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**Timber structures — Test method  
— Static load tests for horizontal  
diaphragms including floors and roofs**

*Structures en bois — Méthode d'essai — Essais de chargement  
statique pour les diaphragmes horizontaux incluant planchers et  
toitures*



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# Contents

|  | Page      |
|--|-----------|
| <b>Foreword</b> .....                        | <b>iv</b> |
| <b>Introduction</b> .....                    | <b>v</b>  |
| <b>1 Scope</b> .....                         | <b>1</b>  |
| <b>2 Normative references</b> .....          | <b>1</b>  |
| <b>3 Terms and definitions</b> .....         | <b>1</b>  |
| <b>4 Symbols</b> .....                       | <b>1</b>  |
| <b>5 Requirements</b> .....                  | <b>2</b>  |
| <b>6 Test method</b> .....                   | <b>2</b>  |
| 6.1 Principle .....                          | 2         |
| 6.2 Apparatus .....                          | 2         |
| 6.2.1 General .....                          | 2         |
| 6.2.2 Test assembly .....                    | 3         |
| 6.2.3 Deformation measurement .....          | 3         |
| 6.2.4 Load measurement .....                 | 3         |
| 6.3 Test specimens .....                     | 3         |
| 6.3.1 Conditioning .....                     | 3         |
| 6.3.2 Dimensions .....                       | 3         |
| 6.3.3 Sampling .....                         | 4         |
| 6.4 Test configuration .....                 | 4         |
| 6.4.1 Cantilever test .....                  | 4         |
| 6.4.2 Simple beam test .....                 | 5         |
| 6.5 Test procedure .....                     | 5         |
| 6.5.1 Determination of frame stiffness ..... | 5         |
| 6.5.2 Test for complete diaphragm .....      | 6         |
| <b>7 Calculation</b> .....                   | <b>6</b>  |
| 7.1 Ultimate shear strength .....            | 6         |
| 7.2 Apparent shear stiffness .....           | 6         |
| <b>8 Report</b> .....                        | <b>7</b>  |
| <b>Bibliography</b> .....                    | <b>9</b>  |

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. [www.iso.org/directives](http://www.iso.org/directives)

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. [www.iso.org/patents](http://www.iso.org/patents)

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 165, *Timber structures*, based on ASTM E 455.

## Introduction

Horizontal diaphragms including floors and roofs are integral parts of light-frame timber buildings to show resistance against horizontal forces such as winds and earthquakes. Their characteristics such as ultimate shear strength have great effects on the behaviour of timber buildings including horizontal diaphragms as floors and/or roofs under winds or seismic loads.

Horizontal diaphragms are those structures which are widely used for timber buildings to form floors and/or roofs. They behave as a simple beam or cantilever beams under horizontal loads caused by wind or earthquake to transmit forces to the structures or structural members supporting them. Horizontal diaphragms should have enough stiffness and strength that they do not undergo large deflection or failures in parts of the structure.

The purpose of this International Standard is to measure the shear stiffness and strength of horizontal diaphragms as one of the basic parameters to interpret the behaviour of diaphragms under horizontal loads such as winds and earthquakes. The requirements are necessary to replicate the same conditions as those for timber structures in the field. Loads can be applied to the specimen either by compression or tension whichever is relevant.



# Timber structures — Test method — Static load tests for horizontal diaphragms including floors and roofs

## 1 Scope

This International Standard defines the test method for horizontal diaphragms including floors and horizontal and sloped roofs under static loads. This test method is designated to evaluate the static shear capacity of a typical segment of a diaphragm under applied static loads, and to evaluate the stiffness of the diaphragm assembly.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13061-2, *Physical and mechanical properties of wood — Test methods for small clear wood specimens — Part 2: Determination of density for physical and mechanical tests*<sup>1)</sup>

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

### 3.1

#### diaphragm

horizontal and sloped assembly of materials designated to transmit lateral forces to vertical resisting elements or foundations through shear resistances in the plane of the construction

Note 1 to entry: A diaphragm is analogous to a horizontal deep beam composed of interconnected membrane elements such as panels, sheathings, or claddings acting as the deep beam web, intermediate elements such as joists or rafters acting as web stiffeners, and perimeter boundary elements such as girders or header joists acting as deep beam chords.

## 4 Symbols

- $E$  modulus of elasticity of flange or web material, depending upon which material is held constant in a transformed section analysis (MPa)
- $G'$  apparent shear stiffness, which is shear stiffness of the diaphragm obtained from test (N/mm)
- $I$  moment of inertia of the transformed section of the diaphragm based on webs or flanges (mm<sup>4</sup>)
- $L$  total span of a simply supported diaphragm (mm)
- $P$  concentrated load (N)
- $R_u$  maximum diaphragm reaction (N)
- $S_u$  ultimate shear strength of the diaphragm (N/m)
- $a$  span length of cantilever diaphragm (mm)

1) Replaces ISO 3131:1975.

$b$  depth of diaphragm (mm)

$\Delta_b$  bending deflection of diaphragm (mm)

$\Delta'_S$  apparent total shear deformation of the diaphragm based on test, which includes both the pure shear deformation and that contributed by distortion of the connection system (mm)

$\Delta_t$  total deflection of diaphragm (mm)

$\Delta_{1,2,\dots}$  deformation measured at points 1, 2, ... (mm)

## 5 Requirements

The materials used to construct diaphragm such as timbers, panels, sheathings, claddings, and fasteners shall be, as far as possible, of the quality allowed by the relevant specification.

## 6 Test method

### 6.1 Principle

The lateral force applied to a horizontal diaphragm is resisted by in-plane shear capacity of the web material of the diaphragm and transmitted to the supporting structures such as shear walls, columns, beams, girders or foundations as shown in [Figure 1](#). The diaphragm assembly, which is assumed to act as a deep beam, spans between shear walls, moment frames, or other constructions that can furnish the end or intermediate reactions to the system. The chord members of the assembly perpendicular to the direction of applied load act as flanges of the deep beam, and the panels covering the frames act as the web of the deep beam, and the framing members such as joists or rafters act as web stiffeners. The test methods evaluate the shear capacity and stiffness of the diaphragm by applying static bending loads to the simple beam or cantilever-type test specimens.

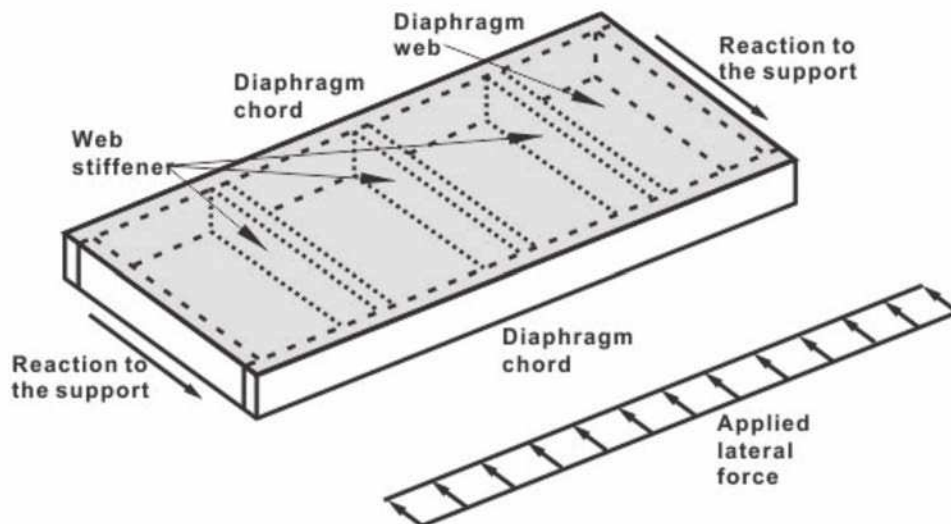


Figure 1 — Schematic drawing of simple span diaphragm

### 6.2 Apparatus

#### 6.2.1 General

The test apparatus shown in [Figures 2](#) and [3](#) shall be capable of producing the boundary conditions that are intended in the test method.



The testing machine shall be capable of applying and continuously recording load and displacement with an accuracy of  $\pm 1$  % of the estimates of  $P_{\max}$  and  $\Delta_{\max}$  or better.

### 6.2.2 Test assembly

The diaphragm test assembly shall consist of a frame or framing system on which the elements comprising the web of the diaphragm are placed. 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 frame shall be calibrated to establish its load-deformation characteristics before attaching the web 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 needs to 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.

The web elements shall be fastened to the frame in a manner equivalent to their attachment in the field. The assembly may be tested horizontally or vertically (for roof diaphragm, test with sloped position may be selected). Either a cantilever or a simple span diaphragm assembly shall be used, with concentrated or distributed loading.

When tested as a simple span diaphragm assembly in the vertical orientation, the self-weight of the diaphragm shall be taken account of in the calculation of strength and stiffness.

### 6.2.3 Deformation measurement

The base of the test frame shall provide a level foundation for the test specimen, and shall be relatively stiff so that its deflections shall be negligible. A rigid datum (independent of the test frame) shall be provided for the measurement of the deformation of the diaphragm specimen. Dial gages or other deformation measuring devices shall be attached to the specimen as shown in [Figures 2](#) and [3](#), and shall record the displacement continuously with an accuracy of  $\pm 1$  % of the displacement, or for displacement less than 2 mm with an accuracy of  $\pm 0,1$  mm.

NOTE 1 Refer to ASTM E455 for deflection equation under various loading configurations.

NOTE 2 The required displacement measurement accuracy for displacement measurements less than 2 mm is reduced as this is not critical to the test and allows commonly available displacement gauges to be used.

### 6.2.4 Load measurement

Loads shall be applied by hydraulic jacks that have been previously calibrated, or by other suitable types of loading apparatus. Load measuring devices shall be accurate to within  $\pm 2$  %.

## 6.3 Test specimens

### 6.3.1 Conditioning

The specimens shall be conditioned at the controlled environment of  $(20 \pm 2)$  °C temperature and  $(65 \pm 5)$  % relative humidity according to ISO 554 as far as possible. The test laboratory shall normally be maintained at the controlled environment, but when other conditions apply, they shall be reported.

The density of wood materials in the diaphragm specimen shall be determined in accordance with ISO 13061-2.

### 6.3.2 Dimensions

The dimensions (e.g. width and length), configuration (e.g. openings), and fabrication details (e.g. member sizes and spacings, tolerances) shall be representative of the intended use.

Where panels are connected to form a diaphragm, diaphragm specimens shall consist of a single or multiple panels of the representative dimensions.

Some diaphragm configurations may have joints between diaphragm units. Those joints should be considered for inclusion in test specimens.

**6.3.3 Sampling**

Sampling shall provide for selection of representative test material on an objective and unbiased basis, covering an appropriate range in physical and mechanical properties.

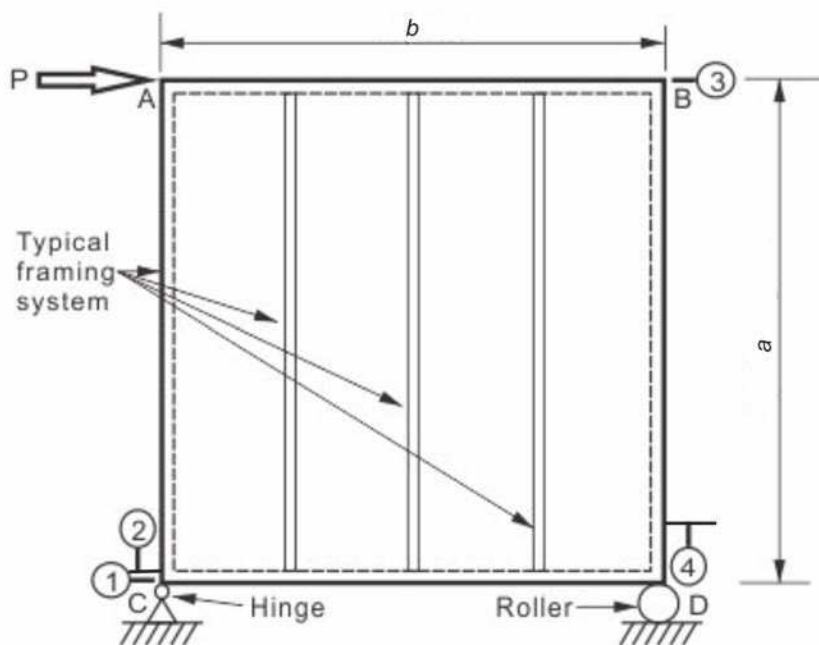
The number of replicates should be selected to achieve the specific objectives and desired reliability.

**6.4 Test configuration**

**6.4.1 Cantilever test**

A pinned frame reaction at corner (C) shall be provided to transfer the horizontal force, P, through the diaphragm into the support system as shown in Figure 2. The pin shall be located as close as possible to the web-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 (D). The frame shall be laterally supported at adjacent corners (A) and (B) by rollers and at other locations as necessary to prevent displacement of the diaphragm from the plane of the testing, but not to restrict in-plane displacements.

The diaphragm shall be tested on a span length a, as shown in Figure 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 2,4 m in either length or width, nor shall it contain less than four elements if the diaphragm consists of individual elements. The diaphragm shall contain typical end and side joints for the elements. When it is expected that the direction of web elements affects the test results, the diaphragm with web elements installed perpendicular to load direction shall be distinguished from the diaphragm with web elements installed parallel to load direction.



**Key**

1 to 4 dial gage or other deformation measuring device

**Figure 2 — Cantilever diaphragm test with a concentrated load for horizontal diaphragm; Lateral restraint devices are not shown**

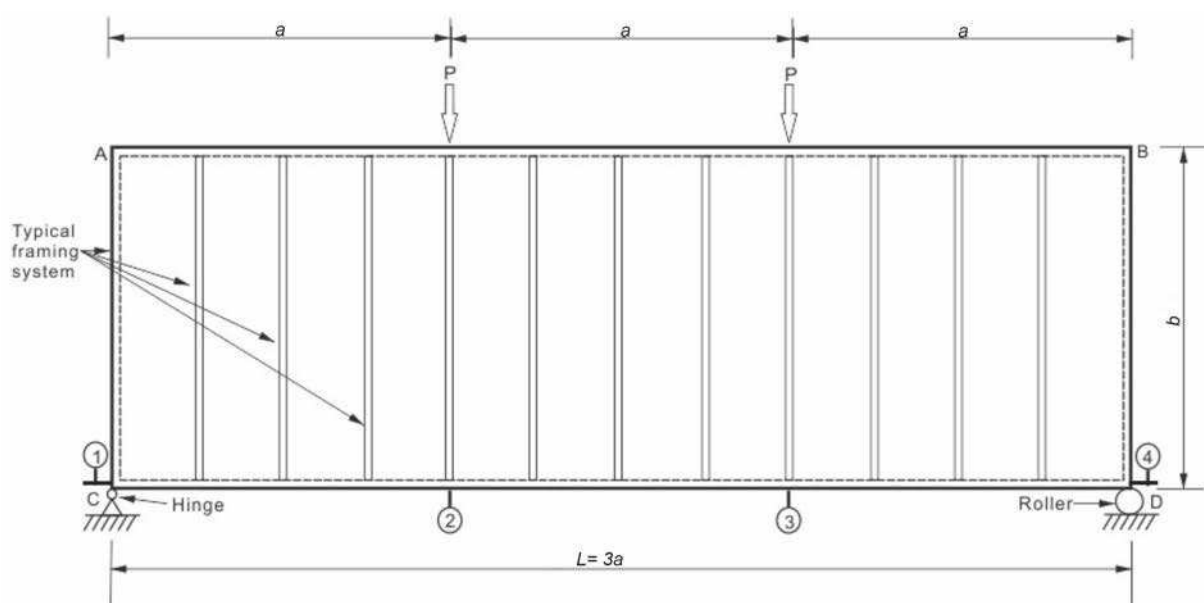
## 6.4.2 Simple beam test

In-plane reactions shall be provided at points (C) and (D) as shown in [Figure 3](#) to resist the applied test loads. The frame shall be supported with rollers at points (A), (B), (C) and (D), and under each loading point. The rollers shall be provided on both sides of the specimen to prevent displacement of the specimen from the plane of testing but not to restrict in-plane displacement.

The length and depth of the diaphragm shall be as shown in [Figure 3](#), where the dimensions  $a$  and  $b$  have the same meaning as shown in [Figure 2](#) with a minimum dimension in either case of 2.4m. The diaphragm shall contain typical end and side joints for the elements.

NOTE 1 Test results from simple beam and cantilever-type specimens might not yield comparable results.

NOTE 2 The simple beam test for horizontal diaphragms can be performed with the uniform load applied along the diaphragm length or with more than two concentrated loads applied at third points as shown in [Figure 3](#). In this case, the apparent shear stiffness cannot be calculated in accordance with [7.2](#). Refer to ASTM E455 for appropriate equations.



### Key

1 to 4 dial gage or other deformation measuring device

**Figure 3 — Simple beam diaphragm test with third-point loading for horizontal diaphragm:  
Lateral restraint devices are not shown**

## 6.5 Test procedure

### 6.5.1 Determination of frame stiffness

The frame stiffness shall be determined by loading the frame structure before the web elements are attached. The loading speed shall be the same as that applied for the loading of the diaphragm with web elements attached.

NOTE If calculations show that the frame stiffness is less than 2 % of the stiffness of the total diaphragm assembly, a separate frame test is not required.

## 6.5.2 Test for complete diaphragm

The loads shall be applied to the diaphragm in a manner duplicating, as far as practical, the in-service loading conditions. When applying loads to the specimen, out-of-plane movement of the test specimen shall not be allowed.

NOTE Any suitable means that do not restrict in-plane movement of the diaphragm are acceptable.

The rate of loading shall be chosen such that the maximum load will be reached between 5 min and 30 min after starting the test. At least 10 sets of uniformly spaced deformation readings shall be taken prior to failure to establish the load-deformation curve. The rate of loading shall permit loads and deformations to be recorded.

## 7 Calculation

### 7.1 Ultimate shear strength

Calculate the ultimate shear strength,  $S_u$ , following Formula (1):

$$S_u = \frac{1\,000R_u}{b} \text{ (N/m)} \quad (1)$$

where

$R_u$  is the maximum reaction at failure in a simple beam test, or the maximum reaction acting parallel to the applied load in a cantilever test, in kilonewtons;

$b$  is the diaphragm depth as shown in [Figures 2](#) and [3](#), in metres.

NOTE 1  $R_u$  is the same as the applied maximum load in a cantilever test with concentrated load at the free end, or as the applied maximum load at one loading point that is half of the total maximum applied load in a simple beam test for horizontal diaphragm with third points loading.

NOTE 2 For the simple beam test method under uniform load,  $R_u$  can be measured with appropriate reaction measuring devices, or it can be calculated by applying officially recognized engineering principles.

### 7.2 Apparent shear stiffness

An apparent shear stiffness,  $G'$ , may be determined for the entire assembly on the basis of the applied load at a reference load level below the proportional limit for use in deflection calculations.

For use in determining the apparent shear stiffness with the concentrated loading conditions given in [Figures 2](#) and [3](#), the total deflection shall be calculated at any load level,  $\Delta_t$ , taking account of the support movements, following Formulas (2) and (3):

For the cantilever test:

$$\Delta_t = \Delta_3 - \left[ \Delta_1 + \frac{a}{b}(\Delta_2 + \Delta_4) \right] \quad (2)$$

For the simple beam test:

$$\Delta_t = \frac{(\Delta_2 + \Delta_3 - \Delta_1 - \Delta_4)}{2} \quad (3)$$

where

$\Delta_1, \Delta_2, \Delta_3, \Delta_4$  are the measured deformations with appropriate signs at locations indicated in [Figures 2 and 3](#);

$a, b$  are the dimensions as given in [Figures 2 and 3](#).

The apparent shear deformations ( $\Delta'_S$ ) shall be calculated at any load following Formula (4):

$$\Delta'_S = \Delta_t - \Delta_b \quad (4)$$

where

$\Delta_b$  is the deflection of a diaphragm caused by diaphragm bending, in millimetres.

NOTE In the above formulas,  $\Delta_b$  is determined using the appropriate formulas from basic engineering principles.

For the concentrated loading conditions as given in [Figures 2 and 3](#), the apparent shear stiffness,  $G'$ , may be calculated following Formula (5):

$$G' = \frac{P}{\Delta'_S} \left( \frac{a}{b} \right) \quad (5)$$

The apparent shear stiffness,  $G'$ , varies depending on the length of the diaphragm. Therefore, a multiple number of tests shall be made with diaphragms having various lengths to determine the range of apparent shear stiffness for given structures.

NOTE 1 Otherwise, the following method can be applied to determine the apparent shear stiffness based on the results of limited tests:

Perform tests by applying one of the methods given in this document for the longest and shortest reasonable diaphragm lengths. Determine  $G'$  by applying the above equation.  $G'$  for any length of diaphragm not tested can be obtained by linear interpolation.

NOTE 2 Flexibility of the tested diaphragm can be obtained as the reciprocal of the apparent shear stiffness expressed in millimetre of deflection per meter of diaphragm span stressed with a shear load of 1 N/m.

NOTE 3 For the purpose of calculations, the apparent EI can optionally be determined by one of the Method A and B as follows:

Method A – Measure the deflection at the mid-span. The apparent EI is determined from the relative deflection between the mid-span and the loading point at the same time during the loading by using a simple beam theory.

Method B – Measure the deflection perpendicular to the loading direction at the two corners of the free end of the diaphragm. The deflection angle is determined from the measured deflections and the distance between two deflection measuring points. The apparent EI is determined from the deflection angle by using a simple beam theory.

## 8 Report

The report shall include the following information:

- a) test date;
- b) specifications for the specimens (manufacturers, dimensions, models, materials, moisture content and density of wood materials, etc.);
- c) drawings of the specimen;
- d) descriptions of test specimen, assembly and conditions;

## ISO 19049:2016(E)

- e) test agency details;
- f) test method (a statement that test was performed in accordance with this International Standard, or with certain deviations, which shall be described);
- g) test results;
- h) the apparent shear stiffness may optionally be reported.

## Bibliography

- [1] ISO 554, *Standard atmospheres for conditioning and/or testing — Specifications*<sup>2)</sup>
- [2] ASTM E 455-11, *Standard Test Method for Static Load Testing of Framed Floor and Roof Diaphragm Construction for buildings*

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2) Withdrawn.

