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Timber structures — Test methods — Floor vibration performance

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Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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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.

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 (see www.iso.org/directives).

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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

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

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Introduction

Dynamic properties of timber structures are of critical importance to designers since they govern how these structures respond to seismic, wind and in-service human-induced dynamic excitation. Seismic and wind can cause structural failure, while in-service human-induced motion generally causes serviceability problems related to human discomfort; this is also true to wind-induced building motion. Since occupants are constantly in contact with the floor system, vibration serviceability of floor systems is often of concern to designers of timber structures. Vibrational performance of a timber floor can be assessed using parameters such as natural frequencies, damping ratios, dynamic responses to an impulse (dynamic displacement, velocity, and acceleration), and static deflection under a concentrated load. These parameters have been found to correlate well with human perceptions. Among these parameters, natural frequencies, damping ratios, and static deflection under concentrated load are commonly used to evaluate timber floor vibrational performance. Design procedures have been developed, and in some cases implemented in design standards, for assessing vibration serviceability of timber floors. These design procedures usually include criteria for floor response parameters, such as those listed above, and mathematical procedures to calculate these parameters. As an alternative to calculation, it is also necessary to provide standardized procedures to measure these parameters experimentally. This is the prime motive for the development of this ISO test standard.

Natural frequencies and damping ratios of a test system can be measured using modal testing. ISO published a series of International Standards on the application of modal testing and analysis to determine natural frequencies, modal damping ratios, and other dynamic properties of an object. The theory of modal testing and analysis has been well documented in Reference.[4] This International Standard provides practical procedures that can be applied either in the laboratory or in the field to measure natural frequencies, modal damping ratios and static deflection under a concentrated load of a timber floor. It is assumed that users of the International Standard have the necessary equipment and fundamental knowledge to perform modal testing.

This International Standard does not address acceptance criteria for vibrational serviceability.

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Timber structures — Test methods — Floor vibration performance

1 Scope

This International Standard specifies test procedures to measure natural frequencies, modal damping ratios and static deflection under a concentrated load of laboratory or field timber floors. These parameters have been found to correlate well with human perception to timber floor vibration response caused by human-induced excitation under normal use. It is intended that the test procedures can be applied in lieu of calculation to quantify some or all of the above parameters that are used to evaluate the vibrational serviceability of the test floor. The subsequent use of the measured parameters to evaluate vibrational serviceability is, however, outside the scope of this International Standard.

ISO published a series of International Standards on the application of modal testing and analysis to determine natural frequencies, modal damping ratios, and other dynamic properties of a structure. For the measurement of dynamic parameters such as natural frequencies and modal damping ratios, modal testing is proposed in this International Standard. It is assumed that the test operators possess the required equipment and fundamental knowledge to perform such a test. The theory of modal testing and analysis has been well documented in Reference [4].

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2 Normative references

There are no normative references in this document.

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3 Terms and definitions

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

3.1
coherence function
indicator of the degree of linearity at each frequency component between the input and output signals, i.e., the noise level at each frequency component in the frequency response function (FRF) spectrum

Note 1 to entry: The value of coherence function is one when there is no noise in the signal, and zero for pure noise in the measured signals.

3.2
damping
parameter relating to the dissipation of energy, or more precisely, to the conversion of the mechanical energy associated with a vibration to a form that is unavailable to the vibration

3.3
natural frequency
frequency, associated with a *vibration mode* (3.12), at which a system naturally vibrates once it has been set into motion with a transient excitation

3.4
frequency response function
response function expressed in frequency domain and normalized to the input force

Note 1 to entry: It is the summation of each mode in the modal space. It shows the response of a system to be a series of peaks. Each peak with identifiable centre-frequency is the natural frequency of the system vibrating as if it was a single degree-of-freedom system.

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3.5
leakage
effect on measured frequency due to truncating the infinite time response signal during Discrete Fourier Transform

3.6
modal damping ratio
damping ratio associated with a *vibration mode* (3.12)

3.7
modal testing
measurement of the *frequency response function* (3.4)

3.8
modal analysis
process of determining the *natural frequencies* (3.3), *modal damping ratios* (3.6), and *mode shapes* (3.9) of a structure (floor) for the *vibration modes* (3.12) in the frequency range of interest from the *frequency response function* (3.4)

3.9
mode shape
pattern of movement (i.e., dynamic displacement, velocity, acceleration) of a structure (floor) for a *vibration mode* (3.12)

3.10
nodal point
point of zero displacement on a vibrating system of a *mode shape* (3.9) associated with a *vibration mode* (3.12)

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3.11
vibration
oscillation of a system about its equilibrium position

3.12
vibration mode
vibration behaviour of a system or object that is characterized by its *natural frequency* (3.3), *modal damping ratio* (3.6) and *mode shape* (3.9)

Note 1 to entry: The free vibration of a continuous structure such as floor system contains a summation of an infinite number of vibration modes.

4 Abbreviated terms

FFT	Fast Fourier Transform
FRF	Frequency Response Function

5 Measurement of natural frequencies and modal damping ratios

5.1 General

This clause specifies the general procedure of applying modal testing and analysis described in ISO 7626 to timber floors to determine their natural frequencies and damping ratios associated with the vibration modes. Specifically, this clause focuses on two techniques of exciting the out-of-plane

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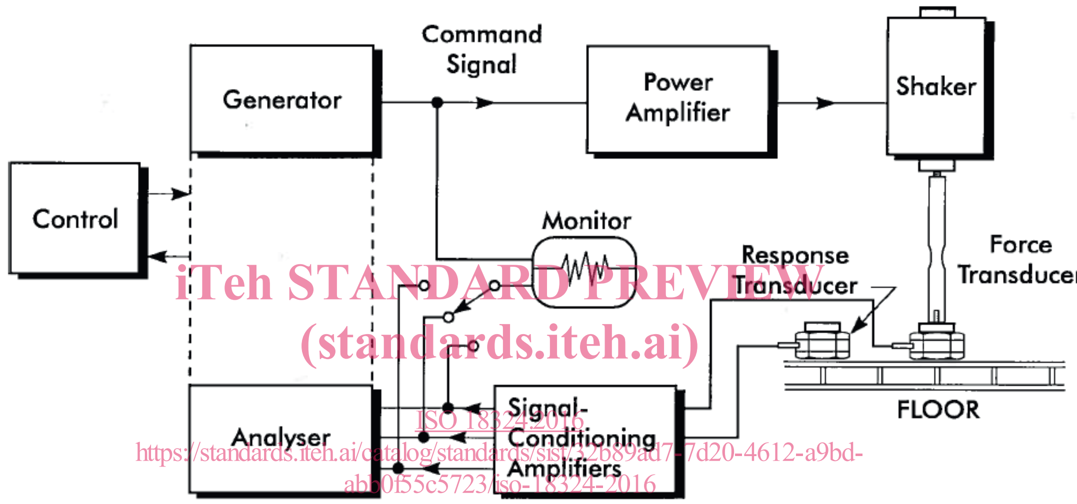
vibration of a floor. One technique uses a shaker that is attached to the test floor, and the other uses an impact device that is not attached to the floor.

NOTE A general understanding of the theoretical basis of modal testing is expected in order to apply the procedures described in this clause. This understanding can be acquired by consulting relevant text, e.g. Reference [4].

5.2 Apparatus

The equipment required for modal testing shall consist of three major items: 1) an exciter for inducing vibration; 2) transducers for measuring the time history signal of excitation force and the vibration response; 3) a signal analyser for recording and analysing the time signals and extracting the desired information from the analysis results. Figure 1 illustrates the layout of a modal test system using a shaker as the exciter.



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NOTE 1 This figure was a modification of the original figure in Reference [4].

Figure 1 — Layout of a modal test system using a shaker as the exciter

5.2.1 Exciter, shall be provided to initiate vibration in a structure. Generally, a satisfactory exciter for floor testing shall have the following capabilities:

a) Sufficient energy to induce floor vibration so that the modal testing measurements made over the entire frequency range of interest has an adequate signal-to-noise ratio without exciting a nonlinear response;

b) A suitable excitation waveform with frequency content that covers the frequency range of interest.

The exciter shall be either a shaker or an unattached impact device.

5.2.1.1 Attached exciter – shaker, shall be an electro-dynamic, electro-hydraulic, or piezoelectric vibration exciter attached to the test floor. The shaker shall be attached to a selected location on the floor during testing to continuously apply the excitation to the floor.

5.2.1.2 Unattached exciter – impact device, an instrumented hammer with a built-in force transducer or an impact device with a separate force transducer placed on a floor shall be used as the unattached exciter. The impact system shall have sufficient energy and appropriate surface contact characteristics to excite all the frequencies that are of interest. Specific requirements on the impact characteristics are given in 5.3.3.

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5.2.2 Transducer and mounting

5.2.2.1 Transducer, for modal testing, both excitation and response signals are required. The transducer shall have sufficient sensitivity and capacity to cover the frequency range of interest and low noise-to-signal ratio, and be insensitive to extraneous environmental effects, such as temperature, humidity, shock, rough field working conditions, etc. It shall also be sufficiently light that its presence on the test floor does not change the dynamic characteristics of the floor. The vibration response shall be measured using accelerometers. A procedure to evaluate any possible influence of mass of transducer is given in 5.3.1.3.

5.2.2.2 Transducer mounting, for an instrumented hammer, the force transducer is built into the hammer. The technique of mounting a force transducer onto a shaker is specified in 5.3.2.1, along with the shaker mounting technique. The accelerometer shall be rigidly attached to the floor structure.

For floors with carpet overlaid on wood-based subfloor, a special mounting base that penetrates the carpet to the subfloor shall be used. The accelerometer shall be attached to the upper face of the base plate of the tripod. A tripod with a heavy metal base plate and pinned legs that can penetrate through the carpet to the subfloor has been found to work well.[5]

For timber floors with floating flooring as finishing or a floating heavy topping, the accelerometer shall be attached to the underside of the floor.

5.2.3 Signal analyser, shall be used to process the time signals and shall use the fast fourier transform (FFT) method to convert the time domain signals into frequency domain. For signal analysers that also acquire the data, the equipment shall have at least two input channels for acquiring the excitation force signal and the floor response signal simultaneously. The sampling frequency shall be at least twice the highest frequency of interest to capture all the target natural frequencies of the test floor. As a minimum, the outputs of the signal analyser shall include the FRF and coherence function.

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5.3 Test procedures

5.3.1 General requirements and principles

The following principles shall be followed when performing the test procedure:

— The locations for exciter and response measurement shall be selected in such a way that all the modal parameters of the modes of interest, such as natural frequencies, modal damping ratios, and mode shapes, can be obtained.

— The modal parameters shall be extracted from a set of frequency response measurements between a fixed reference point on the floor and a number of roving points over the floor. The number of frequency response measurements shall be larger than or equal to the number of modes of interest.

The general procedure of modal testing shall consist of the following five steps:

a) Selection of excitation location (see 5.3.1.1);

b) Selection of response measurement location (see 5.3.1.2);

c) Mounting of transducers;

d) Excitation of the test system;

e) Validation of the measurements (see 5.3.1.3)

5.3.1.1 Selection of excitation location

The exciter shall not be placed at the nodal points of the modes of interest and be located as close to the floor centre as possible to ensure that the first natural frequency is excited.

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5.3.1.2 Selection of response locations

The response measurements shall be recorded at a sufficient number of locations to allow the full mode shape of each interested mode to be obtained.

For joisted floors, a measurement grid consisting of three equally spaced rows along the span direction and joist lines is recommended.

For plate-like timber slab floors, such as cross laminated timber (CLT) floors, on each of the equally space rows, the accelerometers should be placed at the middle of each timber panel and each joint between two adjacent panels.

5.3.1.3 Measurement check and validation

The measurements shall be checked and validated using the coherence function.

After testing a floor, a reciprocity check shall be performed by interchanging the excitation and response points, then retesting the floor. The FRF measurements shall then be compared with those obtained from the previous test. Any discrepancy between the two sets of measurement may indicate transducer mounting problems, or presence of nonlinearity.

Effects of mass loading caused by presence of a transducer on a floor can be evaluated by modal testing with and without a mass equal to a transducer added on the floor and comparing the FRF measurements. If the difference is greater than 3%, an investigation of the possible cause shall be carried out.

Coherence function can be interpreted as a measure of the noise level in the signals, the degree of correlation between excitation and response signals, errors during averaging, and sign of non-linearity in the response. For reliable characterization of dynamic properties, the value of the coherence function at a resonance frequency should be close to 1. A coherence value significantly less than 1 is an indication of possible poor data quality, or that the vibration response is not excited by the input excitation.

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NOTE Comparison of the FRF measurements using one type of excitation with those obtained using an alternate means of excitation gives additional confidence to the results obtained, but this is not always practical.

5.3.2 Shaker test procedure

5.3.2.1 Mounting of shaker

The shaker shall be placed on a solid ground and excite the floor from underneath. If this is not achievable, an alternative configuration is to suspend the shaker from the test structure using spring. If this attachment technique is used, the spring shall be selected in such a way that the natural frequency of the suspended shaker system shall be not more than one-tenth that of the lowest natural frequency of the test floor. The natural frequency of the suspended shaker system can be determined either by testing or calculation using the formula for one-degree mass-spring system with the known mass of the shaker and the spring stiffness.

The force from the shaker shall be applied to the floor through a drive rod or stinger. A suitable drive rod made of Teflon is shown in Figure 2. The drive rod shall have sufficient stiffness in the axial direction to transmit the intended excitation, while being relatively flexible in other directions. Such a drive rod ensures that the shaker is capable of applying a force in axial direction only, which also provides protection to the shaker and the force transducer to avoid damage caused by unintended high lateral force.

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