Designation: D6111 – 13a

Standard Test Method for Bulk Density And Specific Gravity of Plastic Lumber and Shapes by Displacement[1]

This standard is issued under the fixed designation D6111; 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 test method covers the determination of the bulk density and specific gravity of plastic lumber and shapes in their "as manufactured" form. As such, this is a test method for evaluating the properties of plastic lumber or shapes as a product and not a material property test method.

1.2 This test method is suitable for determining the bulk specific gravity or bulk density by immersion of the entire item or a representative cross section in water. This test method involves the weighing of a one piece specimen in water, using a sinker with plastics that are lighter than water. This test method is suitable for products that are wet by, but otherwise not affected by water for the duration of the test.

1.3 Plastic lumber and plastic shapes are currently made predominately from recycled plastics. However, this test method would also be applicable to similar manufactured plastic products made from virgin resins where the product is non-homogeneous in the cross-section.

1.4 The values stated in SI units are to be regarded as standard.

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

NOTE 1—There is no known ISO equivalent to this test method.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

D883 Terminology Relating to Plastics

D1622 Test Method for Apparent Density of Rigid Cellular Plastics

D1898 Practice for Sampling of Plastics (Withdrawn 1998)[3]

D5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics (Withdrawn 2007)[3]

D6108 Test Method for Compressive Properties of Plastic Lumber and Shapes

E1 Specification for ASTM Liquid-in-Glass Thermometers

E12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases (Withdrawn 1996)[3]

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions:*

3.1.1 *density, bulk*—the weight per unit volume of a material including voids inherent in material as tested. (Terminology D883)

3.1.1.1 *Discussion*—Specific gravity at 23/23°C can be converted to density 23°C, g/cm^3, as follows:

$$D^{23C}, \text{g/cm}^3 = \text{sp gr } 23/23°\text{C} \times 0.9976 \quad (1)$$

3.1.2 *plastic lumber, n*—a manufactured product made primarily from plastic materials (filled or unfilled), typically used as a building material for purposes similar to those of traditional lumber, which is usually rectangular in cross-section. (Terminology D883)

3.1.2.1 *Discussion*—Plastic lumber is typically supplied in sizes similar to those of traditional lumber board, timber and dimension lumber; however the tolerances for plastic lumber and for traditional lumber are not necessarily the same. (Terminology D883)

3.1.3 *plastic shape, n*—a manufactured product composed of more than 50 weight percent resin, and in which the product generally is not rectangular in cross-section, may be filled or unfilled, and may be composed of single or multiple resin blends.

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.20 on Plastic Lumber (Section D20.20.01).

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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.

***A Summary of Changes section appears at the end of this standard**

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3.1.4 *resin, n*—a solid or pseudosolid organic material often of high molecular weight, which exhibits a tendency to flow when subjected to stress, usually has a softening or melting range, and usually fractures conchoidally. (Terminology D883)

3.1.4.1 *Discussion*—In a broad sense, the term is used to designate any polymer that is a basic material for plastics.

3.1.5 *specific gravity, bulk (of solids)*—the ratio of the weight in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of expression shall be the following:

$$\text{bulk specific gravity } x/y°\text{C} \quad (2)$$

where:

x = temperature of the material, and
y = temperature of the water.

3.1.5.1 *Discussion*—The accuracy of bulk density determinations is so low that corrections for air buoyancy and variations in the value for the acceleration of gravity are not warranted. Hence, this definition is based on weights in air. (Terminology E12)

3.2 Additional definition of terms applying to this test method appear in Terminology D883 and Guide D5033.

4. Summary of Test Method

4.1 Determine the weight of a specimen of the plastic lumber or shape in air. The specimen is then immersed in water, its weight upon immersion is determined, and its bulk specific gravity calculated.

5. Significance and Use

5.1 The specific gravity or density of a solid is a property that can be measured conveniently to follow physical changes in a sample, to indicate degree of uniformity among different sampling units or specimens, or to indicate the average density of a large item.

5.2 It is possible that variations in density of a particular plastic lumber or shapes specimen will be due to changes in crystallinity, loss of plasticizer/solvent content, differences in degree of foaming, or to other causes. It is possible that portions of a sample will differ in density because of difference in crystallinity, thermal history, porosity, and composition (types or proportions of resin, plasticizer, pigment, or filler).

NOTE 2—Reference is made to Test Method D1622.

5.3 Density is useful for calculating strength to weight and cost to weight ratios.

5.4 If the cross-sectional area of the specimen is required for future testing on a particular sample, it is acceptable to determine it from a specific gravity measurement, see Eq 5.

6. Apparatus

6.1 *Balance*—A balance large enough to accommodate the specimen conveniently, with a precision within 1.0 mg, accuracy within 0.05 % relative (that is 0.05 % of the weight of the specimen in air), and equipped with a means of support for the immersion cage.

6.1.1 Calibrate the balance at least annually in accordance with the manufacturer's instructions for zero point, sensitivity, and absolute accuracy.

6.2 *Immersion Cage:*

6.2.1 *Wire*—A corrosion-resistant wire for suspending the cage.

6.2.2 *Cage*—A device large enough to support the bottom of the specimen and when weighted will transfer the sinker force to the specimen to keep it from floating. Refer to the sample immersion cage diagrammed in Fig. 1.

6.2.3 *Sinker*—A sinker for use with specimens of plastics that have specific gravities less than 1.000. The sinker shall: be corrosion-resistant; have a specific gravity of not less than 7.0; have smooth surfaces and a regular shape; and be slightly heavier than necessary to sink the specimen. It is important that the sinker be easily attached to the cage.

6.3 *Immersion Vessel*—A beaker, bucket, or other wide-mouthed vessel for holding the water and immersed cage.

6.4 *Thermometer*—A thermometer having not fewer than four divisions per °C over a temperature range of not less than 5°C above and below the standard temperature, and having an ice point for calibration.

NOTE 3—A thermometer short enough to be handled inside the balance case will be found convenient. ASTM Thermometer 23C (see Specification E1) and Anschütz-type thermometers have been found satisfactory for this purpose. Alternative thermometers with equivalent or better accuracy, precision, and properties while covering the temperature range of 6.4 are acceptable.

7. Materials

7.1 *Water*—The water shall be distilled, deionized, or demineralized.

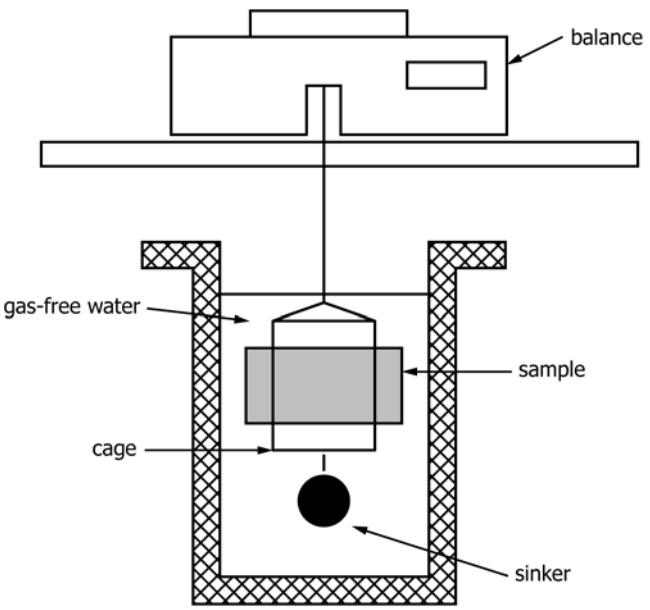

FIG. 1 Typical Configuration of Test Apparatus

8. Sampling

8.1 The sampling units used for the determination of specific gravity shall be representative of the quantity of product for which the data are required, in accordance with Practice D1898.

8.2 Plastic lumber and shapes are typically foamed, layered or hollow, varying in material properties over the cross section. To establish the overall specific gravity for a section, complete unmachined elements or representative cross sections of these elements shall be used.

9. Test Specimens

9.1 Test specimens for determining the bulk specific gravity or bulk density of plastic lumber and shapes shall be cut from the "as manufactured" profile. Plastic lumber is generally non-uniform through the cross-section; no machining operations other than those required to provide flat, parallel ends shall be conducted. Care must be taken in cutting specimens to avoid changes in density resulting from compressive stresses or frictional heating.

9.2 The standard test specimen shall be in the form of a right cylinder or prism where height is twice its minimum cross-section or diameter.

NOTE 4—Expect for specified tolerances, the specimen requirements given in 9.1 and 9.2 above are the same for Test Method D6108. It is acceptable, therefore, to use specimens prepared in accordance with Test Method D6108 to determine bulk specific gravity or density prior to being subjected to the destructive compression tests.

9.3 When the cross section of the material being tested is known or suspected to be porous, hollow, or contain voids, or both, seal the cut ends to prevent ingress of water from producing false results.

9.3.1 Unreinforced plastic packaging tape that is nominally 0.05 mm in thickness has been found suitable for sealing the cut ends. Because the weight of the tape is small compared to the weight of the specimens, use of the plastic tape will have a negligible effect on the final density and specific gravity calculations. Use of a different type of tape or any other method to seal the cut ends will require correction factors for accurate results.

9.4 The specimen shall be free from oil, grease, and other foreign matter.

10. Conditioning

10.1 *Conditioning*—Unless otherwise specified by the customer or product specifications, condition the test specimens at 23 ± 2°C and 50 ± 5 % relative humidity for not less than 40 hours prior to test in accordance with Procedure A of Practice D618. In cases of disagreement, the tolerances shall be ±1°C and ±2 % relative humidity.

10.2 *Test Conditions*—Unless otherwise specified by the customer or product specification, conduct tests in the standard laboratory atmosphere of 23 ± 2°C and 50 ± 5 % relative humidity. In cases of disagreement, the tolerances shall be ±1°C and ±2 % relative humidity.

11. Procedure

11.1 Weigh the specimen in air to the nearest 1.0 mg. Record this as *a*, the weight of the specimen in air.

11.1.1 It is acceptable to weigh the specimen in air after hanging from the wire. When this is done, record the weight of the specimen, *a* = (weight of specimen + wire + cage, in air) – (weight of wire + cage, in air).

11.2 Attach to the balance a piece of fine wire sufficiently long to reach from the balance to the base of the immersion vessel. Attach the immersion cage to the wire such that it is suspended a marked distance above the base of the immersion vessel. Place the specimen in the cage, using sinkers if needed.

11.3 Completely immerse the suspended specimen (and sinkers, if used) in water (see 7.1) at a temperature of 23 ± 1°C. The vessel must not touch wire or specimen.

11.4 Remove any bubbles adhering to the specimen, wire, cage, or sinker. Usually these bubbles can be removed by rubbing them with another wire. If the bubbles cannot be removed by this method or if bubbles are continuously formed (as from dissolved gases), the use of vacuum is recommended. If the water does not wet the specimen, a few drops of a wetting agent shall be added.

11.5 Determine the weight of the suspended specimen to the nearest 1.0 mg. Record this weight as *b* (the weight of the immersed specimen, wire, cage, and sinker). Unless otherwise specified, weigh rapidly in order to minimize absorption of water by the specimen.

11.5.1 For some materials, it will be necessary to change the sensitivity adjustment of the balance to overcome the damping effect of the immersed specimen.

11.6 Weigh the wire, cage, and sinker, if used, in water with immersion to the same depth as used in the previous step. Record this weight as *w* (weight of the wire, cage, and sinker in liquid).

11.6.1 It is acceptable to mark the level of immersion by means of a shallow notch in the wire. The finer the wire, the greater the tolerance permitted in adjusting the level of immersion between weighing.

11.6.2 When the wire and cage are left attached to the balance during a series of determinations, determine the weight *a* with the aid of a tare on the balance. When this done, take care that the change in weight of the wire and cage (for example, from visible water) between readings does not exceed the desired precision.

11.7 Repeat the procedure for a minimum of five specimens per sample.

12. Calculation

12.1 Calculate the bulk specific gravity of the sample as follows:

$$\text{Sp gr } 23/23°\text{C} = a/(a + w - b) \quad (3)$$

where:

a = overall weight of specimen, without wire or sinker, in air,

b = overall weight of specimen (and of cage and sinker) completely immersed and of the wire partially immersed in liquid, and

w = overall weight of totally immersed sinker, cage, and partially immersed wire.

12.2 Calculate the bulk density of the sample as follows:

$$D^{23C},\ \mathrm{g/cm^3} = \mathrm{Sp\ Gr\ 23/23°C} \times 0.9976 \quad (4)$$

12.2.1 The following formula is a means of converting bulk density in g/cm^3 to lb (mass)/ft^3:

$$\mathrm{g/cm^3} \times 62.43 = \mathrm{lb/ft^3} \quad (5)$$

12.2.2 For right prismatic plastic lumber and shapes, the cross sectional area is often difficult to determine utilizing conventional measurement techniques. The following formula is a means to use specific gravity results to calculate the cross sectional area, by calculating the effective cross sectional area:

$$\mathrm{area,\ cm^2} = (a + w - b)/(0.9976 \times \mathrm{length,\ cm}) \quad (6)$$

13. Report

13.1 Report the following information:

13.1.1 Complete identification of the material or product tested, including type, source, manufacturer's code number, form, principal dimensions, and previous history,

13.1.2 Laboratory name,

13.1.3 Date of test,

13.1.4 Method of specimen preparation and conditioning,

13.1.5 Dimensions of the specimen as tested,

13.1.6 Average overall specific gravity for all specimens from a sampling unit, reported as sp gr 23/23°C = ____, or average density reported as D^{23C} = ____g/cm^3,

13.1.7 A measure of the degree of variation of specific gravity or density within the sampling unit such as the standard deviation and number of determinations,

13.1.8 Any evidence of porosity of the specimen including material or method used to seal the cut ends, and

13.1.9 Make and model of balance used for testing, as well as configuration of complete test apparatus if different than shown in Fig. 1.

14. Precision and Bias

14.1 Table 1 is based on a round-robin test conducted in 2001, in accordance with Practice E691, involving two materials tested by six laboratories. For each material, all the specimens were prepared at one source. Each "test result" was the average of five individual determinations. Each laboratory obtained one test results for each material.

NOTE 5—Practice E691 describes the basic principles for conducting interlaboratory experiments to determine repeatability and reproducibility limits.

TABLE 1 Specific Gravity

Material	Mean	Values as a Percent of the Mean			
	ksi	V_r	V_R	I_r	I_R
Plastic Lumber 1	0.7297	1.70 %	1.95 %	4.82 %	5.51 %
Plastic Lumber 2	0.7436	4.47 %	5.22 %	12.66 %	14.77 %

V_r = Repeatability
I_r = 2.83 V_r
V_R = Reproducibility
I_R = 2.83 V_R

NOTE 6—Practice E691 for developing Precision and Bias Statement calls for using six materials and six laboratories. While only two materials were used, the data have been analyzed and presented for use by laboratories.

14.1.1 Do not apply the data given in Table 1 rigorously to accept or reject materials, as this data is specific to the round-robin and not necessarily representative of other lots, conditions, materials, or laboratories. It is important that users of this test method conduct experiments, based on statistically appropriate procedures specific to their material and the laboratories involved, to determine repeatability and/or reproducibility limits for their material.

14.1.2 The explanations shown in 14.2 – 14.2.3 regarding r and R are intended only to present a meaningful way of considering the approximate precision of these test methods.

14.2 *Concept of "r" and "R" in* Table 1—If S_r and S_R have been calculated from a large enough body of data, and for test results that were averages from testing five specimens for each test result, then:

14.2.1 *Repeatability*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the r value for that material. r is the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment on the same day in the same laboratory.

14.2.2 *Reproducibility*—Two test results obtained by different laboratories shall be judged not equivalent if they differ by more than the R value for that material. R is the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

14.2.3 The judgments in 14.2.1 and 14.2.2 will have an approximately 95 % (0.95) probability of being correct.

14.3 *Bias*—It is not possible to make a statement about the bias of these test methods, as there is no standard reference material or reference test method that is applicable.

15. Keywords

15.1 density; plastic lumber; plastic shapes; recycled plastic; specific gravity

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D6111 – 13) that may impact the use of this standard. (September 1, 2013)

(1) Revised 6.4 by creating Note 3.

Committee D20 has identified the location of selected changes to this standard since the last issue (D6111 – 09) that may impact the use of this standard. (June 1, 2013)

(1) Revised the term *plastic lumber* in 3.1.2.

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