



SLOVENSKI STANDARD
SIST EN 15512:2009
01-maj-2009

GHUV]b]`Y_`Yb]`g]ghYa]`nUg_`UX]y Yb`Y!`G]ghYa]`nUbUghUj``j] YfY[UY`nUdUYH`!
BU YUX]a Ybn]cb]fUb`U

Steel static storage systems - Adjustable pallet racking systems - Principles for structural design

Ortsfeste Regalsysteme aus Stahl - Verstellbare Palettenregale - Grundlagen der statischen Bemessung

Systèmes de stockage en acier - Systèmes de rayonnages à palettes réglables - Principes applicables au calcul des structures

<https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009>

Ta slovenski standard je istoveten z: EN 15512:2009

ICS:

53.080 ù|æã } æ]!^ { æ Storage equipment

SIST EN 15512:2009 **en,fr**

iTeh STANDARD PREVIEW
(standards.iteh.ai)

SIST EN 15512:2009

<https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009>

EUROPEAN STANDARD

EN 15512

NORME EUROPÉENNE

EUROPÄISCHE NORM

March 2009

ICS 53.080

English Version

Steel static storage systems - Adjustable pallet racking systems - Principles for structural design

Systèmes de stockage statiques en acier - Systèmes de rayonnages à palettes réglables - Principes applicables au calcul des structures

Ortsfeste Regalsysteme aus Stahl - Verstellbare Palettenregale - Grundlagen der statischen Bemessung

This European Standard was approved by CEN on 17 January 2009.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

[SIST EN 15512:2009](https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009)

<https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009>



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Contents

Page

Foreword.....	6
Introduction	7
1 Scope	9
2 Normative references	9
3 Terms and definitions	10
4 Symbols	11
5 Basis of design	15
5.1 Requirements	15
5.1.1 Basic requirements.....	15
5.1.2 Un-braced racking systems.....	15
5.1.3 Braced racking systems	17
5.1.4 Design working life.....	19
5.1.5 Floor tolerances and deformations.....	19
5.2 Methods of design	19
5.2.1 General.....	19
5.2.2 Ultimate limit state.....	19
5.2.3 Serviceability limit state.....	20
5.3 Imperfections	20
5.3.1 General.....	20
5.3.2 Sway frame imperfections in un-braced systems.....	20
5.3.3 Bracing system imperfections.....	21
5.3.4 Imperfections in racks partially braced in the down-aisle direction.....	23
5.3.5 Member imperfections	23
6 Actions and combinations of actions.....	23
6.1 General.....	23
6.2 Permanent actions.....	24
6.2.1 General.....	24
6.2.2 Weights of materials and construction	24
6.3 Variable actions	24
6.3.1 General.....	24
6.3.2 Unit loads to be stored.....	24
6.3.3 Vertical placement loads.....	25
6.3.4 Horizontal placement loads	26
6.3.5 Effects of rack-guided equipment.....	27
6.3.6 Floor and walkway loads (see also EN 1991-1-1)	29
6.3.7 Actions arising from installation.....	30
6.4 Actions due to impact (accidental loads).....	30
6.4.1 General.....	30
6.4.2 Accidental vertical actions	30
6.4.3 Accidental horizontal load	31
6.5 Wind loads.....	31
6.6 Snow loads	31
6.7 Seismic actions.....	32
7 Partial factors and combination rules	32
7.1 General.....	32
7.2 Combinations of actions for the ultimate limit state.....	32
7.3 Combination of actions for serviceability limit states	32
7.4 Load factors	33

7.5	Material factors	34
7.6	Stability against overturning	34
7.7	Racks braced against the building structure	35
8	Steel	35
8.1	General	35
8.1.1	Preliminary considerations	35
8.1.2	Material properties	35
8.1.3	Design values of material coefficients (general mechanical properties)	35
8.1.4	Steels with no guaranteed mechanical properties	36
8.1.5	Untested steels	36
8.2	Average yield strength of sections	36
8.3	Special selection of production material	36
8.4	Fracture toughness	37
8.5	Dimensional tolerances	37
8.5.1	General	37
8.5.2	Thickness of material	37
8.5.3	Tolerances on thickness	37
8.5.4	Width and depth of a cold-formed section	37
8.5.5	Member straightness	38
8.5.6	Twist	38
8.5.7	Tolerances with regard to design and assembly	38
8.6	Bracing eccentricities	39
8.7	Eccentricities between beams and uprights	40
8.8	Requirements for beam connector locks	41
8.9	Durability	41
9	Structural analysis	41
9.1	Structural modelling for analysis and basic assumption	41
9.2	Calculation of section properties	41
9.2.1	General	41
9.2.2	Effect of corner radii	42
9.2.3	Effect of perforations	42
9.2.4	Effect of cross-section distortion	43
9.2.5	Effect of local buckling	44
9.3	Beams	45
9.3.1	General	45
9.3.2	Moment of resistance of members not subject to lateral-torsional buckling	46
9.4	Design of beams	46
9.4.1	General	46
9.4.2	Loads on beams	47
9.4.3	Design bending moments for beams	47
9.4.4	Design shear force for beams	49
9.4.5	Deflection of beams	49
9.4.6	Beams as tie beams in braced pallet racks	50
9.4.7	Design resistance with respect to web crippling	51
9.4.8	Design resistance with respect to shear forces	51
9.4.9	Combined shear force, axial force and bending moment	51
9.4.10	Combined bending moment and web crippling	51
9.5	Design of beam end connectors	51
9.5.1	General	51
9.5.2	Design bending moments in beam end connectors	51
9.5.3	Design shear force for beam end connectors	52
9.5.4	Design shear force and bending moment for beam end connectors	52
9.6	Beams subject to bending and torsion	52
9.6.1	General	52
9.6.2	Lateral torsional buckling of beams	53
9.7	Compression, tension and bending in members	54
9.7.1	Non-perforated compression members	54
9.7.2	Perforated compression members	54

EN 15512:2009 (E)

9.7.3	Cross sectional verification	55
9.7.4	Design strength with respect to flexural buckling	55
9.7.5	Torsional and flexural-torsional buckling	62
9.7.6	Combined bending and axial loading	64
9.8	Design of splices	68
9.9	Design of base plates	69
9.9.1	General	69
9.9.2	Effective area A_{bas} for base plates	69
9.10	Floor materials	70
9.10.1	Concrete floors	70
9.10.2	Bituminous floors	70
9.10.3	Other floor materials	71
9.10.4	Design of anchorages	71
9.11	Design of run spacers	72
10	Global analysis of beam pallet racks	72
10.1	General considerations	72
10.1.1	General	72
10.1.2	Two dimensional analysis	73
10.1.3	Advanced three-dimensional analysis	73
10.2	Design procedure	73
10.2.1	Actions	73
10.2.2	Procedure	73
10.2.3	Analysis of braced and un-braced racks in the down-aisle direction	76
10.2.4	Moment-rotation characteristics of beam end connectors	78
10.2.5	Moment-rotation characteristics of the connection to the floor	78
10.3	Analysis of braced and un-braced racks in the cross-aisle direction	79
10.3.1	General	79
10.3.2	Out of plane stability	79
10.3.3	Frame classification	79
10.4	Methods of global analysis	81
10.5	Simplified methods of analysis for stability in the cross-aisle direction	83
10.6	Design of uprights	83
10.6.1	General	83
10.6.2	Design axial forces and bending moments	83
11	Serviceability limit states	83
11.1	General	83
11.2	Serviceability limit states for racking	83
12	Marking and labelling	84
12.1	Identification of performance of rack installations	84
13	Test methods and evaluation of results	84
13.1	General	84
13.2	Requirements for tests	85
13.2.1	Equipment	85
13.2.2	Support conditions	85
13.2.3	Application of the load	86
13.2.4	Increments of the test load	86
13.2.5	Assembly of test specimens	86
13.2.6	Test reports	86
13.3	Interpretation of test results	87
13.3.1	Definition of failure load	87
13.3.2	Corrections to test results	87
13.3.3	Derivation of characteristic values	87
13.3.4	Characteristic values for a family of tests	88
13.3.5	Corrections to failure loads or moments	89
Annex A	(normative) Testing	90
A.1	Materials tests	90
A.1.1	Tensile test	90

A.1.2	Bend tests	90
A.2	Tests on components and connections.....	91
A.2.1	Stub column compression test.....	91
A.2.2	Compression tests on uprights - Checks for the effects of distortional buckling.....	93
A.2.3	Compression tests on uprights - Determination of buckling curves.....	94
A.2.4	Bending tests on beam end connectors	98
A.2.5	Looseness tests on beam end connectors.....	104
A.2.6	Shear tests on beam end connectors and connector locks	106
A.2.7	Tests on floor connections.....	108
A.2.8	Tests for the shear stiffness of upright frames.....	111
A.2.9	Bending tests on upright sections	113
A.2.10	Bending tests on beams	115
A.2.11	Tests on upright splices	116
Annex B	(informative) Amplified sway method for down-aisle stability analysis	119
B.1	General	119
B.2	Linear elastic analysis	120
B.3	Elastic critical value	120
B.4	Amplification factor.....	120
Annex C	(informative) Approximate equations for the design of a regular storage rack in the down-aisle direction	121
C.1	Approximate equation for regular construction	121
C.2	Additional bending moments due to pattern loading	123
C.3	Design Moments.....	123
C.4	Design loads in outer columns	124
Annex D	(informative) Background to the acceptance of materials of low f_u/f_y ratio (cold reduced steel)	125
Annex E	(informative) Position inaccuracies	126
Annex F	(informative) Equivalent beam loads	127
Annex G	(informative) Simplified method for cross-aisle stability analysis in circumstances where there is uniform distribution of compartment loads over the height of the upright frame	129
G.1	General	129
G.2	Global buckling of upright frames	129
G.3	Shear stiffness of upright frame	130
G.4	Amplification factor β	130
Annex H	(informative) Factory production control (FPC)	133
H.1	General	133
H.2	Frequency of tests.....	133
H.3	Bending tests on beam end connectors	133
H.4	Bend tests	134
Annex I	(informative) A–deviations	135
I.1	Dutch national legislative deviations	135
I.2	German national legislative deviations.....	135
Bibliography	137

Foreword

This document (EN 15512:2009) has been prepared by Technical Committee CEN/TC 344 "Steel static storage systems", the secretariat of which is held by UNI.

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 September 2009, and conflicting national standards shall be withdrawn at the latest by September 2009.

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.

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, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

iTeh STANDARD PREVIEW (standards.iteh.ai)

[SIST EN 15512:2009](https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009)

<https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009>

Introduction

0.1 Racking

Racking systems are load bearing structures for the storage and retrieval of goods in warehouses. The goods to be stored are generally on pallets or in box-containers.

Racking is constructed from steel components including upright frames, beams and decking. Special beam to column (upright) connections and bracing systems are utilised, in order to achieve a three dimensional steel 'sway' or 'braced' structure with "aisles" to enable order pickers, industrial trucks or stacker cranes to reach the storage positions. Although components are standardised they are only standard to each manufacturer. These components differ from traditional column and beam structures in the following regard.

- 1) Continuous perforated uprights.
- 2) Hook-in connections.
- 3) Structural components for racking generally consist of cold formed thin gauge members.

0.2 Requirement for EN Standards for racking and shelving in addition to the Eurocodes

Because of the differences in shape of structural components, detailing and connection type's additional technical information to the Eurocodes are required, in order to have reliable state of the art guidance for the practicing designer involved in designing racking.

The scope of CEN/TC 344 is to establish European Standards providing guidance for the specification, design, methods of installation, accuracy of build and guidance for the user on the safe use of steel static storage systems.

This, together with the need for harmonised design rules was the reason that the European Racking Federation ERF / FEM Racking and Shelving has taken the initiative for CEN/TC 344. CEN/TC 344 is in the course of preparation of a number of European Standards for specific types of racking and shelving and particular applications which exist as European Standards (EN) and working group activities (WG) as follows:

EN 15512: Steel static storage systems - Adjustable pallet racking systems - Principles for structural design.

EN 15620: Steel static storage systems - Adjustable pallet racking - Tolerances, deformations and clearances.

EN 15629: Steel static storage systems - The specification of storage equipment.

EN 15635: Steel static storage systems - The application and maintenance of storage equipment

WG 3c: Terms and Definitions.

WG 4: Technical Principles for the Design of Adjustable Drive-in and Drive-through Racking Systems.

WG 5a: Technical principles for the Design of Pallet Racking Systems in Seismic Regions.

WG 5b: Technical Principles for the Design of Drive-in and Drive-through Racking Systems in Seismic Regions.

WG 6: Technical Principles for the Design of Shelving Systems.

EN 15512:2009 (E)

WG 7: Technical Principles for the Design of Cantilever Racking Systems.

WG 8: Technical Principles for the Design of Mobile Racking Systems.

WG 9: Principles of Health and Safety during the installation of Racking Systems.

The intention is for these EN-Series “Racking and Shelving” to be published sequentially over a period of ten years.

In drafting these documents, liaisons with other CEN/TC's will occur as appropriate.

0.3 Liaison

CEN/TC 344 “Steel Storage Systems” liaise with CEN/TC 250 “Structural Eurocodes”, CEN/TC 135 “Execution of steel structures and aluminium structures” and CEN/TC 149 “Power-operated warehouse equipment”.

0.4 Racking and Shelving and Work Equipment regulations

Although racking is a load bearing structure, national regulatory requirements may require that racking be considered as ‘work equipment’ and therefore may be subject to the European Directive 89/391/EEC. This document is not a stand alone document and is intended to be used in conjunction with EN15620, EN 15629 and EN 15635.

0.5 Additional information specific to EN 15512

EN 15512 is intended to be used with EN 1990 – Basis of Structural Design, EN 1991 – Actions on structures, and EN 1993 for the Design of steel structures.

EN 1993-1 is the first of six parts of EN 1993 – Design of Steel Structures. It gives generic design rules intended to be used with the other parts EN 1993-2 to EN 1993-6. It also gives supplementary rules applicable only to buildings.

EN 1993-1 comprises eleven subparts EN 1993-1-1 to EN 1993-1-11, each addressing specific steel components, limit states or materials.

EN15512 may also be used for design cases not covered by the Eurocodes (other structures, other actions, other materials) serving as a reference document for other CEN TC’s concerning structural matters.

EN 15512 is intended for use by

committees drafting design related product, testing and execution standards,

designers and structural engineers,

relevant authorities.

Numerical values for partial factors and other reliability parameters are basic values that provide an acceptable level of reliability assuming an appropriate level of workmanship and quality management.

As part of the design process, reference to EN 15629 and EN 15635 shall be required to ensure that both specifier and designer are aware of the interface constraints in each other's responsibility and to allow an effective design to be produced.

1 Scope

This European Standard specifies the structural design requirements applicable to all types of adjustable beam pallet rack systems fabricated from steel members intended for the storage of unit loads and subject to predominantly static loads. Both un-braced and braced systems are included.

This European Standard gives guidelines for the design of clad rack buildings where requirements are not covered in EN 1993. The requirements of this European Standard also apply to ancillary structures, where rack components are employed as the main structural members.

This European Standard does not cover other generic types of storage structures. Specifically, this European Standard does not apply to mobile storage systems, drive-in, drive-through and cantilever racks or static steel shelving systems, nor does this European Standard establish specific design rules for the assessment of racking in seismic areas.

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.

EN 528, *Rail dependent storage and retrieval equipment - Safety*

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*

[SIST EN 15512:2009](#)

EN 1993-1-1:2005, *Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings*

[04296ecde4fb/sist-en-15512-2009](#)

EN 1993-1-3:2006, *Eurocode 3 - Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting*

EN 10002-1, *Metallic materials - Tensile testing – Part1: Method of test at ambient temperature*

EN 10143, *Continuously hot-dipped coated steel sheet and strip - Tolerances on dimensions and shape*

EN 10162, *Cold rolled steel sections - Technical delivery conditions - Dimensional and cross-sectional tolerances*

EN 10326, *Continuous hot-dip coated strip and sheet of structural steels - Technical delivery conditions*

EN 15620, *Steel static storage systems - Adjustable pallet racking - Tolerances, deformations and clearances*

EN 15629, *Steel static storage systems - The specification of storage equipment*

EN 15635, *Steel static storage systems - The application and maintenance of storage equipment*

prEN 15878, *Steel static storage systems - Terms and definitions*

EN ISO 7438, *Metallic materials - Bend test (ISO 7438:2005)*

EN ISO 9001, *Quality management systems - Requirements (ISO 9001:2000)*

ETAG No 001, *Guideline for European Technical Approval of Metal Anchors for Use in Concrete*

EN 15512:2009 (E)**3 Terms and definitions**

For the purposes of this document, the following terms and definitions given in prEN 15878 apply.

- 3.1 accidental action**
action, usually of short duration but of significant magnitude, that is unlikely to occur on a given structure during the design working life
- 3.2 basic material**
flat steel sheets or coiled strip, possibly cold reduced from which the rack components are pressed or rolled
- 3.3 batch of steel**
quantity of steel, all to the same specification, produced by one supplier at one time
- 3.4 beam**
horizontal member linking adjacent frames and lying in the horizontal direction parallel to the operating aisle
- 3.5 beam end connector**
connector, welded to or otherwise formed as an integral part of the beams, which has hooks or other devices which engage in holes or slots in the upright
- 3.6 compartment load**
load which can be loaded into one compartment of a rack or shelving structure from one side
- 3.7 double entry rack**
run of racking accessible from two adjacent operating aisles connected by run spacers
- 3.8 global analysis**
determination of a consistent set of internal forces, moments and displacements that represent the entire three dimensional load bearing rack structure, which are in equilibrium with a particular set of actions on the structure
- 3.9 perforated member**
member with multiple holes regularly spaced along its length
- 3.10 placement load**
load caused by deposit and picking operations of a unit load into and out of the system, reflecting good practice
- 3.11 single entry rack**
run of racking accessible from a single operating aisle
- 3.12 spine bracing**
sway bracing in the vertical plane parallel to the main aisle of the rack, linking adjacent frames

3.13**spring-back**

tendency of a cold-formed section to undergo spontaneous cross-sectional distortion when it is cut from a longer length

3.14**stiffened element**

stiffened element of a cross-section is a part of the cross-section which is connected to the remainder of the section along both longitudinal edges

3.15**sway**

horizontal displacement of structure in addition to any initial out of plumb

3.16**unit load**

individual stored item that can be placed or retrieved in one operation

3.17**un-stiffened element**

an un-stiffened element of a cross-section is a part of the cross-section which is connected to the remainder of the section along one longitudinal edge only

3.18**upright frame**

two (often perforated) upright sections linked together by a system of bracing members

NOTE Typical examples are shown in Figure 1

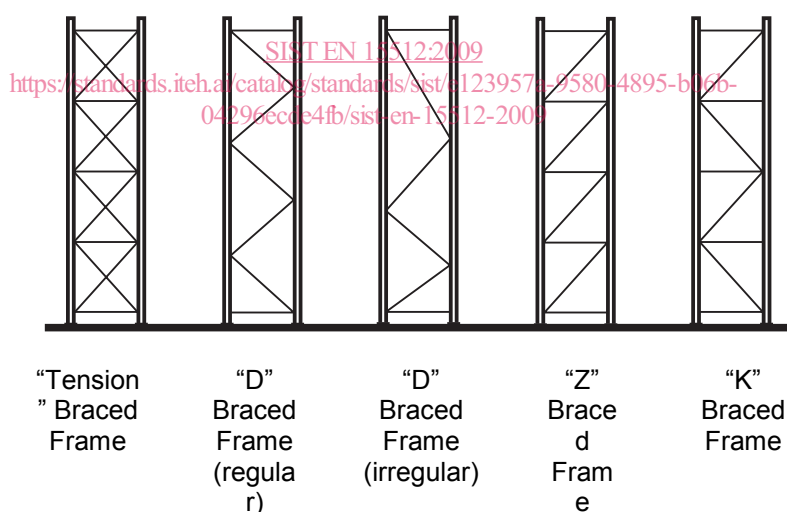


Figure 1 — Typical forms of upright frames

4 Symbols

For the purpose of this document a number of the following symbols may be used together with standard subscripts which are given later.

Additional symbols and subscripts are defined where they first occur.

EN 15512:2009 (E)

A symbol and subscript may have several meanings in this document.

In general primary symbols are not defined with all the standard subscripts with which they may be used.

A accidental action

A cross sectional area

A_{eff} effective cross sectional area

A_g gross cross sectional area

A_{ph} accidental horizontal placement force

A_{pv} accidental vertical placement force

b width of upright

b_p notional plane width of element

E modulus of elasticity

e effective bearing width of base plate

e eccentricities

f_{ck} characteristic cylinder strength of concrete

f_t observed yield strength in test specimen

f_u ultimate strength

f_y yield strength

f_{ya} average yield strength

f_{yb} basic yield strength ($=f_y$)

G shear modulus

G_k characteristic value of permanent loads (dead loads)

h storey height

I second moment of area

I_T St Venant torsion constant

I_w warping constant

i radius of gyration

i_0 polar radius of gyration

K effective length factor

k_b stiffness of beam to column connector

iTeh STANDARD PREVIEW
(standards.iteh.ai)

SIST EN 15512:2009

<https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009>

k_s	coefficient related to number of tests
L	span
l	length
l	effective length or buckling length
M	bending moment
N	axial load
n	number of tests
n_c	number of uprights in the down aisle direction in a run of bays
n_s	number of beam levels
Q	variable load
Q_f	concentrated load on floor
Q_h	maximum specified lateral load per crane
Q_{ph}	horizontal placement load
Q_{pv}	vertical placement load
Q_u	weight of unit load
q	distributed load
R_m	mean value of adjusted test results
R_n	corrected failure load
R_t	observed failure load
s_n	standard deviation of the normalised test results
t	thickness of material
t_c	core thickness of material exclusive of coatings
t_t	observed core thickness in test specimen
V	shear force
V	vertical load
V_{cr}	elastic critical value of vertical load
W	section modulus
W	total load on a beam
α	coefficient of linear thermal expansion

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[SIST EN 15512:2009](https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009)

<https://standards.iteh.ai/catalog/standards/sist/e123957a-9580-4895-b06b-04296ecde4fb/sist-en-15512-2009>