Designation: D6513 – 14

Standard Practice for
Calculating the Superimposed Load on Wood-frame Walls for Standard Fire-Resistance Tests[1]

This standard is issued under the fixed designation D6513; 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 practice covers procedures for calculating the superimposed axial load required to be applied to load-bearing wood-frame walls throughout standard fire-resistance and fire and hose-stream tests.

1.2 The calculations determine the maximum load allowed by design for wood-frame wall assemblies under nationally recognized structural design criteria.

1.3 This practice is only applicable to those wood-frame assemblies for which the nationally recognized structural design criteria is the *National Design Specification for Wood Construction (NDS).*[2]

1.4 The system of units to be used is that of the nationally recognized structural design criteria. For the NDS, the units are inch-pound.

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.6 *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:*[3]

D9 Terminology Relating to Wood and Wood-Based Products

E119 Test Methods for Fire Tests of Building Construction and Materials

E176 Terminology of Fire Standards

E1529 Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies

2.2 *Other Standards:*

NDS—National Design Specification for Wood Construction[2]

NDS Supplement—Design Values for Wood Construction[2]

3. Terminology

3.1 *Definitions*—Definitions used in this practice are in accordance with Terminology D9 and Terminology E176, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *gross area, n*—section area calculated from overall actual dimensions of member.

3.2.2 *net section area, n*—section area calculated by deducting from the gross section area the projected area of all materials removed by boring, grooving, dapping, notching, or other means.

3.2.3 *superimposed load, n*—The additional external load needed to be applied to the assembly to result in the calculated stresses within the assembly when any dead load of the assembly itself is accounted for in the calculations.

4. Significance and Use

4.1 Test Methods E119 and E1529, and other standard fire resistance test methods specify that throughout exposures to fire and the hose stream, a constant superimposed axial load be applied to a load-bearing test specimen to simulate a maximum load condition. They specify that this superimposed load shall be as nearly as practicable the maximum load allowed by design under nationally recognized structural design criteria. For this practice, the nationally recognized structural design criteria is the *National Design Specification for Wood Construction (NDS).*

4.1.1 Alternatively, the standard fire resistance test methods shall be conducted by applying an axial load that is less than the maximum allowable axial load as addressed by the NDS and this practice, but these tests shall be identified in the test report as being conducted under restricted load conditions. The

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[1] This practice is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.05 on Wood Assemblies.

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[2] Available from American Forest & Paper Association, American Wood Council, 1111 19th Street, NW, Suite 800, Washington, DC 20036

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

superimposed axial load, as well as the superimposed axial load as a percentage of the maximum allowable axial design load as addressed by the NDS and this practice shall be included in the test report.

4.2 This practice describes procedures for calculating the superimposed axial load to be applied in standard fire resistance tests of wood-frame wall assemblies.

4.3 Statements in either the fire resistance test method standard or the nationally recognized structural design standard supercede any procedures described by this practice.

4.4 The NDS shall be consulted to ensure calculations are in compliance with all applicable provisions of that document.

5. Test Assumptions

5.1 Wood-frame walls consist of vertical compression members and horizontal plates.

5.1.1 Compression members support a vertical axial load.

5.1.2 Bearing ends of the compression members are supported by the horizontal plates.

5.2 *Load:*

5.2.1 The test load is determined from the vertical axial capacity of the wall.

5.2.2 The test load calculations are based on standard design conditions including normal load duration, that is, ten years load duration.

5.3 *Dimensions:*

5.3.1 Gross cross-sectional areas are the section areas based on the standard dressed size of the member as given in the NDS for the nominal size member.

5.3.1.1 Net section area, A, is the gross area minus the projected area of all materials removed by boring, grooving, dapping, notching, or other means.

5.3.1.2 For nailed connections, the net section area equals the gross section area.

5.3.2 Height of vertical columns is the actual length of the vertical member.

6. Design Load Calculations

6.1 For structural sawn lumber, reference design values for the grade and species of lumber are multiplied by all applicable adjustment factors to determine the allowable design values.

6.1.1 Reference design values $F_{C\perp}$, F_C, and E_{min} (E is reference design value in pre-2005 editions of the NDS) are given in the separate Supplement to the NDS.

6.1.2 Compression perpendicular to grain, $F_{C\perp}$, is multiplied by C_M, C_t, C_i and C_b.

6.1.3 Compression parallel to the grain, F_C, is multiplied by C_D, C_M, C_t, C_F, C_i, and C_P.

6.1.4 Modulus of elasticity, E, is multiplied by C_M, C_t, C_i, and C_T.

6.2 *Adjustment Factors for Design Values:*

6.2.1 If values less than those listed in this section (6.2) are used for the adjustment factors, the appropriate load restriction shall be reported in the test report.

6.2.2 Load duration factor, C_D, is 1.0.

6.2.3 Wet service factor, C_M, is 1.0.

6.2.4 Temperature factor, C_t, is 1.0.

6.2.5 Size factor, C_F, is taken from tables in the NDS.

6.2.5.1 Size factor for F_C and the appropriate table within NDS depends on the width, species, and grade of the lumber.

6.2.6 Incising factor, C_i, is 1.0.

6.2.7 Column stability factor, C_P.

6.2.7.1 Buckling of compression member in plane of wall is prevented by the sheathing which normally provides support throughout its length and C_P equals 1.

6.2.7.2 For buckling of compression member perpendicular to plane of wall, C_P depends on the slenderness ratio of the columns. The equation for C_P is given in the NDS. The effective column length shall be the actual length of the vertical member for calculating the slenderness ratio and C_P.

6.2.8 Buckling stiffness factor, C_T, is 1.0.

6.2.9 Bearing area factor, C_b, is 1.0.

NOTE 1—The NDS provides for a bearing area factor of 1.25 for a bearing length of 1.5 in. when the bearings are not nearer than 3 in. to the end of a member. Due to the random layup of platform framing, the location of butt joints in top and bottom plates cannot be specified. For this reason, the bearing area increase is not generally taken in the design of wood frame walls. Historically, a bearing area factor of one has been used in the calculations of the load for fire resistance tests of wood-frame walls.

6.2.10 For lumber and structural-glued laminated timber pressure-treated with fire-retardant chemicals, the allowable design values, including connection design values, shall be obtained from the company providing the treatment and redrying service.

6.2.11 For load duration factor, C_D, equal to 1.0, there is no additional reduction for wood products pressure treated by an approved process and preservative.

6.3 For vertical compression members of simple solid wood columns, the load per vertical compression member is the maximum superimposed load that satisfies the following:

6.3.1 Actual compression stress parallel to grain based on minimum net section area does not exceed the reference compression design value parallel to grain multiplied by all applicable adjustment factors except the column stability factor, C_P.

6.3.2 Actual compression stress parallel to grain based on gross section area at critical part of column length that is most subject to potential buckling of compression member perpendicular to plane of wall does not exceed the allowable compression design value parallel to grain (that is, reference design value multiplied by all applicable adjustment factors).

6.3.3 Actual compression stress perpendicular to grain in horizontal plates does not exceed the allowable compression design value perpendicular to grain which includes the adjustment factor for bearing area, C_b, and the other applicable adjustment factors.

6.4 Actual stress in a member in 6.3 includes both that due to the superimposed load applied to the assembly and that due to the dead load or weight of the components being supported by the member.

6.5 Total superimposed load to be applied to the test assembly during the fire test is the sum of the maximum superimposed load of each of the vertical compression members in the assembly.

7. Keywords

7.1 fire endurance; fire resistance; superimposed load; wall assembly; wood studs

APPENDIXES

X1. Calculating the Superimposed Load on Wood-Frame Walls for E119 Standard Fire-Resistance Tests

X1.1 Scope

X1.1.1 During an E119 standard fire resistance wall test, the wall assembly is required to be subjected to a superimposed load to simulate a maximum load condition per nationally recognized structural design criteria.

NOTE X1.1—In the United States, the nationally recognized structural design procedures for wood construction are contained in the *National Design Specification for Wood Construction® (NDS®)*. In accordance with these standard design procedures, the superimposed load applied to wood stud wall assemblies is typically limited by the adjusted compression design stress parallel to grain of the wood stud.

X1.1.2 The maximum superimposed load for a wall being tested in accordance with E119 is the sum of the maximum allowable design loads for each stud in the wall assembly.

X1.1.3 As an alternative, E119 permits testing at less than the maximum load, however, these tests must be reported as being conducted under restricted load conditions.

X1.2 Design Example

X1.2.1 The following example calculations are based on 2005 *National Design Specification for Wood Construction® (NDS®)* design procedures and the requirements of this standard.

X1.2.2 Example Construction (See Fig. X1.1):

Studs: Douglas fir – Larch (DFL) Select Structural (SS) grade 2 × 4 lumber (1.5 in. × 3.5 in. @ 16 in. o.c., 115.5 in. long)

Plates: DFL SS grade 2 × 4 lumber (1.5 in. × 3.5 in.): one bottom plate 120 in. long, two top plates 120 in. long.

Configuration: nine studs arranged symmetrically

Insulation: 3.5 in. thick Mineral Wool Insulation

Sheathing: 5/8 in. Type X gypsum wallboard each side

X1.2.3 Compressive resistance of the example wood stud wall loaded parallel to grain, P_r, determined in accordance with the *NDS* using Allowable Stress Design (ASD) procedures:

F_c = reference compression design value parallel to grain = 1700 psi

$F_c{}^*$ = reference compression design value multiplied by all applicable adjustment factors except C_P
= $F_c\ C_D\ C_M\ C_t\ C_F\ C_i$(Table 4.3.1, *NDS* 2015)
= (1700 psi)(1.0)(1.0)(1.0)(1.15)(1.0) = 1955 psi

Where:

F_c = reference compression design value parallel to grain = 1700 psi
C_D = load duration factor = 1.0
C_M = wet service factor = 1.0
C_t = temperature factor = 1.0
C_F = size factor = 1.15 (for 1.5 in. × 3.5 in. studs, SS grade DFL)
C_i = incising factor = 1.0
C_P = column stability factor
A = area of cross-section = (3.5 in.)(1.5 in.) = 5.25 in^2

Due to the slenderness of the studs, the adjusted compression design stress parallel to grain is affected by the buckling resistance of each stud. For strong-axis buckling of the stud (perpendicular to the plane of wall):

$$C_P = \frac{1+(F_{cE}/F_c^*)}{2c} - \sqrt{\left[\frac{1+(F_{cE}/F_c^*)}{2c}\right]^2 - \frac{F_{cE}/F_c^*}{c}} = \frac{1+(521/1955)}{(2)(0.8)} - \sqrt{\left[\frac{1+(521/1955)}{(2)(0.8)}\right]^2 - \frac{521/1955}{0.8}} \quad (X1.1)$$

$$C_P = 0.7915 - \sqrt{(0.7915)^2 - 0.3330} = 0.2498 \quad (X1.2)$$

Where:

$$F_{cE} = \frac{0.822E_{min}}{(l_e/d)^2} = \frac{(0.822)(690\,000\ psi)}{(33)^2} = 521 \text{ psi}$$

E_{min} = reference minimum modulus of elasticity design value = 690 000 psi

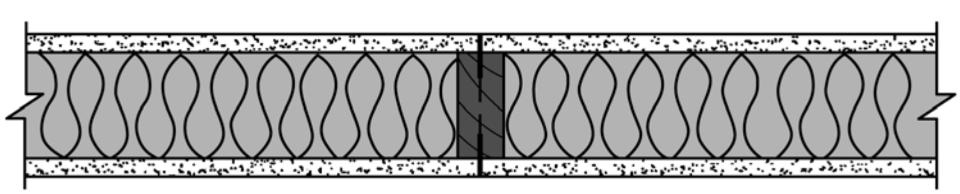

FIG. X1.1 Example of Calculation Construction

E_{min}' = adjusted minimum modulus of elasticity design value for beam and column stability multiplied by all applicable adjustment factors
= $E_{min}\ C_M\ C_t\ C_i\ C_T$(Table 4.3.1, *NDS* 2015)
= (690 000 psi)(1.0)(1.0)(1.0)(1.0) = 690 000 psi
C_T = buckling stiffness factor = 1.0
l_e/d = slenderness ratio = 115.5 in. / 3.5 in. = 33
c = 0.8 for sawn lumber

F_c' = adjusted compression design value parallel to grain
= $F_c^*\ C_P$ = (1955 psi)(0.2498) = 488 psi

P_r = $F_c'A$ = (488 psi)(5.25 in^2) = 2564 lb/stud

X1.2.4 In typical construction, weak-axis buckling of the stud (in the plane of the wall) is prevented by the gypsum wallboard fastened to the stud. Each fastener acts as a bracing point along the stud length.

X1.2.5 Compressive resistance of wood plates loaded perpendicular to grain, Q_r, as determined in accordance with the *NDS* (ASD Method) for the Example construction:

$F_{c\perp}$ = reference compression design value perpendicular to grain = 625 psi

$F_{c\perp}'$ = adjusted compression design value perpendicular to grain multiplied by all applicable adjustment factors
= $F_{c\perp}\ C_M\ C_t\ C_i\ C_b$ (Table 4.3.1, NDS 2015)
= (625 psi)(1.0)(1.0)(1.0)(1.0) = 625 psi

Where:

C_M = wet service factor = 1.0
C_t = temperature factor = 1.0
C_i = incising factor = 1.0
C_b = bearing area factor = 1.0
A = area of cross-section = (3.5 in.)(1.5 in.) = 5.25 in^2

Q_r = $F_{c\perp}'A$ = (625 psi)(5.25 in^2) = 3281 lb/stud
X1.2

X1.2.6 Compression perpendicular to grain resistance does not control ($Q_r > P_r$). Accordingly, the superimposed load is limited by compression parallel to grain resistance of 2564 lb/stud.

X1.2.7 Determine the required superimposed load on wall assembly Construction:

$$W_s = P_r(\text{Number of studs}) = (2564\ \text{lb/stud})(9\ \text{studs}) = 23.1\ \text{kips} \quad (X1.3)$$

X2. Total Superimposed Loads

X2.1 Table X2.1 presents the results of using the calculation procedure and the reference design stresses from the 2015 NDS.

TABLE X2.1 Total Superimposed Loads Obtained Using the D6513 Calculation Procedure and the Reference Design Stresses from the 2015 NDS

Species	Grade	Size	F_c[A] psi	$F_{c\text{-perp}}$[A] psi	E[A] psi	E_{min}[A] psi	Stud Load[B] lb/stud	Total Load[C] lb
Douglas Fir-Larch	SS	2x4	1700	625	1 900 000	690 000	2564	23 073
	#1	2x4	1500	625	1 700 000	620 000	2300	20 703
	#2	2x4	1350	625	1 600 000	580 000	2145	19 307
	Standard	2x4	1400	625	1 400 000	510 000	1890	17 011
	Stud	2x4	850	625	1 400 000	510 000	1797	16 176
Southern Pine	Dense SS	2x4	2050	660	1 900 000	690 000	2573	23 154
	SS	2x4	1900	565	1 800 000	660 000	2455	22 096
	#1 Dense	2x4	1750	660	1 800 000	660 000	2439	21 952
	#1	2x4	1650	565	1 600 000	580 000	2156	19 400
	#2 Dense	2x4	1500	660	1 600 000	580 000	2139	19 250
	#2	2x4	1450	565	1 400 000	510 000	1895	17 058
	Stud	2x4	850	565	1 300 000	470 000	1664	14 980
	Standard	2x4	1300	565	1 200 000	440 000	1640	14 759
Hem-Fir	SS	2x4	1500	405	1 600 000	580 000	2126	19 136
	#1	2x4	1350	405	1 500 000	550 000	2043	18 386
	#2	2x4	1300	405	1 300 000	470 000	1761	15 846
	Standard	2x4	1300	405	1 200 000	440 000	1640	14 759
	Stud	2x4	800	405	1 200 000	440 000	1570	14 130
Spruce-Pine-Fir	SS	2x4	1400	425	1 500 000	550 000	2048	18 436
	#1/#2	2x4	1150	425	1 400 000	510 000	1881	16 931
	Standard	2x4	1150	425	1 200 000	440 000	1624	14 617
	Stud	2x4	725	425	1 200 000	440 000	1548	13 931

[A] Reference design stresses from the 2015 NDS.
[B] Stud load is calculated based on F_c' using a stud length of 115.5", resulting in L_e/d = 33, and plates of the same species as the studs.
[C] The total superimposed wall load values for a wall with nine studs.