



**NSAI**  
Standards

Irish Standard  
I.S. EN 15512:2009

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

## I.S. EN 15512:2009

*Incorporating amendments/corrigenda issued since publication:*

<i>This document replaces:</i>	<i>This document is based on:</i> EN 15512:2009	<i>Published:</i> 18 March, 2009	
This document was published under the authority of the NSAI and comes into effect on: 15 May, 2009		ICS number: 53.080	
<b>NSAI</b> 1 Swift Square, Northwood, Santry Dublin 9	T +353 1 807 3800 F +353 1 807 3838 E standards@nsai.ie W NSAI.ie	<b>Sales:</b> T +353 1 857 6730 F +353 1 857 6729 W standards.ie	<b>Price Code:</b> AC
Údarás um Chaighdeáin Náisiúnta na hÉireann			

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.



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

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

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

## **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.



## **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.

## I.S. EN 15512:2009

### 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*

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

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*

This is a free preview. Purchase the entire publication at the link below:

[Product Page](#)

- 
- [Looking for additional Standards? Visit Intertek Inform Infostore](#)
  - [Learn about LexConnect, All Jurisdictions, Standards referenced in Australian legislation](#)
-