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Standard Guide for Evaluating Mechanical and Physical Properties of Wood-Plastic Composite Products[1]

This standard is issued under the fixed designation D7031; 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 This guide covers test methods appropriate for evaluating a wide range of performance properties for wood-plastic composite (WPC) products. It was developed from evaluations of both experimental and currently manufactured products, and is not intended to suggest that all the tests listed are necessary or appropriate for each application of a WPC. The user must determine which test methods apply to the particular application being evaluated (see Appendix X1).

1.2 Details of manufacturing processes may be proprietary and are beyond the scope of this guide.

1.3 *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]

C1308 Test Method for Accelerated Leach Test for Diffusive Releases from Solidified Waste and a Computer Program to Model Diffusive, Fractional Leaching from Cylindrical Waste Forms

D9 Terminology Relating to Wood and Wood-Based Products

D143 Test Methods for Small Clear Specimens of Timber

D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement

D883 Terminology Relating to Plastics

D1037 Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials

D1038 Terminology Relating to Veneer and Plywood

D1413 Test Method for Wood Preservatives by Laboratory Soil-Block Cultures

D1554 Terminology Relating to Wood-Base Fiber and Particle Panel Materials

D1761 Test Methods for Mechanical Fasteners in Wood

D1929 Test Method for Determining Ignition Temperature of Plastics

D2017 Test Method of Accelerated Laboratory Test of Natural Decay Resistance of Woods (Withdrawn 2014)[3]

D2047 Test Method for Static Coefficient of Friction of Polish-Coated Flooring Surfaces as Measured by the James Machine

D2394 Test Methods for Simulated Service Testing of Wood and Wood-Base Finish Flooring

D2395 Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials

D2481 Test Method for Accelerated Evaluation of Wood Preservatives for Marine Services by Means of Small Size Specimens (Withdrawn 2014)[3]

D2565 Practice for Xenon-Arc Exposure of Plastics Intended for Outdoor Applications

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

D3345 Test Method for Laboratory Evaluation of Wood and Other Cellulosic Materials for Resistance to Termites

D4000 Classification System for Specifying Plastic Materials

D4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

D4092 Terminology for Plastics: Dynamic Mechanical Properties

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

D4495 Test Method for Impact Resistance of Poly(Vinyl Chloride) (PVC) Rigid Profiles by Means of a Falling Weight

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

D5379/D5379M Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method

[1] This guide 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] 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.

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D5456 Specification for Evaluation of Structural Composite Lumber Products
D5764 Test Method for Evaluating Dowel-Bearing Strength of Wood and Wood-Based Products
D6109 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastic Lumber and Related Products
D6341 Test Method for Determination of the Linear Coefficient of Thermal Expansion of Plastic Lumber and Plastic Lumber Shapes Between –30 and 140°F (–34.4 and 60°C)
D6662 Specification for Polyolefin-Based Plastic Lumber Decking Boards
E84 Test Method for Surface Burning Characteristics of Building Materials
E108 Test Methods for Fire Tests of Roof Coverings
E661 Test Method for Performance of Wood and Wood-Based Floor and Roof Sheathing Under Concentrated Static and Impact Loads
E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter
F1679 Test Method for Using a Variable Incidence Tribometer (VIT) (Withdrawn 2006)[3]
G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials

2.2 *AWPA Standards:*[4]

AWPA Standard E1 Standard Method for Laboratory Evaluation for Determination of Resistance to Subterranean Termites
AWPA Standard E7 Standard Method for Evaluating Wood Preservatives by Field Tests with Stakes
AWPA Standard E10 Standard Method of Testing Wood Preservatives by Laboratory Soil-Block Cultures

3. Terminology

3.1 *Definitions*—Terminology used to describe WPCs is defined in Terminology D9, D883, D1038, D1554, D4092, and Classification D4000.

3.2 *Definitions of Terms Specific to this Standard:*

3.2.1 *recycled products*—products composed of post-consumer material or recovered material, or both, that may or may not have been subject to additional processing steps of the types used to make the products.

3.2.2 *thickness*—the lesser dimension perpendicular to the long axis.

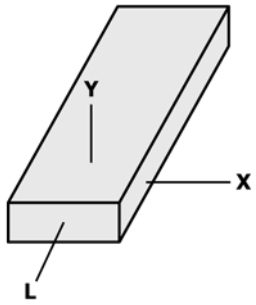
3.2.3 *virgin material*—a material that has not been subjected to use or processing other than that required for its initial manufacture

3.2.4 *width*—the greater dimension perpendicular to the long axis.

3.2.5 *wood-plastic composite (WPC)*—a composite made primarily from wood- or cellulose-based materials and plastic(s).

3.3 *Orientation*—WPCs have three principal directions (see Fig. 1).

[4] Available from American Wood-Preservers' Association (AWPA), P.O. Box 388, Selma, AL 36702-0388, http://www.awpa.com.



L direction - Parallel to the longitudinal direction of the member (length)
X direction - Parallel to the wide surface of the member and normal to the *L* direction (width)
Y direction - Normal to both the *L* and *X* direction (thickness)

FIG. 1 Orientation for Wood-Plastic Composites

4. Significance and Use

4.1 WPCs are intended for use in both structural and non-structural applications. The test methods described within are intended to address products that are manufactured from virgin or recycled wood and thermoplastic sources. These methods provide a reference for the evaluation of several mechanical and physical properties important for structural and non-structural uses of WPCs.

5. Determination of Mechanical and Physical Properties

5.1 The following mechanical and physical properties are included to provide a complete set of reference tests for a broad range of users. Some applications of WPCs will not require assessment of all properties. For example, products that will be limited to flexural applications will not require assessment of tension or compression properties.

5.2 *Sampling*—Samples for testing shall be representative of the population being evaluated. Sampling shall be conducted in accordance with applicable portions of Practice D2915 and be representative of the possible variations due to changes in raw materials and process variables over time. It is essential to consider batch-to-batch and shift-to-shift variability when sampling actual production. Test specimens shall be selected from several production runs of a given item.

5.3 *Sample Size*—Selection of a sample size depends upon the property to be estimated, the actual variation in the property occurring in the population, and the precision with which the property is to be estimated. The principles of Practice D2915 shall be followed.

NOTE 1—If code listed allowable design values or performance ratings are the objective, it is recommended that all sampling and testing be conducted or witnessed, or both, by a qualified inspection agency.

5.4 *Conditioning*—Prior to testing, all specimens shall be conditioned to environmental conditions appropriate for the intended end use of the product.

5.4.1 When temperature and relative humidity are important considerations, the test specimens shall be conditioned for a period of time such that the average daily mass change of the test specimen is less than 2 % of the mass at time of measure.

5.4.2 When the product is to be subjected to a water soak environment, the test specimens shall be tested within 30 min upon removal from the treatment.

5.5 *Bending*—Modulus of rupture (*MOR*) or moment capacity and apparent modulus of elasticity (*E*) or flexural stiffness shall be determined in accordance with principles of Test Methods D4761 or D6109. For some applications and products, moment capacity and flexural stiffness are preferable performance measures. Whenever possible, the test specimen shall be the full cross section of the as-manufactured product. Selection of specimen dimensions establishes the unit volume for analysis of volume effects in accordance with Specification D5456, when applicable. A span-to-depth ratio of not less than 16 shall be used. The specimens shall be loaded at a constant strain rate of 1 % per minute (±10 %). Average time to failure for each test configuration shall be recorded (see X1.5). A constant strain rate of 1 % per minute is achieved by using a constant rate of test machine cross-head motion, *R*, (inches/minute) computed in terms of the test span, *L*, and the member depth, *d*, by the following equation:

$$R = 0.00185 \times \frac{L^2}{d}$$

NOTE 2—WPCs often exhibit exceptionally large deformations prior to failure in bending. Users are cautioned to take particular care in test machine set-up to accommodate large deflections, both in terms of deflection measuring devices and support conditions.

5.5.1 *MOR*—Maximum load for the calculation of *MOR* shall be reported for each specimen. If the calculation is based on a load other than the maximum load, the load basis shall be reported.

NOTE 3—For products that exhibit large deformations, the *MOR* value is commonly based on the load at 3 % strain.

5.5.2 *E*—Apparent flexural modulus of elasticity and its calculation basis shall be reported for each specimen. Characterization of the modulus of elasticity depends upon the use of the data. For material property information, *E* can be calculated in a variety of ways. For design value assignment purposes linear least squares fit of the stress-strain curve over an appropriate range of stress shall be used.

NOTE 4—To assign design values to structural members the least squares fit over a range of 10 to 40 % of ultimate stress is commonly chosen as representative for service loadings. An alternative calculation method based on the secant modulus to 1 % strain is commonly used for all-plastic products.

5.6 *Tension Parallel to the L Direction*—Tension strength parallel to the *L* direction shall be evaluated by testing in accordance with the principles of Test Methods D4761. Specimen cross section shall not be less than the minimum anticipated structural size. Specimen length between grips shall be a minimum of 12 times the actual test specimen width. The specimens shall be loaded at a constant strain rate of 1 % per minute (±10 %). Average time to failure for each test configuration shall be recorded. If required, selection of specimen dimensions establishes the unit volume for the analysis of volume effects per Specification D5456.

5.7 *Compression Parallel to the L Direction*—Short column compression strength parallel to the *L* direction shall be determined in accordance with the principles of Test Methods D4761. Tests shall be conducted on a cross section no less than the minimum anticipated structural size. Length of the specimen shall be such that *l/d* is less than 4.5 and greater than 3.0, where *l* is the effective unsupported length and *d* is the minimum cross-sectional dimension. For non-solid cross-section materials, the actual cross-sectional area shall be calculated.

5.8 *Compression Perpendicular to the L Direction*—Compression strength perpendicular to the *L* direction shall be determined following the measurement and bearing requirements of Test Method D143, except that the specimen dimensions shall be the full cross-section dimension of the WPC, and the length shall be three times the depth. Load shall be applied through a metal bearing plate across the full width of the test specimen. Stress at both 0.02 and 0.04 in. (0.5 and 1.0 mm) of deformation shall be reported. Testing shall be conducted with stresses applied normal to the *L-X* or *L-Y* plane, or both, when required for general product application. The objective of this test is to determine the load carrying capacity of the as-manufactured product. The allowable stress derived from this test will only apply to the actual cross section tested.

5.9 *Shear Strength:*

5.9.1 *Shear Parallel to the L Direction (Longitudinal Shear)*—Shear strength parallel to the *L* direction shall be determined in accordance with the principles of Test Method D143 using the shear block test. Testing shall be done to produce shear failure in the *L-X* or *L-Y* plane, or both. For solid cross-section products, a minimum dimension of 1.0 in. (25 mm) in the shear area is acceptable provided that the total shear area is at least 1.0 in^2. For non-solid cross-section products, the full cross section shall be tested using the shear block tests with the actual shear area based on wall thickness(s) subjected to the shearing stress.

5.9.2 *Shear Perpendicular to the L Direction*—Shear strength perpendicular to the *L* direction shall be determined in accordance with the principles of Test Method D143 using the shear block test. The Test Method D143 shear block test has been shown to provide a conservative estimate of the shear strength of wood-based materials. Other test methods may be applicable. Testing shall be done to produce shear failure in the *X-Y* plane. For solid cross-section products a minimum dimension of 1.0 in. (25 mm) in the shear area is acceptable provided that the total shear area is at least 1.0 in^2.

NOTE 5—For non-solid cross-section products, a shear block test perpendicular to the *L* direction may not be practical. For some special cases, such as nonhomogeneous materials or non-solid cross-section products, alternative test methods such as Test Method D5379/D5379M, will provide additional insight into actual shear strength material properties.

5.10 *Creep-Recovery and Creep-Rupture:*

NOTE 6—When building code listed design values are the objective of the investigation, consideration of creep-recovery and creep-rupture are generally required.

5.10.1 *Creep-Recovery*—A minimum of ten specimens representative of the population being sampled shall be loaded in flexure in accordance with 5.5 to a bending stress appropriate

for the intended end use. The test specimens are loaded for 24 h, unloaded, and allowed to recover with no load for 24 h. Deflection at mid-span is measured a minimum of four times: (*1*) prior to the application of load, (*2*) at 24 h with load on, (*3*) within one minute after the load is removed, and (*4*) after the 24-h recovery period. Total deflection is the amount of deflection that occurred during the first 24-h period. The percent recovery for each test specimen is defined as the recovered deflection times 100, divided by the total deflection. The average percent recovery, rounded to the nearest percent shall be reported.

5.10.2 *Creep-Rupture*—A minimum of ten specimens representative of the population being sampled shall be loaded in flexure in accordance with 5.5 to a stress level appropriate for the intended end use. Prior to loading, the test specimens shall be allowed to equilibrate to the test temperature conditions (for example, 68 ± 4°F (20 ± 2°C)) and be maintained throughout the experiment. The load shall be maintained for a minimum of 90 days with deflection measurements taken at regular intervals to adequately describe the creep curve. It is recommended that for the first eight hours, measurements be taken hourly, for the following 24 h, measurements at eight-hour intervals are suggested, followed by daily measurements for the next seven days. Weekly measurements should be adequate for the remainder of the 90-day period unless there is evidence of tertiary creep (increasing creep rate).

NOTE 7—It is recognized that maintaining a constant temperature for a long period of time may be difficult. It is, therefore, recommended that temperature be recorded with a frequency sufficient to establish the magnitude and duration of temperature fluctuations.

5.11 *Mechanical Fastener Holding Tests*—When testing WPC materials for fastener holding properties, the principles of Test Methods D1037, D1761, or D5764 shall be followed with the following exception: conditioning of the test material prior to specimen preparation shall be conducted in accordance with 5.4. Testing with nails, screws, and staples, when required, shall be performed in accordance with Test Methods D1037 or D1761. Testing with bolts, when required, shall be in accordance with Test Method D5764.

NOTE 8—The procedures of Annex A2 on Establishing Equivalent Sawn Lumber Species Connection Properties for SCL of Specification D5456 have been accepted by model code evaluation services for WPCs as an alternative method of establishing connection properties.

5.12 *Impact Resistance*—Depending upon the objective of the testing program, Test Methods D4495 or E661 shall be used to determine the impact resistance of WPCs. When required for a specific product application, this test shall be conducted on each surface where impacts are possible in service. The diameter of the impact weight in Test Method D4495 shall be 1.0 in. (25 mm) producing a contact area of 0.785 in^2.

NOTE 9—For non-solid cross-section materials, the impact strength may be measured at several locations on the surface to determine the effect of the cross-section geometry.

5.13 *Fire Performance:*

5.13.1 Flame spread shall be determined using Test Method E84.

5.13.2 Other fire performance properties may be determined using Test Methods E1354 or D1929, as appropriate. These test methods provide an assessment of one or more of the following properties: smoke release rate, mass loss rate, heat release rate, and ignition temperatures.

5.14 *Specific Gravity*—Specific gravity specimens may be taken from an undamaged portion of each bending test specimen and measured in accordance with Test Method D2395 or D792.

5.15 *Moisture Content*—Moisture content shall be measured in accordance with Test Method D4442. Using the specific gravity specimens (from 5.14) to measure moisture content is permissible.

5.16 *Slip Resistance*—The coefficient of friction shall be determined in accordance with accepted test methods. Test Method F1679 has proven to be useful for this purpose. Alternatively, Test Method D2394 and D2047 have long been used as a historical benchmark. Wet and dry slip resistance both parallel and perpendicular to the *L* direction shall be evaluated.

NOTE 10—Choice of an appropriate test method depends on the specific needs of the end user. Recently developed methods are usable both in the laboratory and under a range of field conditions, and are believed to provide more reliable friction property estimates than historical methods.[5] ASTM is currently coordinating slip resistance specification issues at the Society level. The results of this effort, when available, will be incorporated into this document. See Appendix X1 for additional discussion.

5.17 *Abrasion*—Test Methods D2394 or D4060 shall be used to compare wear properties to solid wood.

5.18 *Thermal Expansion*—The procedures specified in Test Method D1037 for linear expansion of panel products shall be used to determine the thermal dimensional change characteristics of the as-manufactured product. The temperature range evaluated shall represent typical in-service conditions. A minimum of ten (10) full cross-section test specimens, no less than 12 inches in length, shall be cut from the actual product. The test specimens shall be equilibrated to a reference condition (for example, 68 ± 4ºF (20 ± 2ºC)). A minimum of one length, width, and thickness measurement for each test specimen shall be recorded. The specimens shall be placed in a temperature controlled chamber at the desired temperature (higher or lower) and allowed to equilibrate. The dimensions for each test specimen shall be measured and recorded within 2 min after removal from the chamber. Care shall be taken to assure that subsequent measurements are taken at exactly the same location as the previous measurement. The deformation measuring equipment shall have an accuracy of ±0.001 in. (±0.025 mm). When comparing the thermal expansion properties of various products, the user is alerted to the potential influence of Poisson's effect for different materials. Therefore, it is recommended that test specimen aspect ratio be consistent. Alternatively, Test Method D6341 shall be permitted.

5.19 *Moisture Absorption, Thickness Swell*—Test Method D1037 shall be used to determine the moisture absorption and thickness swell properties of WPCs. The test specimens shall be prepared using the full cross section of the as-manufactured

[5] Flynn, J.E. and Underwood, D., "Summary: Spring 1998 V.I.T. (English XL)," Round Robin, 1998

product. Test conditions often used include submersion in water or exposure to high humidity conditions. Submersion time, or the duration the product is subjected to a high humidity environment, shall be representative of in-service conditions.

5.20 *Freeze-Thaw Resistance*—To determine the effect of freeze-thaw exposure, a minimum of three specimens shall be subjected to the cycle described below. Whenever possible, the test specimens shall be prepared using the full cross-section of the as-manufactured product. Test specimens shall be submerged underwater (using weights to hold them down, if necessary) for a period of 24 h. The specimens shall then be placed in a freezer set at -20°F (-29°C) for 24 h. After being subjected to freezing, the specimens shall be returned to room temperature for a period of 24 h. This process comprises one hygrothermal cycle. The above procedure shall be repeated two more times, for a total of three cycles of water submersion, freezing, and thawing. After completion of a minimum of three freeze-thaw cycles, the specimens shall be allowed to return to room temperature followed by flexure testing as described in Test Methods D4761 or D6109.

5.21 *Biodeterioration*—Test methods appropriate for the intended application shall be selected from the list below. Testing shall be conducted on full-size test specimens whenever possible. When testing equipment does not allow either full-size or full-thickness test specimens, coupon specimens removed from the surface of the full-size cross section shall be used. However, when using coupon specimens, the user must justify the estimation of the impact on the full-size product.

5.21.1 *Fungal Decay*—Resistance to fungal decay shall be determined in accordance with accepted methods. Test Method D2017 (or its alternate Test Method D1413) or AWPA Standard E10 is commonly used for this purpose.

NOTE 11—This is an accelerated laboratory decay test. Results are subjective and comparisons between tests and materials should be used with caution. However, mean specimen weight losses greater than 5 % or significantly greater than controls should be cause for concern.

5.21.2 *Termites*—Test Methods D3345 or AWPA AWPA Standard E1 shall be used for evaluation of resistance to termite attack.

5.21.3 *Termites and Decay*—AWPA AWPA Standard E7 shall be used to assess the strength loss from both termite attack and fungal decay. This field "stake" test for termite and rot resistance shall be performed on full-size specimens whenever possible, otherwise coupons cut from the full-size product may be used. After exposure, flexural testing shall be conducted in accordance with 5.5.

NOTE 12—When assessing material properties after field exposure, it is important to consider the impact of moisture alone on any observed material property changes.

5.21.4 *Marine Borers*—For products to be submerged in seawater or brackish water, marine borer resistance shall be determined according to Test Method D2481.

5.22 *Leaching*—Depending upon the chemical formulation of the WPC, leaching may be important. For example, when inorganics (for example, zinc borate) are used, Test Method C1308 shall be performed. The test duration shall be at least 90 days. At regular intervals leachate aliquots are taken and analyzed for principal inorganics (for example, zinc and boron). The number of aliquots and sampling intervals must be sufficient to allow for a reliable estimate of long-term leach rates. Preliminary tests indicate a minimum of five sample leachate aliquots of five specimens each over the 90-day period is sufficient.

5.23 *Ultraviolet (UV) Resistance*—Products exposed to sunlight in service shall be evaluated for UV degradation in accordance with Test Method D2565 or G154 for a minimum test duration of 2000 h. Flexural strength shall be determined in accordance with 5.5 before and after exposure. Either full-size test specimens or coupons removed from the surfaces of the materials shall be tested. When surface coupons are used they shall be at least 0.25 in. (6 mm) thick or the wall thickness for nonsolid products.

NOTE 13—Specification D6662 provides additional UV test protocols.

6. Report

6.1 Report the sampling plan and testing in accordance with the applicable standard used. Report the sample size and data used to make statistical inferences. When nonparametric statistics are used, report the order statistic used to calculate the tolerance limits. When parametric statistics are used, report the mean, standard deviation, and any other distribution parameters estimated to describe the population. When testing is witnessed by a third-party inspection agency, evidence of the witnessing shall be provided.

7. Keywords

7.1 biodeterioration; fire performance; mechanical properties; physical properties; test methods; wood-plastic composite

APPENDIXES

(Nonmandatory Information)

X1. COMMENTARY

X1.1 *General*—The intent of this guide is to provide a set of test methods to assess a wide range of performance characteristics for a new class of wood-based products, known as WPCs. In some cases, the user will find more than one test method is provided to assess a given property. For example, depending on the intended end use of the product, the notion of impact strength can take on very different connotations. One may be interested in soft-body impact (bag drop) or concentrated load impact (steel rod drop). In other cases, such as specific gravity determination, two methods are offered simply because various laboratories are equipped to conduct specific gravity differently. Even though numerous test methods are listed in this guide, it should not be construed that this is an exhaustive list for all possible applications of these products.

X1.2 *Commentary to Section 1, Scope*—WPC products are not to be confused with structural lumber. Although the test methods cited in this guide primarily address WPCs produced in common lumber sizes, this compendium of test methods is not intended to be limited to lumber applications alone.

X1.3 *Commentary to Section 3, Terminology*—The chairs of ASTM Committees D20 and D07 had previously agreed that the distinction between WPC and "plastic lumber" is that a WPC must contain less than 50 % plastic resin by weight (using an oven-dry basis for the wood fiber content).

X1.4 *Commentary to 5.4, Conditioning*—The time it takes to condition a WPC to an equilibrium moisture content is a function of its wood content, plastic matrix materials, and cross-section geometry. Plastic lumber (greater than 50 % plastic resin in accordance with ASTM definition) has approved standards that specify 40 h of conditioning at 50 % RH. The 40-h requirement comes from a long history of plastics testing where it is specified. The preponderance of currently available data for WPCs shows that moisture effects are minimal compared to temperature effects. Moisture travels in and out of WPCs very slowly. However, as previously stated, wood content has an effect on moisture absorption/desorption, therefore, an average daily mass change criterion is provided to assess "equilibrium." True equilibrium may take months or even years to achieve. It is incumbent upon the user of these test methods to select appropriate "equilibrium" conditions.

X1.5 *Commentary to 5.5, Bending* —Test Methods D4761— has been selected as a primary reference standard for several reasons. First, it is a comprehensive test method for determination of flexural capacity in applications similar to those that will be encountered by these products in service. Second, it provides capacity estimates that are directly comparable to those used by competing products, like sawn lumber, in the marketplace. Additionally, Test Methods D6109 is provided as an alternative test method. The provisions of Test Methods D6109 are similar to those in Test Methods D4761 with several key differences. First, Test Methods D6109 is only applicable to rectangular or square members (Test Methods D4761 is more generally applicable). Second, Test Methods D6109 permits only 1/3-point loading (Test Methods D4761 is more flexible in this regard). And third, Test Methods D6109 prescribes loading at a 1 % (constant) rate of strain (Test Methods D4761 prescribes a constant time to failure). Because this last point has been raised as a potential technical disparity between the two approaches, 5.5 of this document specifies the constant strain rate approach.

X1.5.1 Due to the relatively low strength and stiffness of WPCs compared to most wood species it is important to establish meaningful criteria to define failure and stiffness. For example, some within ASTM Committee D20 (Plastics) define flexural strength somewhat differently than traditionally defined in wood-based material test methods. Subcommittee D20.20.01 determined that a product that exhibits 3 % strain and has not yet reached a maximum load, has indeed failed due to excessive deflection. At 3 % strain the product is no longer considered suitable for most flexural applications. Flexural strength is, therefore, determined using the load at 3 % strain.

X1.5.2 Flexural modulus poses an additional dilemma. For many wood-based products the apparent E is defined from an early portion of the load-deformation plot. Depending on the sensitivity of the measuring device, there often appears to be a linear portion of the curve for wood-based products. For WPCs there is typically little or no linear portion of the curve. We are often interested in the stiffness of a product near a design load level. Therefore, to estimate E, it was deemed appropriate to select a portion of the stress-strain curve in this vicinity. Many testing machines utilize a "best-fit" procedure, between two relatively low load levels, based on a percentage of ultimate load. A 10 % lower limit was judged to be above the point where initial specimen seating (in the testing machine) occurs. A 40 % upper limit was judged to be approximately at the design load level. The precedent for the selection of 40 % of ultimate load can be found in ASAE EP558-1998 Load Tests for Metal-Clad Wood-Frame Diaphragms and Test Method E455-76 Static Load Testing of Framed Floor or Roof Diaphragm Construction for Buildings.

X1.5.3 When conducting flexural tests, all product properties are affected by the rate at which load is applied to the test specimen. The current guide has attempted to address rate of loading in a manner that is compatible with practices and methods of Subcommittee D20.20.01. While this approach differs somewhat from the traditional approach used for wood-based structural materials, it was chosen because: (*1*) it eliminates strain rate as a discrepancy between ASTM methods for comparable products that compete in the marketplace, (*2*) when adopted with an appropriate tolerance, such as ±50 %, the 1 % per minute strain rate yields times to failure generally

within the Test Methods D4761 range, and (*3*) a predetermined constant strain rate is preferable from a testing perspective.

X1.6 *Commentary to 5.6, Tension Parallel to the L Direction*—The distance between grips of 12 times the test specimen width is based on the recommendations of Test Methods D4761. This is probably an excessive distance based on the elastic properties of the WPC material. However, using an 8-ft specimen for a nominal 2 by 6 in. deck board is reasonable.

X1.7 *Commentary to 5.9, Shear Strength*—Imparting true shear into either solid or non-solid cross-section materials is difficult. It was deemed appropriate to select a test method that would not overestimate the shear capacity while providing ease of use and repeatability. Test Method D143 shear block tests have been used for lumber products for decades. Ever since the test method was implemented there has been discussion regarding how accurately this test actually defines shear strength. For distinctly orthotropic materials such as lumber, shear strength parallel to the *L* direction may be predicted adequately with this test method. For shear strength perpendicular to the *L* direction the issue becomes whether or not the test actually measures shear. For materials, such as plastic, Test Method D5379/D5379M has long been used. This is a coupon test designed to evaluate the shear strength on relatively thin sections. Using this test method, recent work done at Washington State University on WPCs showed that shear strength is more accurately characterized using Test Method D5379/D5379M. However, Test Method D143 consistently provided lower strength values than found with the Test Method D5379/D5379M test. This can be attributed to the fact that Test Method D143 was not actually evaluating pure shear strength but rather a combination of shear parallel and perpendicular tensile strength. As expected, when using Test Method D5379/D5379M, it was found that as the degree of orthotropy increases the longitudinal shear strength (parallel to extrusion or *L* direction) began to become more of a tension test than a shear test (similar to Test Method D143). This suggests that the shear strength of the material is greater than the perpendicular tensile strength. Under these conditions, assigning shear design values, based on Test Method D143 would be conservative. If the intent of the test is to determine the actual material property of the composite, Test Method D5379/D5379M is deemed more appropriate, particularly to those products that tend toward anisotropy. However, for design value assignment purposes, it was deemed appropriate to continue to use Test Method D143 on full-size cross sections of either solid or tubular section (non-solid) products.

X1.8 *Commentary to 5.11, Mechanical Fastener Holding Tests*—The particular fastener or test configuration to be evaluated is the responsibility of the individual or company pursuing the information. Not all tests described in Test Methods D1037 or D1761 may be applicable. Depending on the application, for non-solid cross-section materials, fastener tests in the various walls may be more appropriate.

X1.9 *Commentary to 5.13, Fire Performance*—For many WPC products, Test Method E84 has been used to assess spread of flame performance. It has been reported that Test Method E84 may not be appropriate for some 100 % plastic products. The recent proliferation of plastic and wood-plastic decking products has driven the investigation of alternate methods to assess the fire propagation characteristics of this new class of construction material. Based on a test protocol developed within Subcommittee D20.20.01, research was conducted by Washington State University to evaluate a test method derived from Test Method E108. A modified version of Test Method E108 was applied to a wide range of decking products including two types of solid wood, a 100 % plastic lumber product, and a variety of WPC materials. Based on that investigation, the following test method and acceptance criteria were developed. See Appendix X2 for further details of this test method and acceptance criteria.

X1.9.1 A second consideration for materials used in building construction is the ignition temperature. Historically, Test Methods D1929 has been used to establish the flash-ignition and self-ignition temperature for plastics. Some believe that this method provides data that is difficult to interpret. Based on this consideration, it has been proposed to use the cone calorimeter Test Method E1354 as an alternative to Test Method D1929.

X1.10 *Commentary to 5.16, Slip Resistance*—Historically, Test Method D2394 has been used as a benchmark for comparative evaluation. This test method was developed for dry tile surfaces but has been applied to a wide variety of conditions. In recent years there has been much discussion regarding this test method as the basis for comparison purposes. Experts in the field of friction properties disagree on the appropriateness of the various test methods. More recently, researchers have proposed Test Method F1679 as the best method for obtaining reliable and repeatable results for various application conditions including wet surfaces. Round robin testing has been done using Test Method F1679 and precision and bias statements have been developed.[5] The data suggest very good repeatability and reproducibility. Based on the currently available data, and because of the importance of slip resistance for exterior walking surfaces, the committee decided to choose a test method with the greatest applicability to a wide range of walking surface materials.

X1.10.1 Due to the extrusion process and potential surface treatments of the products, it is important to evaluate slip resistance both parallel and perpendicular to the extrusion direction.

X1.11 *Commentary to 5.23, Ultraviolet (UV) Resistance*—Full-size specimen testing is recommended whenever possible, particularly when design value assignment is the objective. When full-size test specimens cannot be tested, full-thickness strips removed from a full-size product is an option. In cases where testing equipment does not allow either full-size or full-thickness test specimens, coupon test specimens removed from the surface of a full-size cross section may be used. However, when using coupon specimen test data it becomes necessary for the user of the test method to justify their estimation of the impact on the full-size product.

X2. FIRE PROPAGATION TEST METHOD AND ACCEPTANCE CRITERIA FOR WPC DECK PRODUCTS

X2.1 This fire test method is intended to be used to determine the acceptability of WPCs for outdoor deck applications where it is permissible (by the US model building codes) to use combustible materials. This test method is based on a modification of the Test Method E108 test method for roof coverings.

X2.2 *Deck Fire Propagation Test Method:*

X2.2.1 *Deck Surface*—A 2 by 4 lumber frame is constructed to support the deck boards. The frame shall be 52 in. long and 40 in. wide with one center support oriented along the 52-in. dimension. The deck boards are cut to 40-in. lengths and fastened to the lumber frame in accordance with the manufacturer's recommendations. See Fig. X2.1 for construction details.

X2.2.2 *Fire Source*—Twenty (20) Class C brands shall be placed over a 24 by 24 in. square area, centered along the leading 40-in. edge of the deck surface per Fig. X2.1. At least one row of 4 brands shall be placed directly across the gap or joint between deck boards. Airflow across the brands shall be maintained in accordance with Test Method E108. The first brand shall be placed in position 1 and all subsequent brands placed at approximate 1-min intervals per Fig. X2.1b.

X2.2.3 *Kraft Paper*—A sheet of 60-lb Kraft paper shall be placed not more than 60 in. below the surface of the deck. The paper shall be conditioned to EMC at 70°F and 50 % RH prior to test.

X2.2.4 *Exposure Time*—The brands shall be allowed to burn for a minimum of 40 min after the last brand has been placed. Brand placement requires approximately 1 min per brand (for example, 20 brands take approximately 20 min to place). Total test duration shall be no less than 60 min.

X2.3 *Acceptance Criteria*—The tested deck is considered to pass if all the following criteria are met.

X2.3.1 *Flame Spread*—Flames shall not spread to any of the deck surface edges.

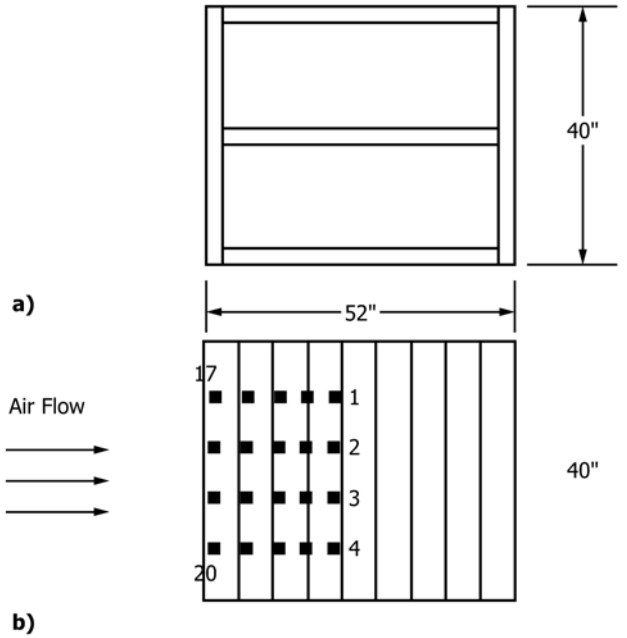


FIG. X2.1 Test Specimen Assembly: a) Lumber Frame, b) Deck Board and Brand Placement

X2.3.2 *Flaming or Glowing Debris*—At no time, throughout the duration of the test, shall combusting material fall below the deck surface in sufficient quantity to ignite and cause to flame a sheet of Kraft paper located 60 in. (or less) below the deck surface.

X2.3.3 *Flame Growth*—After the 40-min exposure period (after the last brand has been placed) the flames shall be diminishing. If it is not clear at the end of the test period that the flames are diminishing the test may be extended to verify diminishing flames. Smoldering materials are acceptable provided that combustion has not extended to the edges of the deck.

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