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Timber structures — Design method for vibrational serviceability of timber floors

~~*Élément introductif — Élément principal — Partie n: Titre de la partie*~~

Structures en bois — Méthode de dimensionnement aux états limites de service pour la vibration des planchers bois

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Foreword

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This document was prepared by Technical Committee ISO/TC 165, *Timber structures*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at ~~www.iso.org/members.html~~www.iso.org/members.html.

Introduction

Timber floors are known to be prone to producing high level of vibration caused by human activities due to the light-weight nature of these systems. As a result, it is critical that the timber floor design process takes into account vibrational serviceability. In the past, static deflection check indirectly provided some degree of control, but it is not a complete solution to the vibration problem. Two ISO publications have been developed over the last few years under the auspices of ISO~~-~~/TC~~-~~ 165. The first publication, ISO~~–~~ 18324~~,~~[1], is intended for testing of floor response parameters for the purpose of evaluating vibrational serviceability of the floor. The second publication is ISO/TR~~–~~ 21136~~,~~[2], which provides guidelines for developing floor vibration performance criterion.

~~This ISO standard provides guidelines for vibration serviceability design of timber floor systems. The standard consists of three elements: 1) a baseline vibrational serviceability design criterion for timber floors using fundamental natural frequency and 1 kN static point load deflection as the design parameters including two types of design criteria, coupled and decoupled criteria; 2) equations for calculating the design parameters; and 3) a guideline for the design values of the physical and mechanical properties of floor components.~~

Annexes A and B recommend limit values for coupled and decoupled criteria respectively. The calculation equations presented herein are based on the assumption that the floor system has a single span and simple support conditions.

~~The standard~~This document provides flexibility for individual jurisdictions to develop their own performance levels within the same performance criterion framework using the procedure described in ISO/TR 21136~~,~~[2], and for using other models to calculate the fundamental natural frequency and 1 kN static deflection if desired.

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Timber structures — Design method for vibrational serviceability of timber floors

1 Scope

The design method provided in this ~~standard~~document address vibration induced by walking action of occupants and covers the following timber floor systems:

~~i~~a) Light frame floors are built with timber joists spaced at a distance of no more than 610 mm with a layer of structural wood-based subfloor that is connected to the joists using mechanical fasteners or adhesive. The area density of a bare light frame floors without screen (topping) and ceiling is not greater than 25 kg/m^2. Figure 1 shows such a light frame floor.

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~~ii~~b) Mass timber floors built with mass timber panels such as cross laminated timber.

~~The standard~~This document consists of three elements:~~ 1)~~

a) a baseline vibrational serviceability design criterion for timber floors using fundamental natural frequency and 1 kN static point load deflection as the design parameters including two types of design criteria, coupled and decoupled criteria;~~ 2)~~

b) equations for calculating the design parameters;~~ and 3)~~

c) a guideline for the design values of the physical and mechanical properties of floor components.

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The design method is based on the assumption that the floor system has a single span and simple support conditions.

~~The standard allows individual jurisdictions to develop their own performance requirement levels following the guidelines and procedure described in ISO/TR 21136,[2] and for adoption of other models to calculate the fundamental natural frequency and 1 kN static deflection.~~

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at ~~https://www.iso.org/obp~~https://www.iso.org/obp

— IEC Electropedia: available at ~~https://www.electropedia.org/~~https://www.electropedia.org/

4 Baseline timber floor vibrational serviceability design criterion

Vibrational serviceability of a timber floor shall be evaluated by comparing its fundamental natural frequency and the static deflection at floor centre under a point load of 1 kN applied at the same location, with the criteria stated in either coupled criteria, ~~Equation~~see Formula (1), or decoupled

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criteria, ~~Equations~~see Formulae (2) to (4). It is the users' decision or preference to select the appropriate criteria that meet their needs.

a) Coupled criteria.

Using the coupled criteria, the vibration performance a floor is considered acceptable if the condition given by ~~Equation~~Formula (1) is satisfied:

$$~~\frac{f^{X}}{d_{1\,kN}^{Y}} \geq Z~~ \frac{f^{X}}{d_{1\,\mathrm{kN}}^{Y}} \geq Z \quad (1)$$

where

f is the fundamental natural frequency, Hz;

~~$d_{1\,kN}$~~ $d_{1\,\mathrm{kN}}$ is the 1 kN static point load deflection at floor centre, mm;

X, *Y* and *Z* are constants determined from subjective evaluation study as per ISO/TR 21136[2].

In the absence of any relevant data for specific country or region, X = 1,56, Y = 1 and Z = 112,20 (~~See~~see Annex A).

b) Decoupled criteria.

Using the decoupled criteria, ~~Equations~~Formulae (2) to (4), the vibration performance of a floor is considered acceptable if the fundamental natural frequency, static deflection under a 1 kN load at floor centre and the velocity meet the respective conditions shown below:

$$f \geq C_1 \quad (2)$$

$$~~d_{1\,kN} \leq C_2~~ d_{1\,\mathrm{kN}} \leq C_2 \quad (3)$$

$$v \leq C_3 \quad (4)$$

where C_1, C_2 and C_3 are constants determined from a subjective evaluation study as per ISO/TR~~-~~ 21136~~.~~[2]. In the absence of any relevant data for specific country or region, C_1 = 8 Hz may be used (see Annex B). Annex B provides ~~Equations~~Formulae (B1) and (B2) to calculate C_2 and C_3 for residential floors, respectively. It is recommended to perform a subjective evaluation study as per ISO/TR 21136[2] on at least two floors to define suitable values for *X*, *Y*, *Z* for individual country.

5 General models for calculating f and $d_{1\,\mathrm{kN}}$

The static deflection under a point load at floor centre, $d_{1\,\mathrm{kN}}$, and the first natural frequency, f, of a timber floor simply supported on all four sides can be calculated using orthotropic plate models~~.~~[3]. The static deflection parameter in mm, $d_{1\,\mathrm{kN}}$, can be calculated using the series-type ~~Equation~~Formula (5) shown below[4]:

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~~$d_{1\,kN} = \frac{4\times10^6}{ab\pi^4}\sum_{m=1,3,5}\sum_{n=1,3,5}\frac{1}{\left(\frac{m}{a}\right)^4 D_x + 4\left(\frac{mn}{ab}\right)^2 D_{xy} + \left(\frac{n}{b}\right)^4 D_y}$~~

$$d_{1\,\mathrm{kN}} = \frac{4\times10^6}{ab\pi^4}\sum_{m=1,3,5}\ \sum_{n=1,3,5}\frac{1}{\left(\frac{m}{a}\right)^4 D_X + 4\left(\frac{mn}{ab}\right)^2 D_{XY} + \left(\frac{n}{b}\right)^4 D_Y} \quad (5)$$

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where ~~D_x~~D_X is the equivalent system flexural rigidity in the span direction, in Nm as defined by ~~Equation~~Formula (6~~);~~):

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~~$D_x = \frac{h^3E_x}{12\left(1-\nu_{xy}\nu_{yx}\right)}$, Nm~~ $$D_X = \frac{h^3E_X}{12(1-\nu_{XY}\nu_{YX})} \quad (6)$$

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D_Y is the equivalent system flexural rigidity in the across-span direction, in Nm as defined by ~~Equation~~Formula (7~~);~~):

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~~$D_y = \frac{h^3E_y}{12\left(1-\nu_{xy}\nu_{yx}\right)}$, Nm~~ $$D_Y = \frac{h^3E_Y}{12(1-\nu_{XY}\nu_{YX})} \quad (7)$$

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D_{XY} is the equivalent system shear rigidity, in Nm as defined by ~~Equation~~Formula (8~~).~~):

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~~$D_{xy} = \frac{h^3G_{xy}}{12}+\frac{\nu_{yx}D_x}{2}$, Nm~~ $$D_{XY} = \frac{h^3G_{XY}}{12}+\frac{\nu_{YX}D_X}{2} \quad (8)$$

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~~E_x is the modulus of elasticity of plate in x direction (span) in N/m², E_y is the modulus of elasticity of plate in y direction (across-span) in N/m², G_{xy} is the in-plane shear modulus of plate in N/m², h is the plate thickness in m, ν_{xy} is the Poisson's ratio with stress applied in x direction and strain measured in y direction, ν_{yx} is the Poisson's ratio with stress applied in y direction and strain measured in x direction, a is the span of floor in m and b is the width of floor in m.~~

where

E_X	is the modulus of elasticity of plate in x direction (span) in N/m²;
E_Y	is the modulus of elasticity of plate in y direction (across-span) in N/m²;
G_{XY}	is the in-plane shear modulus of plate in N/m²
h	is the plate thickness in m
ν_{XY}	is the Poisson's ratio with stress applied in *x* direction and strain measured in *y* direction
ν_{YX}	is the Poisson's ratio with stress applied in *y* direction and strain measured in *x* direction
a	is the span of floor in m;
b	is the width of floor in metres.

The first natural frequency, f, in Hz~~, f,~~ can be calculated from the following ~~Equation~~Formula (9):

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~~$f=\frac{\pi}{2\sqrt{\rho}}\sqrt{D_x\left(\frac{1}{a}\right)^4+4D_{xy}\left(\frac{1}{ab}\right)^2+D_y\left(\frac{1}{b}\right)^4}$, Hz~~ $f=\frac{\pi}{2\sqrt{\rho}}\sqrt{D_X\left(\frac{1}{a}\right)^4+4D_{XY}\left(\frac{1}{ab}\right)^2+D_Y\left(\frac{1}{b}\right)^4}$ (9)

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where ρ is the mass per unit floor area, kg/m^2.

For light wood frame joisted floor systems, the simplified method presented in Clause 6 can be used. For mass timber panel floor systems, the simplified method presented in Clause 7 can be used.

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NOTE See Annex C for background on orthotropic plate models.

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6 Simplified calculation procedures for light-frame timber joisted floors

6.1 Floor construction

Figure 1 shows the construction details of the type of light-frame timber floor system addressed by this simplified method.

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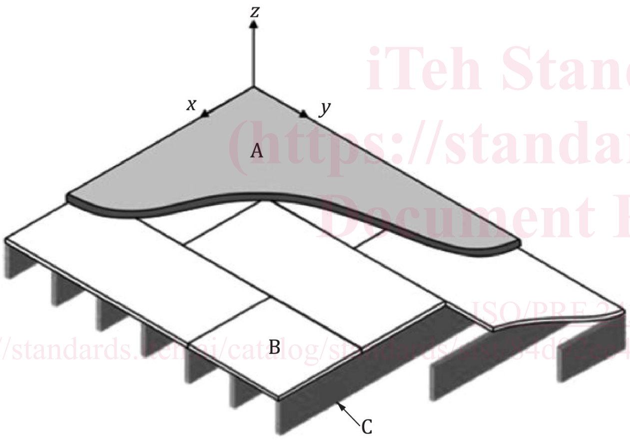

Key

A topping layer
B subfloor panel
C floor joist

Figure 1 — Applicable light-frame timber floor system

6.2 Calculation of first natural frequency and static deflection under a 1 kN load at floor centre

The fundamental natural frequency, *f*, in Hz, of a floor shown in Figure 1 can be calculated using the following ~~Equation~~Formula (10~~)~~ ~~[)~~[5,][6]:

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~~$f=\frac{\pi}{2l^2}\sqrt{\frac{D_{ef}}{m_l}}$, Hz~~ $f=\frac{\pi}{2l^2}\sqrt{\frac{D_{\mathrm{ef}}}{m_{\mathrm{l}}}}$ (10)

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