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Standard Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products[1]

This standard is issued under the fixed designation D2915; 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.

INTRODUCTION

Sampling and data analysis should be integrated in the design and evaluation of wood and wood-based structural products. This practice is useful in assessing the appropriateness of the assigned properties and for checking the effectiveness of grading procedures. Statistical methodologies are provided to serve as a basis for the empirical establishment and evaluation of mean and near minimum property estimates. These population estimates are then used by product standards to assign structural design values for use with an established design methodology (that is, allowable stress design, load and resistance factor design, limit states design, etc.). Near-minimum property estimates are typically used by the product standards to define the performance for a variety of structural properties where strength is a primary consideration (that is, extreme fiber stress in bending, axial tension, axial compression, shear, and elasticity for buckling concerns). Population mean estimates are often used to assess serviceability design criteria where strength is not the primary design concern (that is, elasticity estimates used for deformation calculations, permissible compression stress at a deformation, etc.).

For situations where a manufactured product is sampled repeatedly or lot sizes are small, alternative test methods as described in Ref (**1**)[2] may be more applicable.

1. Scope

1.1 This practice covers sampling and analysis procedures for the investigation of specified populations of wood and wood-based structural products referred to in this standard as products. Appropriate product standards should be referenced for presentation requirements for data. Depending on the interest of the user, the population from which samples are taken may range from the products produced at a specific manufacturing site to all the products produced in a particular grade from a particular geographic area, during some specified interval of time. This practice generally assumes that the population is sufficiently large so that, for sampling purposes, it may be considered infinite. Where this assumption is inadequate, that is, the population is assumed finite, many of the provisions of this practice may be employed but the sampling and analysis procedure must be designed to reflect a finite population. The statistical techniques embodied in this practice provide procedures to summarize data so that logical judgments can be made. This practice does not specify the action to be taken after the results have been analyzed. The action to be taken depends on the particular requirements of the user of the product.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 This practice does not purport to address the adjustment factors needed to adjust test data to standardized mechanical and environmental conditions (that is, temperature, moisture, test span, or load duration). Additionally, it provides a basis for statistical estimates that will typically require further adjustment to determine design values for use with an accepted design methodology (that is, allowable stress, limit states, or load and resistance factor design). It shall be the responsibility of the user to seek out the appropriate adjustments in specific product standards.

1.4 *This practice 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.*

[1] This practice 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.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D9 Terminology Relating to Wood and Wood-Based Products
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
D2555 Practice for Establishing Clear Wood Strength Values
D3737 Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)
D5055 Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists
D5456 Specification for Evaluation of Structural Composite Lumber Products
D6570 Practice for Assigning Allowable Properties for Mechanically Graded Lumber
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E105 Practice for Probability Sampling of Materials

3. Terminology

3.1 *Definitions*—For definitions of terms related to wood, refer to Terminology D9.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *established design methodology, n*—methodology used to determine if a structure will perform adequately using structural design values.

3.2.1.1 *Discussion*—

Established design methods currently used include allowable stress design, load and resistance factor design, limit states design.

3.2.2 *products, n*—wood and wood-based structural products.

3.2.3 *serviceability, n*—condition other than the building strength under which a building is still considered useful.

3.2.3.1 *Discussion*—

Serviceability limit state design of structures includes factors such as durability, overall stability, fire resistance, deflection, cracking, and excessive vibration.

3.2.4 *strength, n*—level of stress expressed in terms of force per area being evaluated for design.

3.2.5 *structural design values, n*—unit stresses and stiffness values utilized in design.

3.2.5.1 *Discussion*—

Structural design values are test results adjusted for duration of load, factor of safety, and expected service conditions.

3.2.6 *tolerance limit (TL), n*—tolerance limit with 95 % content and 75 % confidence.

4. Statistical Methodology

4.1 Two general analysis procedures are described under this practice: parametric and nonparametric. A nonparametric approach requires fewer assumptions and is generally more conservative than a parametric procedure. The parametric approach assumes a known distribution of the underlying population, an assumption which, if incorrect, may lead to inaccurate results. Some examples of parametric distributions are normal, lognormal and Weibull. Therefore, if a parametric approach is used, appropriate statistical tests shall be employed to substantiate this choice along with measures of test adequacy (**2**). For parametric approaches in this practice, the examples provided are based on assuming normality.

NOTE 1—The assumption of "normality" in the examples is not a given and should be verified before using in real cases. A nonparametric approach requires fewer assumptions and is generally more conservative than a parametric procedure.

[3] 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.

4.2 *Population:*

4.2.1 It is imperative that the population to be evaluated be clearly defined, as inferences made pertain only to that population. In order to define the population, it may be necessary to specify (*1*) grade name and description, (*2*) geographical area over which sampling will take place (nation, state, manufacturing site, etc.), (*3*) species or species group, (*4*) time span for sampling (a day's production, a month, a year, etc.), (*5*) material dimensions, and (*6*) moisture content.

4.2.2 The sampling program should consider the population from which the test specimens originated, including types of processing methods or marketing practices with respect to any influence they may have on the representative nature of the sample. Test specimens may be collected from stock at manufacturing sites, centers of distribution, at points of end use or directly from current production. Sampling programs should consider potential effects of the sample source, timing, and location on the variability of specimen properties.

4.3 *Sampling Procedure:*

4.3.1 *Random Sampling*—The sampling unit is commonly the individual test specimen. When this is not the case, see 4.3.3. The sampling shall assure random selection of sampling units from the population described in 4.2 with all members of the population sharing equal probability of selection. The principles of Practice E105 shall be maintained. When sampling current production, refer to Practice E105 for a recommended sampling procedure (see Appendix X3 of this practice for an example of this procedure). If samples are selected from inventory, random number tables may be used to determine which pieces will be taken for the sample.

4.3.2 *Sampling with Unequal Probabilities*—Under some circumstances, it may be advisable to sample with unequal but known probabilities. Where this is done, the general principles of Practice E105 shall be maintained, and the sampling method shall be completely reported.

4.3.3 *Sequential Sampling*—When trying to characterize how a certain population may perform in a structure, it may be deemed more appropriate to choose a sampling unit, such as a package, that is more representative of how the product will be selected for use. Such a composite sampling unit might consist of a sequential series of pieces chosen to permit estimation of the properties of the unit as well as the pieces. Where this is done, the principles in 4.3.1 and 4.3.2 apply to these composite sampling units and the sampling method shall be completely reported.

4.4 *Sample Size:*

4.4.1 Selection of a sample size depends upon the property or properties to be estimated, the actual variation in properties occurring in the population, and the precision with which the property is to be estimated. For any property, strength values, or the modulus of elasticity, various percentiles of the population may be estimated and for all properties, nonparametric or parametric techniques are applicable. Commonly, the mean is estimated for properties which will eventually be used by the product standard to evaluate a serviceability design concern. Near minimum property estimates are typically evaluated for properties where strength is the primary objective.

4.4.2 Determine sample size sufficient for estimating the mean by a two-stage method, with the use of the following equation. This equation assumes the data is normally distributed and the mean is to be estimated to within 5 % with specified confidence:

$$n = \left(\frac{ts}{\alpha \bar{X}}\right)^2 = \left(\frac{t}{\alpha} CV\right)^2 \quad (1)$$

where:

n = sample size,
s = standard deviation of specimen values,
$\bar{X}$ = specimen mean value,
CV = coefficient of variation, $s/\bar{X}$,
α = estimate of precision, (0.05), and
t = value of the t statistic from Table 1.

Often, the values of s,$\bar{X}$, and t or CV and t are not known before the testing program begins. However, s and $\bar{X}$, or CV, may be approximated by using the results of some other test program, or they may simply be guessed.

NOTE 2—An example of initial sample size calculation is:

Sampling a grade of lumber to determine its mean modulus of elasticity (E). Assuming a 95 % confidence level, the t statistic can be approximated by 2.

s = 300 000 psi (2067 MPa)
$\bar{X}$ = assigned E of the grade = 1 800 000 psi (12 402 MPa)
CV = (300 000 ⁄1 800 000) = 0.167
t = 2
$n = \left(\frac{2}{0.05} \times 0.167\right)^2 = 44.622$ (45 pieces)

Calculate the sample mean and standard deviation and use them to estimate a new sample size from Eq 1, where the value of t is taken from Table 1. If the second sample size exceeds the first, the first sample was insufficient; obtain and test the additional specimens.

NOTE 3—More details of this two-stage method are given in Ref (**3**).

4.4.3 Tolerance intervals and their associated tolerance limits can be one-sided or two-sided. In the examples of this standard, it is assumed that the limits are one-sided lower limits. To determine sample size based on a tolerance limit (TL), the desired

TABLE 1 Values of the *t* Statistics Used in Calculating Confidence Intervals[A]

df *n* – 1	*CI* = 75 %	*CI* = 95 %	*CI* = 99 %
1	2.414	12.706	63.657
2	1.604	4.303	9.925
3	1.423	3.182	5.841
4	1.344	2.776	4.604
5	1.301	2.571	4.032
6	1.273	2.447	3.707
7	1.254	2.365	3.499
8	1.240	2.306	3.355
9	1.230	2.262	3.250
10	1.221	2.228	3.169
11	1.214	2.201	3.106
12	1.209	2.179	3.055
13	1.204	2.160	3.012
14	1.200	2.145	2.977
15	1.197	2.131	2.947
16	1.194	2.120	2.921
17	1.191	2.110	2.898
18	1.189	2.101	2.878
19	1.187	2.093	2.861
20	1.185	2.086	2.845
21	1.183	2.080	2.831
22	1.182	2.074	2.891
23	1.180	2.069	2.807
24	1.179	2.064	2.797
25	1.178	2.060	2.787
26	1.177	2.056	2.779
27	1.176	2.052	2.771
28	1.175	2.048	2.763
29	1.174	2.045	2.756
30	1.173	2.042	2.750
40	1.167	2.021	2.704
60	1.162	2.000	2.660
120	1.156	1.980	2.617
∞	1.150	1.960	2.576

[A] Adapted from Ref **(3)**. For calculating other confidence levels, see Ref **(3)**.

content (C) and associated confidence level must be selected (Note 4). The choice of a specified content and confidence is dependent upon the end-use of the material, economic considerations, current design practices, code requirements, etc. For example, a content of 95 % and a confidence level of 75 % may be appropriate for a specific property of structural lumber. Different confidence levels may be suitable for different products or specific end uses. Appropriate content and confidence levels shall be selected before the sampling plan is designed.

NOTE 4—The content is an estimate of the proportion of the population that lies above the tolerance limit. For example, a tolerance limit with a content of 95 % describes a level at which 95 % of the population lies above the tolerance limit. The confidence level is the percentage of time that the desired content is expected to be achieved through sampling.

4.4.3.1 To determine the sample size for near-minimum properties, the nonparametric tolerance limit concept of Ref **(3)** may be used (Table 2). This will provide the sample size suitable for several options in subsequent near-minimum analyses. Although the frequency with which the tolerance limit will fall above (or below) the population value, corresponding to the required content, is controlled by the confidence level selected, the larger the sample size the more likely the tolerance limit will be close to the population value. It is, therefore, desirable to select a sample size as large as possible commensurate with the cost of sampling and testing (see also 5.4).

4.4.3.2 If a parametric approach is used, then a tolerance limit with stated content and confidence can be obtained for any sample size; however, the limitation expressed in 4.4.3.1 applies. That is, although the frequency that the tolerance limit falls above (or below) the population value, corresponding to the required content is controlled, the probability that the tolerance limit will be close to the population value depends on the sample size. For example, if normality is assumed, the parametric tolerance limit (PTL) will be of the form
$PTL = \bar{X} - Ks$, (see Ref **(3)**), and the standard error (SE) of this statistic may be approximated by the following equation:

TABLE 2 Sample Size and Order Statistic for Estimating the 5 % Nonparametric Tolerance Limit, NTL[A]

75 % Confidence[B]		95 % Confidence		99 % Confidence	
Sample Size[C]	Order Statistic[D]	Sample Size	Order Statistic	Sample Size	Order Statistic
28	1	59	1	90	1
53	2	93	2	130	2
78	3	124	3	165	3
102	4	153	4	198	4
125	5	181	5	229	5
148	6	208	6	259	6
170	7	234	7	288	7
193	8	260	8	316	8
215	9	286	9	344	9
237	10	311	10	371	10
259	11	336	11	398	11
281	12	361	12	425	12
303	13	386	13	451	13
325	14	410	14	478	14
347	15	434	15	504	15
455	20	554	20	631	20
562	25	671	25	755	25
668	30	786	30	877	30
879	40	1013	40	1115	40
1089	50	1237	50	1349	50

[A] Adapted from Ref **(8)**. For other tolerance limits or confidence levels, see Ref **(5)**, **(8)**, or **(9)**.

[B] The shaded columns indicate the tolerance levels traditionally used for most wood and wood-based products.

[C] Where the sample size falls between two order statistics (for example, 27 and 28 for the first order statistic at 75 confidence), the larger of the two is shown in the table, and the confidence is greater than the nominal value.

[D] The rank of the ordered observations, beginning with the smallest.

$$SE = s\sqrt{\frac{1}{n}+\frac{K^2}{2(n-1)}} \tag{2}$$

where:

s = standard deviation of specimen values,
n = sample size, and
K = confidence level factor from Table 3.

The sample size, n, may be chosen to make the standard error sufficiently small for the intended end use of the material.

NOTE 5—An example of sample size calculation where the purpose is to estimate a near minimum property is shown in the following calculation based on the assumption of normality of population.

Estimate the sample size, n, for a compressive strength parallel to grain test in which normality will be assumed. A CV of 22 % and a mean strength of 4600 psi are assumed based on other tests. The target PTL of the grade is 2700 psi. The PTL is to be estimated with a content of 95 % (5 % PTL) and a confidence of 75 %.

CV = 0.22
$\bar{X}$ = 4600 psi (31.7 MPa)
s = (0.22) (4600) = 1012 psi (7.0 MPa)
K = $(\bar{X} - PTL)/s$ = (4600-2700)/1012 = 1.877

From Table 3:

K = 1.869 for $n = 30$

Therefore, $n \approx 30$ specimens.

$$SE = 1012\sqrt{\frac{1}{30}+\frac{1.877^2}{2(30-1)}} \tag{3}$$

$$=310 \text{ psi } (2.14 \text{ MPa})$$

Consequently, although 30 specimens is sufficient to estimate the 5 % PTL with 75 % confidence, the standard error (approximately 12 % of the PTL) illustrates that, with this size sample, the PTL estimated by test may not be as close to the true population fifth percentile as desired. A larger n may be desirable.

TABLE 3 K Factors for One-Sided Tolerance Limits for Normal Distributions[A]

	75 % Confidence (g = 0.25)				95 % Confidence (g = 0.05)				99 % Confidence (g = 0.01)			
1-p	0.75	0.90	0.95[B]	0.99	0.75	0.90	0.95	0.99	0.75	0.90	0.95	0.99
*n*3	1.464	2.501	3.152	4.397	3.805	6.156	7.657	10.555	8.726	13.997	17.374	23.900
4	1.255	2.134	2.681	3.726	2.617	4.162	5.145	7.044	4.714	7.381	9.085	12.389
5	1.151	1.962	2.464	3.422	2.149	3.407	4.203	5.742	3.453	5.362	6.580	8.941
6	1.087	1.859	2.336	3.244	1.895	3.007	3.708	5.063	2.847	4.412	5.407	7.336
7	1.043	1.790	2.251	3.127	1.732	2.756	3.400	4.643	2.490	3.860	4.729	6.413
8	1.010	1.740	2.189	3.042	1.617	2.582	3.188	4.355	2.253	3.498	4.286	5.813
9	0.984	1.702	2.142	2.978	1.532	2.454	3.032	4.144	2.083	3.241	3.973	5.390
10	0.964	1.671	2.104	2.927	1.465	2.355	2.912	3.982	1.954	3.048	3.739	5.075
11	0.946	1.646	2.074	2.886	1.411	2.276	2.816	3.853	1.852	2.898	3.557	4.830
12	0.932	1.625	2.048	2.852	1.366	2.210	2.737	3.748	1.770	2.777	3.411	4.634
13	0.919	1.607	2.026	2.823	1.328	2.156	2.671	3.660	1.702	2.677	3.290	4.473
14	0.908	1.591	2.008	2.797	1.296	2.109	2.615	3.585	1.644	2.593	3.189	4.338
15	0.899	1.577	1.991	2.776	1.267	2.069	2.566	3.521	1.595	2.522	3.103	4.223
16	0.890	1.565	1.977	2.756	1.242	2.033	2.524	3.465	1.552	2.460	3.028	4.124
17	0.883	1.555	1.964	2.739	1.220	2.002	2.487	3.415	1.514	2.405	2.963	4.037
18	0.876	1.545	1.952	2.724	1.200	1.974	2.453	3.371	1.480	2.357	2.906	3.961
19	0.869	1.536	1.942	2.710	1.182	1.949	2.424	3.331	1.450	2.314	2.854	3.893
20	0.864	1.528	1.932	2.697	1.166	1.926	2.396	3.296	1.423	2.276	2.808	3.832
21	0.858	1.521	1.924	2.686	1.151	1.906	2.372	3.263	1.398	2.241	2.767	3.777
22	0.854	1.514	1.916	2.675	1.138	1.887	2.349	3.234	1.376	2.209	2.729	3.727
23	0.849	1.508	1.908	2.666	1.125	1.869	2.329	3.207	1.355	2.180	2.695	3.682
24	0.845	1.502	1.901	2.657	1.113	1.853	2.310	3.182	1.336	2.154	2.663	3.640
25	0.841	1.497	1.895	2.648	1.103	1.838	2.292	3.159	1.319	2.129	2.634	3.602
30	0.825	1.475	1.869	2.614	1.058	1.778	2.220	3.064	1.247	2.030	2.516	3.447
35	0.812	1.458	1.849	2.588	1.025	1.732	2.167	2.995	1.194	1.958	2.430	3.335
40	0.802	1.445	1.834	2.568	0.999	1.697	2.126	2.941	1.154	1.902	2.365	3.249
45	0.794	1.434	1.822	2.552	0.978	1.669	2.093	2.898	1.121	1.857	2.312	3.181
50	0.788	1.426	1.811	2.539	0.960	1.646	2.065	2.863	1.094	1.821	2.269	3.125
60	0.777	1.412	1.795	2.518	0.932	1.609	2.023	2.808	1.051	1.764	2.203	3.039
70	0.769	1.401	1.783	2.502	0.911	1.581	1.990	2.766	1.019	1.722	2.153	2.974
80	0.762	1.393	1.773	2.489	0.894	1.560	1.965	2.733	0.994	1.689	2.114	2.924
90	0.757	1.386	1.765	2.479	0.881	1.542	1.944	2.707	0.974	1.662	2.083	2.884
100	0.753	1.380	1.758	2.470	0.869	1.527	1.927	2.684	0.957	1.639	2.057	2.850
120	0.745	1.371	1.747	2.456	0.851	1.503	1.900	2.650	0.930	1.604	2.016	2.797
140	0.740	1.364	1.739	2.446	0.837	1.485	1.879	2.623	0.909	1.577	1.985	2.758
160	0.736	1.358	1.733	2.438	0.826	1.471	1.862	2.602	0.893	1.556	1.960	2.726
180	0.732	1.353	1.727	2.431	0.817	1.460	1.849	2.585	0.879	1.539	1.940	2.700
200	0.729	1.350	1.723	2.425	0.809	1.450	1.838	2.570	0.868	1.524	1.923	2.679
250	0.723	1.342	1.714	2.414	0.794	1.431	1.816	2.542	0.846	1.496	1.891	2.638
300	0.719	1.337	1.708	2.406	0.783	1.417	1.800	2.522	0.830	1.476	1.868	2.609
350	0.715	1.332	1.703	2.400	0.775	1.407	1.788	2.507	0.818	1.461	1.850	2.586
400	0.712	1.329	1.699	2.395	0.768	1.398	1.778	2.495	0.809	1.449	1.836	2.568
450	0.710	1.326	1.696	2.391	0.763	1.391	1.770	2.484	0.801	1.438	1.824	2.553
500	0.708	1.324	1.693	2.387	0.758	1.385	1.763	2.476	0.794	1.430	1.815	2.541
600	0.705	1.320	1.689	2.382	0.750	1.376	1.753	2.462	0.783	1.416	1.799	2.521
700	0.703	1.317	1.686	2.378	0.745	1.369	1.744	2.452	0.775	1.406	1.787	2.506
800	0.701	1.315	1.683	2.374	0.740	1.363	1.738	2.443	0.768	1.398	1.777	2.493
900	0.699	1.313	1.681	2.371	0.736	1.358	1.732	2.436	0.762	1.391	1.769	2.483
1000	0.698	1.311	1.679	2.369	0.733	1.354	1 728	2.431	0.758	1.385	1.763	2.475
1500	0.694	1.306	1.672	2.361	0.722	1.340	1.712	2.411	0.742	1.365	1.741	2.447
2000	0.691	1.302	1.669	2.356[C]	0.715	1.332	1.703	2.400[C]	0.733	1.354	1.727	2.431[C]
2500	0.689	1.300[C]	1.666 [C]	2.353[C]	0.711	1.326	1.697[C]	2.392[C]	0.727	1.346	1.719[C]	2.419[C]
3000	0.688	1.299[C]	1.664 [C]	2.351[C]	0.708	1.323[C]	1.692[C]	2.386[C]	0.722	1.340[C]	1.712[C]	2.411[C]
inf	0.674	1.282	1.645	2.326	0.674	1.282	1.645	2.326	0.674	1.282	1.645	2.326

[A] Obtained from a noncentral *t* inverse approach; see Ref **(10)**.
[B] The shaded column indicates the tolerance level traditionally used for most wood and wood-based products.
[C] Computed using formula X5.2.

4.4.4 Often, the objective of the evaluation program will be to estimate mean and near-minimum properties simultaneously. When this is the case, only one sample size need be used. It should be the greater of the two obtained in accordance with 4.4.2 and 4.4.3.

4.4.5 If a sampling unit other than an individual test specimen is to be used, as provided for in 4.3.3, then the required sample size must be determined by procedures that are statistically appropriate for the sampling method chosen. In the case of multisource data, as in the sampling of some or all manufacturing sites in a defined region, special procedures may be required, for example, those based on the methodology introduced in Ref (**4**). In all cases, the procedures shall be fully described.