Designation: ~~E455 – 11~~ E455 – 16

Standard Test Method for Static Load Testing of Framed Floor or Roof Diaphragm Constructions for Buildings[1]

This standard is issued under the fixed designation E455; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers procedures designed (*1*) to evaluate the static shear capacity of a typical segment of a framed diaphragm under simulated loading conditions, and (*2*) to provide a determination of the stiffness of the construction and its connections. A diaphragm construction is an assembly of materials designed to transmit shear forces in the plane of the construction.

1.2 No effort has been made to specify the test apparatus, as there are a number that can be used as long as the needs of the testing agency are met. If round-robin testing is to be conducted, test apparatus and testing procedures shall be mutually agreed upon in advance by the participants.

1.3 The text of this standard contains notes and footnotes that provide explanatory information and are not requirements of the standard. Notes and footnotes in tables and figures are requirements of this standard.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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.* For specific precautionary statements, see Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E575 Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies

E631 Terminology of Building Constructions

3. Terminology

3.1 For definitions of terms used in this standard, refer to Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *deflection*—in-plane deformation (distortion) of a diaphragm due to bending and shear excluding translational displacement due to movement of supports.

3.2.2 *diaphragm*—horizontal or sloped system acting to transmit lateral forces to the vertical resisting elements.

[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.11 on Horizontal and Vertical Structures/Structural Performance of Completed Structures.

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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.

3.2.2.1 *Discussion*—

A diaphragm is analogous to a horizontal deep beam with interconnected membrane elements such as panels, sheathing, or cladding acting as the deep beam web, intermediate elements such as joists acting as web stiffeners, and perimeter boundary elements such as girders acting as deep beam chords.

3.2.3 *displacement*—the distance between the initial and the final position of a point on the diaphragm in a given direction.

3.3 *Symbols Specific to This Standard:*

E = modulus of elasticity of flange or web material, depending upon which material is held constant in a transformed section analysis, psi (or MPa).
G = shear modulus of the web material, psi (or MPa).
~~G' = shear stiffness of the diaphragm obtained from test (includes shear deformation factor for the connection system), lbf/in. (or N/mm).~~
G' = apparent shear stiffness of the diaphragm, which is derived from the apparent shear deflection of the diaphragm, lbf/in. (or N/mm).
I = moment of inertia of the transformed section of the diaphragm based on webs or flanges, in.^{4} (or mm^4).
~~L = total span of a simply supported diaphragm, in. (or mm).~~
L = total span of diaphragm, in. (or mm).
P = concentrated load, lbf (or N).
P_{max} = maximum jack load applied to test frame, lbf (or N).
R_u = maximum diaphragm reaction, lbf (or N).
S_u = ultimate shear strength of the diaphragm, lbf/ft (or N/m).
~~a = span length of cantilever diaphragm, in. (or mm).~~
~~b = depth of diaphragm, in. (or mm).~~
b = depth of diaphragm parallel to applied loads, in. (or mm).
t = thickness of web material, in. (or mm).
w = uniform load, lbf/in. (or N/mm).
~~Δ_b = bending deflection of diaphragm, in. (or mm).~~
Δ_b = portion of the diaphragm deflection attributed to bending, in. (or mm).
~~Δ_k = empirical expression for that portion of the diaphragm deflection contributed by the shear deformation of the connection system, in. (or mm).~~
Δ_k = portion of the diaphragm deflection attributed to deformation of the diaphragm fasteners and connections, in. (or mm).
~~Δ_s = pure shear deformation of diaphragm, in. (or mm).~~
Δ_s = portion of the diaphragm deflection attributed to shear deflection of the diaphragm web, in. (or mm).
~~Δ_s' = apparent total shear deformation of the diaphragm based on test (see 10.1.2.2), in. (or mm). This factor includes both the pure shear deformation and that contributed by distortion of the connection system.~~
Δ_s' = apparent shear deflection of the diaphragm (see 10.1.2.2), which includes the deflection due to shear deflection of the diaphragm web and deformation of the diaphragm fasteners and connections, in. (or mm).
Δ_t = total deflection of diaphragm, in. (or mm).
~~$\Delta_{1,2,\_\_\_}$ = deformation measured at Point 1,2, _ _ _, in. (or mm).~~
$\Delta_{i,\_\_\_}$ = displacement measured at Point i (i = 1,2, _ _ _), in. (or mm).

4. Summary of Test Method

4.1 The general purpose of this test method is to evaluate the shear forces that can be carried by the web of a framed floor or roof diaphragm assembly by testing a simulation of the construction. The test method outlines basic procedures for the static load testing of these constructions using simple beam or cantilever-type test specimens. Suggested specimen and test setup details are provided, along with loading procedures, instrumentation, and evaluation methods.

4.2 *Construction:*

4.2.1 *Diaphragm Performance Assumptions*—These diaphragm assemblies, assumed to act as deep beams, span between shear walls, moment frame bents, or other constructions that furnish the end or intermediate reactions to the system. The chord members of the assembly perpendicular to the line of applied load act as the flanges of the deep beam, and the plate or panel elements act as the web of the deep beam, and the framing members act as web stiffeners. A schematic drawing of a simple span diaphragm is shown in Fig. 1.

4.2.2 *Connections*—The performance of the diaphragm is influenced by the type and spacing of the plate or panel element attachments, framing connections, and perimeter anchorage at intermediate and perimeter supports. It is necessary to ensure that the type of connection system used and its application as nearly as possible duplicate the system intended for use in the prototype construction.

4.3 ~~*Deformations—*~~*Displacements—*~~The~~ To calculate deflections, the in-plane diaphragm ~~deformation(s)~~displacement(s) shall be recorded. The total ~~in-plane deformation of a~~deflection of a diaphragm consists of bending ~~and shear deformation plus any additional deformation caused by distortion~~deflection, shear deflection of the diaphragm web, and any additional deflection attributed to deformation of the diaphragm ~~web to support connection system.~~ fasteners and connections. Table 1 contains some useful ~~deformation~~deflection equations.

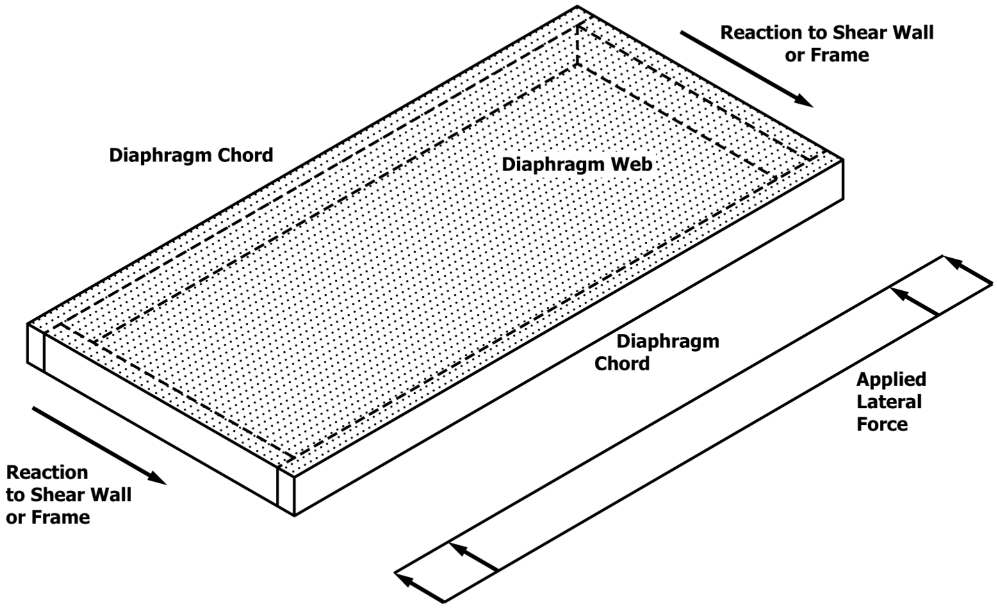


FIG. 1 Schematic of Simple Span Diaphragm

TABLE 1 Useful Deflection Equations

NOTE 1—Other equations may be applicable depending on the number of load points used.

Type of Beam	Loading Condition	Maximum Deflections[A]		
		Δ_b	Δ_s	Δ_s'
~~Simple beam~~	~~uniform load~~	~~$5wL^4/384EI$~~	~~$wL^2/8Gbt$~~	~~$wL^2/8G'b$~~
Simple beam	uniform load	$5wL^4/(384EI)$	$wL^2/(8Gbt)$	$wL^2/(8G'b)$
~~Simple beam~~	~~third-point load[B]~~	~~$23PL^3/648EI$~~	~~$PL/3Gbt$~~	~~$PL/3G'b$~~
Simple beam	third-point load[B]	$23PL^3/(648EI)$	$PL/(3Gbt)$	$PL/(3G'b)$
~~Cantilever beam~~	~~uniform load~~	~~$wa^4/8EI$~~	~~$wa^2/2Gbt$~~	~~$wa^2/2G'b$~~
Cantilever beam	uniform load	$wL^4/(8EI)$	$wL^2/(2Gbt)$	$wL^2/(2G'b)$
~~Cantilever beam~~	~~concentrated load at free end~~	~~$Pa^3/3EI$~~	~~Pa/Gbt~~	~~$Pa/G'b$~~
Cantilever beam	concentrated load at free end	$PL^3/(3EI)$	$PL/(Gbt)$	$PL/(G'b)$

[A] At midspan of simple beam and free end of cantilever beam. ~~Make appropriate adjustment in units as required for compatibility when SI units are used.~~

[B] For bending deflection at the load points under a third-point load, use the following equation:

~~$$\Delta_{b\,(at\ L/3)} = (5PL^3/162EI$$~~

$$\Delta_b(at\ \ L/3) = 5PL^3/(162EI)$$

5. Significance and Use

5.1 Framed floor and roof systems are tested by this test method for static shear capacity. This test method will help determine structural diaphragm properties needed for design purposes.

6. Apparatus

6.1 *Test Assembly:*

6.1.1 *General*—The diaphragm test assembly consists of a frame or framing system on which the elements comprising the web of the diaphragm are placed. The elements are fastened to the frame in a manner equivalent to their attachment in the field. The assembly may be tested horizontally or vertically. Either a cantilever or a simple span diaphragm assembly may be used, with concentrated or distributed loading.

6.1.2 *Frame Requirements*—The frame is a part of the test assembly and shall consist of members of the same or similar materials as those intended for use in the prototype construction. The test frame members shall be of equal or less strength than those intended for use in the prototype construction. If the test objective is to force failure to occur elsewhere in the assembly, make the test frame members stronger and note the modification in the test report. The frame shall be calibrated to establish its ~~load-deformation~~load-deflection characteristics before attaching the diaphragm elements. If the frame has a stiffness equal to or less than 2 % of the total diaphragm assembly, no adjustment of test results for frame resistance need be made. However, if the frame stiffness is greater than 2 % of the total assembly, the test results shall be adjusted to compensate for frame resistance.

6.1.2.1 *Cantilever Frame* (see Fig. 2)—A pinned frame reaction at corner (*C*) shall be provided to transfer the horizontal force (*P*) through the diaphragm into the support system. The pin shall be located as close as possible to the diaphragm-to-frame contact plane to minimize warping of the diaphragm surface. A vertical reaction roller or rollers shall be provided in the diaphragm plane at corner (*H*). The frame shall be laterally supported at adjacent corners (*D*) and (*E*) on rollers and at other locations as necessary to prevent displacement of the diaphragm from the plane of testing, but not to restrict in-plane displacements.

6.1.2.2 *Simple Span Frame* (see Fig. 3)—In-plane reactions shall be provided at points (*E*) and (*H*) as shown to resist the applied test load or loads. The frame shall be supported with rollers at points (*C*), (*D*), (*E*), and (*H*), and under each loading point. Hold-downs with rollers shall be provided to prevent displacement of the specimen from the plane of testing but not to restrict in-plane displacements. The diaphragm can also be supported by tension reactions at points (*C*) and (*D*) instead of reactions shown at points (*E*) and (*H*) in Fig. 3.

6.1.3 *Diaphragm Size:*

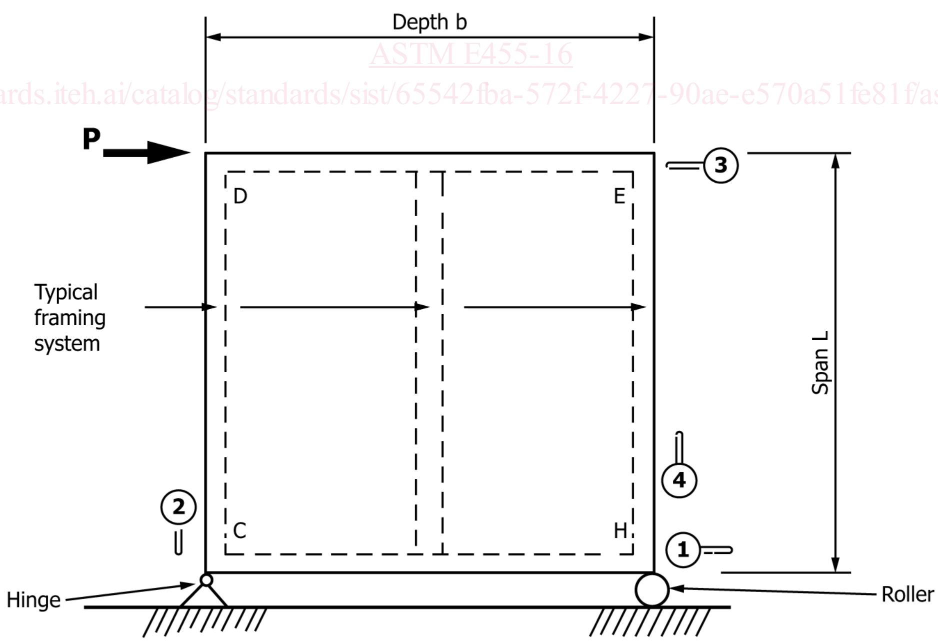
6.1.3.1 *Cantilever Diaphragm*—The diaphragm shall be tested on a span ~~length *a*,~~*L*, as shown in Fig. 2, equal to or greater than the typical support spacing likely to be used in the building. The test assembly shall not be less than 8 ft (2.4 m) in either ~~length~~span *L* or ~~width;~~depth *b*; nor shall it contain ~~less~~fewer than four elements if the diaphragm consists of individual elements. The diaphragm shall contain typical end and side joints for the elements.

NOTE 1—When the web of the diaphragm is made of individual elements, they might not be equally effective for the same span length if laid perpendicular or parallel to the load direction.

6.1.3.2 *Simple Beam Diaphragm*—The diaphragm ~~length~~span *L* and depth *b* shall be as shown in Fig. 3, where the dimensions ~~*a*~~*L* and *b* have ~~the same connotation as above~~ similar meaning as used in 6.1.3.1 with a minimum dimension in either case of 8 ft (2.4 m). The diaphragm shall contain typical end and side joints for the elements.

7. Safety Precautions

7.1 Tests of this type can be dangerous. Equipment and facilities must be designed with ample safety factors to ensure that it is the specimen that fails and not the test apparatus or facilities. Observers and sensitive instrumentation must be kept away from diaphragms when loading to failure or in a load range where performance is unknown.



NOTE 1—~~Dial gage or other deflection measuring device.~~

Dial gage or other displacement measuring device.

NOTE 2—Lateral restraint devices are not shown, and should not restrict movement in the plane of the diaphragm.

FIG. 2 Plan of a Cantilever Beam Diaphragm Test with a Concentrated Load