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

This standard is issued under the fixed designation D7746; 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 load required to be applied to load-bearing wood-frame floor-ceiling assemblies throughout standard fire-resistance tests.

1.2 These calculations determine the maximum superimposed load to be applied to the floor-ceiling assembly during the fire resistance test. The maximum superimposed load, calculated in accordance with nationally-recognized structural design criteria, shall be designed to induce the maximum allowable stress in the wood floor-ceiling fire test configuration being tested.

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

1.4 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.

1.5 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this 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:*[2]

D9 Terminology Relating to Wood and Wood-Based Products

D6513 Practice for Calculating the Superimposed Load on Wood-frame Walls for Standard Fire-Resistance Tests

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:*[3]

NDS National Design Specification for Wood Construction

NDS Supplement Design Values for Wood Construction

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, E1529, and other standard fire resistance test methods specify that throughout the fire-resistance test, a constant superimposed load shall be applied to a load-bearing test specimen to simulate a maximum load condition. This superimposed load shall be the maximum load allowed by design under nationally recognized structural

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[2] 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.

[3] Available from American Wood Council (AWC), 803 Sycolin Road, Suite 201, Leesburg, VA 20175, http://www.awc.org.

design criteria for the tested floor configuration (that is, joist selection, spacing, and span).

4.1.1 For this Practice, the nationally recognized structural design criteria to be used to determine the maximum load condition are those for allowable stress design in the NDS (National Design Specification for Wood Construction).

4.1.2 Alternatively, the standard fire resistance test methods shall be permitted to be conducted by applying a load less than the maximum allowable load in 4.1.1 for the tested configuration; however, these tests shall be identified in the test report as being conducted under restricted loading conditions.

4.2 This practice describes procedures for calculating the superimposed load to be applied in standard fire resistance tests of wood floor-ceiling assemblies. Practice D6513 provides a similar methodology for calculating the superimposed load on wood-frame walls.

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

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

5. Test Assumptions

5.1 *Floor Assembly*—For design considerations, wood-frame floor-ceiling assemblies consist of horizontal structural members (that is, joists), the floor decking or sheathing, and the perimeter rim boards.

5.2 *Loading Conditions*—Horizontal framing members support a vertical load that is uniformly distributed on the floor assembly. It is assumed that load application system for the test distributes load between and along framing members in a manner consistent with a uniform load assumption and provides load distribution to members that is representative of the end-use application.

NOTE 1—The calculation procedure in this standard is not appropriate for a test that uses a load application system that incorporates discrete point load distribution beams or frames with spanning capabilities that serve to artificially re-distribute load from a failing member to the adjacent framing. Such a system would require a higher load to be applied that considers the enhanced load-sharing between members provided by the load frame and the departure from a uniform load condition. An example of a system that conforms to the calculation assumption would be one in which each discrete load element (that is, dead weight pack, water barrel, hydraulic cylinder, pneumatic cylinder, etc.) is applied to the floor at not more than two locations along the length of the framing by distribution beams that span across not more than three framing members.

5.3 Lateral or torsional end support, including but not limited to bridging, blocking, or bracing, shall be provided at points of bearing to prevent rotation. When additional lateral or torsional support is used away from the ends to enhance performance of the floor-ceiling assembly, description and locations of the support shall be reported

5.4 Where required to ensure that bearing capacity does not limit the test load, stiffeners or an increased bearing length shall be permitted at the bearing locations to increase capacity.

6. Design Load Calculations

6.1 *Design Values*—-Reference design values: F_b, F_v, $F_{c\perp}$, E and E_{min} for rectangular sections are given in the NDS Supplement, product literature, or code evaluation report. Reference design values: M, V, R_r, E_I, EI_{min}, and K for I-joists are given in the product literature, or code evaluation report.

6.2 *Design Value Adjustments*—Reference design values shall be multiplied by all applicable adjustment factors to determine the adjusted design values. Additional adjustments may be required to address special design considerations for the specific member type. Not all factors may be applicable to all product types.

6.2.1 *Bending—F_b* for rectangular sections and M for I-joists shall be multiplied by all applicable NDS adjustment factors including: C_D, C_M, C_t, C_L, C_F, C_V, C_{fu}, C_i, C_r, C_c.

6.2.2 Compression parallel to the grain, F_c, shall be multiplied by all applicable NDS adjustment factors including: C_D, C_M, C_t, C_F, C_i, and C_P.

6.2.3 *Shear parallel to grain—F_v* for rectangular sections and V for I-joists shall be multiplied by all applicable NDS adjustment factors including: C_D, C_M, C_t, C_i.

6.2.4 Tension parallel to grain, F_t, shall be multiplied by all applicable NDS adjustment factors including: C_D, C_M, C_t, C_F, C_i.

6.2.5 *Bearing:*

6.2.5.1 *Compression perpendicular-to-grain—$F_{c\perp}$* for rectangular sections shall be multiplied by all applicable NDS adjustment factors including: C_M, C_t, C_i, C_b.

6.2.5.2 *I-joist Reference Design Reaction—R_r*, shall be multiplied by all applicable NDS adjustment factors including: C_D, C_M, C_t.

6.2.6 *Modulus of elasticity—E* or E_{min} for rectangular sections and E_I and EI_{min} for I-joists shall be multiplied by all applicable NDS adjustment factors including: C_M, C_t, C_i, C_T.

6.3 *Adjustment Factors for Design Values*—The following adjustment factors are to be assumed by default. If values less than those listed below are employed, then the appropriate load restriction shall be reported in the test report and used to adjust the design bending and shear capacity in application:

6.3.1 Load duration factor, C_D, is 1.0.

6.3.2 Wet service factor, C_M, is 1.0.

6.3.3 Temperature factor, C_t, is 1.0.

6.3.4 Beam stability factor, C_L, is 1.0 for a single span, sheathed fire test assembly.

6.3.5 Size factor, C_F, is the value taken from tables in the NDS Supplement for the sawn lumber joist material in the test assembly.

6.3.6 Volume factor, C_V, per NDS provisions for glued-laminated timber members. The value of C_v for structural composite lumber shall be defined by the product literature or code evaluation report. The value of C_v used shall be the value for the joist material in the test assembly.

6.3.7 Flat-use factor, C_{fu}, the value per NDS provisions for the sawn lumber joist material in the test assembly.

6.3.8 Incising factor, C_i, the value per NDS provisions for the sawn lumber joist material in the test assembly.

6.3.9 Repetitive member factor, C_r, the value per the NDS provisions for the joist material in the test assembly.

6.3.10 Curvature factor, C_C, the value per the NDS provisions for structural glued laminated timber.

6.3.11 Column stability factor, C_P, is calculated from equations in the NDS.

NOTE 2—When a compression member is supported throughout its length to prevent lateral displacement in all directions, $C_P = 1$.

6.3.12 Bearing area factor, C_b, is 1.0.

6.3.13 Buckling stiffness factor, C_T, is 1.0.

6.3.14 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.

6.4 *Dimensions:*

6.4.1 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 sawn lumber or glue laminated timber member. The gross cross-sectional areas for I-joists and structural composite lumber are given in the product literature or code evaluation report.

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

6.4.1.2 For nailed or screwed connections, the net section area equals the gross section area.

6.4.2 The span of the horizontal structural member is the distance from face to face of supports, plus half of the required bearing length at each end.

6.5 *Test Load:*

6.5.1 The load to be applied in the test shall be calculated in accordance with nationally recognized design criteria. The superimposed load shall be the lesser of the load calculated in accordance with 6.5.1.1 or 6.5.1.2.

6.5.1.1 A superimposed load which induces a bending moment equal to the full design capacity at the critical cross-section along the length of the horizontal structural members of the floor-ceiling configuration being tested.

6.5.1.2 A superimposed load which induces a bending shear force equal to the full design capacity at the critical cross-section along the length of the horizontal structural members of the floor-ceiling configuration being tested. Any holes or notches present in the test specimens shall be neglected for the purpose of establishing the available shear capacity of the horizontal structural members.

6.5.2 A lower superimposed load than described by 6.5.1 shall be permitted provided it corresponds to a stiffness limit, reaction limit, connection limit, or other alternative design criteria. However, these tests shall be identified in the test report as being conducted under restricted loading conditions. Where stiffness increases for partial composite action are permitted by design and the load is governed by the system stiffness, the maximum partial composite action between the horizontal structural member and the floor decking or sheathing permitted in application shall be included in the calculation of the stiffness for the tested floor assembly.

6.5.3 The superimposed load, as well as the superimposed load expressed as a percentage of the maximum superimposed load from 6.5.1 or 6.5.2, shall be included in the test report. Where the maximum superimposed load based on flexure and the maximum superimposed load based on shear are both less than 100 % of the full design capacity, the greater of the two percentages shall be used to reduce the design shear and bending capacities in application.

6.5.4 Actual stress in a member in 6.5.1 and 6.5.2 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.

6.5.5 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 structural horizontal flexure members in the assembly. Where the first and last horizontal floor-ceiling members are flexural members spanning the furnace, the load on these members is allowed to be reduced by half due to the reduced tributary area.

7. Keywords

7.1 fire resistance; floor assembly; superimposed load; wood

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE CALCULATION (ALLOWABLE STRESS DESIGN METHOD)

Construction

Joists: S-P-F (North) No. 2, 1.5 in. x 9.25 in. (nominal 2x10) @ 16 in. o.c., 12.5 ft. span

Subfloor: ½ in. thick plywood

Ceiling: 5/8 in. Type X gypsum board – 2 layers, direct applied

Calculation of Test Load

Allowable bending moment of member, M_a, determined in accordance with the NDS using Allowable Stress Design (ASD) for the conditions listed above:

Bending Design:

F_b' = adjusted bending design value, psi

(Table 4.3.1, NDS)

$$F_b' = F_b C_D C_M C_t C_L C_F C_{fu} C_i C_r$$

$$= (875)(1.0)(1.0)(1.0)(1.0)(1.1)(1.0)(1.0)(1.15) = 1107\ lb/in^2$$

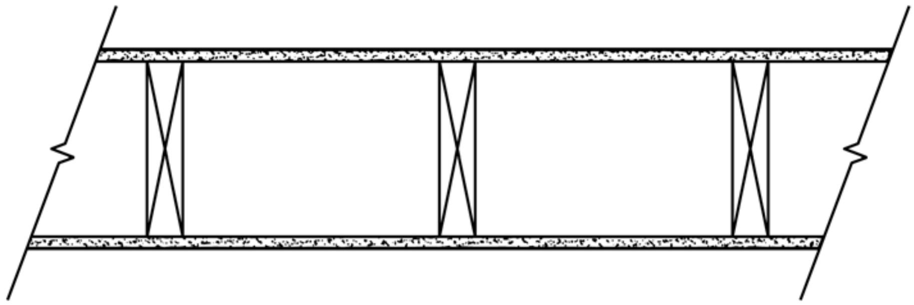

FIG. X1.1 Wood Joist Floor Assembly

where:

F_b, *reference bending design value*	=	875 lb/in^2
C_D, *Load duration factor*	=	1.0
C_M, *Wet service factor*	=	1.0
C_t, *Temperature factor*	=	1.0
C_L, *Beam stability factor*	=	1.0
C_F, *Size factor*	=	1.1
C_{fu}, *Flat use factor*	=	1.0
C_i, *Incising factor*	=	1.0
C_r, *Repetitive member factor*	=	1.15

$$Moment\ (M) = F_b{}'S = (1107)(21.39) = 23\,679\ in. - lbs$$

where:

S, Section modulus = 21.39 in.^{3}

$$w_{tot} = 8M/L^2 = 8(23\,679)/(150)^2 = 8.42\ lb/in. = 101.0\ lb/ft$$

where:

L, span of member = 150 in.

$$w_{tot\ @\ 16\ in.\ o.c.} = 101.0/(16/12) = 75.8\ lb/ft^2$$

Shear Design:

$F_v{}'$ = adjusted shear design value, psi

(Table 4.3.1, NDS)

$$F_v' = F_v C_D C_M C_t C_i$$

$$= (135)(1.0)(1.0)(1.0)(1.0) = 135\ lb/in^2$$

$$Shear\ (V) = 2/3 * F_v{}'A = (2/3)(135)(13.88) = 1249\ lb$$

where:

A, Area of cross-section = 13.88 in.^{2}

$$w_{tot} = 2V/L = 2(1249)/(150) = 16.65\ lb/in. = 199.8\ lb/ft$$

$$w_{tot\ @\ 16\ in.\ o.c.} = 199.8/(16/12) = 150\ lb/ft^2$$

Bearing Design:

$F_{c\perp}{}'$ = adjusted compression design value perpendicular to grain, psi

(Table 4.3.1, NDS)

$$F_{c\perp}' = F_{c\perp} C_M C_t C_i C_b$$

$$= (425)(1.0)(1.0)(1.0)(1.0) = 425\ lb/in^2$$

$$Bearing\ (R) = F_{c\perp}'A_b = (425)(3.0) = 1275\ lb$$

where:

A_b, *Bearing Area of joist* = 3.0 in.^{2}

$$w_{tot} = 2R/L = 2(1275)/(150) = 17.0\ lb/in. = 204.0\ lb/ft$$

$$w_{tot\ @\ 16\ in.\ o.c.} = 204.0/(16/12) = 153\ lb/ft^2$$

Bending Controls:

Test Load	=	75.8 lb/ft^2 (100 % of bending design load, 51 % of shear design load)
Assembly Dead Load, w_{dead}	=	10.4 lb/ft^2
Superimposed Live Load, w_{live}	=	65.4 lb/ft ^{2}

Check Deflections

$$Bending\ Stiffness,\ EI = (1\,400\,000)(98.93) = 138.5 \times 10^6\ lb - in.^2$$

where:

E, Modulus of elasticity = 1 400 000 lb/in.^{2}
I, Moment of inertia = 98.93 in.^{4}

Live Load Deflection (Assuming no Composite Action with Sheathing):

$$\Delta_{live} = \left[\frac{5 w_{live} L^4}{384 EI}\right]$$

$$= \left[\frac{5\left(65.4\ psf(16\ in.)\left(\frac{1\ ft}{12\ in.}\right)^2\right)(150\ in.)^4}{384(138.5 \times 10^6\ lb - in.^2)}\right]$$

$$= 0.346\ in.$$

$$L/\Delta_{live} = 434\ \ (ok)$$

Total Load Deflection (Assuming no Composite Action with Sheathing):

$$\Delta_{total} = \left[\frac{5 w_{total} L^4}{384 EI}\right]$$

$$= \left[\frac{5\left(75.8\ psf(16\ in.)\left(\frac{1\ ft}{12\ in.}\right)^2\right)(150\ in.)^4}{384(138.5 \times 10^6\ lb - in.^2)}\right]$$

$$= 0.400\ in.$$

$$L/\Delta_{total} = 375\ \ (ok)$$

In this case, the deflections were deemed acceptable.

Since the applied load of 75.8 lbs/ft^2 achieved 100 % of the horizontal structural member's flexure capacity, this load satisfied the conditions of 6.5.1.1 and the restricted load provisions of 6.5.1.2 do not apply. Had a criteria other than the full shear of flexure capacity been used to limit the superimposed load, then the provisions of 6.5.1.2 would apply and the test would be reported as a Restricted Loading condition in application.