SLOVENSKI STANDARD
SIST EN 16481:2014

01-september-2014

Lesene stopnice - Dimenzioniranje konstrukcij - Računska metoda

Timber stairs - Structural design - Calculation method

Holztreppen - Bauplanung - Berechnungsverfahren

Escaliers en bois - Conception de la structure - Méthode de calcul

Ta slovenski standard je istoveten z: **EN 16481:2014**

ICS:

91.060.30 Stropi. Tla. Stopnice Ceilings. Floors. Stairs

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English Version

Timber stairs - Structural design - Calculation methods

Escaliers en bois - Conception de la structure - Méthodes de calcul

Holztreppen - Bauplanung - Berechnungsmethoden

This European Standard was approved by CEN on 17 April 2014.

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COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This document (EN 16481:2014) has been prepared by Technical Committee CEN/TC 175 “Round and sawn timber”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2014, and conflicting national standards shall be withdrawn at the latest by December 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document takes into account the following standards:

— EN 1990;

— EN 1991-1-1;

— EN 1995-1-1.

This document is addressed for structural designers to design timber stairs from a common European method; it should be useful for SMEs as an alternative to testing where applicable.

This European Standard takes into account the current state of the art regarding safety concept, loading assumptions, determination of stress resultants, as well as dimensioning in the field of wood engineering.

The requirements and verification procedures essential for the verification of mechanical performance characteristics, serviceability and load-bearing capacity of stairs and their components are compiled and described in the following clauses.

The mechanical performance characteristics of stairs may be verified by using the following methods:

— testing of stairs as a whole or in part;

— mathematical verification on the basis of structural analysis following the principles of this European Standard;

— assessment based on experience: conventionally accepted performance (CAP) which should be defined in national documents.

All methods are equally valid.

This document needs to be read in conjunction with EN 15644.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard constitutes a frame standard for the design of timber stairs as well as wood and wood-based components used in stairs by calculation methods. Some calculation methods can be derived from testing results, for example CEN/TS 15680. This document specifies the design and the requirements for materials and components to be used in these calculation methods. It may be complemented by national application documents based on this European Standard.

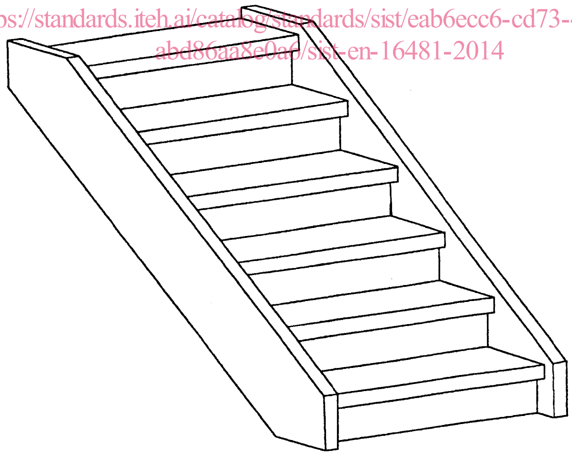
This European Standard applies to coated and uncoated components. This document covers load-bearing components such as strings, treads, risers, posts and guardrails. Requirements for a timber stair are defined in the product standard, EN 15644. This document does not cover stairs that contribute to the overall stability of the works or the strength of the structure.

This European Standard is valid for the verification of mechanical performance characteristics, usability and load-bearing capacity and their related durability. Other requirements, e.g. requirements for acoustic properties, are not covered by this European Standard.

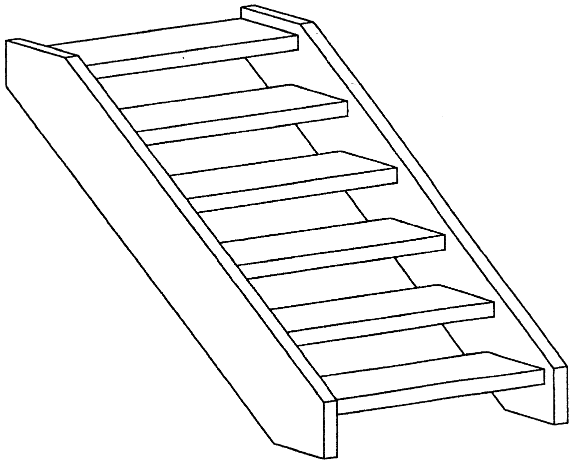
For the design, calculation and determination of not solely resting actions, additional requirements need to be taken into account (to be checked).

For the dimensioning with special reference to resistance to fire and earthquake/seismic action, additional requirements may be taken into account.

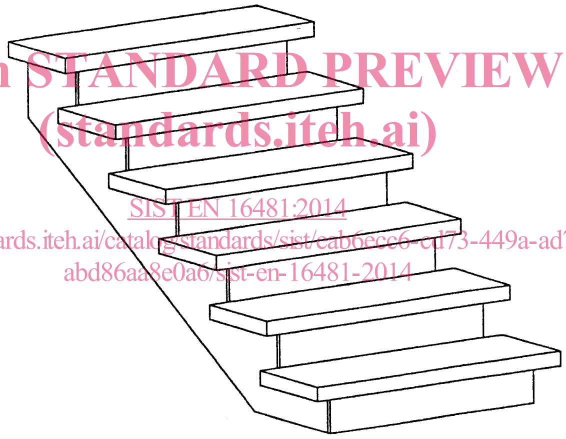
Without further verification, the methods in this European Standard are valid for different types of stair structures and their components, as illustrated in Figure 1:



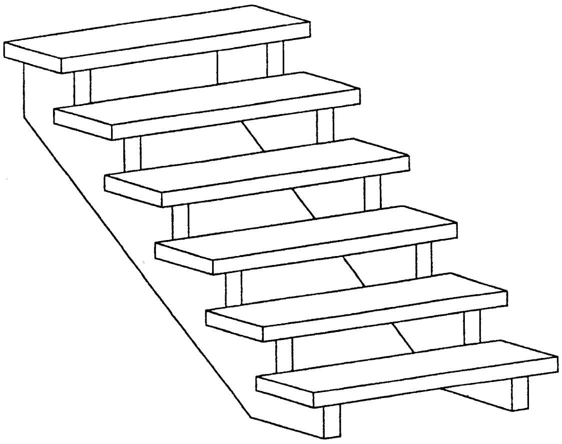
a) Stair with closed string and riser



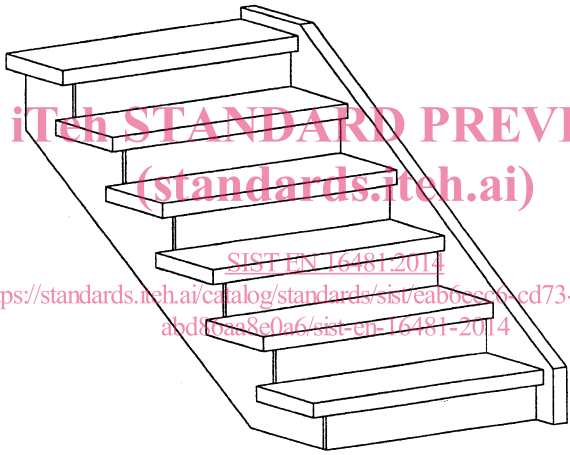
b) Stair with closed string without riser



c) Stair with cut strings and riser



d) Stair with cut strings without riser



e) Combination of stairs with closed string and cut string with or without riser

Figure 1 — Types of stair structures and their components

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.

EN 338, *Structural timber — Strength classes*

EN 1990, *Eurocode — Basis of structural design*

EN 1991-1-1:2002, *Eurocode 1: Actions on structures — Part 1-1: General actions — Densities, self-weight, imposed loads for buildings*

EN 1993-1-1, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings*

EN 1995-1-1, *Eurocode 5: Design of timber structures — Part 1-1: General — Common rules and rules for buildings*

NOTE Eurocode includes its National Application Documents (NAD).

EN 14076, *Timber stairs — Terminology*

EN 15644, *Traditionally designed prefabricated stairs made of solid wood — Specifications and requirements*

EN ISO 80000-1, *Quantities and units — Part 1: General (ISO 80000-1)*

3 Terms and definitions, formula symbols and SI-units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990, EN 1995-1-1 and EN 14076 and the following apply.

NOTE The general terms used in the context of actions and resistance as well as terms referring to the safety concept are given in EN 1990.

The specific valid terms used in the field of wood construction are found in EN 1995-1–1.

Specific terms regarding stair construction are given in EN 14076.

3.1.1
cross-bracing
tie-bars
system designed to provide torsional restraint to strings

EXAMPLE Screws, nails, glues.

3.2 Notation of formula symbols

In most cases, the notation of formula symbols consists of a main symbol (main indicator) and one or more subscript indicators. The following list defines the most common notations. Explanations of further notations either follow immediately the formula in which they appear or are described in the accompanying text.

α	pitch
γ	partial safety factor for loads
φ_x	torsional angle around the x-axis
φ_y	torsional angle around the y-axis
φ_z	torsional angle around the z-axis
γ_M	partial safety factor for a material property
Ψ_0	combination coefficient
A	cross-sectional area
A_y	cross-sectional shear area in the direction of the y-axis
A_z	cross-sectional shear area in the direction of the z-axis
$A_{cross\text{-}bracing}$	cross-sectional area of the cross-bracing
A_{string}	calculated cross-sectional area of the string

$A_{string,I-I}$	real cross-sectional area of the string in section I-I
$A_{string,III-III}$	real cross-sectional area of the string in section III-III
$A_{y,string}$	calculated shear area of the string in the direction of the y-axis
$A_{z,string}$	calculated shear area of the string in the direction of the z-axis
corner_i	connecting rod, bottom string-corner section
corner_i+1	connecting rod, top string-corner section
D_{max}	maximum distance between lower edge of string and lower edge of housing
D_{medium}	average value of D_{max} und D_{min}
D_{min}	smallest distance between upper edge of string and upper edge of housing
d	cross-sectional thickness, subscript for rated value
$d_{housing}$	depth of housing
d_{tread}	thickness of the tread
d_{string}	thickness of the string
E	modulus of elasticity
e	eccentricity
EA	stretch stiffness of a component
E_d	value of influence regarding the verification
EI_y	bending stiffness around the y-axis
EI_z	bending stiffness around the z-axis
$EI_{y,tread}$	bending stiffness of the tread around the y-axis
$EI_{z,tread}$	bending stiffness of the tread around the z-axis
e_{tread}	distance of the plumb line of tread and the idealized plumb line of the cut string
F	force, point load
f_1	fundamental frequency
G	rigidity modulus
GA_y	rigidity stiffness of a component in the direction of the y-axis
GA_z	rigidity stiffness of a component in the direction of the z-axis
GI_t	torsional stiffness of a component
G_k	permanent action of construction including all fasteners
g	going
H	acting horizontally live load
h	height of cross-section
$h_{balustrade}$	distance between horizontal rail load and tread
h_{max}	real maximum section height of the cut sting
h_{min}	real minimum section height of the cut sting
$h_{c,string,max}$	real maximum distance between the plumb line of a cut string to lowest edge of the string
$h_{c,string,min}$	real minimum distance between the plumb line of a cut string to lowest edge of string
h_{cut}	maximum height of the cut string area ($h_{cut} = h_{max} - h_{min}$)
h_{string}	height of the string

$h_{housing}$	height of the housing
$h^*_{c,string}$	calculated distance of the plumb line of a cut string to lowest edge of string
h^*_{string}	calculated height of the cut string
H^*_{string}	orthogonal projection of the calculated height of the cut string
$H^*_{c,string}$	orthogonal projection of the calculated distance of the plumb line of a cut string to lowest edge of string
I	moment of inertia
$I_{cross\text{-}bracing}$	calculated moment of inertia of the cross-bracing by stairs with cut strings
I_t	torsional moment of inertia
$I_{t,string}$	calculated torsional moment of inertia from the string
I_y	moment of inertia around the y-axis
$I_{y,string}$	calculated moment of inertia of the string around the y-axis
$I_{y,string,\ I\text{-}I}$	real moment of inertia of the string around the y-axis in section I-I
$I_{y,string,III\text{-}III}$	real moment of inertia of the string around the y-axis in section III-III
I_z	moment of inertia around the z-axis
$I_{z,string}$	calculated moment of inertia of the string around the z-axis
k	spring stiffness
k^D	torsion spring stiffness
$k^D{}_y$	torsion spring stiffness in bending around the y-axis
$k^D{}_z$	torsion spring stiffness in bending around the z-axis
k^F	stretch spring stiffness
k_m	coefficient
k_{mod}	modifications coefficient that takes into account the impact of the service class and load duration on the strength properties
K_{shape}	coefficient according to the cross-sectional shape
L	length of cross-section or length of system
L_a	calculated support length at the wall side of a kite winder before the corner
L_b	calculated support length at the wall side of a kite winder after the corner
L_c	calculated support length at the outer side of a kite winder before the corner
L_d	calculated support length at the outer side of a kite winder after the corner
$L_{cantilever}$	calculated length of the overhang of a cut tread
L_{cut}	maximum length of cut string area
L_{load}	length of the actual line load
L_{stair}	length stair
L_{tread}	calculated span of tread
M	moment, bending moment, point load
$M_{k,1}$	net mass of the structure, including all fasteners
$M_{k,2}$	single mass
$M_{rail,k}$	bending moment for the computational modelling of the rail load

$M_{x,d,corner\ i}$	governing torsional moment around the x-axis before the corner due to the load combinations
$M_{x,d,corner\_i+1}$	governing torsional moment around the x-axis after the corner due to the load combinations
$M_{x,Rd,corner\_i}$	determined by tests in the link design value of the torsional recordable
$M_{x,d,tread}$	governing torsional moment at the beginning of the tread or end result of the load combination
$M_{x,Rd,tread}$	by test or calculation determined design value of recordable torsion in the tread
$M_{y,d,corner\_i}$	governing bending moment around the y-axis before the corner due to the load combinations
$M_{y,corner\_i+1}$	governing bending moment around the y-axis after the corner due to the load combinations
$M_{y,Rd,corner\_i}$	rated value of the absorbable bending moment in the connection around the y-axis, determined by tests (corner)
$M_{y,d,tread}$	governing bending moment around the y-axis at the beginning of the tread or end due to the load combinations
$M_{y,Rd,tread}$	rated value of the absorbable bending moment in the connection around the y-axis, determined by tests (tread)
$M_{z,d,corner\_i}$	governing bending moment around the z-axis before the corner due to the load combinations
$M_{z,corner\_i+1}$	governing bending moment around the z-axis after the corner due to the load combinations
$M_{z,Rd,corner\_i}$	rated value of the absorbable bending moment in the connection around the z-axis, determined by tests (corner)
$M_{z,d,tread}$	governing bending moment around the z-axis at the beginning of the tread or end due to the load combinations
$M_{z,Rd,tread}$	rated value of the absorbable bending moment in the connection around the z-axis, determined by tests (tread)
m_{lower}	lower margins
m_{upper}	upper margins
o	overlap
Q	variable action, point load
$Q_{k,1}$	concentrated point load
q	variable action, uniformly distributed load
$q_{k,1}$	equally distributed vertical load
$q_{k,2}$	equally distributed horizontal load
$q_{k,left}$	maximum value of variable line load to be applied on a winder tread
$q_{k,right}$	minimum value of variable line load to be applied on a winder tread
r	rise
$T_{d,cross\text{-}bracing}$	governing tension force in the cross-bracing as a result of load combinations
$T_{Rd,cross\text{-}bracing}$	rated value of the tension force absorbable in the cross-bracing traction, determined by tests or calculation
u, v, w	deformation, deflexion
w	width section,

w_1	outer side real tread width
$w_{1,id}$	idealized outer side step width
w_2	wall side real tread width
$w_{2,id}$	wall side idealized tread width
w_{i_stair}	internal width of the stair
$w_{av,id}$	average value of idealized tread widths
w_{stair}	width of flight
w_{tread}	tread depth
w_G	vertical deformation due to permanent action
$w_{q,k1}$	vertical deformation due to variable uniformly distributed vertical load
$w_{Q,k1}$	vertical deformation due to vertical point load of size 2 kN in an unfavourable position
X	property of building material
X_k	characteristic value of a material property
X_{Rd}	design value of material property
x, y, z	coordinates
$x_{cross\text{-}bracing}$	local x-axis of the cross-bracing
$y_{cross\text{-}bracing}$	local y-axis of the cross-bracing
$z_{cross\text{-}bracing}$	local z-axis of the cross-bracing
x_{string}	local x-axis of the string
y_{string}	local y-axis of the string
z_{string}	local z-axis of the string
x_{tread}	local x-axis of the tread
y_{tread}	local y-axis of the tread
z_{tread}	local z-axis of the tread

3.3 SI-units

SI-units shall be applied in accordance with EN ISO 80000-1.

For calculations, the following units shall be applied:

— forces and loads: kN, kN/m, kN/m^2;

— bulk density: kN/m^3;

— density: kg/m^3;

— tension, stress and stability: N/mm^2 (=MN/m^2 or MPa);

— elasticity and rigidity modulus: N/mm^2 (= MN/m^2 or MPa);

— moments (bending moment): kNm.

4 Principles for verification of mechanical performance characteristics

4.1 Performance characteristics to be verified

The fulfilment of the following mechanical performance characteristics shall be verified.

a) **Serviceability** – a stair is deemed to satisfy this requirement when:

1) under the actions applied, the deformation of the stair as a whole and/or its parts (e.g. steps and strings) shall not at any point exceed the preset maximum deformation values defined in EN 1995-1-1 (Eurocode 5) and National Application Document (NAD) when applicable,

2) under the action applied, the fundamental frequency of the stair as a whole shall fulfil the value defined in EN 1995-1-1 (Eurocode 5) and National Application Document (NAD) where applicable.

b) **Load-bearing capacity** - a stair is deemed to satisfy this requirement when

1) the existing use of the stair as a whole or of one of its single parts under the applied actions shall not exceed at any point the nationally set maximum values with regard to admissible use.

The fulfilment of both performance characteristics shall be verified. For the purpose of evaluating the results, the most unfavourable case is significant.

Stairs assessed based on experience, e.g. conventionally accepted performance (CAP) may be accepted according to national decisions.

4.2 Typical actions

Types and sizes of actions to be applied follow indications found in EN 1991-1-1 and are combined with relevant national regulations. In order to verify the mechanical performance characteristics of stairs, the following action types shall be considered:

— G_k Dead load of construction including all fasteners according to EN 1991–1–1:2002, Clause 5.

— $q_{k,1}$ Equally distributed vertical load [kN/m^2] according to EN 1991–1–1:2002, 6.3.
Without a further national value, the default value should be applied as, $q_{k,1}$ **= 3 kN/m^2**.

— $Q_{k,1}$ Concentrated single load [kN] according to EN 1991–1–1:2002, 6.3.
Without a further national value, the default value should be applied as, $Q_{k,1}$ **= 2 kN**.

— $q_{k,2}$ Equally distributed horizontal load [kN/m] according to EN 1991–1–1:2002, 6.4.
Without a further national value, the default value should be applied as $q_{k,2}$ **= 0,5 kN/m**.

— $M_{k,1}$ Permanent mass of construction including the mass of all fasteners.

— $M_{k,2}$ Single mass for fundamental frequency.

Without a further national value, the default value should be applied as $M_{k,2}$ **= 1 kN** .

4.3 Significant action combinations

4.3.1 General

Types and sizes of applied action combinations are chosen on the basis EN 1991-1-1 in combination with relevant national regulations. In order to verify the mechanical performance characteristics of a prefabricated stair or of one of its parts, the following typical action combinations shall be examined.

Without national values, the default values should be applied as given below.

4.3.2 Action combinations relevant for verification of usability/serviceability

The verification of usability/serviceability shall be carried out by using three action combinations.

1) Action combination "**Deformation_$q_{k,1}$**"

   The significant actions E_d consist of:

$$E_d = E\left\{1,0 \cdot G_k + 1,0 \cdot q_{k,1}\right\} \tag{1}$$

2) Action combination "**Deformation_$Q_{k,1}$**"

   The significant actions E_d consist of:

$$E_d = E\left\{1,0 \cdot G_k + 1,0 \cdot Q_{k,1}\right\} \tag{2}$$

3) Action combination "**Fundamental frequency_$M_{k,2}$**"

   The significant actions E_d consist of:

$$E_d = E\left\{1,0 \cdot M_{k,1} + 1,0 \cdot M_{k,2}\right\} \tag{3}$$

4.3.3 Action combination for verification of the load-bearing capacity

The verification of the load-bearing capacity shall be carried out by using two action combinations.

1) Action combination "**Rupture Load_$q_{k,1}$**"

   The significant actions E_d consist of:

$$\begin{aligned} E_d &= E\left\{1,35 \cdot G_k + 1,5 \cdot q_{k,1} + 1,5 \cdot \psi_0 \cdot q_{k,2}\right\} \\ &= E\left\{1,35 \cdot G_k + 1,5 \cdot q_{k,1} + 1,05 \cdot q_{k,2}\right\} \end{aligned} \tag{4}$$

2) Action combination "**Rupture Load_$Q_{k,1}$**"

   The significant actions E_d consist of:

$$E_d = E\left\{1,35 \cdot G_k + 1,5 \cdot Q_{k,1}\right\} \tag{5}$$

4.4 Bearing resistance within the verification of the load-bearing capacity

The properties of building materials are indicated by characteristic values, X_k.

For wood and wood-based materials, and in the absence of relevant national directives, the assessment values X_{Rd} used within the limit state of the load-bearing capacity result from:

$$X_{Rd} = \frac{k_{mod} \cdot X_k}{\gamma_m} \tag{6}$$