



Designation: D 6111 – 9703

Standard Test Method for Bulk Density And Specific Gravity of Plastic Lumber and Shapes by Displacement¹

This standard is issued under the fixed designation D 6111; 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 the 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 similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

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 Products (Section D20.20.01).

Current edition approved ~~July~~ March 10, 1997; 2003. Published ~~February~~ April 2003. Originally approved in 1997. Last previous edition approved in 1997 as D 6111 - 97

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

- D 618 Practice for Conditioning Plastics for Testing²
- D 883 Terminology Relating to Plastics²
- D 1622 Test Method for Apparent Density of Rigid Cellular Plastics²
- D 1898 Practice for Sampling of Plastics²
- D 5033 Guide for the Development of Standards Relating to the Proper Use of Recycled Plastics³
- D 6108 Test Method for Compressive Properties of Plastic Lumber and Shapes³
- E 1 Specification for ASTM Thermometers⁴
- E 12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases⁵
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method⁶

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. (See Terminology D 883.)

3.1.1.1 *Discussion*—Specific gravity at 23/23°C can be converted to density 23°C, g/cm³, as follows:

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

3.1.2 *plastic lumber, n*—a manufactured product composed of more than 50 weight percent resin, and in which the product generally is rectangular in cross-section and typically supplied in board and dimensional lumber sizes, may be filled or unfilled, and may be composed of single or multiple resin blends.

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.

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. (See Terminology D 883.)

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:

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

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. (See Terminology E 12.)

3.2 Additional definition of terms applying to this test method appear in Terminology D 883 and Guide D 5033.

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 Variations in density of a particular plastic lumber or shapes specimen may be due to changes in crystallinity, loss of plasticizer/solvent content, differences in degree of foaming, or to other causes. Portions of a sample may 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 D 1622.

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 may be determined from a specific gravity measurement, see Note 10 (Eq 5).

² Annual Book of ASTM Standards, Vol 08.01.

³ Annual Book of ASTM Standards, Vol 08.03.

⁴ Annual Book of ASTM Standards, Vol 14.03.

⁵ Annual Book of ASTM Standards, Vol 15.05.

⁶ Annual Book of ASTM Standards, Vol 14.02.

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.

NOTE 3—Assurance that the balance meets the performance requirements should be provided by frequent checks on adjustments of zero point and sensitivity and by periodic calibration for absolute accuracy, using standard masses.

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, and should 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. A thermometer short enough to be handled inside the balance case will be found convenient. ASTM Thermometer 23C (see Specification E 1) and Anschütz-type thermometers have been found satisfactory for this purpose.

7. Materials

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

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 D 1898.

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.

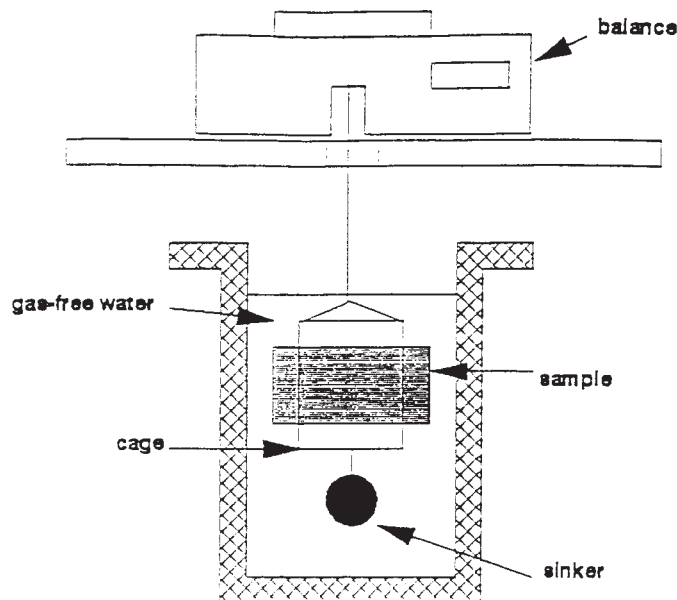


FIG. 1 Typical Configuration of Test Apparatus

NOTE 4—Expect for specified tolerances, the specimen requirements given in 9.1 and 9.2 above are the same for Test Method D 6108. Specimens prepared in accordance with Test Method D 6108 may, therefore, be used to determine bulk specific gravity or density prior to being subjected to the destructive compression tests.

9.3 In such cases where the cross section is known or suspected to be porous, hollow or contain voids, or both, the cut ends should be sealed to prevent the ingress of water from producing false results.

NOTE 5—Nominal 0.05 mm thick, unreinforced plastic packaging tape has been found suitable for sealing the cut ends. Considering the weight of the tape compared to the weight of the specimen, as well as the relative density of the tape, use of this plastic tape to seal the cut ends will have a negligible effect on the final density and specific gravity calculations. Use of a different type of tape or an other method to seal the cut ends may, however, 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 $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ relative humidity for not less than 40 hours prior to test in accordance with Procedure A of Practice D 618. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ and $\pm 2\%$ relative humidity.

10.2 *Test Conditions*—Unless otherwise specified by the customer or product specification, conduct tests in the standard laboratory atmosphere of $23 \pm 2^\circ\text{C}$ and $50 \pm 5\%$ relative humidity. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ and $\pm 2\%$ 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.

NOTE 6—The specimen may be weighed in air after hanging from the wire. In this case, record the weight of the specimen, $a = (\text{weight of specimen} + \text{wire} + \text{cage, in air}) - (\text{weight of wire} + \text{cage, in air})$.

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 $23 \pm 1^\circ\text{C}$. 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.

NOTE 7—It may 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).

NOTE 8—It is convenient to mark the level of immersion by means of a shallow notch filed in the wire. The finer the wire, the greater the tolerance which may be permitted in adjusting the level of immersion between weighing.

NOTE 9—If the wire and cage are left attached to the balance during a series of determinations, the weight a may be determined either with the aid of a tare on the balance. In such cases, care must be taken that the change of 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:

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

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:

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

NOTE 10—Bulk density in g/cm^3 may be converted to lb (mass)/ft^3 as follows:

$$\text{g/cm}^3 \times 62.43 = \text{lb/ft}^3 \tag{5}$$

NOTE 11—For right prismatic plastic lumber and shapes, the cross sectional area is often difficult to determine utilizing conventional measurement techniques. The specific gravity results may be used to calculate the cross sectional area by calculating effective cross sectional area from:

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

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 $D^{23C} = \text{__} \text{g/cm}^3$,

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 This

14.1 Table 1 is based on a round-robin test conducted in 2001, in accordance with Practice E 691, 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 ~~w~~ each material. (**Warning**—The following explanations of *r* and *R* (14.2-14.2.3) are intended only to present a meaningful way of considering the approximate precision of these test methods. The data given in Table 1 should not be applied rigorously to the acceptance or rejection of materials, as those data are specific to the round robin and ~~bias have~~ may not been determined. Interlaboratory studies will be representative of other lots, conditions, materials, or laboratories. Users of these test methods should apply the principles outlined in Practice E 691 to generate data specific to their laboratory and materials, or between specific laboratories. The principles of 14.2-14.2.3 would then be valid for such data.)

NOTE 12—Practice E 691 for developing Precision and Bias Statement calls for using six materials and six laboratories. While only two materials were used, the reproducibility data have been analyzed and presented for use by laboratories.

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 this practice:

14.2 It 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 intent of Subcommittee D20.20 to publish this practice 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 then begin 14.2.2 will have an investigation approximately 95 % (0.95) probability of its precision and bias. Anyone wishing to participate in this work being correct.

14.3 *Bias*—No statement may ~~contact~~ be made about the ~~Chairman~~ bias of Subcommittee D20.20 at ASTM Headquarters. ~~these~~ test methods, as there is no standard reference material or reference test method that is applicable.

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

15. Keywords

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

SUMMARY OF CHANGES

This section identifies the location of selected changes to this test method. For the convenience of the user, Committee D20 has highlighted those changes that may impact the use of this test method. This section may also include descriptions of the changes, or reasons for the changes or both.

D 1111 - 03:**(I) Added Precision and Bias section.**

ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or service@astm.org (e-mail); or through the ASTM website (www.astm.org).