INTERNATIONAL STANDARD

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Timber structures — Joints made with mechanical fasteners — Quasi-static reversed-cyclic test method

Structures en bois — Joints réalisés avec des connecteurs mécaniques — Méthode d'essai cyclique réversible quasi statique

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 16670 was prepared by Technical Committee ISO/TC 165, *Timber structure*.

Introduction

Evaluation of the structural performance of joints under reversed-cyclic loading has become a requirement in seismic design. The objective of this International Standard is to provide a cyclic test procedure as a basis for the development of characteristics of joints for use in seismic design. The cyclic displacement schedule was developed in consultation with a group of international experts with the intention that the cyclic displacement schedule shall produce

a) data that sufficiently describes the elastic and inelastic properties of the joint, and

b) representative demands imposed on joints by earthquakes.

Supplementary information is given in Annex A to provide the rationale behind the cyclic displacement schedule, recommendations for cases for which a modified schedule would be more appropriate, and typical test results obtained on a joint by following this cyclic displacement schedule.

Timber structures — Joints made with mechanical fasteners — Quasi-static reversed-cyclic test method

1 Scope

This International Standard is intended to provide a cyclic test method as a basis for the derivation of parameters which are required in seismic design of timber structures. The method includes procedures to develop the envelope curves (backbone or skeleton curves; an example is given in Clause A.5.) for joints subjected to a cyclic displacement schedule which produces representative demands imposed on the joints by earthquakes. It does not include criteria for parameters which are, at times, stipulated in national standards or building codes.

This standard is intended for joints subjected to lateral load ans is not applicable to joints subjected to withdrawal forces.

This International Standard is applicable to joints made with mechanical fasteners used in timber structures loaded under seismic action.

NOTE 1 In the context of this Standard, the term "joint" means "connection" in present-day North-American English.

NOTE 2 It is recognized that, for some special types of joints, modification of the test method may be necessary provided the test objectives in this clause and the principles in Clause 6 are achieved. See Clause A.2 for details.

2 Normative references

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

ISO 554, *Standard atmospheres for conditioning and/or testing — Specifications*

ISO 3131, *Wood — Determination of density for physical and mechanical tests*

ISO 8970, *Timber structures — Testing of joints made with mechanical fasteners — Requirements for wood density*

ISO 6891, *Timber structures — Joints made with mechanical fasteners — General principles for the determination of strength and deformation characteristics*

3 Symbols and definitions

F Applied load, in newtons, or newton-millimetres in the case of joint rotation

F_{max} Maximum load, in newtons, or newton-millimetres in the case of joint rotation (as defined in Figure 1)

k Joint stiffness, in newtons per millimetre, or newton-millimetres per radian in the case of joint rotation

v Joint displacement, in millimetres, or radians in the case of joint rotation

v_u Ultimate joint displacement, in millimetres, or radians in the case of joint rotation (as defined in Figure 1)

NOTE "Load" and "displacement" are taken as generic terms. Load could be axial, shear, moment or torsion. Displacement could be any displacement (or slip) or rotation.

4 Test specimens

4.1 Conditioning

Attention shall be given to the conditioning of the timber before the manufacture of the joint and also to the conditioning of the joints after their fabrication.

The conditioning shall be conducted in such a way that the test conditions correspond in a realistic manner to the in-service conditions of joints in structures.

Where the purpose of testing is to compare joints under similar conditions, the standard atmosphere of 20 °C and 65 % relative humidity according to ISO 554 shall be used for conditioning. Density of the specimens shall comply with the requirements given in ISO 8970.

4.2 Form and dimension

Joint geometry, loading configuration and fabrication details (e.g. elapsed time between the fabrication and test, predrilling of holes, tolerances, conditioning details before and after fabrication) shall be representative of the intended end use.

4.3 Sampling

Sampling should provide for selection of representative test material on an objective and unbiased basis, covering an appropriate range in density and properties as circumstances suggest.

4.4 Number of replicates

The number of replicates depends on the specific objectives and desired reliability.

NOTE A minimum of 6 replicates is recommended for each of the static and cyclic tests to obtain a reliable estimate of mean mechanical properties.

5 Apparatus

The test apparatus, tolerances and restraints shall be of realistic forms that are representative of the intended end use.

The testing machine shall be able to apply and continuously record load and joint displacement with an accuracy of ± 1 % of the estimates of F_{max} and v_{u} or better.

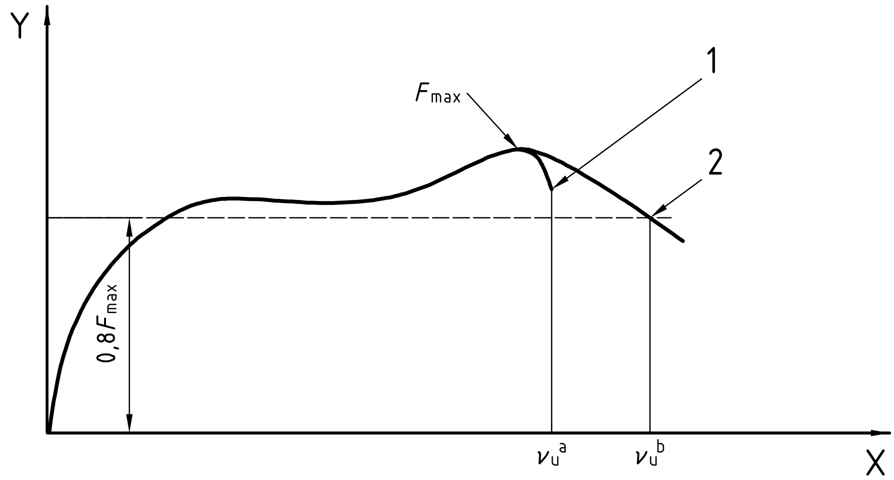
It is recommended that displacement measurements be made in such a way that the amount of member deformation included in displacement readings is minimized.

6 Test procedure

6.1 Properties from static (monotonic) tests

Static (monotonic) tests shall be conducted on a matched group (or specimen) according to ISO 6891 with the exception of preloading. The mean value (where applicable) of the ultimate displacement or rotation (v_{u}) of the static tests will be determined by following the definition of v_{u} in Figure 1.

NOTE Static (monotonic) test data previously obtained on a matched group (or specimen) may also be used.



Key

X Displacement, v

Y Load, F

1 case a

2 case b

a Displacement at failure (case a).

b Displacement at $0{,}8F_{max}$ in the descending portion of the load-displacement curve (case b).

Figure 1 — Definition of ultimate joint displacement: v_u corresponds to either v_u^a or v_u^b, whichever occurs first in the test

6.2 Cyclic displacement schedule

The cyclic displacement schedule shall produce

a) data that sufficiently describe the elastic and inelastic cyclic properties of the joint, and

b) representative demands imposed on the joints by earthquakes.

The cyclic displacement schedule given in Figure 2 shall be followed with a rate of slip between 0,1 mm/s and 10 mm/s. The amplitudes of the reversed cycles are a function of the mean value (where applicable) of the ultimate displacement (v_u) obtained in the monotonic test. Table 1 presents the amplitudes as a percentage of the ultimate joint displacement.

NOTE An alternative cyclic displacement schedule — either velocity or frequency based — that satisfies the principles given above may also be employed to achieve the test objectives.

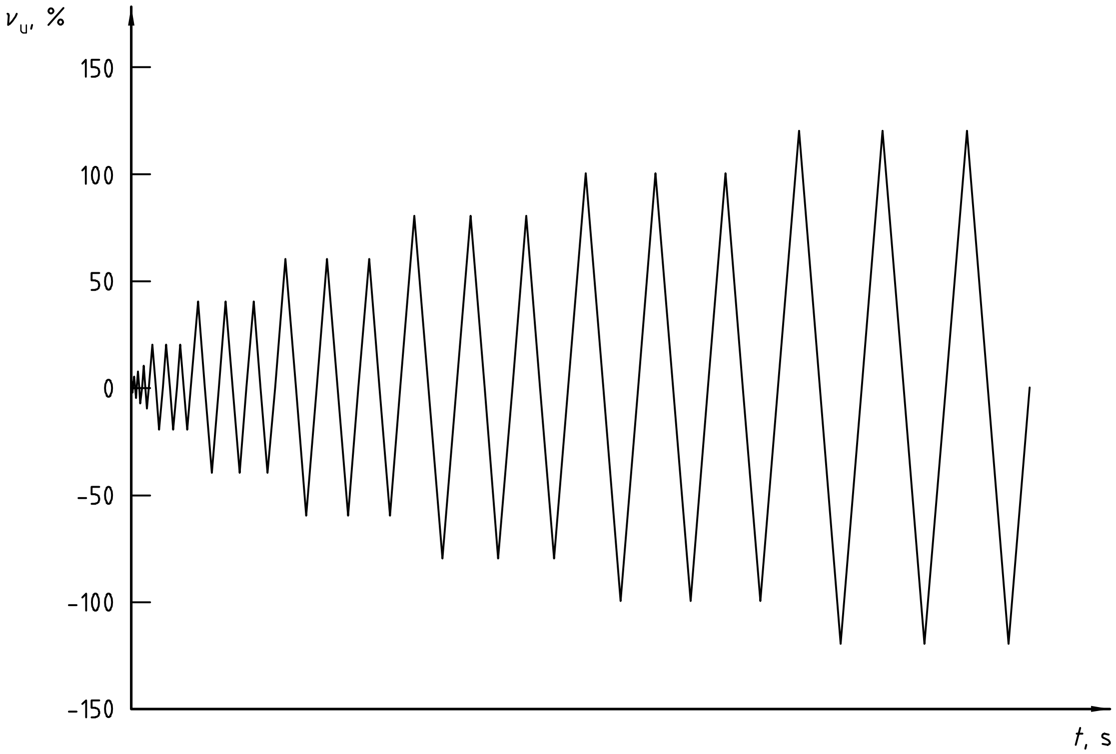


Figure 2 — Cyclic displacement schedule

Table 1 — Amplitudes of the reversed cycles

Step	No. of cycles	Amplitude
1	1	1,25 % of v_u
2	1	2,5 % of v_u
3	1	5 % of v_u
4	1	7,5 % of v_u
5	1	10 % of v_u
6	3	20 % of v_u
7	3	40 % of v_u
8	3	60 % of v_u
9	3	80 % of v_u
10	3	100 % of v_u
11	3	increments of 20 % of v_u

NOTE Some of the initial steps (1,25 % to 10 % v_u) may be omitted or repeated (or new steps may be added) depending on the stiffness of the joint or accuracy of the measurement system, as long as the principles given in 6.2 are satisfied. Clause A.2 identifies cases where modification of the standard cyclic displacement schedule may be warranted.

7 Test results

7.1 Hysteresis data

The complete hysteretic response data (load-displacement or moment-rotation data) shall be plotted and stored for each test joint. In organizing raw data (whether tabulated on paper or stored in a computer file), the following shall be included: time, input displacement, measured load and measured displacement.

7.2 Envelope curves

The first, second and third envelope curves for the cyclic tests shall be established by connecting the points of maximum load in the hysteresis plot in each slip level in the first, second and third reversed cycles, respectively. The maximum load values and their associated displacements obtained in the first five single reversed cycles shall be taken to be the same for all envelope curves. The envelope curves shall be reported in tabular form.

NOTE An example is given in Figure A.1 and Table A.1 in Clause A.5.

7.3 Joint properties

The maximum loads and ultimate displacements (both defined in Figure 1) in both directions taken from the three envelope curves shall be reported in tabular form.

NOTE An example is given in Table A.1 in Clause A.5.

8 Test report

The test report shall include the following information:

a) specification of the source, species, density and relevant strength properties of the timber members, and the sampling and conditioning methods;

b) specification and sampling of the fasteners including dimensions, and surface coating;

c) a description of the fabrication details (e.g., elapsed time between the fabrication and test, predrilling of holes, and tolerances);

d) a description of the joint geometry (e.g., dimensions of the joint members, number of fasteners, arrangement and spacing, details of the gaps between members) and the loading configuration;

e) a test matrix showing the number of replicates for each test group;

f) a description of the test apparatus and a diagram of the test set-up with location of measuring devices, tolerances and any restraints;

g) a description of the cyclic displacement schedule including the displacement rate;

h) a statement of any deviations from this International Standard;

i) a report of the sampling speed for data collection;

j) a plot of the hysteresis data (load-displacement or moment-rotation data), and tabulated envelope curves, maximum loads, ultimate displacement, moisture content of the wood at the time of fabrication and test, density and failure modes.

Annex A
(informative)

Additional information

A.1 Rationale behind the cyclic displacement schedule

This International Standard is intended to provide a cyclic test method to develop the envelope (backbone or skeleton) curves for joints subjected to a cyclic displacement schedule with a displacement pattern that results in a similar failure mode and energy dissipation as would occur under seismic action. (See [1] and [2] in the Bibliography.)

a) The cyclic displacement schedule includes the application of reversed cycles in terms of percentage of the joint's ultimate displacement from static test, a property which can be easily determined and which is defined with reasonable agreement throughout the world.

   The method does not depend on a yield displacement. It is difficult to reach an agreement on its definition because of differences in national standards. However, one can use the monotonic and cyclic test results to determine the yield displacement according to any given definition.

b) The method generates suitable data in the elastic and in-elastic ranges. In the elastic range, only one cycle is applied for each of the displacement levels (1,25 %, 2,5 %, 5 %, 7,5 % and 10 % of ultimate displacement). In the in-elastic range, the method generates three envelope curves which are evenly distributed along the displacement axis. These envelope curves may be used to determine impairment of strength, ductility and yield displacement according to the definitions adopted in different jurisdictions.

c) It is desirable to perform the reversed cyclic tests within a few minutes because earthquakes do not generally last more than 1 min. The upper limit (10 mm/s) was selected as the fastest rate which may be employed with the intention of avoiding dynamic effects to the test specimen. The lower limit (0,1 mm/s) was selected as the lowest rate to accommodate the use of test equipment which have limitations in applying relatively high rates of displacements. This International Standard allows the use of both velocity- or frequency-based test protocols.

A.2 Modification of ISO displacement schedule

The ISO displacement schedule should be modified in cases where

a) the behaviour of the joint is significantly different in two opposite directions. In this case, monotonic tests should be performed in both directions. The ultimate displacement in cyclic displacement schedule should then be determined for each direction based on their respective ultimate displacement obtained in monotonic tests.

b) the joint exhibits in-elastic behaviour within five initial steps. In this case,

   1) new single steps may be added to ensure a minimum of three steps for obtaining sufficient data within the elastic range, and

   2) initial steps beyond the elastic range should be repeated three times to generate three envelope curves.

c) the amplitudes of the first and second steps are too small to be accurately applied. In this case, the first and second steps may be omitted.

d) decreasing cycles are necessary (for example, to generate suitable data for calibration of hysteresis models). In this case, application of single decreasing cycles before increasing to the next displacement cycle may be added to the displacement schedule.

e) specific earthquake effects are studied (e.g. near-fault earthquake effects, cumulative damage effects, etc.).

f) the joint-displacement increases at zero load at the beginning of the test due to fastener tolerance (e.g. bolted joints). In this case, this tolerance may be subtracted from measured displacement values when determining the amplitudes for cyclic displacement schedules.

A.3 Comparison of test results with different test procedures

In the absence of an International Standard, a considerable amount of data have been generated previously using different cyclic displacement and force schedules. In the future, it will be worthwhile to establish simple methods to compare or correlate results from this Standard with those obtained using other cyclic schedules.

A.4 Joint properties

Joint properties such as stiffness, yield displacement, ductility and impairment of strength can be determined from the envelope curves according to the definitions adopted in different jurisdictions.

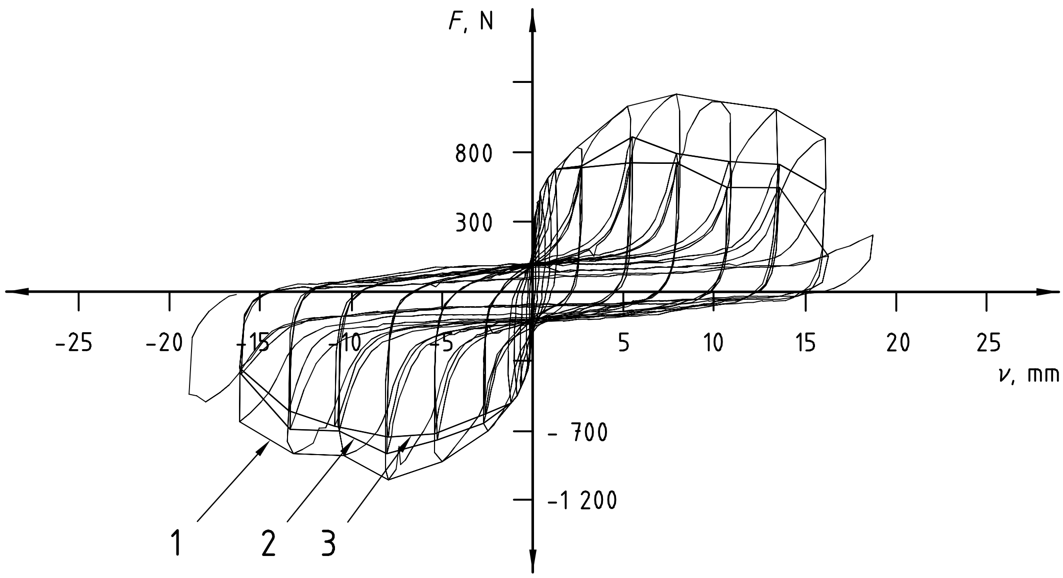
In most cases, the joint stiffness may be calculated by

$$K = \frac{0{,}3F_{\max}}{v_{40\%F\max} - v_{10\%F\max}}$$

for the static (monotonic) and first, second and third envelope curves of the cyclic test specimens. $v_{40\ \%F\max}$ and $v_{10\ \%F\max}$ are the displacement values obtained at 40 % and 10 % of the ultimate load ($F_{\max}$) respectively for the respective envelope curve.

In the future, there may be a need to determine some additional properties such as energy dissipation. For that purpose, it is recommended that data be stored preferably in digital form for complete description of the hysteresis loops, as described in 7.1.

A.5 Example of load-displacement curve and tabular form



Key

1 1st envelope curve
2 2nd envelope curve
3 3rd envelope curve

Figure A.1 — Envelope curves traced from hysteresis data

Table A.1 — Tabulated values of points defining the envelope curves.

First envelope curve				Second envelope curve				Third envelope curve			
Positive		Negative		Positive		Negative		Positive		Negative	
mm	N	mm	N	mm	N	mm	N	mm	N	mm	N
0,2	448,4	–0,2	–360,2	0,2	448,4	–0,2	–360,2	0,2	448,4	–0,2	–360,2
0,4	524,3	–0,3	–450,8	0,4	524,3	–0,3	–450,8	0,4	524,3	–0,3	–450,8
0,5	563,5	–0,6	–543,9	0,5	563,5	–0,6	–543,9	0,5	563,5	–0,6	–543,9
0,9	646,8	–0,9	–600,3	0,9	646,8	–0,9	–600,3	0,9	646,8	–0,9	–600,3
1,3	695,8	–1,2	–641,9	1,3	695,8	–1,2	–641,9	1,3	695,8	–1,2	–641,9
2,5	818,3	–2,5	–808,5	2,7	717,9	–2,7	–764,4	2,7	708,1	–2,6	–705,6
5,2	1 058,4	–5,0	–982,5	5,5	886,9	–5,3	–857,5	5,4	732,6	–5,4	–818,3
7,9	1 131,9	–7,9	–1 082,9	7,9	786,5	–8,0	–933,5	8,0	732,6	–8,0	–837,9
10,4	1 087,8	–10,4	–945,7	10,8	742,4	–10,6	–801,2	10,7	597,8	–10,9	–776,7
13,5	1 043,7	–13,2	–933,5	13,6	725,2	–13,3	–796,3	13,6	595,4	–13,4	–688,5
16,1	877,1	–16,1	–752,2	16,2	578,2	–16,0	–477,8	16,3	193,6	–16,1	–441,0

		Maximum load N	**Ultimate displacement** mm
First envelope curve	Positive	1 131,9	15,6
	Negative	–1 082,9	–14,3
Second envelope curve	Positive	886,9	13,8
	Negative	–933,5	–13,7
Third envelope curve	Positive	732,6	13,7
	Negative	–837,9	–13,6

NOTE In this example, the ultimate displacement is defined as the displacement at 80 % of the maximum load in the descending portion of the load-displacement envelope curve.

Bibliography

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[2] KARACABEYLI, E., CECCOTTI, A. 1998. *Nailed wood-frame shear walls for seismic loads: test results and design considerations*. Proc. Structural Engineers World Congress; San Francisco, CA. USA. Reference: T207-6

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