Designation: D6662 – 17

Standard Specification for
Polyolefin-Based Plastic Lumber Decking Boards[1]

1. Scope*

1.1 This specification covers polyolefin-based plastic lumber products for use as exterior residential decking boards.

1.2 Plastic lumber products are currently made predominantly with recycled polyolefin plastics (in particular high-density polyethylene) where the products are more or less non-homogenous in the cross-section. However, this specification is also potentially applicable to similar manufactured plastic products made from other plastic and plastic composite materials that have non-homogenous cross-sections.

1.3 This specification details a procedure to calculate recommended span lengths for spacing of support joists. This procedure was developed using experimental data from a typical unreinforced plastic lumber made predominantly from recycled high-density polyethylene. The methodology to develop span lengths for other types and compositions of plastic lumber is detailed in Appendix X1 of this standard.

1.4 The values are stated in inch-pound units, as these are currently the most common units used by the construction industry. Equivalent SI units are indicated in parentheses. However, the units stated for irradiance exposure in the weatherability section (6.3) are in SI units as these are the units commonly used for testing of this type.

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 The following documents of the issue in effect on the date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]
D883 Terminology Relating to Plastics
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
D4329 Practice for Fluorescent Ultraviolet (UV) Lamp Apparatus Exposure of Plastics
D5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics (Withdrawn 2007)[3]
D6109 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastic Lumber and Related Products
D6112 Test Methods for Compressive and Flexural Creep and Creep-Rupture of Plastic Lumber and Shapes
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)
E84 Test Method for Surface Burning Characteristics of Building Materials
E108 Test Methods for Fire Tests of Roof Coverings
G151 Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources
G154 Practice for Operating Fluorescent Ultraviolet (UV) Lamp Apparatus for Exposure of Nonmetallic Materials
G155 Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

3. Terminology

3.1 *Definitions:*

3.1.1 *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)

3.1.1.1 *Discussion*—Plastic lumber is typically supplied in sizes similar to those of traditional lumber board, timber and

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

dimension lumber; however the tolerances for plastic lumber and for traditional lumber are not necessarily the same. (Terminology D883)

3.1.2 *resin, n*—a solid or pseudo solid 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)

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bulge*—convex distortion (away from the center of the cross-section) of the face of the board from a straight line drawn from edge to edge across the width of the board.

3.2.2 *crook*—distortion of the board in which there is a deviation in a direction perpendicular to the edge from a straight line from end to end of the board.

3.2.3 *cup*—concave distortion (towards the center of the cross-section) of the face of the board from a straight line drawn from edge to edge across the width of the board.

3.2.4 *edge*—the side of a rectangular-shaped board corresponding to the thickness of the board.

3.2.5 *face*—the side of a rectangular-shaped board corresponding to the width of the board.

3.2.6 *thickness*—the lesser dimension of the cross-sectional profile of a rectangular-shaped board.

3.2.7 *width*—the greater dimension of the cross-sectional profile of a rectangular-shaped board.

3.3 Additional definition of terms applying to this specification appear in Terminology D883 and D5033.

4. Ordering Information

4.1 The information contained in this specification is intended to be helpful to producers, distributors, regulatory agencies and users. The information can also promote understanding between purchasers and sellers. The purchaser shall state whether this specification is to be used, select the preferred options permitted herein, and include the allowable design information in the invitation to bid and purchase order from the following:

4.1.1 Title, number and date of this specification,

4.1.2 Minimum allowable bending strength and allowable bending stiffness,

4.1.3 Percent recycled content (if requested),

4.1.4 Flame spread index,

4.1.5 Color,

4.1.6 Quantity in lineal feet,

4.1.7 Cut length,

4.1.8 Cross-sectional dimensions,

4.1.9 Packing requirements,

4.1.10 Palletization, if required,

4.1.11 Marking, if other than specified.

4.2 If specific mechanical property values are not required by the purchaser (for example, when purchasing materials for general retail sales distribution and not for a specific project), the manufacturer shall provide minimum allowable design

information, as would be determined under this specification, to aid in the application of the decking board material by the end user.

5. Dimensions and Permissible Variations

It is permissible to produce decking boards either in sizes that are similar to the standard dimensions of the wood industry, or to proprietary dimensions designed by manufacturers. This specification does not limit the dimensional range of production. For reference, the standards of the wood industry are as follows:

5.1 *Thickness*—Unless otherwise specified in 4.1.8, boards shall be:

Nominal (in.)	Actual (in.)	Tolerance (in.)
1	¾	± ¹⁄₁₆
⁵⁄₄	1	± ¹⁄₁₆
2	1-½	± ¹⁄₁₆

Tolerance on thickness of boards thicker than 2 inches (nominal) shall be ± ¹⁄₁₆ inch.

5.2 *Width of Boards*—Unless otherwise specified in paragraph 4.1.8, board widths shall be:

Nominal (in.)	Actual (in.)	Tolerance (in.)
3	2-½	± ¹⁄₁₆
4	3-½	± ¹⁄₁₆
6	5-½	± ¹⁄₁₆
8	7-¼	± ¹⁄₁₆
10	9-¼	± ¹⁄₁₆
12	11-¼	± ¹⁄₁₆

Tolerance on width of boards wider than 12 inches (nominal) shall be ± ¹⁄₁₆ inch.

5.3 *Length of Boards*—unless otherwise specified in 4.1.7, boards up to 20 feet shall have tolerances of +½ inch or -¹⁄₁₆ inch. Over 20 feet, the tolerances will be +½-inch or -¹⁄₁₆ inch per 20-ft of length or fraction thereof. Measurement of lengths to be made at 73 ± 2 °F and relative humidity of 50 ± 5 %.

5.4 *Flatness Tolerance*—Board shall be flat with maximum cup or bulge in the board face limited to the tolerances in Table 1. Linear interpolation of the values is acceptable for dimensions other than listed.

5.5 *Squareness*—Unless a specially shaped member is specified, the cross-section of all boards shall be visually rectangular (that is, the face and edge of the board are perpendicular to each other) and suited for the intended purpose.

5.6 *Crook*—Crook shall conform to the tolerances in Table 2. Linear interpolation of the values is acceptable for dimensions other than listed.

5.7 *Tongue and Groove*—Boards shall be without tongue and groove unless otherwise specified in 4.1.8. Because of load transfer between adjacent boards, the methodology and equations presented in section 6.1.4 for determining recommended

TABLE 1 Cup or Bulge Tolerances Relative to Nominal Width of the Board Face

Face Width, in.	≤4 in.	6 in.	8 in.	10 in.	12 in.
Tolerance	¹⁄₃₂ in.	¹⁄₁₆ in.	⅛ in.	³⁄₁₆ in.	¼ in.

TABLE 2 Crook Tolerances Relative to Nominal Length and Width of the Board

Length in Feet	≤4 in. Width	6 in. Width	8 in. Width	10 in. Width	12 in. Width
4–6	⅜ in.	¼ in.	3⁄16 in.	⅛ in.	⅛ in.
8	½ in.	½ in.	⅜ in.	¼ in.	3⁄16 in.
10	¾ in.	⅝ in.	½ in.	7⁄16 in.	⅜ in.
12	1 in.	⅞ in.	13⁄16 in.	¾ in.	9⁄16 in.
14	1¼ in.	1⅛ in.	1 in.	⅞ in.	¾ in.
16	1½ in.	1⅜ in.	1⅛ in.	1 in.	⅞ in.

maximum span lengths are not applicable to tongue and groove boards. Manufacturers of tongue and groove decking boards shall provide recommended span lengths based on sound engineering practice, taking into account some of the issues described in 6.1.4 below, as well as previous, in-service performance history.

6. Performance Requirements

6.1 *Flexural Properties:*

6.1.1 *Test Procedure*—D6109.

6.1.2 *Specimens Tested*—A minimum of 15 specimens shall be tested.

6.1.3 *Criteria*—(*1*) The mean value of the secant flexural modulus at 1 % outer fiber strain estimated statistically to within 5 % with 75 % confidence shall equal or exceed 50 000 psi. Table 3 shows the number of specimens required to establish the mean value at 75 % confidence interval with ± 5 % error using Practice D2915. (*2*) The 5 % lower tolerance limit at 75 % confidence flexural stress at 3 % outer fiber strain shall equal or exceed 1000 psi. If any specimen fails prior to reaching 3 % strain, then the flexural strength at failure for that specimen shall equal or exceed 1000 psi. The 5 % lower tolerance limit at 75 % confidence is computed by subtracting K-times the standard deviation from the mean value, where K is tabulated in statistics handbooks (and in Table 3 of Practice D2915) as a factor for a one-sided tolerance limit for the distribution. Table 4 shows the value of K for several sample sizes.

NOTE 2—Many standards require a minimum sample size of approximately 30 to balance testing costs against the large reductions in the allowable values for very small sample sizes.

NOTE 3—A16 in. on center joist spacing is considered typical standard spacing for residential deck construction. While 50 000 psi is given as a minimum flexural modulus, a modulus greater than 50 000 psi is potentially required for some decking board sizes in order to meet this spacing when determining span lengths per the guidance presented in 6.1.4 below. Alternatively, use span lengths less than 16 in. on center as needed.

NOTE 4—Concurrent to the development of this specification for Plastic Lumber Decking, a Standard Guide for the Design and Construction of Plastic Lumber Decking is being developed by Section D20.20.01 (under the Subcommittee D20.20 on Plastic Products). This Standard Guide is expected to be available sometime after this Specification has been approved and in use.

TABLE 3 Number of Specimens Required to Establish the Mean Value with an Error of ± 5 % with 75 % Confidence for Various Coefficients of Variation (COV) in the Data Set

COV Range, %	10–15	>15–20	>20–25	>25
No. of Specimens, N	15	23	34	~60

TABLE 4 Value of K for Establishing the Lower 5 % Lower Tolerance Limit with 75 % Confidence for Various Sample Sizes

No. of Specimens, N	15	30	Infinite
Value of K	1.991	1.869	1.645

6.1.4 *Span Lengths*—Recommended maximum span lengths shall be determined using the following equations:

For concentrated loads on boards which are continuous over a minimum of two spans (such as decking boards) as shown in Fig. 1, the maximum recommended span shall be limited by either the stress or the deflection formula as follow, whichever provides the lesser span:

Stress Formula:

$$L = (64 S F_b')/(13P) \tag{1}$$

Deflection Formula:

$$L = [(67E'I)/(P\,k\alpha)]^{\frac{1}{2}} \tag{2}$$

For distributed (or uniform) loads on boards which are continuous over a minimum of two spans (such as decking boards) as shown in Fig. 2, the maximum span shall be limited by either the stress or the deflection formula as follow, whichever provides the lesser span:

Stress Formula:

$$L = [(8 S F_b')(144)/(qb)]^{\frac{1}{2}} \tag{3}$$

Deflection Formula:

$$L = [(185E'I)(144)/(qb\,k\alpha)]^{\frac{1}{3}} \tag{4}$$

where:
L = computed span length, in.,
S = section modulus, in.^{3},
F_b' = allowable flexural stress as computed in 6.1.4.1, psi,
P = concentrated load, lb,
E' = effective modulus of elasticity as computed in 6.1.4.2, psi,
I = moment of inertia, in.^{4},
k = factor used to limit deflection to L/k (for example L/360 with k = 360; or L/120 with k = 120),
q = uniformly distributed load, lb/sq-ft,
b = actual board width, in., and
α = Creep Adjustment Factor = 1.5.

NOTE 5—The attached commentary in Appendix X1 provides a rationale for the Creep Adjustment Factor, α.

6.1.4.1 *Allowable Flexural Stress*—The allowable flexural stress, F_b', of the decking board is given as follows:

$$F_b' = (F_b/FS) \cdot C_D \cdot C_T \tag{5}$$
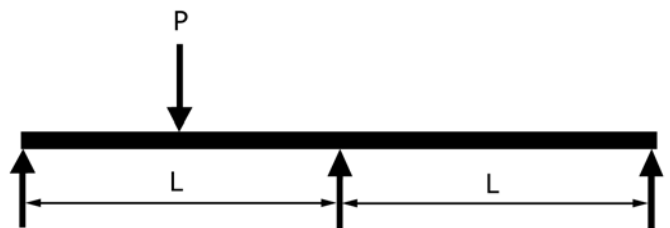
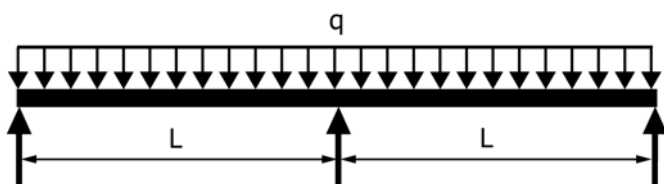**FIG. 1 Schematic of Concentrated Load on Boards that are Continuous Over Two Spans**

FIG. 2 Schematic of Distributed Load on Boards that are Continuous Over Two Spans

TABLE 5 Load Duration Factor, C_D

Duration of Load	Load Duration Factor
Impact Load—1 s	4.81
1 min	3.62
3 min	3.34
Wind/Seismic Load—10 min	3.04
1 h	2.64
6 h	2.28
1 day	2.04
Construction Load—7 days	1.73
Snow Load—2 months	1.44
1 year	1.22
Floor Load—10 years	1.00
Permanent Load—30 years	0.91

Use linear interpolation to estimate C_D for any other duration of load, noting that the abscissa in Fig. 3 is on a logarithmic scale.

TABLE 6 Temperature Factor, C_T

Temperature, °F	C_T
32	1.71
63	1.14
73	1.00
100	0.63
122	0.43
140	0.30

Use linear interpolation to estimate C_T for any other temperature value.

The Load Duration Factors C_D and Temperature Factor C_T were developed using one typical unreinforced polyolefin-based plastic lumber. The methodology to obtain these factors for boards of other composition is outlined in Appendix X1.

where:

F_b = the base flexural stress value for plastic lumber made of HDPE-type polyolefins for normal duration loading (10 yr. duration), psi,

FS = Factor of Safety = 1.5,

C_D = Load Duration Factor for flexural stress, presented in Fig. 3 and Table 5, depends on the shortest-duration load in combination, applied either cumulatively or continuously, and

C_T = Temperature Factor, Table 6.

F_b, the base flexural stress value for plastic lumber made of HDPE type polyolefins, is determined as follows:

$$F_b = F_{bt} \cdot 0.3 \tag{6}$$

where:

F_{bt} = the 5 % lower tolerance limit at 75 % confidence of the flexural stress at 3 % outer fiber strain determined from flexure tests conducted in accordance with Test Method D6109, and

0.3 = factor to convert the 3 minute test value to a ten year normal duration value (that is, a flexural stress equal to 30 % of F_{bt} will induce a 3 % outer fiber strain in ten years).

Note 6—The attached commentary in Appendix X1 provides a more detailed description of the development of C_D, C_T and 0.3 factors above, based on experimental data on typical plastic lumber. A general procedure to develop these factors for other types of plastic lumber is also provided in Appendix X1.

6.1.4.2 *Effective Modulus of Elasticity and Adjustment for Creep*—The effective modulus of elasticity, E', shall be determined as follows:

$$E' = (E \cdot C_T) \tag{7}$$

where:

E = the secant flexural modulus as defined in section 6.1, psi, and

C_T = Temperature Factor, Table 6.

The deflection, Δ_T, for the decking board can then be calculated as follows:

$$\Delta_T = \Delta_{e1} \cdot \alpha \tag{8}$$

where, Δ_{el}, the instantaneous elastic deflection for the cases in Fig. 1 is given as

$$\Delta_{e1} = [PL^3]/[67E'I] \text{ for concentrated loads} \tag{9}$$

$$\Delta_{e1} = [qbL^4]/[(144) \cdot (185E'I)] \text{ for distributed loads} \tag{10}$$

For distributed loading at an average ambient temperature of 90°F the maximum creep deflection of the decking boards shall not exceed L/240.

Note 7—An example problem for the case of distributed loading is described in Appendix X2, Table X2.1.

6.2 *Dimensional Stability—Thermal Expansion:*

6.2.1 *Test Procedure—D6341.*

6.2.2 *Specimens Tested*—A minimum of 15 specimens shall be tested to establish the average value.

Report the measured coefficient of thermal expansion in the longitudinal direction to two significant figures for use in deck design calculations.

Note 8—This value has the potential to be of significant importance when the plastic lumber decking boards are used with other dissimilar materials involving differential thermal expansion under varying temperature conditions. For tongue and groove boards, the transverse thermal expansion coefficient is also occasionally needed to estimate required spacing between boards.
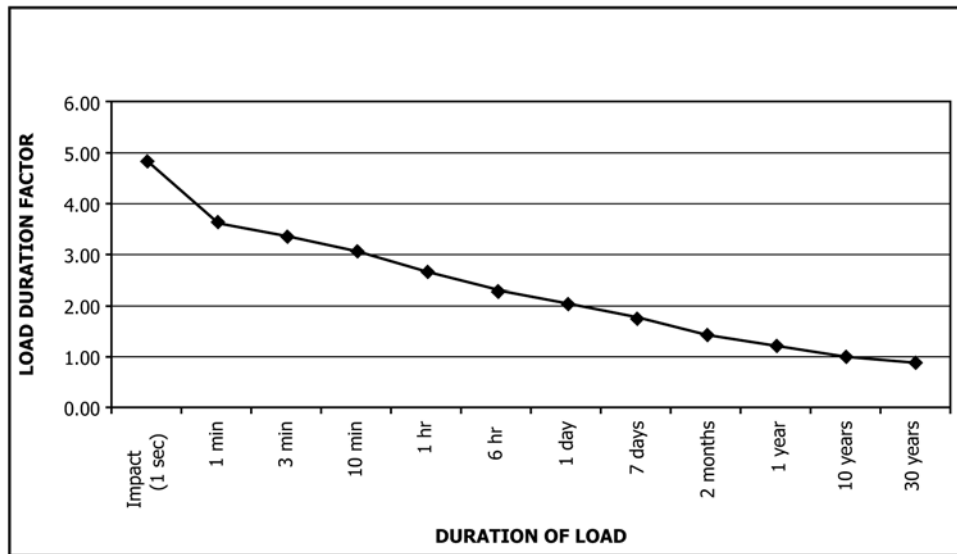
FIG. 3 Load Duration Factor for Plastic Lumber

6.3 *Weatherability*

6.3.1 *Test Procedure for Surface Appearance Changes:*

6.3.1.1 *Exposure Conditions:* 6.3.1.1.1 Specimens to be tested shall be exposed to the xenon arc light source with daylight filters in accordance with Practices G151, G155 and D2565.

6.3.1.1.2 Use the following exposure conditions (control setpoints and control tolerances) for a total period of 2000 hours continuous light, cycling between:

2 hours light only	
Irradiance:	0.7 ± 0.02 W/(m²·nm) @340 nm
	or
	77.0 ± 4.5 W/m² @300–400 nm
	or
	736.0 ± 44.0 W/m² @300–800nm
Humidity (if used):	50 ± 5 % RH
Uninsulated Black Panel Temperature:	158 ± 4°F (70 ± 2.2°C)
2 hours light with water spray (on the exposed surface)	
Irradiance:	0.7 ± 0.02 W/(m²·nm) @340 nm
	or
	77.0 ± 4.5 W/m² @300–400 nm
	or
	736.0 ± 44.0 W/m² @300–800 nm
Humidity:	Not applicable
Uninsulated Black Panel Temperature:	Not applicable

Note 9—Immersion can be used as an alternative method to water spray to introduce moisture to the material surface.

6.3.1.2 *Specimens Tested:* 6.3.1.2.1 *Coupon Specimens*—Triplicate specimens of a size required to fit into the standard weathering chamber specimen holder.

6.3.1.3 *Period(s) of Exposure*—Specimens to be tested shall be exposed for a period of 2000 hours in accordance with section 6.3.1.1.

6.3.1.4 *Criteria of Degradation:* 6.3.1.4.1 Exposed samples shall be free of any visual surface changes such as peeling, chipping, cracking, flaking, pitting and non-uniform color changes.

6.3.2 *Test Procedure for Flexural Property Changes:*

6.3.2.1 *Exposure Conditions:* 6.3.2.1.1 Specimens to be tested shall be exposed to fluorescent UVA-340 radiation in accordance with Practices G151, G154 and D4329 Procedure 7.2.2 Cycle B.

6.3.2.1.2 Use the following exposure conditions (control setpoints and control tolerances) for a total period of 2000 hours, cycling between:

8 hours light only	
Irradiance:	0.72 ± 0.2 W/(m²·nm) @340 nm
Uninsulated Black Panel Temperature:	158 ± 5°F (70 ± 2.8°C)
4 hours no light with condensation	
Irradiance:	Not applicable
Uninsulated Black Panel Temperature:	Not applicable

6.3.2.1.3 The surface of the plastic lumber specimens will need to be immersed in or sprayed with water in order to assure a wet surface during the no-light portion of the test cycle. The plastic lumber specimens are too thick and too great of an insulator to expect water to condense on the face of the specimen during the no light cycle.

6.3.2.2 *Specimens Tested:* 6.3.2.2.1 *Full Member Boards*—15 representative specimens shall be prepared and tested in flexure as described in Test Method D6109 with the loading noses on the unexposed side so that the exposed side is under tensile stress.

6.3.2.3 *Period of Exposure*—Specimens to be tested shall be exposed for a period of 2000 hours in accordance with section 6.3.2.1.

Note 10—The Building Officials and Code Administrators (BOCA) has accepted a screening test with Test Method D4329 at 1080 hour exposure in approving polyolefin based decking boards per BOCA International Evaluation Research Report 97-63, December 1999.

Note 11—As detailed in Appendix X3, there is experimental data that indicate that outdoor weathering over an 11 year period has negligible effect on the flexural strength and stiffness of polyolefin based plastic lumber decking boards. Thus, a 2000 hour screening test, such as that described above, can only be used to identify the products that are most susceptible to UV degradation and with the potential to deteriorate in two

years or less under actual outdoor exposure.

6.3.2.4 *Criteria of Degradation*—The flexural secant modulus shall retain 90 % of the average value at 75 % confidence when tested without exposure.

6.3.3 *Hygrothermal Cycling:*

6.3.3.1 *Test Procedure*—Specimens shall also be prepared as described in Test Method D6109. Each specimen shall then be weighed to the nearest 0.00022 lb (0.1 g). Specimens shall then be totally submerged underwater (using weights to hold down, if necessary) for a period of 24 h. After removal from water, each specimen shall then be dried with a dry cloth on the outside surfaces and weighed again within 20 min. Specimens which exceed a 1 % weight gain shall be resoaked until such time as the weight changes less than 1 % per 24 hour period. Such specimens will then be considered to have reached moisture absorption equilibrium. Upon reaching this equilibrium the specimens shall be frozen to -20 °F (-29 °C) for 24 h, then returned to room temperature. This process comprises one hygrothermal cycle.

The above procedure shall be repeated two more times, for a total of three cycles of water submersion, moisture absorption equilibrium, and freezing. After completion of these steps, the specimens shall be returned to room temperature and tested as described in Test Method D6109.

6.3.3.2 *Specimens Tested*—A minimum of 15 specimens shall be prepared as per Test Method D6109 and tested.

6.3.3.3 *Criteria*—Note any obvious physical changes that occur as a result of the hygrothermal cycling. The flexural secant modulus and the greater of the stress level at 3 % strain or the stress at fracture as defined in Test Method D6109 shall retain 90 % of the average value at 75 % confidence when tested without hygrothermal cycling.

6.4 *Fire Properties:*

6.4.1 The flame spread index of plastic lumber decking boards shall be determined by testing in accordance with Test Method E84.

6.4.2 The test specimen shall either be self-supporting by its own structural characteristics or held in place by added supports along the test specimen surface. The test specimen shall remain in place throughout the test duration. Test results are invalid if one of the following occurs during the test: (a) the test specimen sags from its position in the ceiling to such an extent that it interferes with the effect of the gas flame on the test specimen or (b) portions of the test specimen melt or drop to the furnace floor to the extent that progression of the flame front on the test specimen is inhibited. Appendix X1 of Test Method E84 provides guidance on mounting methods.

6.4.3 Products shall have a flame spread index no greater than 200 when tested in accordance with Test Method E84.

NOTE 12—For combustible construction, codes often require fire performance at least equivalent to that of wood. A maximum flame spread index of 200 when tested in accordance with Test Method E84 is considered to be equivalent to that of wood. For outdoor applications, there is no requirement specified for smoke developed index.

NOTE 13—Fire retardants are available to increase the resistance to ignitability and flame spread of plastic lumber and shall be incorporated as needed.

6.4.4 The plastic lumber industry has developed a qualification fire test based on end-use of the material in decking.

This method, a modification of Test Methods E108 originally intended for roofing materials, is presented in Appendix X4 along with a commentary for its use.

6.5 *Slip Resistance:*

6.5.1 There is currently no universal consensus of requirements for slip resistance for residential decking regardless of the material of construction. Over the years, a variety of ASTM test methods have been developed to measure the slip resistance or the coefficient of friction of various materials. However, the test results can be significantly influenced by climatic and interfacial conditions, which the different methods do not necessarily take into account. The existing ASTM test methods are, therefore, not considered sufficient to establish minimum slip resistance criteria for publication in this plastic lumber decking board standard.

NOTE 14—ASTM is currently coordinating slip resistance specification issues at a Society level. Committee Section D20.20.01 on Plastic Lumber will continue to look to the recommendations from this effort for guidance on this issue.

6.5.2 As with all types of decking materials, in some cases egress areas will require specific surface treatments in order to reduce the possibility of accidental slipping.

7. Specimen Conditioning

7.1 *Conditioning of Specimens for Tests*—Unless specifically stated otherwise, all specimens shall be conditioned and tested in accordance with the appropriate test method.

8. Workmanship, Finish, and Appearance

8.1 The decking furnished in accordance with this specification shall be an acceptable match to approved samples in pattern, color, and surface appearance. The product shall be free of defects that adversely affect performance or appearance. Such defects include blemishes, spots, indentations, cracks, blisters, and breaks in corners or edges.

9. Certification

9.1 When requested, a manufacturer's certification and any other documents required to substantiate certification shall be furnished stating that the material was manufactured to meet this specification.

10. Product Marking

10.1 Unless otherwise specified in the purchase order or contract, shipping containers shall be marked with the name of the material as defined by the contract under which the shipment is made, the size, thickness, length, color, quantity, lot number, date, location and name of the manufacturer shall be included.

11. Quality Assurance

11.1 This section presents a quality assurance program for the manufacturer to put into place to verify compliance with specific portions of this specification. The program shall include the following at a minimum:

11.1.1 *Material Specification,* including incoming material inspection and acceptance requirements.

11.1.2 Sampling and inspection frequencies shall be devised to encompass all variables that affect the quality of the finished product including lot-to-lot variations from different production runs. Increased frequencies shall be used in connection with new or revised facilities. A random sampling scheme shall generally be used for specimen selection. As a minimum, properties to be verified in the quality assurance program include: (*1*) Dimensions and Permissible Variations, per Section 5 and (*2*) Flexural Properties, per Section 6.

Note 15—Increased sampling and test frequencies shall be a useful procedure when investigating apparent data trends or adjustments in process. It is desirable at times to deviate from a random sampling scheme while investigating effects of specific variables.

11.1.3 Procedures to be followed upon failure to meet specifications or upon out of control conditions shall be specified. Included shall be re-examination criteria for suspect material and material rejection criteria.

11.1.4 Finished product marking, handling, protection, and shipping requirements as they relate to the performance of the finished product shall be defined.

11.2 *Inspection Personnel*—All manufacturing personnel responsible for quality control shall have knowledge of the inspection and test procedures used to control the process of the operation and calibration of the recording and test equipment used and of maintenance and interpretation of quality control records.

11.3 *Record Keeping*—All pertinent records shall be maintained on a current basis and be available for review. Records shall include:

11.3.1 Inspection reports and records of test equipment calibration, including identification of personnel conducting tests.

11.3.2 All test data, including retesting and data associated with rejection production and corrective actions taken.

11.4 *Testing Equipment*—Testing equipment shall be properly maintained, calibrated and evaluated for accuracy and adequacy at a reasonable frequency.

11.5 *Retest and Rejection*—If the results of any selected quality tests do not meet the requirements, conduct the test(s) again in accordance with statistically valid sampling techniques if agreed upon between the purchaser and the seller. There shall be no agreement to lower the minimum requirements or omitting tests that form a part of this specification, substituting or modifying a test method or by changing the specification limits. In retesting, the product requirements of this specification shall be met. If upon retest, failure occurs, the quantity of product represented by the test(s) shall be rejected.

12. Packaging and packing

12.1 The decking shall be packaged in accordance with normal commercial practice and packed to assure acceptance by common carrier and to provide protection against damage during normal shipping, handling, and storage.

13. Keywords

13.1 plastic lumber; plastic decking; recycled plastics; residential decks

APPENDIXES

(Nonmandatory Information)

X1. RATIONALE (COMMENTARY) REGARDING SECTION 6.1.4—RECOMMENDED SPAN LENGTHS

X1.1 The determination of span lengths is relatively straightforward and uses elementary analysis principles. The maximum recommended span is controlled by either the maximum permissible flexural stress or the deflection limit. The allowable flexural stress, F_b', and the effective modulus of elasticity E' are needed to compute the maximum recommended span lengths as detailed in section 6.1.4.1 for unreinforced polyolefin-based plastic lumber materials.

X1.2 Extensive experimental and analytical work conducted at Louisiana State University (LSU) over a four-year period ("Flexural Creep Analysis of Recycled Polymer Structural Elements," Ph.D. dissertation by Jose N. Martinez-Guerrero, Department of Civil and Environmental Engineering, LSU, Baton Rouge, LA, August 1999) has led to the development of an empirical creep model which predicts the strain, ε, as a function of time, t, the applied stress, σ, and the service temperature, T. These creep experiments were conducted per Test Methods D6112 under four point flexure. This model, given below, has been verified by creep tests conducted at different combinations of stress and temperature levels. The model below was chosen from several empirical and micromechanical models that were developed and evaluated:

$$\varepsilon = (a_1 + a_2 t^m) exp\left(\frac{T}{a_3}\right)(\sigma^n) \qquad (X1.1)$$

where:

ε = strain in the outer fibers at time t, in./in.,
t = elapsed time after initial loading at which strain is being evaluated, hours,
T = service temperature, °F, and
σ = calculated outer fiber stress, psi.

The semi-empirical constants in Equation (X1.1) were obtained at LSU in the above referenced study as:

a_1 = 7.67×10^{-8}
a_2 = 4.76×10^{-7}
a_3 = 58.95 °F
m = 0.121
n = 1.3

Thirty-five flexural creep tests were conducted at seven different stress levels to verify the empirical creep model given by Eq X1.1.

X1.3 The strain values predicted by the model at different stress and temperature levels compare extremely well with the experimental values as shown in Figs. X1.1 and X1.2. The long term predictions of the recommended model were verified and showed that the equation developed using 700 hour data successfully predicted experiments up to 3000 hours. Fig. X1.3 shows a sample comparison between data and model predictions. As seen, the LSU model was found to be superior to other existing mechanical models in predicted experimental data.

X1.4 *Base Flexural Stress, F_b:* The models show that the flexural strength—stress at 3 % extreme fiber strain—for normal load duration (10 years) is approximately 30 % of the flexural strength corresponding to a 3-min load duration. While any duration of time for normal load may be chosen, the value of 10 years was selected as a reasonable benchmark for assessment of long-term behavior of these products. The Test Method D6109 flexural test results conducted at a constant strain-rate for 3 min can be taken as those corresponding to a 3-min constant load duration without significant error. This approach is similar to that used in the wood products industry which uses results obtained from a 10-minute constant strain-rate test as values corresponding to a 10-minute constant load duration test.

Solving for stress in Eq. X1.1, we have:

$$\sigma = \left[\frac{\varepsilon}{(a_1 + a_2 t^m) \exp\left(\frac{T}{a_3} \right)} \right]^{1/n} \qquad (X1.2)$$

For ε = 3 % (or 0.03 in./in.), temperature T = 73 °F, the stress values σ from Eq X1.1 for times t = 10 years (= 5.26 × 10^6 min) and 3 min are obtained as 640 psi and 2136 psi respectively.

$$\text{The base flexural stress factor} = \frac{\sigma_{t=10\,yrs}}{\sigma_{t=3min}} = \left[\frac{(a_1 + a_2 t^m_{3min})}{(a_1 + a_2 t^m_{10\,yrs})} \right]^{1/n} = 0.30$$
$$(X1.3)$$

The ratio of these values 0.3 is independent of temperature and stress level as shown in Eq X1.3. Therefore, this value of 0.3 is used to adjust the base flexural strength in section 6.1.4.1.

X1.5 *Load Duration Factor, C_D:* Load Duration Factor, C_D is defined as the ratio of the stress required to induce failure, in this case a strain of 3 % in a given duration of time to the stress required to induce failure in a "normal" duration of 10 years. The value of this ratio from Eq X1.1 can be obtained as:

$$C_D = \frac{\sigma_t}{\sigma_{t=10\,yrs}} = \left[\frac{(a_1 + a_2 t^m_{10\,yrs})}{(a_1 + a_2 t^m)} \right]^{1/n} = 4.062 \cdot 10^5 (a_1 + a_2 t^m)^{-1/n}$$
$$(X1.4)$$

The values of this ratio, C_D, for load durations ranging from 30 years to 1 s (impact) are provided in Fig. 3 and Table 5 for convenience.

Though the creep model, which underpins the procedure presented, was developed based on experimental data collected
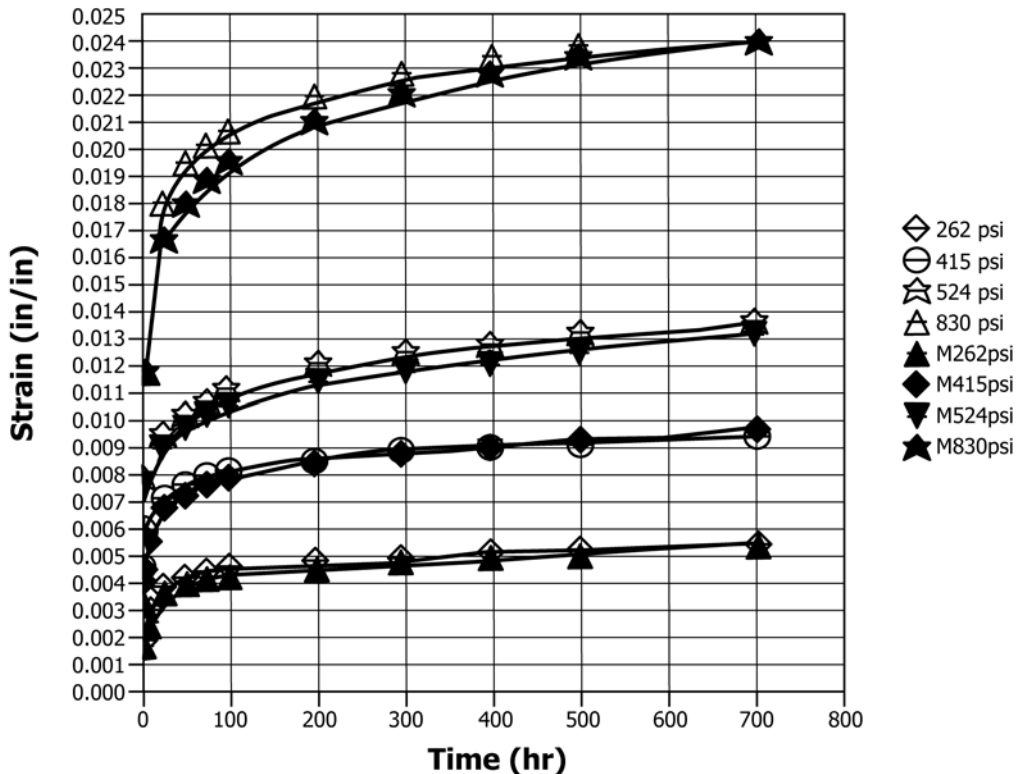

FIG. X1.1 Strain versus Time Creep Curves for Plastic Lumber under Four-Point Flexural Loading at Various Stress Levels—Comparison between Model, Eq X1.1, and Experimental Data
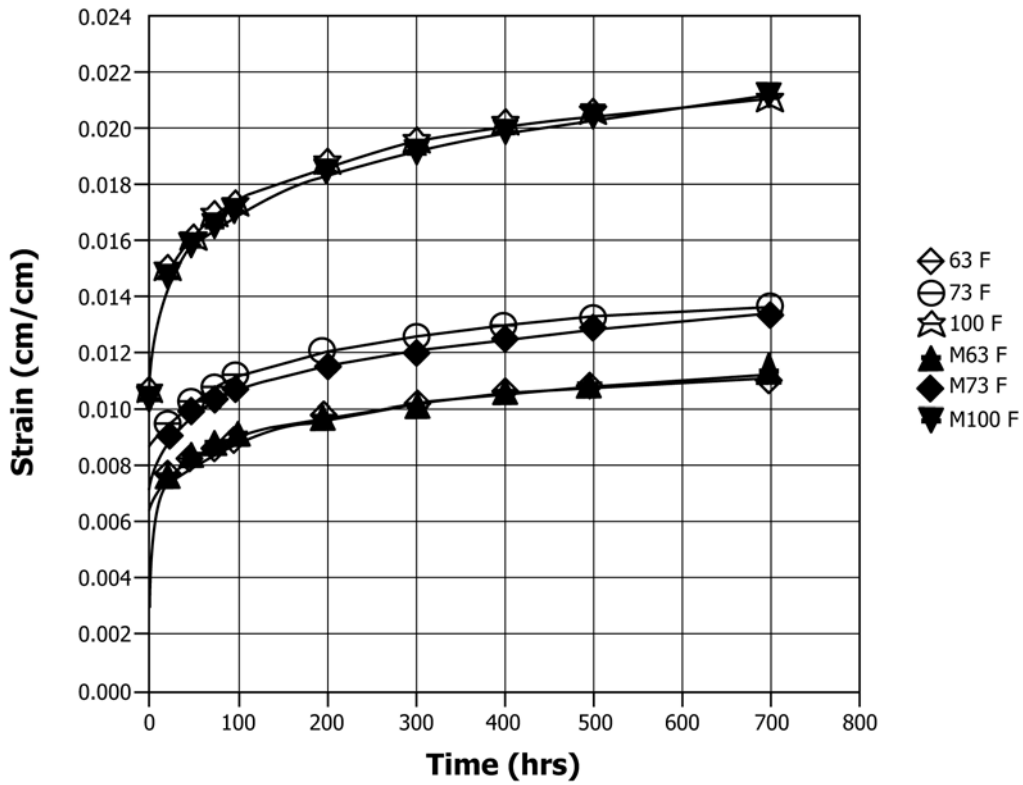
FIG. X1.2 Strain versus Time Creep Curves for Plastic Lumber under Four-Point Flexural Loading at Various Temperature Levels—
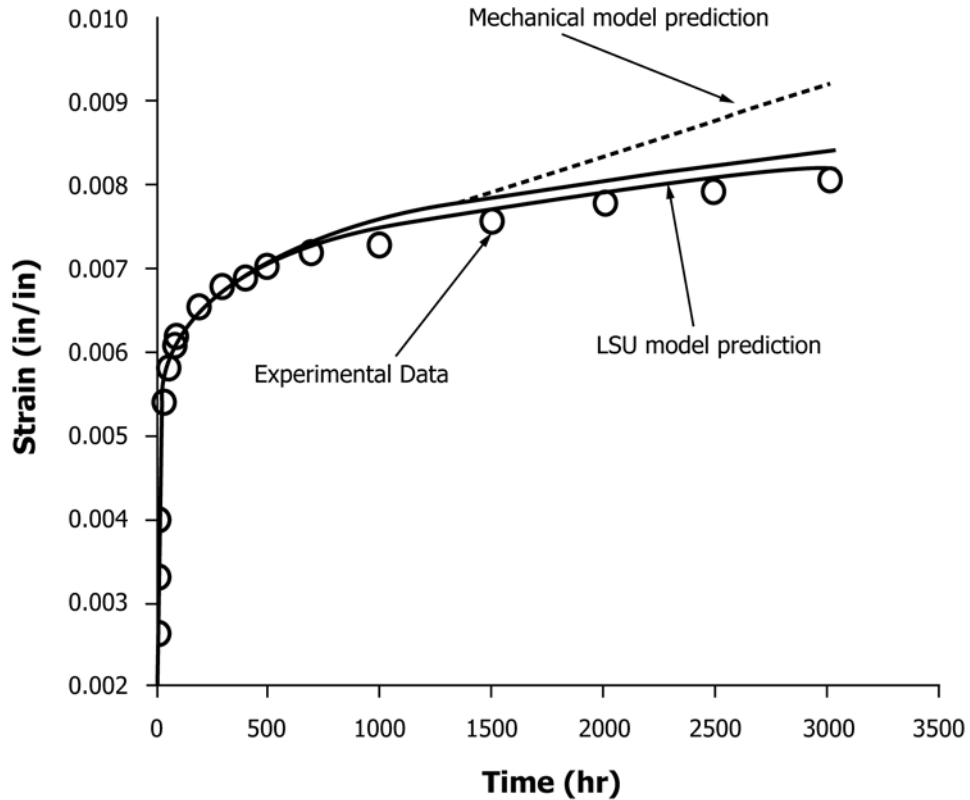Comparison between Model, Eq X1.1, and Experimental Data

FIG. X1.3 Strain versus Time Creep Showing Model Predictions versus Experimental Data

for plastic lumber obtained from one manufacturer, the non-   dimensional parameters obtained from the model can be

extended to plastic lumber decking boards made from other polyolefins as well as reinforced plastic lumber.

X1.6 *Temperature Factor, C_T:* Temperature has a significant effect on the strain response of plastic lumber. Since the flexural strength is related to a specified strain value, the service temperature impacts flexural strength. The higher the service temperature, the higher the strain and hence lower the strength. The creep model given by Eq X1.1 can be used to estimate the change in flexural strength with temperature and develop temperature factor using T = 73 °F for normalization as:

$$C_T = \frac{\sigma_T}{\sigma_{T=73F}} = \left[\frac{exp\left(\frac{T_{73F}}{a_3}\right)}{exp\left(\frac{T}{a_3}\right)} \right]^{1/n} = 2.592 exp\left(-\frac{T}{na_3}\right) \quad (X1.5)$$

As indicated in the earlier sections, temperature also has a significant influence on the deflections. Fig. X1.4 shows that the shape of the strain versus time curves for different test temperatures and a sustained stress of 524 psi are similar. In other words, the temperature only shifts the values on the strain axis. On a log-log scale, the strain response at different temperatures can be represented by a family of lines as shown in Fig. X1.4. This figure clearly shows that the shift in the response is independent of time. From Eq X1.1, the influence of temperature on the flexural modulus E is given by another temperature factor as described below (normalized at T = 73 °F). Solving for E (=σ/ε) in Eq X1.1:

$$C'_T = \frac{E_T}{E_{T=73F}} = \left[\frac{exp\left(-\frac{T}{a_3}\right)}{exp\left(-\frac{T_{73F}}{a_3}\right)} \right] = 3.45 exp\left(-\frac{T}{a_3}\right) \quad (X1.6)$$

Eq X1.5 and X1.6 yield temperature factors that are very close in values over the entire range of service temperatures. For simplicity, therefore, a single lower bound temperature factor from the two equations is recommended. These lower-bound values are shown in Table 6.

X1.7 *Creep Adjustment Factor, α:* The instantaneous elastic deflections in plastic lumber members can be estimated using the modulus of elasticity (MOE) value determined from Test Method D6109. The MOE value determined in this test corresponds to a 1 % strain level achieved in 1 min. For this reason, it is appropriate to use this value only to calculate instantaneous elastic deflections.

The creep behavior of plastic lumber results in the deflections increasing with time under sustained loads. These deflections have to be determined by utilizing a lower effective modulus, E', and a creep adjustment factor, α. For the case of residential decking boards, even at load levels of 60 psf, the maximum stress in the outer fiber of the board is less than 40 psi for a 2×6 board at a 16-inch span. However, the data from LSU used to determine the other factors above, were obtained in the stress range of 250 to 850 psi. The effect of time-dependent creep is negligible at low stress levels as the material is nearly linear viscoelastic. In residential decking applications, the applied loads are essentially transient in nature and, therefore, a conservative creep factor of α = 1.5 is recommended based on engineering judgment. It is recommended that the total creep deflection be limited to L/240 for distributed loading per section 6.1.4.2.

X1.8 *Material Property Constants for Other Types of Plastic Lumber:* The above methodology has been developed using extensive creep data on one specific type of polyolefin based
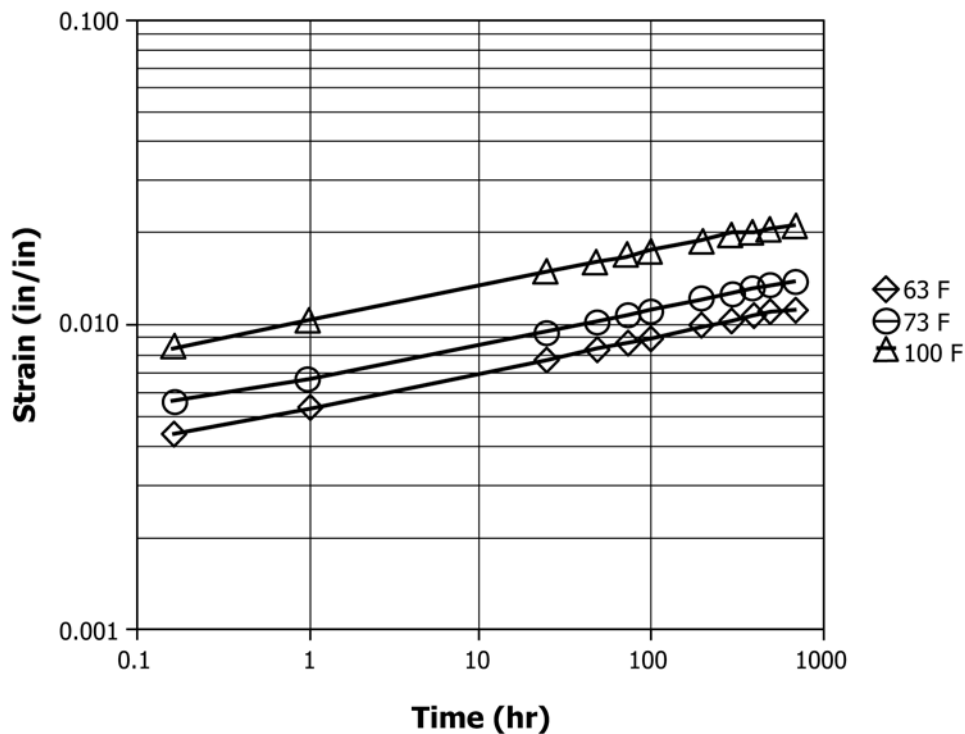

FIG. X1.4 Effect of Temperature on Flexural Creep of Plastic Lumber on a Log-Log Plot

plastic lumber. However, as stated above, this model can be used to characterize other types of plastic lumber materials where the properties are affected both by temperature and by time duration of the load. The following provides a brief description of the procedure to develop the material constants a_1, a_2, a_3, m, and n that are needed to develop the various factors in Eq X1.2-X1.6 above:

(1) Obtain 'F' the 5 % lower tolerance limit at 75 % confidence of the 'stress at 3 % strain' (or flexural strength) and E, the average value of the secant modulus at 73 °F using Test Method D6109.

(2) Conduct flexural creep tests on the plastic lumber material per Test Methods D6112 so as to obtain outer fiber strain versus time data at 3 temperatures that represent the range of use for the materials, and at least 4 stress levels. Figs.

X1.1 and X1.2 show sample creep curves illustrating the effect of stress and temperature respectively.

(3) Using a general nonlinear multiple regression analysis software package (such as SAS, Kaliedagraph, etc.) fit the creep data—'ε' versus 't' at various 'σ' and 'T' values—to obtain the material constants a_1, a_2, a_3, m, and n with the square of the correlation coefficient (r^2) greater than 0.85.

Once the constants that characterize the plastic lumber material using the model in Eq X1.1 are known, all the other adjustment factors required can be determined using the approach in Sections X1.4 – X1.6. These factors along with the flexural test data in Step 1 above provide all the necessary information for computation of maximum recommended span lengths in section 6.1.4.

X2. SAMPLE CALCULATION OF MAXIMUM RECOMMENDED SPAN LENGTH

X2.1 An example case is presented below for computing the maximum recommended span length for a nominal 2×6 decking board with a 60 psf distributed load that has a duration of 24 h at a service temperature of 90°F. The material property values per Test Method D6109 have been selected to be the minimum allowable per section 6.1.3. The allowable deflection is restricted to (Span/240), that is, k = 240 in Eq 4. For this case, the maximum recommended span length computation is shown in the Table X2.1 below.

X2.2 Since plastic lumber is essentially an insulating material, the surface temperature may reach the maximum ambient values, while internally the variation in temperature over a 24-hour period is negligible. Therefore, a temperature of 90°F is selected as a conservative value for the maximum

recommended span computation.

X2.3 As seen in Table X2.1, the deflection limit of L/240 prescribed by 6.1.4.2 is met for a distributed load of 60 psf using the minimum prescribed material properties in section 6.1.3. The maximum recommended span lengths would be even greater if typical properties of plastic lumber, which are higher than the minimum prescribed in section 6.1.3, are used in the example.

X2.4 This example is provided for informational purposes only. The user is cautioned to establish environmental parameters, to check load type and magnitude, and to select deflection criteria in accordance with applicable building code requirements.

TABLE X2.1 Sample Calculation of Maximum Recommended Span Length for Distributed Loading Using Minimum Plastic Lumber Properties

	Item	Value	Units	Reference/Comment
Input Values	Board width, b	5.5	in	
	Board thickness, d	1.5	in	
	Secant Modulus per D6109, E	50 000	psi	min value per 6.1
	Flexural Strength per D6109, F_{bt}	1 000	psi	min value per 6.1
	Distributed Load, q	60	psf	
	Load Duration, t	24	hrs	for decking boards
	Allowable Deflection Factor, k	240		L/k per 6.1.4.2
	Service Temperature, T	90	F	
	Factor of Safety, FS	1.5		per 6.1.4.1
	Creep Adjustment Factor, α	1.5		per 6.1.4.2
Calculated Values	Load Duration Factor, C_D	2.04		Fig. 3 or Table 5
	Temp Factor, C_T	0.77		Table 6
	Section Modulus, S	2.06	in^3	
	Moment of Inertia, I	1.55	in^4	
Allowable/ Effective Properties	Base Flexural Stress, F_b	300	psi	per Eq 6
	Allowable Flexural Stress, F_b'	314	psi	per Eq 5
	Effective Modulus, E'	38 500	psi	per Eq 7
Results	Max Span, L - Based on Flexural Strength	47.5	in	per Eq 3
	Max Span, L - Based on Deflection Limit	23.0	in	per Eq 4
	Recommended Maximum Span Length	23.0	in	smaller of above values

X3. RATIONALE (COMMENTARY) REGARDING SECTION 6.3—WEATHERABILITY

X3.1 Polyolefin based plastic lumber decking boards were used to install a deck at Rutgers University, New Brunswick, NJ in 1989 using the state of the art technology for manufacturing at that time. The material used was primarily waste plastics from curbside tailings. No UV stabilizers were added to the feedstock and the decking boards were exposed to direct sunshine. The flexural property data for the original material were evaluated using three point bend tests for the whole member before they were installed in 1989. These data included flexural tangent modulus and strength.

X3.2 In 2000, the decking boards were replaced with the new recycled plastic lumber. As might be expected, the original boards were discolored or faded due to natural weathering. Samples were prepared from the weathered decking boards and both 3-point bend tests (for comparison with the original data) and 4-point bend test per Test Method D6109 were conducted to determine the change in flexural strength and stiffness (modulus). Both the exposed side and the unexposed side of the weathered specimen were tested in tension. Table X3.1 shows the data for modulus and strength before and after the 11-year outdoor weathering. The results show an increase in the tangent modulus after weathering most likely due to annealing of the high-density polyethylene. The flexural strength is virtually unchanged.

The major conclusion from the data in Table X3.1 is that outdoor weathering is a surface phenomenon that may affect the color of polyolefin based plastic lumber but does not affect the structural performance of the material in service.

TABLE X3.1 Flexural Test Data on Decking Boards Before and After 11 Years of Outdoor Exposure

	Flexural Tangent Modulus psi		Flexural Strength psi	
	1989	2000	1989	2000
3-Point Bend				
Unexposed Side in Tension	171 000	213 300	2 500	2 600
Exposed Side in Tension	171 000	219 000	2 500	2 600
4-Point Bend				
Unexposed Side in Tension	N/A	218 000	N/A	2 700
Exposed Side in Tension	N/A	214 000	N/A	2 600

X4. RATIONALE (COMMENTARY) REGARDING SECTION 6.4—FIRE PROPERTIES

X4.1 Flame Spread Index

X4.1.1 Codes have traditionally used Test Method E84 to assess fire performance of building materials, including wood products. Wood materials that are not specifically fire retarded usually comply with a flame spread index of 200 (Class C).

X4.1.2 Test Method E84 is not ideal for assessing the fire performance of some thermoplastic materials. In some cases, if unsupported, some samples will melt to the furnace floor, which can result in relatively low flame spread index values. If supported, these plastic materials may be engulfed in flame, and a questionable comparison made between the surface flame spread index of red oak (the reference standard material, with an assigned flame spread index of 100) and the flame spread index of thermoplastic materials. However, the flame spread index required for this specification will be conducted only on test specimens that are either self-supporting by their own structural characteristics or held in place by added supports along the test specimen surface. Therefore, materials that severely sag and melt to the furnace floor are not allowed.

X4.2 *Burning Brand Fire Test*—The following test method for flammability/ignitability has been developed by the plastic lumber industry in cooperation with Underwriters Laboratories.[4] This was done primarily to address some general basic concerns regarding flammability of plastics when used as building materials.

NOTE X4.1—To date, a limited number of tests have been performed on plastic lumber materials using this method. The method is, therefore, subject to future modifications as additional testing experience is gained.

X4.2.1 *Test Method*—Modified E108—Burning Brand Test.

X4.2.2 *Applicability*—This test is intended to provide a measure of ignitability for deck boards under a burning briquette such as that dropped from a charcoal grill. It is not intended to provide any information related to standard fire performance measures, such as flame spread index (as determined in Test Method E84) or of fire resistance, when subjected to fire conditions from below (as might occur for a raised deck). This method also does not address fire performance and any additional considerations beyond a 20 minute test duration. A20 minute test duration was selected as corresponding to a typical 20 minute maximum response time by a local fire fighting unit.

X4.2.3 *Specimens Tested*—A minimum of two decks shall be tested. Each deck shall be 40 inches wide by at least 52 inches long. Each deck shall be constructed by placing plastic lumber decking boards over three nominal 2-inch by-4 inch wood supports as shown in Fig. X1.4. The board lengths shall run parallel to the 40 inch dimension. Spacing (gaps) between the boards shall be per manufacturer's recommendations and representative of end use applications. The plastic lumber boards shall be mechanically fastened to the wood supports using screws, nails, or other manufacturer provided fastening system.

X4.2.4 *Test Procedure*—Follow the procedure in Test Methods E108 for Class C brand test with the following modifications:

X4.2.5 With the deck in a horizontal position, place fifteen Class C brands on the deck. All the brands are to be located within 24 inches from the front of the deck. The last row of five brands shall be placed 24 inches from the front of the test specimen. The other two rows of Class C brands shall be located at a spacing not exceeding 8 inches from the 24 inch distance. At least one row of brands shall be placed on the joint between adjacent decking boards. The spacing between the brands in a row shall be 4 inches. A schematic of the brand location is shown in Fig. X4.2.

X4.2.6 Terminate the test at 20 minutes or if the flame extends beyond the length of the deck (52 in.) or spreads laterally to the width of the deck (40 in.).

X4.2.7 *Failure Criteria*—At the termination of the test (20 min), the flames shall not extend beyond the length of the deck (52 in.) or spread laterally to the width of the deck (40 in.).

X4.2.8 *Commentary*—The fire test method described above determines the ignitability characteristics of plastic decking boards using a small ignition source. The method consists of a modified version of the Test Methods E108, Class C Burning Brand Test, in which the plastic board test deck is exposed to several flaming wood brands, measuring 1 ½ in. by 1 ½ in. by $^{25}/_{32}$ in. The method has been modified for this standard to specify a horizontal orientation (0-degree slope) to represent the orientation of residential decks.

This test method is not intended to provide any basis for determining the fire resistance characteristics when exposed to a large, fully developed fire originating in the building to which the exterior decking boards may be attached or adjacent. It

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[4] Underwriters Laboratories (UL), 333 Pfingsten Rd., Northbrook, IL 60062-2096, http://www.ul.com.
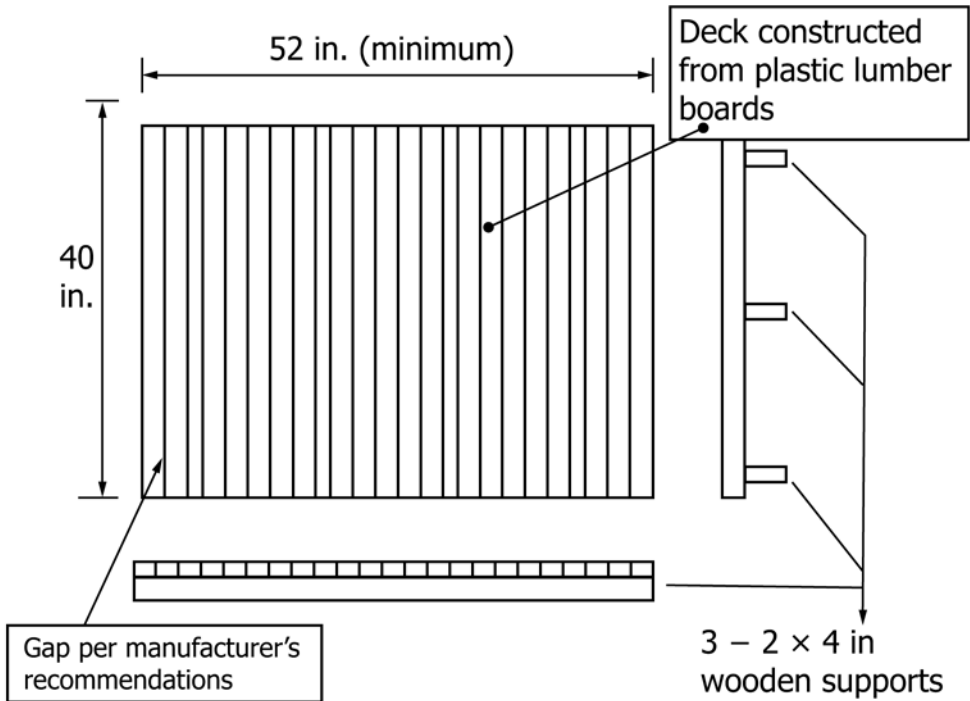
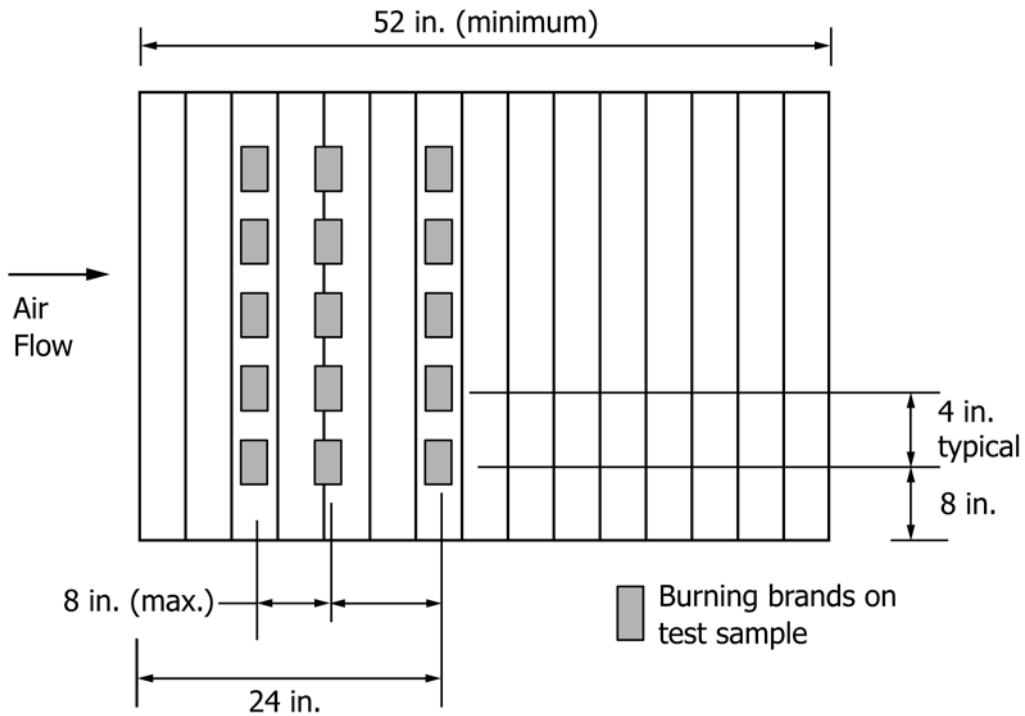**FIG. X4.1 Plastic Lumber Deck for Flame Spread Test**

FIG. X4.2 Schematic of Brand C Location

does, however, provide a basis for determining the fire performance of the material using an ignition source that might be considered representative of a small fire source likely to occur on an exterior, residential deck, such as burning briquettes from an outdoor cooking grill.

X4.3   For additional commentary on Test Methods E84 and E108, refer to the respective appendices of these standards.

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SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D6662 - 13) that may impact the use of this standard. (March 1, 2017)

(1) Revised 6.4.2.