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Timber structures — Strength graded timber — Test methods for structural properties

Structure en bois — Bois classé selon la résistance — Méthodes d'essai des propriétés structurelles

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Foreword

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The committee responsible for this document is ISO/TC 165 *Timber Structures*.

This second edition cancels and replaces the first edition (ISO 13910:2005), which has been technically revised.

Introduction

This International Standard provides requirements for testing of structural properties for a specific grade and size of sawn timber. In accordance with the requirements of performance-based International Standards, it is concerned with the measurement of properties similar to those that occur under service conditions and are intended for deriving engineering properties in structural design codes. Hence, terms such as "bending strength", "shear strength", "bearing strength", etc. relate to the loading configuration used and to the targeted mode of failure.

It is not the intent to imply that every property of every grade and size of timber used in building construction needs to be assessed according to this International Standard. The requirements for any assessment typically are specified in building regulations, quality manuals or other material standards and specifications.

This document is an internationally-agreed reference standard for measurement of structural properties of strength-graded timber. Other standards related to the measurement of structural properties may be deemed to comply with this International Standard, provided that the adjustments necessary to establish equivalency between this and other standards are applied appropriately

Timber structures — Strength graded timber — Test methods for structural properties

1 Scope

This International Standard specifies test procedures for full-size sawn timber that has been strength-graded, for the derivation of design properties in codes dealing with structural engineering design. It is applicable to sawn timber of rectangular cross-section subjected to a short-duration load.

2 Terms and definitions

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

2.1
grade
population of timber with defined design properties in a design standard

2.2
piece of timber
timber of rectangular cross-section manufactured for construction purposes of a specific grade

2.3
test specimen
length of timber, cut from a piece, for purposes of testing to evaluate a timber property

3 Symbols and abbreviated terms

3.1 General notation

a	distance between a load point and nearest support in a bending test set-up, expressed in mm
b	thickness (smaller dimension of a cross section) of a rectangular piece or specimen of timber, expressed in mm
E	modulus of elasticity parallel to direction of grain, expressed in MPa
F	applied load, expressed in N
f	strength, expressed in MPa
G	shear modulus of rigidity, expressed in MPa
h	width (larger dimension of a cross section) of a rectangular piece or specimen of timber, expressed in mm
K	stiffness, expressed in N per mm deformation
L	length along a piece or specimen of timber, expressed in mm
L_T	length of test specimen subjected to torsion forces, expressed in mm
l_h	length cut from a specimen, expressed in mm
l_t	lever arm of applied torsion load, expressed in mm
e	displacement of beam, expressed in mm
m	mass of specimen, expressed in kg
SH_v	volumetric shrinkage of wood from green fibre saturation point (FSP) to oven-dry condition
w	ratio of mass of water to mass of oven-dry wood, equivalent to moisture content
w_{FSP}	moisture content at fibre saturation point
x_i	data value
θ	rotational deformation in a torsion test, in radians
ρ	density, expressed in kg/m^3
ρ_{12}	density, expressed in kg/m^3, at 12% moisture content
ρ_{test}	density, expressed in kg/m^3, at time of test

3.2 Subscripts

0.1h	value at deformation of 0.1h
0	property in a direction of 0° to the grain
90	property in a direction of 90° to the grain
c	compression
m	bending
t	tension
ult	value at failure
v	shear

4 Test specimens

All test specimens are of full-size cross section. The length required for a test specimen shall be related to the specific test (see Clause 6).

Unless otherwise stated, test specimens shall be selected from random locations within a piece of timber. Specimens cut from pre-defined locations (centre of a piece of timber, a randomly selected end within a piece or clear sections, etc.) may be deemed to comply with this requirement provided this does not produce any bias in the measured properties.

Each test specimen for a given size, grade or property shall be cut from a different piece of timber and more than one type of test specimen may be cut from each piece.

5 Test conditions

Unless otherwise specified in the description of the reference population, the reference moisture content at the time of testing shall be consistent with conditioning at a temperature of 20°C (±2°C) and 65 % (±5 %) relative humidity. Other test procedures and conditioning criteria may be used provided they are more conservative; otherwise, an equivalency in performance for these alternative procedures and conditions shall be established. The rate of loading shall be selected that targets average time-to-failure in 1 min to 5 min.

NOTE The intent here is not to reject data for weak pieces that fail in a short time.

At the time of testing, the moisture content of the timber, the temperature of the timber, and the time to failure shall be recorded.

6 Test configurations

6.1 Density

The specimens for the measurement of density shall be free of knots and comprise the full cross-section of the piece of timber. The length of the test specimen shall be a minimum of 50 mm. The mass, *m*, and moisture content, w, are measured for each test specimen. The density at the time of test, ρ_{test}, shall be calculated from

$$\rho_{test} = \frac{m \times 10^9}{Lbh} \quad (1)$$

The density at 12 % moisture content, ρ_{12}, shall be calculated from

$$\rho_{12} = \rho_{test}\,[1 - 0{,}5(w - 0{,}12)] \quad (2)$$

where w is the moisture content at the time of test as determined by the oven-dry method.

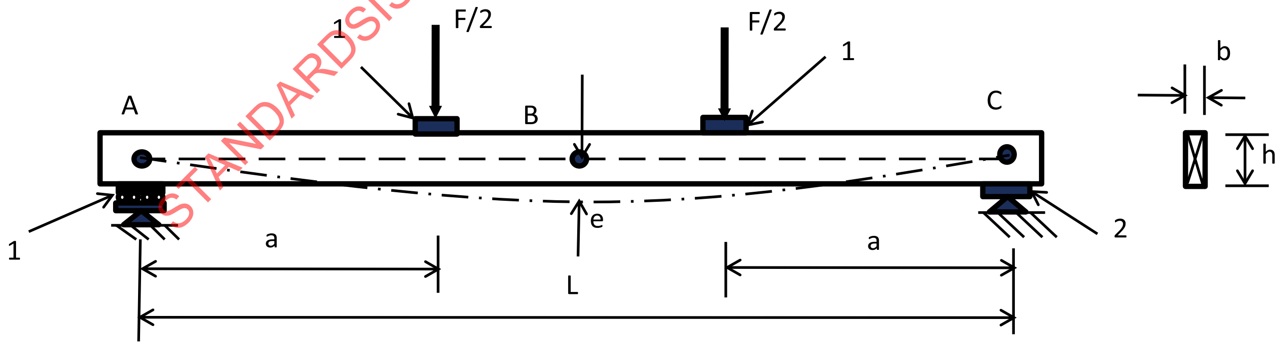
Alternatively, it may be sufficiently accurate to measure moisture content by means of a moisture meter, provided that the meter is calibrated against moisture content measurements determined by the oven dry method. Where such moisture meter measurements are made, they shall be made at several locations along each specimen.

NOTE If specific gravity (e.g. based on oven-dry mass and oven-dry volume, SG_{OD}) is desired, it can be estimated from wood density at test, ρ_{test}, moisture content, w, fibre saturation point, w_{FSP}, and wood volumetric shrinkage, SH_v, as follows:

$$SG_{OD} = \frac{(1 + wSH_v / w_{FSP})\rho_{test}}{1\,000(1 + w)}$$

6.2 Bending strength and stiffness

The bending strength and stiffness test configuration shall be as shown in Figure 1. The beam specimen shall be loaded at two points, equally spaced between the end supports, with each load equal to $F/2$. The distance between load points shall be 6 h and the distance between a load point and the nearest support, a, shall be 4,5 h to 7 h. The tension edge of the beam shall be chosen randomly. If the beam has a slenderness where there could be a tendency for the compression edge to buckle during loading, lateral restraints may be provided to the compression edge. Such restraints shall not resist any movement in the direction of the loading. Bearing blocks at loading and support points (see Figure 1), shall be of sufficient thickness and extend entirely across the beam thickness to eliminate high-stress concentrations at places of contact between beam and bearing blocks. Load shall be applied to the blocks in such a manner that the blocks may rotate about an axis perpendicular to the span. The slider bearing plate in Figure 1 shall allow rotation and horizontal movement whereas the bearing plate shall allow only rotation.



Key

1 slider bearing plate

2 bearing plate (rocker)

Figure 1 — Test set-up for measuring bending strength and stiffness

Modulus of elasticity, E, shall be calculated from measurement of e, the centre-point deflection of the centre-line of the beam relative to the position of the centre-line at the ends of the beam, i.e. the deflection of point B relative to points A and C as shown in Figure 1.

NOTE Centre-point deflection measured by referencing the displacement transducer against the top or bottom edge of the beam or by using loading head movement usually contains unintended displacement component due to the indentation of the wood material at the support and loading points, etc. Deflection measured by such methods can be used for calculation of E provided it can be shown that it leads to more conservative result.

The applied load, F, shall be increased until the maximum load is reached.

To evaluate the modulus of elasticity in bending, E_m, the incremental deflection Δe for an incremental load ΔF shall be selected from the linear elastic part of the load-deformation graph. E_m is calculated from:

$$E_m = \frac{a}{4bh^3}\left(\frac{\Delta F}{\Delta e}\right)(3L^2 - 4a^2) \quad (3)$$

The range of 10 % to 40 % of the maximum load shall be used to determine $\Delta F/\Delta e$. The deflection e may be evaluated by the measurement of the movement of points other than those described above, provided that an acceptable equivalency for these procedures is established, or it can be shown that the alternative procedures produce conservative results.

NOTE The test set-up will lead to the determination of apparent modulus of elasticity. Shear-corrected modulus of elasticity can be estimated by adjusting the measured deflection, Δs, using the following formula assuming shear modulus is known (For structural timber, G can be assumed to be $E/16$.), and substituting Δe into Formula (3):

$$\Delta e = \Delta s\left(1 - \frac{3\Delta Fa}{5bhG\Delta s}\right)$$

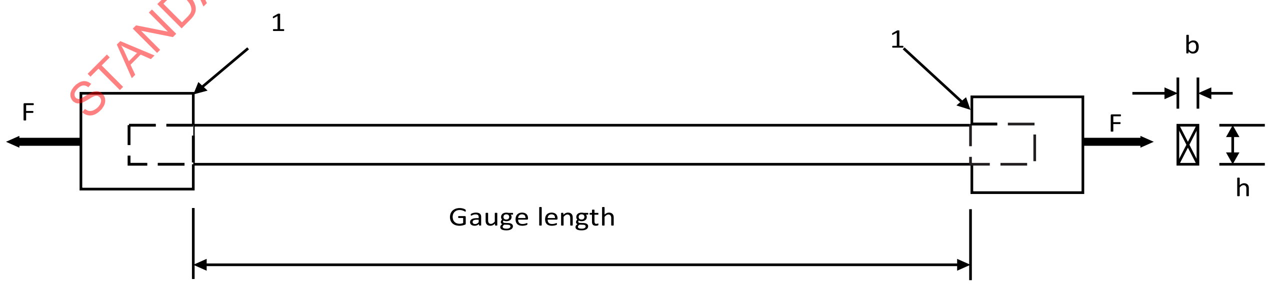
The bending strength, f_m, shall be calculated from

$$f_m = \frac{3F_{ult}a}{bh^2} \quad (4)$$

where F_{ult} is the value of the applied load at failure.

6.3 Tension strength parallel to the grain

NOTE The gauge length used is typically longer than the stated minimum to increase the likelihood that the critical strength-reducing defect is captured within the gauge length.



Key

1 grip

Figure 2 — Test setup for measuring tension strength parallel to the grain

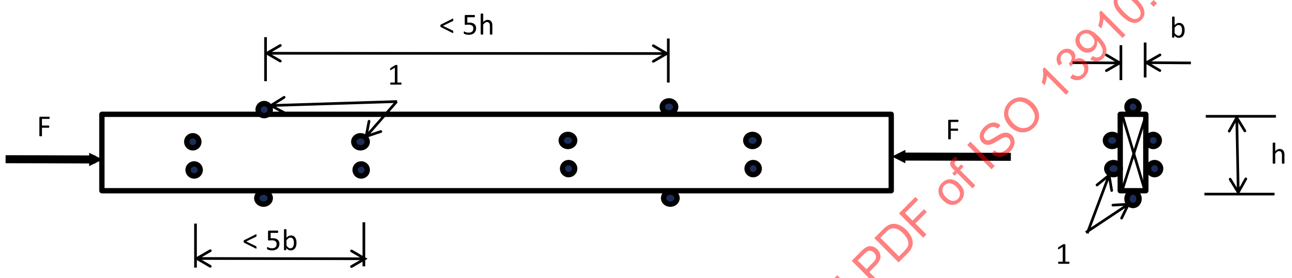
The tension strength $f_{t,0}$ shall be calculated from

$$f_{t,0}=\frac{F_{\text{ult}}}{bh} \quad (5)$$

where F_{ult} is the value of the applied load at failure.

6.4 Compression strength parallel to the grain

The compression strength parallel to the grain test configuration shall be as shown in Figure 3. The test specimen shall be the full length of the piece of timber. It shall be compressed axially by a load F until failure occurs. The specimen should be restrained against lateral buckling with the spacing of the lateral restraints not greater than 5h for buckling about the major axis and 5b for buckling about the minor axis. The lateral restraint shall not provide any resistance in the direction of the loading.



Key

1 lateral restraint

Figure 3 — Test setup for measuring compression strength parallel to the grain using the full length test specimen

The compression strength $f_{c,0}$ shall be calculated from

$$f_{c,0}=\frac{F_{\text{ult}}}{bh} \quad (6)$$

where F_{ult} is the value of the applied load at failure.

An alternative test procedure using short compression specimen is permitted to be used provided that the relationship between the full-length and short-length test strengths is established for the population. In this alternative test procedure, compression strength parallel to the grain strength of a piece of timber is determined from testing two short specimens cut from the piece. These two short test specimens are selected to contain, to the extent possible, the worst defects based on critical visual strength-reducing characteristics, such as knots and slope of grain. The length of the test specimens shall be six times the smaller cross-sectional dimension (6b). It shall be compressed axially by a load F until failure occurs. The end grain surfaces shall be accurately prepared to ensure that they are plane and parallel to one another and perpendicular to the axis of the piece. F_{ult} is the lower value of the applied load at failure for the two short test specimens.

For either the long specimen or short specimen test, bearing blocks shall be used at the ends of the test specimen to transmit the compressive load from the testing machine to the test specimen such that the load is uniformly applied over the full contact surfaces. In order to minimize eccentric loading of the specimen, at least one of these bearing block shall be spherical.

6.5 Shear strength parallel to the grain

Two methods that have been used in various jurisdictions are presented for measuring shear strength parallel to grain. These methods provide different results as the stress fields generated by each set-up and applied load arrangement are different.

NOTE Published softwood shear strengths measured using Method B suggest that the results may be up to approximately one-third greater than strengths based on Method A.

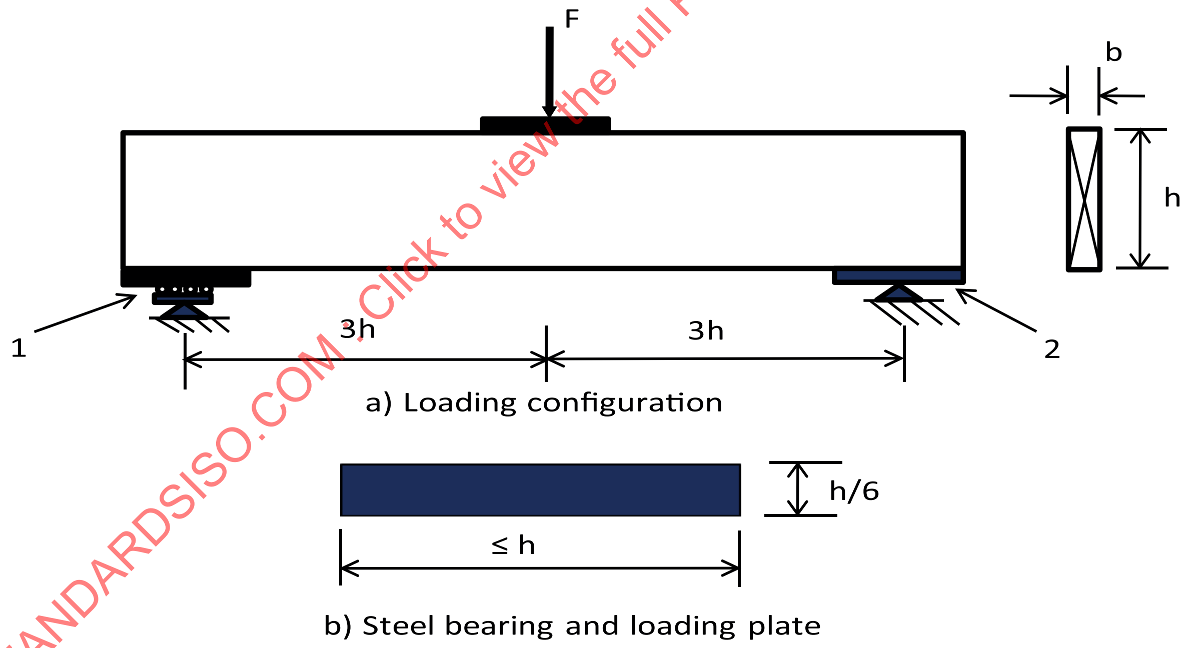
Method A

The shear strength parallel to the grain test configuration based on Method A shall be as shown in Figure 4. The bearing length shall be sufficient to avoid bearing failure, but not greater than h. F shall be increased to F_{ult}, the value at which failure of the specimen occurs. The shear strength f_v shall be calculated from

$$f_v = \frac{0{,}75 F_{ult}}{bh} \quad (7)$$

Some specimens may fail in modes other than shear, e.g. in bending or compression perpendicular to the grain. However, all test results shall be used to evaluate shear strength properties. Formula (7) gives the nominal shear strength of a beam by providing a normalized description of the load-carrying capacity of the beam.

NOTE Steps can be taken to reduce the likelihood of failure by modes other than shear, provided that such steps do not increase the shear resistance of the test specimen.



Key

1 slider bearing plate

2 bearing plate on a rocker

Figure 4 — Test set-up for measuring shear strength parallel to the grain using a bending test arrangement (Method A)

Method B

Method B for measuring shear strength parallel to grain of a piece of timber is based on a two-rail testing approach. The test piece shall be glued to two steel plates, which shall be tapered as shown in Figure 5. The thickness of the steel plate shall be 10mm. (Plate thickness may be increased for strong specimens.). The test piece shall be free of defects and machined from a piece of structural size timber. It shall have the following dimensions: 32 mm ± 2 mm × 55 mm ± 1 mm × 300 mm ± 2 mm ($b \times h \times L$).

All surfaces shall be accurately prepared to ensure that adjacent surfaces are perpendicular and opposite surfaces are parallel to each other. This preparation shall be carried out after conditioning.

NOTE 1 A suitable adhesive for fixing the steel plates to the timber test piece is a two-part epoxy. Immediately prior to gluing, the surfaces to be joined should be prepared by planing the timber surfaces and sandblasting the steel plates.

NOTE 2 Variation in specimen dimensions are permitted within the stated tolerance, in order to achieve the objective of an angle of 14° in the test.

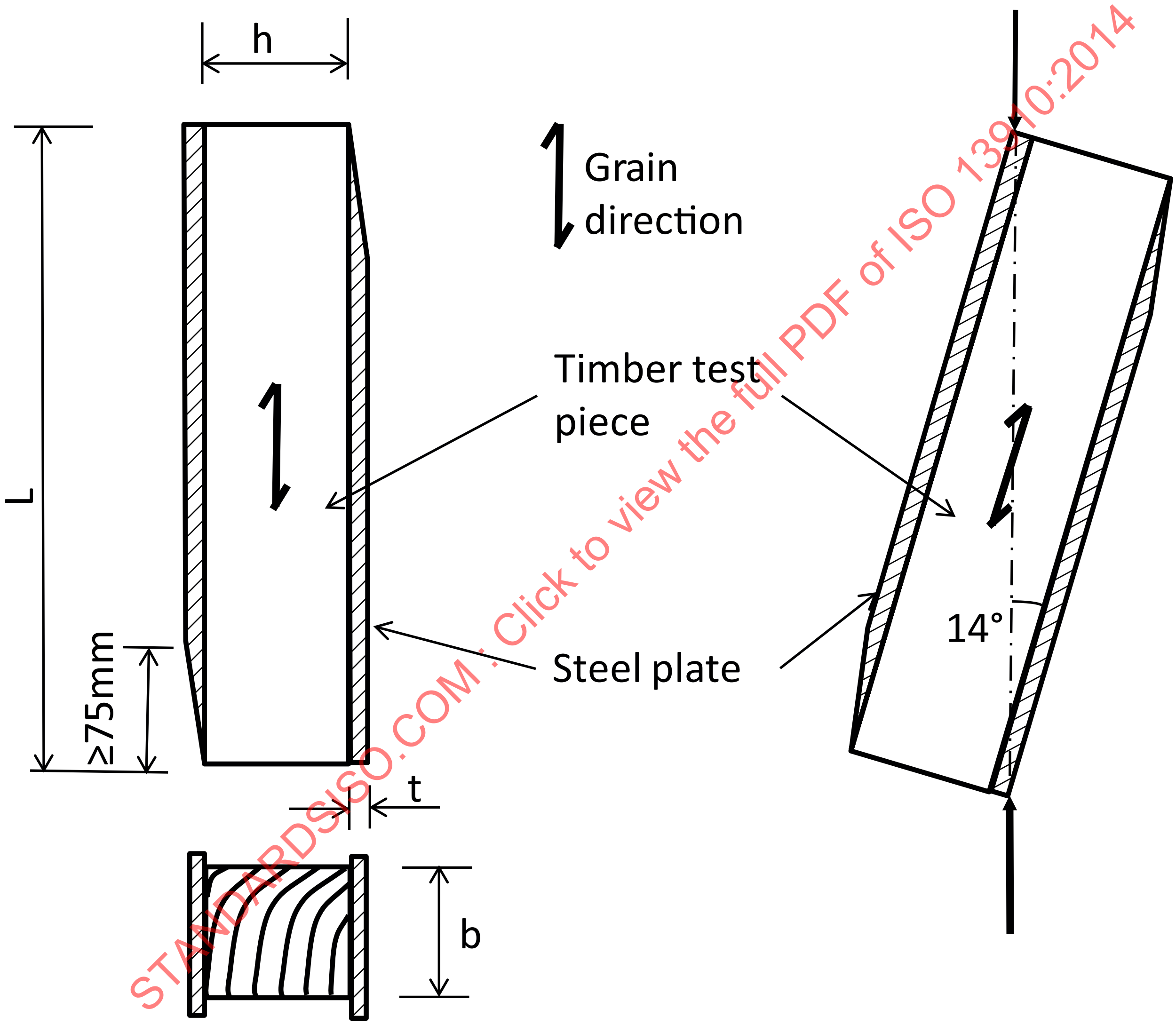


Figure 5 — Shear strength parallel to grain test specimen with glued steel plates (Method B)

The test piece shall be mounted in a test machine as shown in Figure 5, and shall be aligned such that continuous contact is maintained where the line load F is applied. The angle between the load direction and the longitudinal axis of the test piece shall be 14° (see Figure 5).

The load, F, shall be applied at a constant rate of loading-head movement so that the failure load, F_{ult}, is reached within (300 ± 120) s. The time to failure of each specimen shall be recorded. Single test pieces diverging more than 120 s from the target of 300 s shall be reported.

If the failure occurs partly in the glued area of the test piece/steel plate interface, the result is valid only if this area is less than 20 % of the area of failure. Otherwise the result is discarded.

The shear strength, f_v,shall be determined from the equation:

$$f_v = \frac{F_{ult} \cos 14°}{Lb} \quad (8)$$

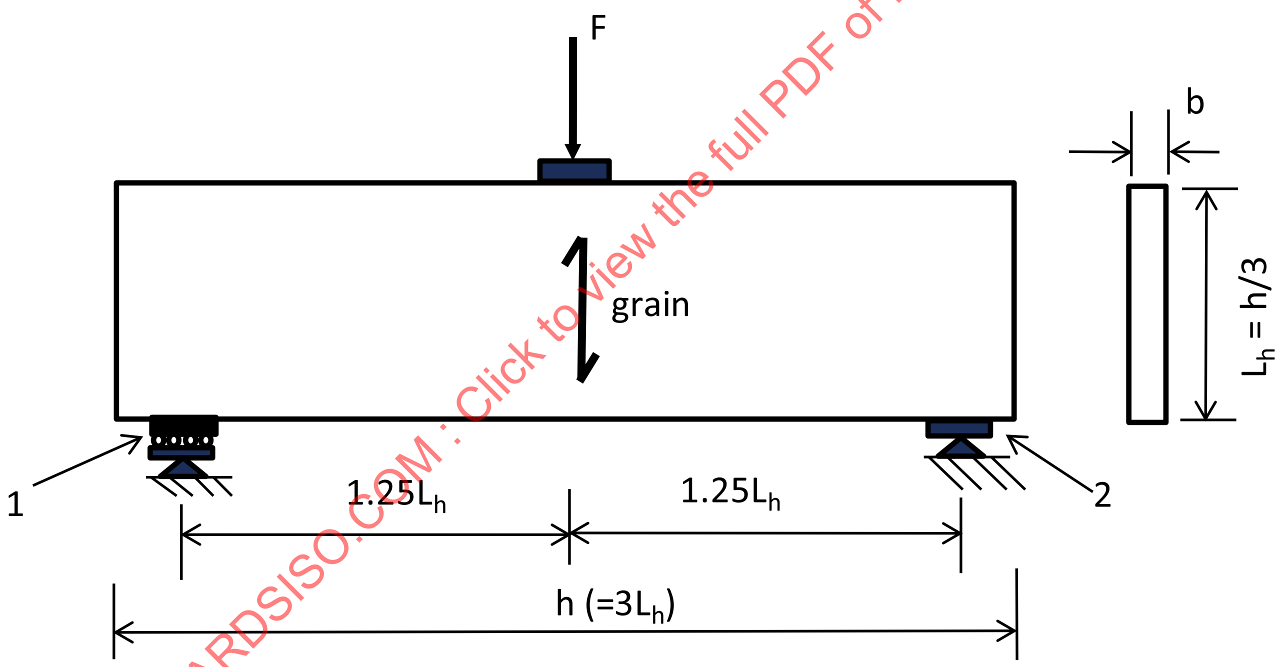
6.6 Tension strength perpendicular to the grain

Two methods that have been used in various jurisdictions are presented for measuring tension strength perpendicular to grain. These methods may provide different results as the stress fields generated by each set-up and applied load arrangement are different.

NOTE Although the methods may provide different results, tension perpendicular to grain values are published on the basis of the lowest boundary limit so test differences are not expected to affect the end use.

Method A

The test set-up for tension strength perpendicular to the grain based on Method A shall be as shown in Figure 6. The specimen for the measurement of tension perpendicular to the grain shall comprise the full cross-section of the piece of timber. The width, L_h, cut from the full-size timber piece shall be equal to h/3. The specimen shall be loaded in a three-point loading arrangement as shown in Figure 6.



Key

1 slider bearing plate

2 bearing plate on a rocker

Figure 6 — Test set-up for measuring tensile strength perpendicular to grain (Method A)

The tension strength, $f_{t,90}$ shall be calculated from

$$f_{t,90} = \left(\frac{3{,}75 F_{ult}}{bh}\right) \times \left(\frac{0{,}03 b L_h^2}{800^3}\right)^{0{,}2} \quad (9)$$

where F_{ult} is the value of the applied load at failure.

NOTE The factor $(0{,}03bL_h^2/800^3)^{0{,}2}$ normalizes the tension strength to the equivalent value for a cube of timber of side length equal to 800 mm.

Method B

Method B is based on measuring tension strength perpendicular to grain using a test set-up that applies an axial load to the test specimen (perpendicular to the grain). In the test set-up the test specimen shall be glued to steel plates or timber blocks. The gluing process shall be capable of ensuring the specified position of the test specimen during testing.

NOTE A suitable adhesive for fixing the steel plates to the timber test piece is a two-part epoxy. Immediately prior to gluing, the surfaces to be joined should be prepared by planing the timber test piece surfaces and sandblasting the steel plates.

The loaded surfaces shall be accurately prepared to ensure that they are plane and parallel to each other and

perpendicular to the test specimen axis. This preparation shall be carried out after conditioning. The test specimen shall have the dimensions of 45 mm × 180 mm × 70 mm ($b \times h \times L$) where the h dimension is in the direction of the applied load, as shown in Figure 7.

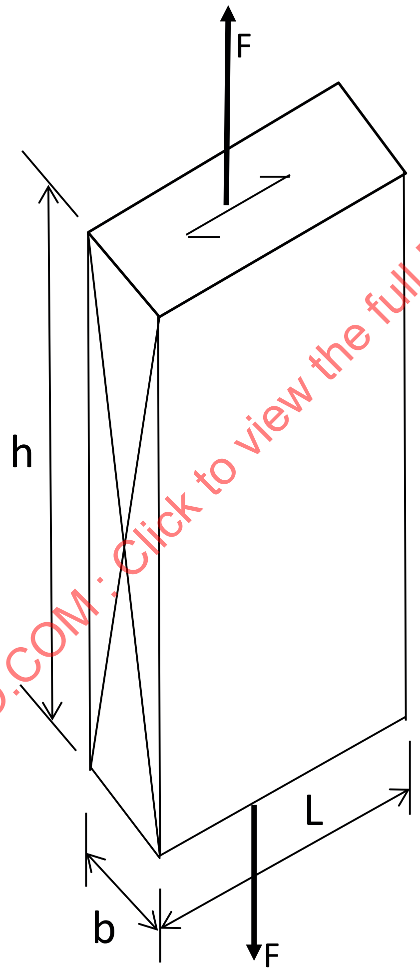


Figure 7 — Tension perpendicular to grain strength test specimen (Method B)

The test specimen shall be mounted vertically between the test machine plates and the appropriate tension load applied. The longitudinal axis of the test piece, h, shall be aligned with the axis of the applied load and fixed in such a way that no initial stresses in the test piece are introduced, except those due to the weight of the test piece and the equipment. The test specimen shall have pinned ends, with the axis of the pin parallel to the grain direction of the test piece.

The test piece shall be loaded concentrically. The load, F, shall be applied at a constant rate of cross head movement throughout the test. The rate of loading shall be adjusted so that the maximum load, $F_{t,90,\max}$ is reached within (300 ± 120) s.

The tensile strength $f_{t,90}$ shall be determined from the equation:

$$f_{t,90} = \frac{F_{t,90,\max}}{bL} \tag{10}$$

The result of a test shall be disregarded where failure occurs on the system used to connect the test piece to the testing machine (e.g. in the glue line between the steel plates and the timber of the test piece). If the failure occurs partly in the glued area of the test piece/steel plate interface, the result is valid only if this area is less than 20 % of the area of failure.

6.7 Compression strength and stiffness perpendicular to the grain

Two methods that have been used in various jurisdictions are presented for estimating compression strength and stiffness perpendicular to grain of full-size structural timber. These methods provide different results as the stress fields generated by each set-up and applied load arrangement are different.

NOTE Published softwood compression perpendicular strengths measured using Method B suggest that the results may be up to about 30 % less than strengths based on Method A.

Method A

The test set-up for compression strength and stiffness perpendicular to the grain shall be as shown in Figure 8 a). The load F shall be applied through a pair of steel-bearing plates of length 90 mm and thickness equal to b + 10 mm. The head of the testing machine shall be fixed against rotation. During loading, a load-deformation plot shall be made [see Figure 8 c)] and the test specimen shall be loaded to failure or to a deformation of 0,1h, whichever occurs first. If the specimen tends to buckle during loading, lateral restraints shall be used to resist buckling.

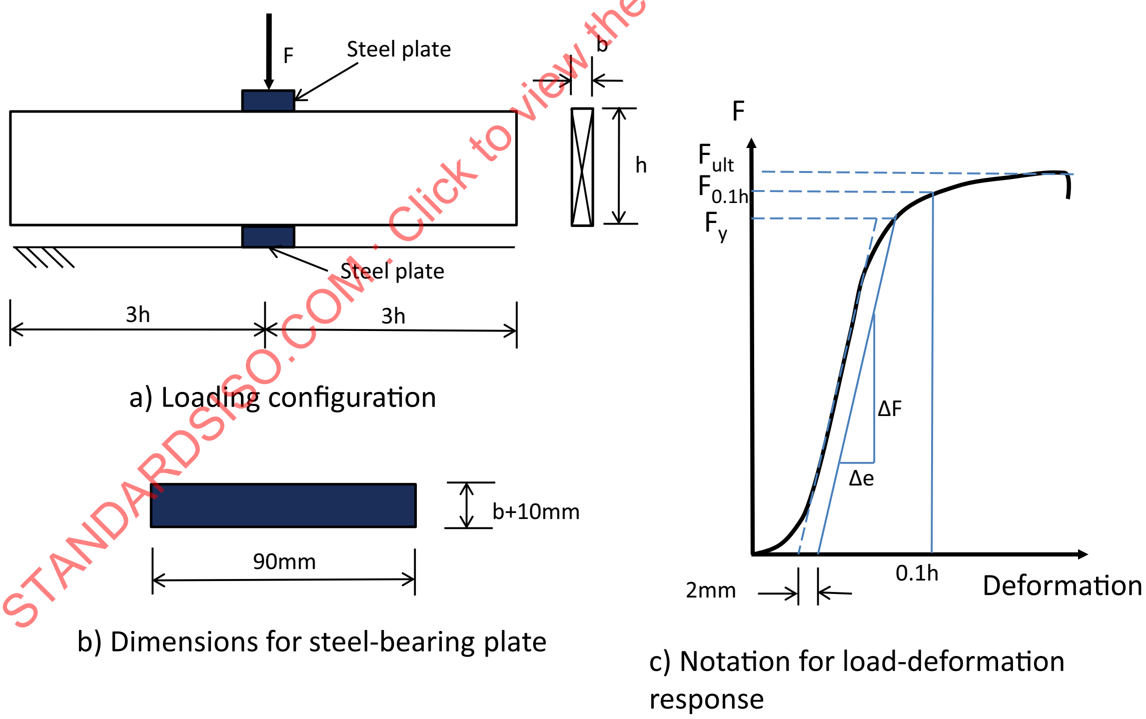


Figure 8 — Configuration for measuring compression strength and stiffness perpendicular to grain (Method A)

The compression strength $f_{c,90}$ shall be calculated as the lesser of

$$f_{c,90} = \frac{F_{ult}}{90b} \tag{11}$$

and

$$f_{c,90} = \frac{F_{0,1h}}{90b} \quad (12)$$

where

F_{ult} is the value of the applied load at failure (ultimate load);

$F_{0.1h}$ is the load at a deformation of 0.1h mm.

The yield strength $f_{c,90y}$ shall be calculated from

$$f_{c,90y} = \frac{F_y}{90b} \quad (13)$$

where F_y is the load at the intersection of a line parallel to the elastic slope of the load deformation graph and offset by 2 mm [see Figure 8 c)]. The compression perpendicular to the grain stiffness, $K_{c,90}$, shall be calculated from

$$K_{c,90} = \frac{\Delta F / \Delta e}{90b} \quad (14)$$

where $\Delta F/\Delta e$ is the elastic slope of the load-deformation graph.

Method B

Method B measures compression strength and stiffness perpendicular to grain using a test set-up that applies an axial load to the test specimen (perpendicular to the grain). The loaded surfaces shall be accurately prepared to ensure that they are plane and parallel to each other, and are perpendicular to the test specimen axis. This preparation shall be carried out after conditioning. The test specimen shall have the dimensions of 45 mm × 90 mm × 70 mm ($b \times h \times L$) where the h dimension is in the direction of the applied load, as shown in Figure 7.

The test specimen shall be mounted vertically between the test machine plates and the appropriate compression load applied. The gauge length, h_0 (approximately 0,6h), shall be located centrally in the test specimen height and not closer than h/3 to the loaded ends. The longitudinal axis of the test piece, h, shall be aligned with the axis of the applied load and fixed in such a way that no initial stresses in the test piece are introduced, except those due to the weight of the test piece and the equipment. To prevent rotation or angular movement during the test, the loading heads shall be locked after an initial load has been applied.

The test piece shall be loaded concentrically. The load F shall be applied at a constant rate of cross head movement throughout the test. The rate of loading shall be adjusted so that the maximum load, $F_{c,90,max}$, is reached within (300 ± 120) s.

The compression strength, $f_{c,90}$, shall be determined from the equation:

$$f_{c,90} = \frac{F_{c,90,max}}{bL} \quad (15)$$

The determination of $F_{c,90,max}$ may be carried out using the iterative process described below:

— Plot the load/deformation curve in the form shown in Figure 9. Estimate a value for the load $F_{c,90,max,est}$.

— Calculate 0,1$F_{c,90,max}$ and 0,4$F_{c,90,max}$ and determine where these two values intersect the load/deformation curve.

— Through these two points draw the straight line 1.

— Parallel to line 1, draw line 2 having its origin at load $F = 0$ and at a distance from it equivalent to a deformation of 0,01h_0.

— Where line 2 intersects the load/deformation curve is $F_{c,90,max}$. If the value of $F_{c,90,max}$ as determined is within 5 % of $F_{c,90,max,est}$ then that value may be used to determine the compression strength;

— Otherwise, repeat the procedure until a value of $F_{c,90,max}$ within that tolerance is obtained.

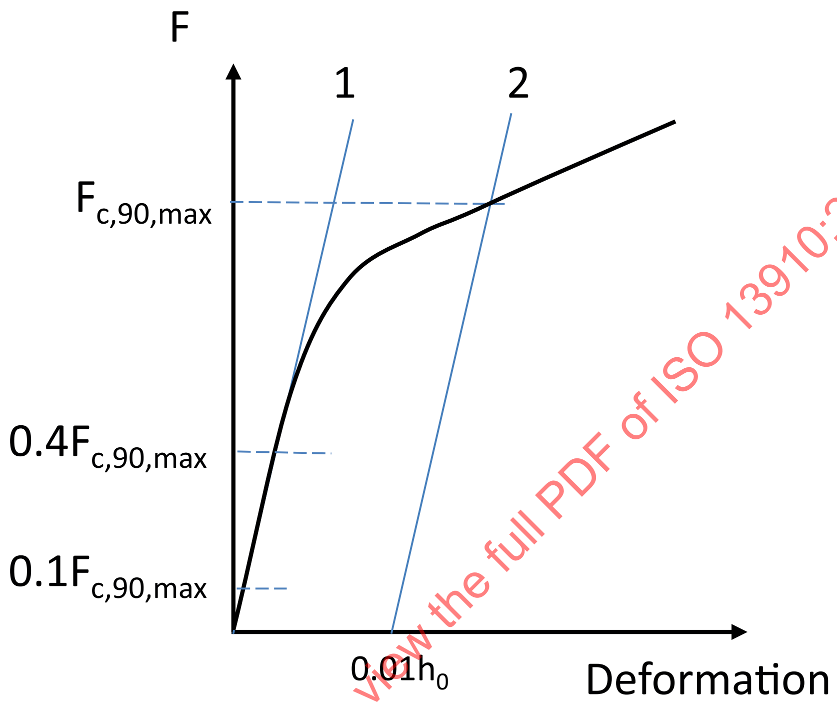


Figure 9 — Load-deformation plot from a compression perpendicular to grain test (Method B)

The result of a test shall be disregarded where failure occurs on the system used to connect the test piece to the testing machine.

The modulus of elasticity in compression perpendicular to grain, $E_{c,90}$ shall be calculated from the equation:

$$E_{c,90} = \frac{(F_{40} - F_{10})h_0}{(w_{40} - w_{10})bL} \quad (16)$$

where

$F_{40} - F_{10}$ is an increment of load on the straight line portion of the load-deformation curve. F_{10} shall be 10 % and F_{40} shall be 40 % of $F_{c,90,max}$.

$w_{40} - w_{10}$ is the increment of deformation corresponding to $F_{40} - F_{10}$.

6.8 Torsional shear modulus

The torsional test configuration shall be as shown in Figure 10. The test specimen has a length of L_T between the clamped end and a torque plane as shown in Figure 10. The torque shall be applied via a load F acting through a lever arm of length l_t.