

ANSI/ASAE EP484.3 DEC2017
Diaphragm Design of Metal-Clad, Wood-Frame Rectangular Buildings



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Diaphragm Design of Metal-Clad, Wood-Frame Rectangular Buildings

Developed by the ASAE Diaphragm Design of Metal-Clad, Post-Frame Rectangular Buildings Subcommittee of the Structures Group; approved by the Structures and Environment Division Standards Committee; adopted by ASAE September 1989; revised December 1990; reaffirmed December 1994, 1995, 1996, 1997; revised June 1998; approved as an American National Standard August 1998; revised editorially February 2000; reaffirmed February 2003; revised editorially August 2003; reaffirmed February 2008, February 2013; revised December 2017.

Keywords: Buildings, Structures, Terminology, Wood-frame

1 Purpose and Scope

1.1 This Engineering Practice is a consensus document for the analysis and design of metal-clad wood-frame buildings using roof and ceiling diaphragms, alone or in combination. The roof (and ceiling) diaphragms, endwalls, intermediate shearwalls, and building frames are the main structural elements of a structural system used to efficiently resist the design lateral (wind, seismic) loads. This Engineering Practice gives acceptable methods for analyzing and designing the elements of the diaphragm system.

1.2 The provisions of this Engineering Practice are limited to the analysis of single-story buildings of rectangular shape.

2 Normative References

The following referenced documents are integral components in the application of this document. For dated references, only the edition cited applies unless noted. For undated references, the latest approved edition of the referenced document (including any amendments) applies.

AWC (American Wood Council) National Design Specification® (NDS®) for Wood Construction. Washington, D.C.)

ASAE EP486, Shallow Post and Pier Foundation Design

ASAE EP558, Load Tests for Metal-Clad, Wood Frame Diaphragms

AISI S310, North American Standard for the Design of Profiled Steel Diaphragm Panels

3 Definitions (see Figures 1 and 2)

3.1 diaphragm: A structural assembly of metal cladding, including the wood or wood product framing, metal cladding, fasteners and fastening patterns, capable of transferring in-plane shear forces through the cladding and framing members.

3.2 diaphragm design: Design of roof (and ceiling) diaphragm(s), sidewall posts, endwalls, shearwalls, component connections, chord splices, and foundation anchorages, for the purpose of transferring lateral (e.g., wind) loads to the foundation structure.

3.3 diaphragm dimensions

3.3.1 diaphragm length, d : Length of a building diaphragm in the plane of the diaphragm.

3.3.2 diaphragm span, b_h : Horizontal span of a building diaphragm having length, d .

3.3.3 diaphragm width, s : Distance between individual building frames; see also 3.10.

3.3.4 model diaphragm length, b : Length of a model diaphragm as measured parallel to the direction of applied load.

3.3.5 model diaphragm width, a : Length of a model diaphragm as measured perpendicular to the direction of applied load.

3.4 diaphragm fasteners: The various fasteners and fastener patterns used to connect the several components of the endwalls, shearwalls, and diaphragms. These include fasteners between cladding and purlins, between cladding and endwall girts, between diaphragm framing members, and between individual sheets of cladding (stitch fasteners).

3.5 diaphragm shear stiffness

3.5.1 model diaphragm shear stiffness, c : The in-plane shear stiffness of a model diaphragm. Defined as the slope of the shear load-deflection curve between zero load and the load corresponding to the diaphragm allowable shear strength.

3.5.2 in-plane shear stiffness, c_p : The in-plane shear stiffness of an individual roof or ceiling diaphragm.

3.5.3 horizontal shear stiffness, c_h : The horizontal shear stiffness of an individual roof or ceiling diaphragm. It is obtained by adjusting diaphragm in-plane shear stiffness, c_p , for slope.

3.5.4 total horizontal diaphragm shear stiffness, C_h : The horizontal shear stiffness of the roof and ceiling assembly is calculated by summing the horizontal shear stiffness values of individual roof and ceiling diaphragms. Alternatively, this stiffness can be obtained from full-scale building tests.

3.6 diaphragm shear strength, V_a : The allowable design shear strength (see ASAE EP558) of a diaphragm in the plane of the cladding.

3.7 eave load, R : A concentrated (point) load, horizontally acting, that is located at the eave of each frame, and results in a horizontal eave displacement identical to that caused by application of the controlling combination of design loads. R is numerically equal to the horizontal force required to prevent horizontal translation of the eave when the controlling combination of design loads is applied to the frame.

3.8 endwall and shearwall stiffness, k_e : The ratio of a horizontal force applied at the eave to the corresponding deflection of an individual unattached wall. A wall is unattached when it is not connected to components that lie outside the plane of the wall.

3.9 frame stiffness, k : The ratio of a horizontal force applied at the eave to the corresponding deflection of the individual unclad post-frames.

3.10 frame spacing, s : The distance between frames. In the absence of stiff frames that resist lateral loads, the frame spacing is generally equated to the distance between adjacent trusses (or rafters) or to the model diaphragm width. Frame spacing defines the width (and therefore stiffness properties) of roof/ceiling diaphragm sections. Frame spacing may vary within a building.

3.11 metal cladding: The metal exterior and interior coverings, usually cold-formed aluminum or steel sheet, fastened to the wood framing.

3.12 model diaphragm: A laboratory tested diaphragm or a diaphragm analyzed using a validated structural model that is used to predict the behavior of a building diaphragm. Laboratory tested diaphragms should be

sized, constructed, supported and tested in accordance with ASAE EP558. AISI S310 shall be considered to be a validated structural model to calculate the strength and stiffness of a profiled steel panel and its connectors, to a wood support.

3.13 post frame: A structural building frame consisting of a wood roof truss or rafters connected to vertical timber columns, or sidewall posts.

3.14 sideways restraining force, Q : The total force applied to a frame by the roof/ceiling diaphragm.

3.15 shear transfer: The transfer of the resultant shear forces between individual sheets of cladding, between the ends of roof/ceiling diaphragms and frames and shear walls, or between the bottom of the shear walls and the base of the posts or foundation.

3.16 shearwall: An endwall or intermediate wall designed to transfer shear from the roof/ceiling diaphragm into the foundation structure.

3.17 wood frame: A structural building frame consisting of wood or wood-based materials. Wood trusses over studwalls and post and beam are examples of wood frames.

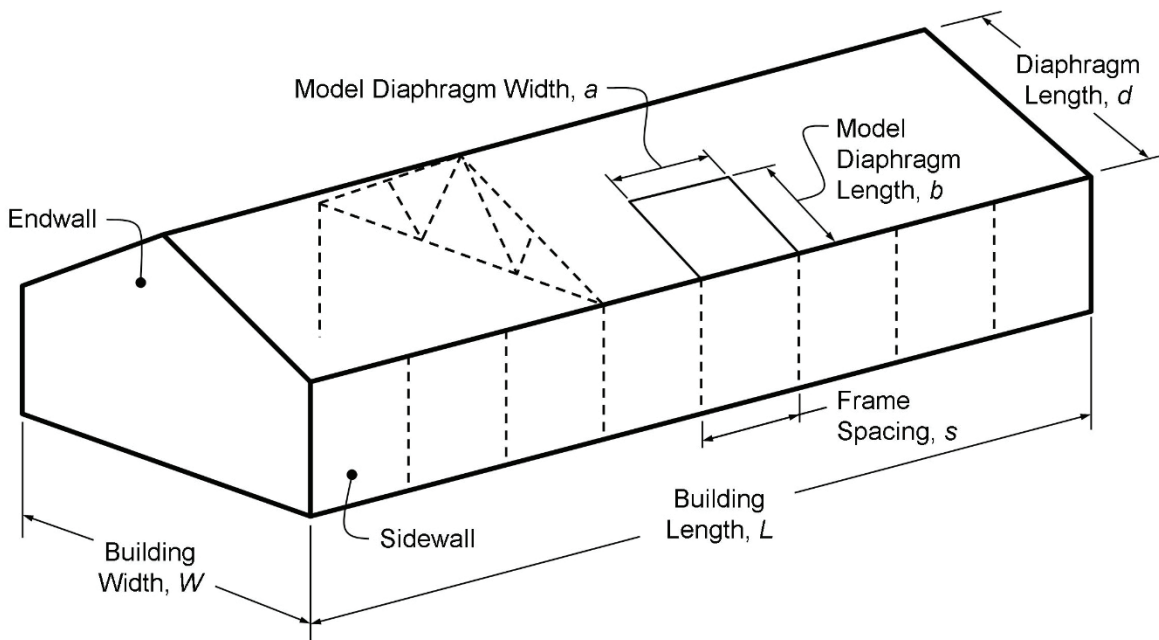


Figure 1 – Definition sketch for terminology

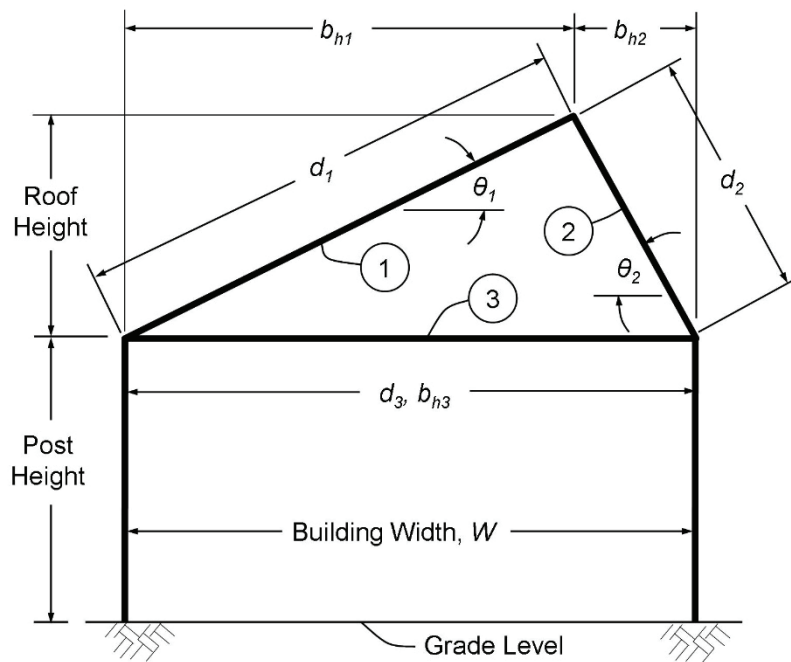


Figure 2 – Building cross section showing roof diaphragms 1 and 2, and ceiling diaphragm 3

4 Diaphragm Stiffness

4.1 General provisions. This section outlines procedures for determining the total horizontal shear stiffness, C_h , of a width, s , of the roof/ceiling assembly. This stiffness is defined as the horizontal load required to cause a horizontal displacement (in a direction parallel to the trusses/rafters) of the roof/ceiling assembly over a spacing, s (Figure 1). This stiffness can be obtained directly from full scale building tests (Gebremedhin *et al.*, 1992), validated structural models, or using procedures outlined in clause 4.2.

4.2 Total horizontal shear stiffness, C_h . The total horizontal diaphragm shear stiffness, C_h , for the frame spacing, s , of the roof / ceiling assembly is defined as:

$$C_h = \sum_{i=1}^n c_{h,i} \quad (1)$$

where:

$c_{h,i}$ = horizontal shear stiffness of diaphragm i with a width, s , from clause 4.3, kN/mm (lbf/in.);

n = number of individual roof and ceiling diaphragms in the roof/ceiling assembly (Figure 2).

When the frame spacing, s , or roof/ceiling diaphragm construction varies along the length of a building, C_h may vary, and the building requires special analysis (see clause 7.3).

4.2.1 Excluding diaphragms. Diaphragm analyses may be simplified by excluding from an analysis any diaphragm that is considerably less stiff than others in the roof/ceiling system. For example, where a ceiling diaphragm is much stiffer than the roof diaphragm(s), the stiffness of the roof diaphragm(s) may be excluded from total stiffness calculations (i.e., Equation 1). For diaphragms that are sheathed with dissimilar materials, the combined allowable design unit shear capacity shall be either two times the smaller allowable design unit shear capacity or the larger allowable design unit shear capacity, whichever is greater.

4.3 Horizontal shear stiffness of an individual diaphragm, $c_{h,i}$. The horizontal shear stiffness of an individual diaphragm can be calculated from the diaphragm's in-plane shear stiffness (Equation 2) or from the in-plane stiffness of a model diaphragm (Equation 3) (Anderson and Bundy, 1989). Model diaphragms used to predict the horizontal stiffness of a building diaphragm shall be functionally equivalent to the building diaphragm. ASAE