and records of test equipment calibration whether accomplished by in-house or qualified agency personnel,

9.3.2 All test data, including retests and data associated with rejected production, and

9.3.3 Details of any corrective actions taken and the disposition of any rejected production, resulting from tests or inspections.

9.4 *Testing Equipment*—Testing equipment is to be properly maintained, calibrated, and evaluated for accuracy and adequacy in accordance with 6.1.1.3, at a frequency satisfactory to the qualified agency.

9.5 *I-Joist Quality Control Testing*:

9.5.1 *Objectives*—The following objectives are to be met simultaneously with the quality-control testing program:

9.5.1.1 Provide test data for use in maintaining and updating design values, and

9.5.1.2 Verify production process and material quality on a daily basis.

9.5.2 *Initial Quality Control*—When qualification is based on no more than the minimum testing required in this specification, the producer shall initiate higher test frequencies and retest levels. All new producers are advised to intensify quality control in early production.

9.5.3 *Required Tests*—The following shall be the scope of a minimum testing program:

9.5.3.1 Test methods shall be identical to those of Section 6.

9.5.3.2 The shear strength test described in 6.2 shall be used for quality control of shear strength. This test is required even if qualification is by calculation.

9.5.3.3 If flanges contain end joints qualified in accordance with ~~6.4~~6.5, daily tension tests of full-section joints shall be conducted and failure loads recorded. The manufacturing standard must include the characteristic joint spacing that will be maintained in production. Durability tests of such joints are required only at such frequency as required to verify adhesive performance in accordance with ~~5.3~~5.4.

9.5.3.4 When flange material is qualified by test in accordance with ~~6.3.1.2~~6.4.1.2 (~~*b*) or 6.3.1.2~~ 2) or 6.4.1.2 (~~*c*~~3), the testing of that section shall be included in daily quality control tests. In all cases, QA provisions shall be established to maintain qualification strength.

9.5.3.5 When moment capacity is determined empirically, the test detailed in ~~6.3.3~~6.4.3 shall be conducted as part of the daily quality-control program. All depths produced shall be tested in this program, and the tests shall include deflection measurement.

9.5.3.6 When the flange material does not have a modulus of elasticity assigned by the code, stiffness measurement of the material shall be part of the quality-control program.

9.5.4 *Data Collection and Analysis*—Test frequency, minimum test values, and rejection criteria for all tests of 9.5.3 shall be chosen to yield quality-control performance which is consistent with design values assigned to the product and its intended use.

10. Qualification and Quality Assurance of I-Joist Components Manufactured by Others

10.1 *Producer's Responsibility*—When the I-joist producer purchases material which would require qualification and quality control under the provision of this specification, the I-joist producer shall be responsible for assuring that, as a minimum, such material conforms to the requirements of Sections 6~~, 8~~, 8, 9, and 11 of this specification.