Designation: D 6341 – 98

Standard 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)[1]

This standard is issued under the fixed designation D 6341; 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 coefficient of linear thermal expansion for plastic lumber and plastic lumber shapes to two significant figures. The determination is made by taking measurements with a caliper at three discrete temperatures. At the test temperatures and under the stresses imposed, the plastic lumber shall have a negligible creep or elastic strain rate, or both, insofar as these properties would significantly affect the accuracy of the measurements.

1.1.1 This test method details the determination of the linear coefficient of thermal expansion of plastic lumber and plastic lumber 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 The thermal expansion of plastic lumber and shapes is composed of a reversible component on which may be superimposed changes in length due to changes in moisture content, curing, loss of plasticizer or solvents, release of stresses, phase changes, voids, inclusions, and other factors. This test method is intended to determine the coefficient of linear thermal expansion under the exclusion of non-linear factors as far as possible. In general, it will not be possible to exclude the effect of these factors completely. For this reason, the test method can be expected to give a reasonable approximation but not necessarily precise determination of the linear coefficient of thermal expansion.

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

1.4 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

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:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 883 Terminology Relating to Plastics[2]

D 4065 Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics[3]

D 5033 Practice for the Development of Standards Relating to the Proper Use of Recycled Plastics[4]

E 831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *plastic lumber*, *n*—a manufactured product composed of more than 50 weight percent resin, 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.

3.1.2 *plastic lumber shape*, *n*—a plastic lumber product which is generally not rectangular in cross-section.

3.1.3 *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. **(D 883)**

3.1.3.1 *Discussion*—In a broad sense, the term is used to designate any polymer that is a basic material for plastics. (1982)

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

[1] This test method is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.20 on Plastic Products.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.02.

[4] *Annual Book of ASTM Standards*, Vol 08.03.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

4. Summary of Test Method

4.1 This test method is intended to provide a means of determining the coefficient of linear thermal expansion of plastic lumber and plastic lumber shapes which may or may not contain inclusions and voids. This test method is a product test method, and not a materials test method. Furthermore, this test method is not designed to provide more than two significant figures of accuracy in the result. The test method involves using solid, full cross-sectioned members (see Note 2), as manufactured, of approximately 12 in. (300 mm) in length. The low thermal conductivity of these materials make dynamic temperature variations in a reasonable length of time impractical. Therefore, measurements are taken on each sample after conditioning 48 h or more at three discrete temperatures, –30, 73.4, and 140°F, ± 3.6°F (–34.4, 23, and 60°C, ± 2°C), no more than 1 min after removal from the temperature chamber. The measuring device used is a caliper capable of measuring to the nearest 0.001 in. (0.025 mm), and is utilized at ambient temperature.

NOTE 2—Hollow cross-section products may be evaluated with this test method provided it can be shown that negligible dimensional changes occur in the prescribed measurement time interval.

5. Significance and Use

5.1 The coefficient of linear thermal expansion, α, between temperatures T_1 and T_2 for a specimen whose length is L_0 at the reference temperature, is given by the following equation:

$$\alpha = \frac{1}{L_0} \cdot \frac{L_2 - L_1}{T_2 - T_1} = \frac{1}{L_0} \cdot \frac{\Delta L}{\Delta T} \qquad (1)$$

Where L_1 and L_2 are the specimen lengths at temperatures T_1 and T_2, respectively. α is, therefore, obtained by dividing the linear expansion per unit length by the change in temperature.

5.2 The nature of most plastics and the construction applications for which plastic lumber and plastic lumber shapes are used, make –30 to 140°F (–34.4 to 60°C) a practical temperature range for linear thermal expansion measurements. Where testing outside of this temperature range or when linear thermal expansion characteristics of a particular plastic are not known through this temperature range, particular attention shall be paid to the factors mentioned in 1.2 and special preliminary investigations by thermo-mechanical analysis, such as that prescribed in Practice D 4065 for the location of transition temperatures, may be required to avoid excessive error. If such a transition point is located, a separate coefficient of expansion for a temperature range below and above the transition point shall be determined. For specification and comparison purposes (provided it is known that no transition exists in this range), the range from –30 to 140°F (–34.4 to 60°C) shall be used. (For reference, glass transition and melting point temperatures of typical resins used in plastic lumber products are given in Appendix X2 of this test method.)

6. Apparatus

6.1 *Conditioning Chamber*, capable of conditioning test specimens at temperatures in the range of –30 to 140°F, ± 1.8°F (–34.4 to 60°C, ± 1°C), at humidity levels of 50 ± 5 %.

6.2 *Caliper*, capable of measuring the length of the specimen with an accuracy of 0.001 in. (0.025 mm). For a given test or test series, the same caliper shall be used for all measurements. The calipers shall be kept and used at room temperature (73.4°F (23°C)).

6.3 *Thermometer or Thermocouple*, capable of an accuracy of ± 0.2°F (± 0.1°C) when measuring the temperature of the conditioning chamber.

7. Test Specimen

7.1 Test specimens for determining thermal expansion of plastic lumber and plastic lumber shapes shall be cut from the "as manufactured" profile. Great care shall be taken in cutting and machining the ends so that smooth, flat, parallel surfaces and sharp, clean edges result and are parallel to within 1/300 of the specimen length perpendicular to the long axis of the specimen. Plastic lumber is generally non-uniform through the cross-section; machining operations other than those required to provide flat, parallel ends shall not be carried out. A line parallel to the length shall be marked with an indelible ink marker on an uncut surface along the full length of the specimen. Length measurements of the sample are to be carried out on the surfaces adjacent to the drawn lines (on the cut faces) at each end of the specimen, at a location very near the ends of the line.

7.2 The standard test specimen shall be in the form of a right cylinder or prism whose length is a minimum of 12 ± 0.25 in. (300 mm ± 6.4 mm) (see Note 3).

NOTE 3—This test method may be utilized to determine the linear coefficient of thermal expansion for other sample directions (that is, width or thickness) if desired. However, the accuracy of the measurements will be significantly reduced due to the generally smaller linear dimension.

8. Conditioning

8.1 *Conditioning*—Condition the test specimens at –30, 73.4, and 140°F ± 3.6°F (–34.4, 23, and 60°C ± 2°C) and 50 ± 5 % relative humidity for not less than 48 h at each temperature prior to testing in accordance with Procedure A of Practice D 618, unless otherwise specified by the customer or product specification. In cases of disagreement, the tolerances shall be ± 1.8°F (± 1°C) and ± 2 % relative humidity.

8.2 *Test Conditions*—Conduct measurements in the standard laboratory atmosphere of 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity, within 1 min or less after removal from the conditioning environment unless otherwise specified by the customer or product specification. In cases of disagreement, the tolerances shall be ± 1.8°F (± 1°C) and ± 2 % relative humidity.

9. Number of Test Specimens

9.1 A sample size of five shall be used. Each specimen shall be tested at each of the three measurement temperatures.

10. Procedure

10.1 Prepare and mark each specimen to be tested in accordance with 7.1 and 7.2. Condition the specimens at –30 ± 3.6°F (–34.4 ± 2°C) in accordance with 8.1.

10.2 Measure the length of each of the conditioned specimens within 1 min of removal from the conditioning chamber at room temperature to the nearest 0.001 in. (0.025 mm) with the caliper (see 6.2 and Note 4). Record the actual conditioning temperature to the nearest 0.2°F (0.1°C) to obtain T_1, and the caliper reading. Average the caliper readings and report this value as L_1.

NOTE 4—To minimize errors due to the formation of ice or condensation on the surface of specimens whose temperature is below the dew point, the surfaces to be measured should be wiped off with an absorbent cotton rag just prior to making the measurements.

10.3 Repeat the steps described in 10.1 and 10.2 at a conditioning temperature of 73.4 ± 3.6°F (23 ± 2°C) to obtain T_2 and L_2.

10.4 Repeat the steps described in 10.1 and 10.2 at a conditioning temperature of 140 ± 3.6°F (60 ± 2°C) to obtain T_3 and L_3.

11. Calculation

11.1 Calculate the coefficient of linear thermal expansion over the temperature range used as follows:

$$\alpha = \frac{1}{L_2} m \qquad (2)$$

where:

α = coefficient of linear thermal expansion,
L_2 = length of test specimen at room temperature, 73.4 ± 3.6°F, and
m = slope of the best fit line to the data points (L_1, T_1), (L_2, T_2), (L_3, T_3), (representing $\Delta L/\Delta T$) determined by the least squares criterion, and is given by:

$$m = \frac{3(\Sigma L_i T_i) - (\Sigma L_i)(\Sigma T_i)}{3(\Sigma T_i^2) - (\Sigma T_i)^2} \text{ for } I = 1 \text{ to } 3 \qquad (3)$$

where:

L_i = the sample length at temperature, T_i.

NOTE 5—The following relationship will prove most useful to those designing with these materials (an example calculation is provided in Appendix X3:

$$\Delta L = L_0 (\alpha \Delta T) \qquad (4)$$

where:

α = Coefficient of linear thermal expansion in (in./in.)/°F [(cm/cm)/°C)],
ΔL = change in length of test specimen, in in. (cm) due to heating or to cooling,
L_0 = length of test specimen in in. (cm) at a reference temperature, T_0 (usually ambient temperature), and
ΔT = temperature difference, in °F (°C), over which the change in the length, ΔL, of the specimen is measured.

12. Report

12.1 Report the following information:

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

12.1.2 Laboratory name,

12.1.3 Date of test,

12.1.4 Method of preparing test specimens,

12.1.5 Type of test specimen and dimensions,

12.1.6 Conditioning procedure used, if non-standard conditioning has been employed,

12.1.7 Atmospheric conditions in test room, if non-standard conditioning has been employed,

12.1.8 Measurement temperatures if other than or in addition to the temperatures specified in this test method,

12.1.9 Number of specimens tested, and

12.1.10 Average coefficient of linear thermal expansion for the specimens tested.

13. Precision and Bias

13.1 This is a new test method for which precision and bias have not been determined by full round robin testing.

13.1.1 Based on tests conducted at Rutgers University, NJ, the coefficient of variation was determined to be at least 0.79.

13.2 It is the intent of Subcommittee D20.20 to publish this test method and then begin an investigation of its precision and bias. Anyone wishing to participate in this work may contact the Chairman, Subcommittee D20.20, ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428. More complete information on precision and bias is expected to be available on or before March 2001.

14. Keywords

14.1 coefficient of expansion; linear expansion; plastic lumber; recycled plastics; thermal expansion

APPENDIXES

(Nonmandatory Information)

X1. RATIONALE

X1.1 This test method has been developed to determine the coefficient of thermal expansion of full cross-sectioned pieces of plastic lumber profiles. These products are new, and an existing test method which addressed the issues of this new products did not exist. These products are known to possibly contain gaseous voids and inclusions of a variety of materials, held together in a matrix of a predominantly polymer resin. Test methods which rely upon testing a small portion of the cross-section will not have the averaging effects on thermal expansion which will occur in this mixture of materials. Test methods which rely upon short pieces of full-cross-sections will be more limited in their accuracy of measurement. This test method was developed to allow the builder of structures with these materials to estimate the magnitude of thermal expansion mismatches among building materials so that this can be allowed for in the structural design.

X2. TRANSITION TEMPERATURES

X2.1 See Table X2.1 for transition temperatures for polymers typically found in plastic lumber.[6]

TABLE X2.1 Transition Temperatures for Polymers Typically Found in Plastic Lumber

Polymer Type	Glass Transition Temperature, T_g, °F (°C)	Melting Point Temperature, T_m, °F (°C)
Polyethylene terephthalate	154–176 (68–80)	414–509 (212–265)
High-density polyethylene	–193 (–125)	266–279 (130–137)
Low-density polyethylene	–13 (–25)	208–239 (98–115)
Polypropylene	–4 (–20)	320–347 (160–175)
Polystyrene	165–221 (74–105)	. . .
Rigid poly(vinyl chloride)	167–221 (75–105)	. . .

X3. SAMPLE CALCULATION FOR CHANGE OF LENGTH

X3.1 The following is an example calculation regarding change of length of a plastic lumber board.

X3.1.1 Suppose that a 12-ft (3.66-m) long board where to be installed at 73.4°F (23°C), in a location where the lowest typical winter temperatures are –4°F (–20°C), and the hottest typical summer temperatures are 122°F (50°C). Also consider that the thermal expansion coefficient, α, as determined by this test method is indicated as $3.3 \cdot 10^{-5}$ per °F ($6 \cdot 10^{-5}$ per °C). The designer is interested in what the length will be at the extreme temperatures, with no stress imparted to the board to change its length. First, consider the low temperature extreme, and then the higher temperature extreme.

X3.1.2 *Low Temperature Extreme*—Referring to Eq 4 of the test method, at –4°F (–20°C), the change in temperature is T_2–T_1, or (–4) – (73.4) = –77.4°F ((–20) – (23) = –43°C). L_0 is 12 ft (3.66 m). The change in length of the board is, therefore, ($3.3 \cdot 10^{-5}$) · (12 ft) · (–77.4) = –0.031 ft ($6 \cdot 10^{-5}$) · (3.66 m) · (–43) = (–0.0094 m)). The total length is 12 ft + (–0.031 ft) = 11.97 ft (3.66 m + (–0.0094 m) = 3.65 m). The board is expected to reduce its length due to low temperature extremes by 0.031 ft or approximately ⅜in. (0.0094 m).

X3.1.3 *High Temperature Extremes*—Again, referring to Eq 4, at 122°F (50°C), the change in temperature is $T_2 – T_1$, or (122) – (73.4) = 48.6°F (50– 23 = 27°C). The change in length is ($3.3 \cdot 10^{-5}$) · (12 ft) · (48.6) = 0.019 ft (($6 \cdot 10^{5}$) · (3.66 m) · (27) = (0.0059 m)). The total length is 12 ft + 0.019 ft = 12.019 ft (3.66 m + 0.0059 m = 3.67 m). The board is, therefore, expected to increase its length due to high temperature extremes by 0.019 ft or approximately 15⁄64 in. (0.0059 m).