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Standard Test Methods for Nondestructive Evaluation of Wood-Based Flexural Members Using Transverse Vibration[1]

This standard is issued under the fixed designation D6874; 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

Nondestructive testing methods are used to determine the physical and mechanical properties of wood-based materials. These test methods help ensure structural performance of products manufactured from a variety of wood species and quality levels of raw materials. These test methods also assist in evaluating the influence of environmental conditions on product performance.

These test methods for transverse vibration nondestructive testing of wood-based materials adopt methods used by various testing and research organizations. These test methods will yield results comparable to traditional methods, permitting standardization of results, interchange and correlation of data, and establishment of a cumulative body of information on wood species and products of the world.

1. Scope

1.1 These test methods cover the determination of the flexural stiffness and modulus of elasticity (E) properties of wood-based materials by nondestructive testing using transverse vibration in the vertical direction.

1.2 The test methods are limited to specimens having solid, rectangular sections.

1.3 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.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D9 Terminology Relating to Wood and Wood-Based Products

D198 Test Methods of Static Tests of Lumber in Structural Sizes

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

D2915 Practice for Sampling and Data-Analysis for Structural Wood and Wood-Based Products

D4442 Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials

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

D7438 Practice for Field Calibration and Application of Hand-Held Moisture Meters

E4 Practices for Force Verification of Testing Machines

E1267 Guide for Astm Standard Specification Quality Statements (Withdrawn 1996)[3]

2.2 *Other Standard:*

ISO 7626/1 Vibration and Shock-Experimental Determination of Mechanical Mobility—Part 1: Basic Definitions and Transducers[4]

3. Terminology

3.1 *Definitions*—See Terminology D9 and Test Methods D198.

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[1] These test methods are under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.01 on Fundamental Test Methods and Properties.

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[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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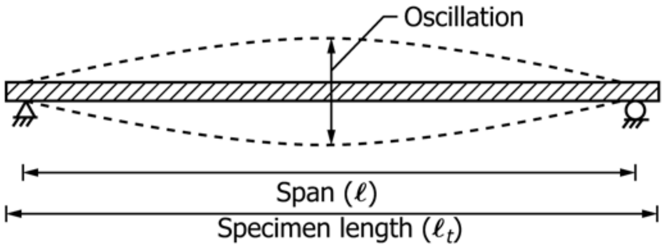

FIG. 1 Transverse Vibration in the Fundamental Mode

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration*—the determination of the relationship between the response of standardized instrumentation to properties of reference material, determined by a standard method.

3.2.2 *fundamental mode of vibration*—the simplest mode of vibration for a simply supported beam is the vertical motion produced from a slight vertical displacement of the member at its mid-span. This is termed its fundamental mode of vibration (Fig. 1) and is the mode to which this standard applies.

3.2.3 *standardization*—the determination of the response of the instrumentation to a reference material.

3.2.4 *transverse vibration*—the oscillation of a simply supported bending member that results from an initial displacement of the member at its mid-span or other means of exciting its fundamental mode of vibration.

4. Summary of Test Method

4.1 The structural member is deflected at its mid-span and allowed to oscillate in a transverse bending mode. Observations of frequency of oscillation are used to calculate modulus of elasticity.

5. Significance and Use

5.1 The dynamic modulus of elasticity provided by these test methods is a fundamental property for the configuration tested. This value can be related to static and other dynamic moduli of elasticity as measured on the same configuration.

5.1.1 The rapidity and ease of application of these test methods facilitate its use as a substitute for static measurements.

5.1.2 Dynamic modulus of elasticity is often used for surveys, for segregation of lumber for test purposes, and to provide indication of environmental or processing effect.

5.2 The modulus of elasticity, whether measured statically or dynamically, is often a useful predictor variable to suggest or explain property relationships.

6. Apparatus

6.1 The testing equipment shall consist of three essential elements:

6.1.1 A support apparatus,

6.1.2 An excitation system, and

6.1.3 A measurement system.

6.2 *Support Apparatus*—The support shall provide vertical support to the ends of the specimen yet permit rotation.

6.2.1 *Reactions*—The specimen shall be supported in a manner to prevent damage to the specimen at the point of contact between it and the reaction support. The reactions shall be such that change in length of the specimen longitudinal movement and rotation of the specimen about the reaction due to deflection will be unrestricted.

6.2.2 *Reaction Alignment*—Provision shall be made at the reactions to allow for initial twist in the length of the specimen. If the bearing surfaces of the specimen at its reaction are not parallel to the bearing surface of the reactions, the specimen shall be shimmed or the bearing surfaces rotated about an axis parallel to the span to provide adequate bearing across the width of the specimen.

6.2.3 *Lateral Support*—No lateral support shall be applied. Specimens unstable in this mode shall not be tested using this method.

6.2.4 *Lengthwise Positioning and Overhang of the Specimen*—The specimen shall be positioned such that an equal portion of the length overhangs each support. Excessive overhang may alter results obtained. If basic equation (Eq 1) is used, then the span (ℓ) to length (ℓ_t) ratio shall exceed 0.98. If other ℓ/ℓ_t ratios are used, more exacting analysis and equations shall be used; see Ref (**1**).[5]

NOTE 1—In testing of dimension lumber, an overhang of approximately 1 in. on each end is often used. The amount of overhang may be influenced by the convenience of handling and positioning but should be kept uniform from specimen to specimen.

6.3 *Excitation System*—The member shall be excited so as to produce a vertical oscillation in a reproducible manner in the fundamental mode. The method of analysis is based on oscillation in this mode (Fig. 1).

6.3.1 *Manual Method*—A manual deflection of the specimen will provide sufficient impetus for oscillation for many products. The deflection shall be vertical with an effort to exclude lateral components; neither excessive impact nor prolonged contact with the specimen are recommended.

NOTE 2—For example, a manual tap on a 16-foot 2-by-12, supported flat-wise having an E of 2.0×10^6 psi will result in a vertical oscillation of between 3 and 4 Hz.

6.3.2 *Mechanical Methods*—The guidelines of 6.3.1 shall be duplicated with mechanical systems. Specimens with very high stiffness require mechanical excitation by a high force or carefully regulated impact/release.

6.4 *Measurement System*—Measurement of the frequency of oscillation shall be obtained by either a force or displacement measuring device calibrated to ensure accuracy in accordance with Practices E4 and ISO 7626/1.

6.4.1 *Force Measuring System*—Changes in the force in response to the vibration at one or both of the supports are methods used to obtain frequency of oscillation.

6.4.2 *Deflection Measuring System*—Measurement of the mid-span displacement in response to the initial displacement is an alternative method to determine frequency of oscillation.

6.4.3 *Measurement of the Fundamental Mode*—In these test methods, it is critical that only the frequency associated with

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[5] The boldface numbers in parentheses refer to a list of references at the end of this standard.

the fundamental vertical oscillation mode be used. Use a short delay before acquiring the data to ensure the data acquired is only related to the fundamental vertical mode.

7. Test Specimen

7.1 Specimens shall be solid and rectangular. Deviations in shape and uniformity in dimension from end-to-end and side-to-side incidental to sampling, such as wane included in a lumber grade description, shall be noted as part of the sample or specimen description.

7.2 *Span to Depth Ratio*—The span-to-depth ratio used shall be greater than 20 unless special precautions are taken to permit higher frequency measurements.

7.3 *Moisture Content*—Moisture content (MC) of specimens shall be measured in accordance with Test Methods D4442 or D7438, or both. Specific reference to the current moisture status of the specimens shall be made; for example, equilibrated, recently kiln dried containing gradients, air dried, packaged specimens of unknown drying history, and so forth. Identification of MC gradients caused by drying or surface wetting is recommended. MC gradients within a piece may affect the dynamic *E* (see X1.1.17).

8. Procedure

8.1 *Standardization and Calibration*—The testing system shall be standardized and calibrated using standard reference materials. The procedures of Annex A1 shall be followed. The results of this test method are conditional upon proper standardization and appropriate choice of calibration method.

NOTE 3—It has been a practice to use aluminum bars as well as lumber specimens as standardization materials and, often, also for calibration against a standard static test results.

8.2 *Excitation*—The procedures of excitation listed under Section 6 shall be followed. Repetitions are recommended to reduce the chance of bias caused by improper excitation.

8.2.1 To quantify measurement uncertainty for precision and bias estimates, specific data sets shall be taken during the test sequence to allow calculation of this contribution to measurement tolerances.

8.3 *Calculation of Modulus of Elasticity:*

8.3.1 *Basic Equation*—The following formula shall be used to calculate modulus of elasticity from the measured oscillation in the fundamental mode (Fig. 1):

$$E_{tv} = \frac{(f_r)^2 w(\ell)^3}{K_d I g} \quad (1)$$

where:

E_{tv} = transverse vibration modulus of elasticity, psi (MPa),

ℓ = span, in. (mm),

w = weight of specimen, lbf (N),

f_r = frequency of oscillation, Hz,

I = specimen moment of inertia, $bd^3/12$,

b = breadth (width), in. (mm),

d = depth, in. (mm),

g = acceleration due to gravity, 386 in./s^2 (9807 mm/s^2), and

K_d = constant for free vibration of a simply supported beam, 2.47.

8.3.2 *Analysis and Presentation of Results*—Analysis of data collected from samples and the presentations of results shall be consistent with the appropriate methods of Practice D2915, Section 4.

8.3.2.1 The presentation of results shall indicate whether the calculations of *E* are based on the actual, individual piece cross section dimensions at the time of test or on standard (design base) dimensions.

8.3.2.2 *Environmental Conditions*—Sensitivity of the test specimens to changes in the test environment shall be considered in calculating apparent modulus of elasticity values. If, for example, the temperature varies during the test and affects the properties of the test material, this shall be considered in presentation of test results. Appropriate adjustments for lumber are included in Practice D1990 and in Ref (**2**).

8.3.2.3 Adjustments to dynamic *E* values for moisture content of specimens above 22 % MC shall be documented (see X1.1.21).

9. Report

9.1 The report shall be sufficiently complete to permit reproduction of the test, including the calibration process. Inadequate explanation of the basis of the modulus of elasticity measurement results in data of unknown comparability.

9.2 Particular attention shall be given to comprehensive reporting of the traceability of transducer calibrations to nationally acceptable references.

9.3 The report shall contain at least the following elements:

9.3.1 *Equipment*—Description of the apparatus, including the manufacturer of the device, the model, and the calibration system if incorporated in the manufactured device. If mechanical excitation is employed, the mechanism shall be described along with the method of assuring adequate excitation.

9.3.2 *Test Setup*—Description of the specimen supports, if not reported as part of 9.3.1; the support surfaces; and the provisions employed for support of twisted or irregular surfaces.

9.3.3 *Environment*—Describe the temperatures during calibration and data collection and other factors in the operating environment that may affect measurement. Note changes in these factors over the data collection period.

9.3.4 *Calibration*—Identify whether the *E* was calculated using the fundamental formula (Eq 1) or the adjusted formula (see A1.2.4). If the latter was used, describe the source of the factors k_s and z. A comprehensive description of the materials used for standardization and for calibration shall be provided.

9.3.5 *Test Data*—Present the test data in the units comparable to those employed in 7.1. The data presentation shall include an estimate of the precision and bias of the data and method of estimation.

9.3.6 *Data Adjustments*—All adjustments made to test data shall be fully explained, including actions taken to meet the reporting requirements of Practice D2915.

10. Precision and Bias

10.1 The precision and bias are dependent upon equipment used (see Section 6) and the Standardization and Calibration practices applied.

ANNEX

(Mandatory Information)

A1. STANDARDIZATION AND CALIBRATION

A1.1 Standardization

A1.1.1 Standardization shall be performed on the dynamic test apparatus to verify the integrity of the system. Suitable reference materials for standardization have properties that are not subject to significant change under the test conditions. Reference materials are often recommended or provided, or both, by the manufacturer of the test system. The standardization test shall provide at least one reference point (output) within the operating range of interest. The standard reference material shall provide vibration performance within the range of vibration frequency of the test.

A1.1.2 Typically, a metal bar had been employed as the reference material for standardization. Care shall be taken to compensate for the effect of temperature variation on the metal properties when standardization tests are repeated over the duration of the test program.

NOTE A1.1—Traditionally, a single metal bar has often been used both for standardization and calibration, thus blurring the distinction between the two functions.

A1.1.3 While wood members and other materials subject to change in properties with change in the test environment may be used, this is discouraged unless the test conditions are maintained sufficiently constant, such as in a conditioning room environment where the wood member is in equilibrium.

A1.1.4 Standardization of the test system shall be repeated at sufficient intervals during the test sequence to ensure continued adequate performance of the system.

A1.2 Calibration

A1.2.1 The test system shall be calibrated against reference materials whose properties are traceable to nationally acceptable standards.

A1.2.2 Transducers incorporated within the test system shall have calibrations traceable to national measurement standards maintained by a National Metrology Institute (NMI).

NOTE A1.2—The NMIs in the United States and Canada are the National Institute of Standards and Technology (NIST) and the National Research Council (NRC), respectively.

A1.2.3 When the E_{tv} values are derived directly from the test system measurements in accordance with Eq 1 of 8.3.1, calibration is dependent solely upon the transducer calibrations; no additional calibration adjustments shall be made.

A1.2.4 When a standardized system output is further adjusted to achieve a calibration against results of another test method (for example, Test Methods D4761 or D198 static tests), Eq 1 shall be modified as follows:

$$E_s = \frac{(f_r)^2 w(\ell)^3}{k_s b d^3} + z \qquad \text{(A1.1)}$$

where E_s is a predicted static modulus of elasticity, k_s is a calibration coefficient established by test with the calibrating material and z is a calibration offset factor.

A1.2.4.1 Calibration of transverse vibration response to predict values related to standard static test values has traditionally often been done with a single reference specimen. With this method, only k_s is determined (z = 0) and the calibration cannot represent any intercept adjustment in the correlation between the vibration response and the static response of the specimens.

(*1*) Reference standards for calibration based on a single point should be those whose mechanical properties do not change significantly with time or environmental conditions. The properties of the reference material shall be determined by standard tests and the vibration characteristics shall be in the range of the test.

(*2*) Reference standards whose physical and mechanical properties may change significantly with the environment should be used only in a carefully controlled environment and only under conditions where the properties have been maintained constant in that environment since the static determination. If the properties change significantly with time, the material use should be restricted to tests of short duration and the time period between the static and dynamic tests be limited. The properties of the reference material shall be determined by standard tests and the vibration characteristics shall be in the range of the test.

A1.2.5 Calibration of transverse vibration response that represents the relationship between the dynamic and static differences over the test range with both slope and intercept adjustment requires regressing the response of specimens in both test modes. The result is information that permits use of both slope and intercept adjustment in the formula (Eq A1.1). All cautions in selecting reference standard material noted in A1.2.4.1 apply. Further, the regression developed must fully represent the material characteristics, the material moisture conditions, and the range of properties anticipated in the test.

A1.3 Report

A1.3.1 Test results obtained using Eq A1.1 for analysis require reporting the following elements in addition to those listed in Section 9.

A1.3.1.1 If dynamic modulus of elasticity values are calibrated by or converted to static modulus of elasticity values, the resulting values will reflect the calibration procedures and the error components from both of the test methods. Reports of the statistical analysis and presentation of results shall consider both test methods.

(*1*) Estimates of precision and bias shall consider both error components.

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY

COMMENTARY—STANDARD TEST METHODS SECTIONS 1 – 10

X1.1 The purpose of this Commentary is to provide background information and recommendations related to specific sections of these test methods. The format of this Commentary is to provide a direct reference to the sections of these test methods by appending the section numbers to the Appendix section numbers. An example: 4.1.1 would be a reference to section 4.1.1 of these test methods.

X1.1.1 *1.1*—This standard is limited to vibration in a vertical mode. Other modes are technically feasible but may be more difficult to obtain in a manner convenient to measure and, in particular, control and measure in field environments. This provision is not meant to prevent addition of other modes to these test methods in the future.

X1.1.2 *1.2*—The fundamentals of transverse vibration do not limit testing to solid, rectangular sections. This limitation is intended as a temporary restriction as the standard is developed. It is anticipated that this restriction will be refined to permit other regular sections in the near future.

X1.1.3 *2.1*—Guide E1267 is included in this list for guidance on issues of measurement uncertainty and precision and bias, as related to the requirements of 9.3.5.

X1.1.4 *3.2.1*—A basic definition of calibration. Calibration is not standardization and often is carried out only once on a system during one test sequence. Standardization subsequently is applied to ensure consistent operation of the system. See Annex A1.

X1.1.5 *3.2.2*—In general, an elastic system or body can vibrate in a variety of patterns (modes). For instance, a stretched wire may vibrate in different shapes depending upon the number of nodes subdividing its length. In the simplest case, the configuration of a vibrating system at any instant can be specified by a single coordinate. These test methods only apply to vibration in the fundamental mode in a vertical plane.

X1.1.6 *3.2.3*—A basic definition of standardization. Standardization is not calibration; it is a method of ensuring consistent system performance by checking response to a standard material. It commonly is initially applied immediately before and after calibration to establish a set point of system function against which subsequent checks can be measured. Subsequent standardization checks are made during the test to ensure consistent function. The frequency of standardization checks during test is chosen by the operator based on observations and prior knowledge; however, these checks are usually made at regular intervals during the test. Deviations noted during the checks indicate potential instrumentation problems and a possible need to re-calibrate. Also see Annex A1.

X1.1.7 *4*—Note that this measurement is restricted to vibration in the fundamental mode.

X1.1.8 *5.1*—See Sections 6 and 7 for the essential elements of measurement. For establishment of relationships to other measurements of moduli of elasticity by calibration, see Annex A1.

X1.1.9 *5.1.1*—The term "substitute" does not imply "equivalency." See Sections 6, 7, and Annex A1 to address the use of these test methods in this regard. Further, the dynamic nature of the measurement and the relatively low influence of the modulus of rigidity on the measured value suggest caution in direct substitution of the results of this method for static measurements where the modulus of rigidity may have more influence. Since the static modulus of elasticity is commonly the base measurement for standards, it is often essential to establish the relationship between static and dynamic values.

X1.1.10 *6.2*—Precautions should be taken to maintain a firm base for the support system. Vibrations entering the support system from external sources are to be avoided or the results should be noted, or both, as conditional upon the testing conditions. See Appendix X2.

X1.1.11 *6.2.4*—The restrictions on lengthwise positioning and overhang are intended to reinforce the need for uniformity across data reported in research and field studies. When these restrictions cannot be maintained, it should be noted that the test procedure or subsequent analysis do not meet these test methods, even though the application may be useful to examine property relationships or environmental effects.

X1.1.12 *6.3.2*—Specimens with very high stiffness may require laboratory equipment, rather than industrial devices, for adequate analysis. It often is desirable to visually inspect the vibration to ensure adequate excitation; extraneous signals generated by an inadequate excitation can be erroneously included in the analysis with highly sensitive equipment. Analysis of the results may require procedures not normally packaged in industrial devices.

X1.1.13 *6.4*—Note that the critical transducers may be furnished as "built-in" elements of an industrial device. Consequently, additional effort may be required to ensure that the necessary standardization and calibration steps are carried out. Traceability of these transducers to reference standards is essential.

X1.1.14 *6.4.3*—Immediately after exciting the specimen, many vibration modes exist. Usually the modes associated with frequencies higher than the fundamental bending frequency dissipate rapidly. Therefore, the short delay after excitation facilitates this decay. This is an effective way to filter the undesirable modes from the analysis; however, as noted in

X1.1.12, additional precautions for measurement may be required for some specimens.

X1.1.15 *7.1*—In accordance with the scope, specimens are limited to solid, rectangular members. As part of further development of these test methods, it is anticipated that this restriction will be removed.

X1.1.16 *7.2*—With small span-to-depth ratios it is difficult to verify that the specimen is oscillating in a bending mode. Experience has revealed that best results are obtained when the frequency of oscillation, calculated from Eq 1 is less than 30 Hz. Exceptions may be adequately addressed with laboratory-type equipment.

X1.1.17 *7.3*—The moisture content of specimens has a direct effect on dynamic E through the weight of the specimen (see Eq 1). If the specimens have a wet core, for example, the dynamic E can be expected to change over time as the weight changes, even if the surface MC is relatively constant. Where comparison of static and dynamic E values is important, MC may affect the static and dynamic E measurement differently. Of principal concern is that a wet core that would have limited effect on a static E will directly affect the force measurement that is an integral part of Eq 1 and Eq A1.1. Consequently, it is necessary to note not only the average moisture content, but also the moisture status of the specimens and, if applicable, the static reference material.

X1.1.18 *8.1*—Quality data is not ensured unless standardization and calibration are carefully carried out. Much past practice has not identified the separate roles of these two elements, as described in Annex A1. Further, the selection of reference material for these procedures is critical. For both it is desirable that the material properties not change significantly with time or temperature; for calibration, there is the additional requirement that the mechanical properties be determined by standard methods. See Annex A1 for further discussion.

X1.1.19 *8.3.2*—Practice D2915 provides a basis for reporting that allows comparison of data on a common base related to end use. However, application of certain sections of Practice D2915 dealing with adjustments for span/depth ratio and moisture adjustment should be used with caution since their applicability to dynamic values may not be well established. While it is commonly assumed that the contribution of the modulus of rigidity is minor in simply supported vibration, the adjustments of Practice D2915 do not anticipate this method of loading. Although an appropriate K value may be derived to adjusted results to other span/depth ratios, this approach may not necessarily produce the same results as following the procedures discussed in Annex A1.

X1.1.20 *8.3.2.2*—Exercise caution and fully document adjustments. The applicability of the adjustments referenced may not have been established for all instances of transverse vibration measurement.

X1.1.21 *8.3.2.3*—Until the response of dynamic E determined by transverse vibration to MC above 22 % has been documented, using the standard MC adjustments of Practice D2915 for test specimens above this MC is not recommended. Particular caution is advised in making MC adjustments for a data set containing specimens both above and below 22 %. The number of specimens above 22 % and the level of MC above 22 % may influence retention of those specimens in the data set if the MC adjustment is critical to the overall analysis.

X1.1.22 *9.3.1*—If mechanical systems and automated, highly sensitive instrumentation are employed, the excitation and signal triggering will, in turn, require sensitive instrumentation to ensure that the signal analysis is adequate.

X1.1.23 *9.3.6*—To generate final results that may relate between tests and/or investigations, it is recommended that test data be adjusted to a common base; however, the applicability of some to the standard adjustments used for statically-determined values to dynamic values has not been demonstrated. Consequently, some adjustments are not recommended (see 8.3.2) and others, such as span/depth ratio adjustment, if used, should be reported in detail.

X1.1.24 *10*—The precision of the test system alone can be determined using standard reference materials; however, use of wood members with natural variability in surfacing can add additional variability. Bias is most easily addressed for systems in which the output is described in 7.1. When the basic output is further modified as discussed in Annex A1, the bias will be dependent upon a number of factors not related directly to transverse vibration. These include the test variables of the reference standard test. In this sense, this test standard includes somewhat unique variability that should be recognized by the user when these further calibration procedures are used. Section 9 requires careful reporting of the system calibration.

COMMENTARY—Annex A1

X1.2 *Annex A1*—The detailed discussion of Annex A1 is a partial response to years of use of transverse vibration in research and industry where calibration procedures were not reported and, for which tests, the reported test data have no common ground with standard test data. Annex A1 requires standardization and calibration procedures; the reporting requirements of Section 9 require documentation of these procedures.

X1.2.1 *A1.1*—Standardization is a means of verifying the consistent function of the testing system. This section requires standardization at intervals during the test sequence; specific requirements and recommendations regarding standardization reference materials are provided. Note A1.1 reminds that while a reference material may have traditionally been used to perform both a standardization and a calibration function, the functions are different.

X1.2.2 *A1.2*—This section requires all reference materials to have calibrations traceable to nationally acceptable standards. This is inclusive of load cells, deflectometers, calibration bars, and so forth, that is, all devices upon which transverse vibration data collection is dependent. Specifically, the system must show calibration traceability (A1.2) and the transducers must be calibrated against traceable reference materials (A1.2.2). This slight distinction allows the use of bars or other objects calibrated in testing machines, the transducers of which have met the direct traceability requirement, to be used for system calibration. This standard does not specify the frequency with which this traceability shall be verified; this latter responsibility is commonly borne by acceptance bodies for whom the collected data must be acceptable.

X1.2.3 *A1.2.4*—The E_s determined using the formula in A1.2.4 is dependent upon the calibration reference standard. Note that there will be estimation errors when attempting to use a dynamic test to estimate the results of a static standard test; the dynamic test technique both applies stress and responds to specimen variables differently than does a standard static test method. While calibration to a non-dynamic test standard may be relevant to a particular objective, it should be noted that the relationship between the resulting calculated E values of the test material and both the basic dynamic E values and the target non-dynamic standard values will be unknown unless care is taken to measure both and a statistical analysis conducted.

X1.2.4 *A1.2.4.1*—This procedure has a tradition of use; the standard clarifies the process, noting the limitation of this method. It is particularly critical that the reference specimen provide data output within the range of the test data.

X1.2.5 *A1.2.4.1 (2)*—This section reflects the concern for use of wood and other materials as calibration reference materials, noting, however, that use under carefully controlled conditions is recognized and traditional (for example, in controlled conditioning room environments).

X1.2.6 *A1.2.5*—This section notes that a calibration of dynamic against static response may require a regression that can respond to shifts in slope and intercept of the relationship. To accomplish this, however, a sample truly representative of the test material will be required. It is beyond the scope of these test methods to prescribe this process; however, the test methods require reporting the process used and the material characteristics, including the range of properties.

X1.2.7 *A1.3*—This section adds reporting requirements relating to the errors of two testing systems.

X2. CONSIDERATIONS FOR FIELD APPLICATION

X2.1 *General*—The principles of proper application of transverse vibration testing involve critical elements of the support conditions, the temperature, humidity and moisture environment, and possible external vibrations. While these are always important, the most severe challenges often occur in the "field" use in a manufacturing facility, a lumber sorting yard, or other non-controlled environment.

X2.2 *Uniform Environmental Conditions*—It should be the goal of the user to provide as uniform a testing environment as possible during the test period. When this is not possible, the quality of the test results are conditional upon the changes that take place during the test period. The following are environmental considerations.

X2.2.1 *Temperature*—When possible, the test site should be chosen to provide as uniform temperature as possible during the test. Providing shade from the sun during the test, especially if the sun exposure varies, may be critical. Some elements of the test equipment likely will be temperature sensitive and variable exposure to the sun can create significant changes. One example is metal calibration bars.

X2.2.2 *Humidity*—Some testing equipment may be sensitive to major swings in humidity during testing; however, if the cautions of X2.2.1 are followed this effect should be minor. More important is the effect on the wood material being tested. Since the outer fibers of the member are affected quickly by the combined effects of temperature and humidity, selecting test sites and times of test to minimize these effects enhances the quality of the data collected.

X2.2.3 *Moisture*—Moisture can be a serious complication, in the form of rain or snow. The sensitivity of the measuring system to moisture should be addressed through the manufacturer's literature or correspondence. A common concern is the "wetting" of the test specimens during the test period, resulting in non-uniform moisture content within the test set. Adjustment of data for moisture is usually conditional upon equilibrated specimens or detailed moisture measurements, conditions not usually applicable to field studies. Every effort should be made to shelter the equipment and the test specimens from moisture.

X2.2.4 *Wind*—This vibrational test can be influenced by wind conditions that gust or otherwise affect the test specimen during the test. Selection of the test site should anticipate sufficient shelter from adverse wind conditions.

X2.3 *Supports/Support Surface*—The supports should support the specimen without vibration in the support itself. This requires a suitable surface for the supports and, on occasion, may require weights be added to the support system. A hard, smooth surface, such as concrete, is essential. The surface should be approximately level. Excessive incline may cause specimens to be unstable on the test supports. In some field conditions, the working area of the installation may be on loose or light fill under an asphalt or other surface. This type of installation can itself be excited to vibrate by mill equipment and should be avoided as a test site.

X2.4 *External Noise and Vibration*—The test site should be away from vibrating machinery, including heavy lifts and trucks. When it is impossible on a field site to eliminate occasional operation of trucks or other machinery in the test vicinity, collection of data should be suspended until the external source has ceased. In some field sites, it may be impossible to find a test site devoid of external noise. This may be at detectable levels by ear but have no effect on the vibration detection apparatus. Care should be taken to evaluate these situations with calibration or test standards, or both, to ensure that the test data is unaffected.

X2.5 *Electrical Power*—A steady source of electrical power not affected by power drops or surges, or both, should be available. If a plug-in power source is used, a portable uninterruptible power supply is recommended. The cord should be routed to avoid damage. Stable power can also be provided through the use of a 12-V inverter powered by an automobile battery. Use of an inverter provides flexibility when choosing a location.

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