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# Standard Practice for Calculating Bending Strength Design Adjustment Factors for Fire-Retardant-Treated Plywood Roof Sheathing[1]

This standard is issued under the fixed designation D 6305; 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.

ϵ[1] NOTE—The title for Table 6 was corrected from "One" to "Three Exposure Temperatures" in October 2002.

## 1. Scope

1.1 This practice covers procedures for calculating bending strength design adjustment factors for fire-retardant-treated plywood roof sheathing. The methods utilize the results of strength testing after exposure at elevated temperatures and computer-generated thermal load profiles reflective of exposures encountered in normal service conditions in a wide variety of climates.

1.2 Necessarily, common laboratory practices were used to develop the methods herein. It is assumed that the procedures will be used for fire-retardant-treated plywood installed using appropriate construction practices recommended by the fire retardant chemical manufacturers, which include avoiding exposure to precipitation, direct wetting, or regular condensation.

1.3 The heat gains, solar loads, roof slopes, ventilation rates, and other parameters used in this practice were chosen to reflect common sloped roof designs. This practice is applicable to roofs of 3 in 12 or steeper slopes, to roofs designed with vent areas and vent locations conforming to national standards of practice and to designs in which the bottom side of the sheathing is exposed to ventilation air. These conditions may not apply to significantly different designs and therefore this practice may not apply to such designs.

1.4 Information and a brief discussion supporting the provisions of this practice are in the Commentary in the appendix. A large, more detailed, separate Commentary is also available from ASTM.[2]

1.5 The methodology in this practice is not meant to account for all reported instances of fire-retardant plywood undergoing premature heat degradation.

1.6 This practice is written in inch-pound units with SI units provided in parentheses for information only.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 9 Terminology Relating to Wood[3]

D 5516 Test Method for Evaluating the Flexural Properties of Fire-Retardant Treated Softwood Plywood Exposed to Elevated Temperatures[3]

## 3. Terminology

3.1 *Definitions*:

3.1.1 Definitions used in this practice are in accordance with Terminology D 9.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bin mean temperature*—10°F (5.5°C) temperature ranges having mean temperatures of 105 (41), 115 (46), 125 (52), 135 (57), 145 (63), 155 (68), 165 (74), and 175°F (79°C).

## 4. Summary of Practice

4.1 The test data determined by Test Method D 5516 are used to develop adjustment factors for fire-retardant treatments to apply to untreated-plywood design values. The test data are used in conjunction with climate models and other factors and the practice thus extends laboratory strength data measured after accelerated aging to design value recommendations.

## 5. Significance and Use

5.1 This practice develops treatment factors that shall be used by fire retardant chemical manufacturers to adjust bending strength design values for untreated plywood to account for the fire-retardant treatment effects. This practice uses data from reference thermal-load cycles designed to simulate temperatures in sloped roofs of common design to evaluate products for 50 iterations.

5.2 This practice applies to material installed using construction practices recommended by the fire retardant chemical manufacturers that include avoiding exposure to precipitation,

[1] This practice is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.07 on Fire Performance of Wood.

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[2] Commentary on this practice is available from ASTM Headquarters. Request File No. D07–1004.

[3] *Annual Book of ASTM Standards*, Vol 04.10.

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direct wetting, or regular condensation. This practice is not meant to apply to buildings with significantly different designs than those described in 1.3.

5.3 Test Method D 5516 caused thermally induced strength losses in laboratory simulations within a reasonably short period. The environmental conditions used in the laboratory-activated chemical reactions that are considered to be similar to those occurring in the field. This assumption is the fundamental basis of this practice.

## 6. Procedure to Calculate Strength Loss Rate

The procedure is a multistep calculation where first an initial strength loss is determined, then the rates of strength loss at various temperatures are calculated, and finally the initial loss and rates are combined into the overall treatment adjustment factor.

6.1 Use the load-carrying capacity in bending, referred to as maximum moment ($M$), as the controlling property for purposes of determining allowable spans.

6.1.1 The ratio of the average maximum moment ($M$) for unexposed treated specimens to the average moment for unexposed untreated specimens shall be designated the Initial treatment effect, $R_o$, associated with the room temperature conditioning exposure of $T_o$.

$$R_o = M_{TRT,\,UNEX}/M_{UNTRT,UNEX} \tag{1}$$

6.1.2 If testing is done at more than one temperature, $R_{oi}$ shall be determined at each temperature and used in subsequent rate calculations for that specific temperature. The average of these values, $R_{o,avg}$ shall be used in initial treatment effect calculations (see 7.1).

6.2 The average maximum moment ($M$) of the treated specimens conditioned at the same temperature for the same period of time shall be computed. The ratio of these moments to the moment of the untreated, unexposed specimens as obtained in 6.2.1 and 6.2.2 shall be designated the test treatment ratio, $R_t$. Include the ratio for specimens conditioned at room temperature but not exposed to elevated temperature prior to testing.

$$R_t = R_{test} = M_{TRT,(UNEX,\,EX)}/M_{UNTRT,UNEX\ (\text{per } 6.2.2)} \tag{2}$$

NOTE 1—When end matching of treated and untreated specimens is employed to reduce variability in accordance with Test Method D 5516, use the ratio of the matched pairs from each panel to calculate the panel mean. The average of the panel means shall be used to calculate $R_t$.

6.2.1 For untreated specimens, linear regressions of the form:

$$M = a(D) + b \tag{3}$$

where:
$M$ = average maximum moment,
$D$ = number of days of elevated temperature exposure,
$a$ = constant, and
$b$ = intercept.

shall be fitted to the maximum moment and exposure time data for each elevated temperature exposure. Average moments for untreated specimens conditioned at room temperature but not exposed to elevated temperature prior to testing shall be included as zero day data in the regression analysis.

6.2.2 The intercept of the regression obtained in 6.2.1 for the untreated specimens shall be designated the unexposed average. If a negative slope of the untreated specimen regression is not obtained, the average of the mean maximum moments at each exposure period, including zero, shall be considered the unexposed average moment for untreated specimens.

NOTE 2—The intercept value obtained in 6.2.2 may be different from the unexposed, untreated value used in 6.1.1 for determining $R_o$.

6.3 The slope and intercept of the linear relationship between the ratios and days of exposure for all elevated temperatures shall be determined by linear regressions of the form:

$$R_{t,i} = k_t\,(D) + c \tag{4}$$

where:
$R_{t,i}$ = test ratios of average maximum moments,
$D$ = number of days of elevated temperature exposure,
$k_t$ = slope, and
$c$ = intercept.

Include the ratio for treated specimens conditioned at room temperature but not exposed to elevated temperature prior to testing as zero day data in the regression analysis.

6.3.1 If a negative slope is not obtained in 6.3, there was no apparent strength loss at the exposure temperature and alternate procedures described in 7.2 are required.

6.3.2 The slope $k_t$ from 6.3 shall be adjusted to a 50 % relative humidity ($RH$) basis by the following equation:

$$k_{50,i} = k_t\,(50/RH_i) \tag{5}$$

where:
$k_{50,i}$ = slope at 50 % $RH$ at temperature $i$, and
$RH_i$ = elevated temperature test $RH$.

6.4 If Test Method D 5516 protocol testing was only done at one elevated temperature, rates at other temperatures shall be estimated by the use of Arrhenius equation, which states that the rate of a chemical reaction is approximately halved for each 10°C the temperature is reduced. (Conversely, the rate approximately doubles for each 10°C that the temperature is increased.)

6.4.1 If testing was done at only one temperature, then to allow for the uncertainty in only one measurement of the ratio, the rate $k_{50,i}$ shall be increased by 10 % prior to the Arrhenius calculations. If testing was done at two temperatures, then the rate at each temperature shall be increased by 5 % prior to the Arrhenius calculations.

NOTE 3—Increasing the rate of $k_{50,i}$ has the effect of increasing the apparent strength loss.

6.4.2 The Arrhenius equation is used to estimate rates at other temperatures. The rate constant, $k_2$, at temperature, $T_2$, is related by

$$In\,\frac{k_{50,i}}{k_2} = \frac{Ea\,(T_1 - T_2)}{R\,T_1\,T_2} \tag{6}$$

where:
$Ea$ = 21 810 cal/mole (91 253 J/mole) (1)[4,5].



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