SLOVENSKI STANDARD
SIST EN 16681:2016

01-september-2016

Stabilni jekleni sistemi za skladiščenje - Sistemi za nastavljive regale za palete - Načela potresno varnega projektiranja

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

Ortsfeste Regalsysteme aus Stahl - Verstellbare Palettenregale - Leitsätze für die erdbebensichere Gestaltung

Systèmes de stockage statique en acier - Systèmes de rayonnages à tablettes ajustables - Principes pour le calcul parasismique

Ta slovenski standard je istoveten z: EN 16681:2016

ICS:

53.080	Skladiščna oprema	Storage equipment
91.120.25	Zaščita pred potresi in vibracijami	Seismic and vibration protection

SIST EN 16681:2016 **en,fr,de**

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 16681

June 2016

ICS 53.080

English Version

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

Systèmes de stockage statique en acier - Systèmes de rayonnages à tablettes ajustables - Principes pour le calcul parasismique

Ortsfeste Regalsysteme aus Stahl - Verstellbare Palettenregale - Leitsätze für die erdbebensichere Gestaltung

This European Standard was approved by CEN on 7 April 2016.

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-CENELEC 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-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of 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 United Kingdom.

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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 16681:2016 E

Contents

Page

European foreword

This document (EN 16681:2016) 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 December 2016 and conflicting national standards shall be withdrawn at the latest by December 2016.

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, 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.

0 Introduction

0.1 Effects of seismic actions on racking systems

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

Racking systems are constructed from steel components; although components are standardized, they are only standard to each manufacturer. These components differ from traditional steel components in the following regard:

a) continuous perforated uprights;

b) hook-in connections;

c) structural components for racking, which generally consist of cold formed thin gauge members.

In respect of the loads, the self-weight of a rack structure is typically very small or negligible with respect to the total mass, whereas in a typical building the percentage of dead and permanent loads will be much greater.

The nature and the distribution of the goods stored on racking systems strongly affect the response and the safety of the structure under seismic actions. In fact:

— unit loads are in general simply supported vertically by the racking structure and kept in their position when loaded by inertial actions only by friction;

— unit loads are in general sub-structures with distinct dynamic characteristics in terms of frequency and damping, and their behaviour affect the response of the system.

During real earthquakes or earthquake simulated on shaking tables, movements of pallets on pallet beams were observed; these were either very small ones, contributing to the dissipation of energy by means of friction, or very large, with movements of the pallets that produced their falling between beams or outside the rack in the aisle. For this reason, friction between pallet and pallet beam and internal damping in the unit load has a relevant influence in the dynamic response of the rack and affects the entity of the inertial actions.

Also, the safety of the installation related to the movement and eventual falling of the pallets requires a proper assessment.

This European Standard deals with all the relevant and specific seismic design issues for racking systems, based on the criteria of EN 1998-1:2004, Eurocode 8.

0.2 Requirements for EN Standards for racking and shelving in addition to Eurocodes

While the basic technical description of an earthquake is the same for all structures, the general principles and technical requirements applicable for conventional steel structures have to be adapted for racking systems, in order to take into account the peculiarities of racking to achieve the requested safety level.

Also, the methods of analysis and the design requirements need to be addressed to the peculiarity of racking structures.

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

This, together with the need of harmonized design rules was the reason that 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 in the European Standards (EN) and working group activities (WG).

0.3 Liaison

CEN/TC 344 “Steel Static 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 Additional information specific to EN 16681

This European Standard is intended to be used with EN 1998-1, EN 15512 and related standards.

EN 1998-1 is the first of 6 parts; it gives design rules intended to be used for structures fabricated with conventional materials, including steel.

EN 15512 is the reference standard for the design of racking structures and components; it addresses the principles of the EN 1990, Eurocode, and EN 1993 series, Eurocode 3, to the adjustable pallet racking systems and it needs to be applied also when actions are produced by an earthquake.

1 Scope

This European Standard specifies the structural design requirements applicable to all types of adjustable pallet racking systems fabricated from steel members, intended for storage of unit loads and subject to seismic actions.

This European Standard gives also guidelines for the design of clad rack buildings in seismic zones, where requirements are not covered in the EN 1998 series.

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.

This European Standard does not apply to the design of seismic isolated racking structures.

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.[1)]

EN 1090-2, *Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures*

EN 1990 (all parts), *Eurocode - Basis of structural design*

EN 1993 (all parts), *Eurocode 3 - Design of steel structures*

EN 1998-1:2004[2)], *Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings*

EN 15512:2009, *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 15629:2008, *Steel static storage systems - Specification of storage equipment*

EN 15635:2008, *Steel static storage systems - Application and maintenance of storage equipment*

EN 15878:2010, *Steel static storage systems - Terms and definitions*

ETAG 001 series, *Guideline for European technical approval of metal anchors for use in concrete*

1) Complementary rules to existing Norms specific for seismic applications are included in the following annexes:

— Annex I "*Data to be exchanged between the Specifier/End User and the rack's Supplier*" as complement to EN 15629:2008
— Annex J "*Complementary rules to* EN 15635" as complement to EN 15635:2008
— Annex K "*Complementary rules to* EN 15629" as complement to EN 15629:2008

2) This document is impacted by the amendment EN 1998-1:2004/A1:2013.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 15878:2010 and EN 1998-1:2004 and the following apply.

3.1
associated mass
portion of the total mass of the structure affecting the seismic behaviour of the structural element or of the substructure analysed

3.2
mass regularity
in elevation: situation in which the mass of the individual load level remains constant or reduces gradually without abrupt changes from the base to the top of the rack

in plan: situation in which the mass is distributed without significant horizontal eccentricity with respect to the lateral resisting system

3.3
principal directions
down aisle direction and cross aisle direction in a rack

[SOURCE: EN 15878:2010, definitions 3.2.14 and 3.2.15, modified — the content of the defined term stems from these two original definitions]

3.4
PRSES
person responsible for storage equipment safety

[SOURCE: EN 15635:2008, 3.18]

3.5
rack filling grade reduction factor
$\mathbf{R_F}$
statistical reduction factor intended to take into account the probability that not all of the pallets will be present and at their maximum weight at the time of the design earthquake

3.6
seismic weight
value of weight of a mass allowed in seismic design for the calculation of the seismic action

3.7
specifier
person or company that provides the supplier with a specification based on user’s requirements

[SOURCE: EN 15629:2008, 3.23]

4 Symbols and abbreviations

4.1 Symbols

For the purposes 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.

$A_{E,d}$	design value of the seismic action for the reference return period
a_g	design ground acceleration on type A ground
a_{gR}	reference ground acceleration (PGA) for the reference return period of 475 years
b	distance between the uprights axes
β	lower bound factor for the design spectrum
$C_{\mu L}$; $C_{\mu H}$	correction factors for unit load-beam friction coefficient (lower and upper bound values)
$d_{r,i}$	design inter-storey drift above storey i
ξ	viscous damping ratio expressed as percentage of critical damping
e_i	height of the centre of gravity of the unit load at level i
E	Young modulus of the material
E_d	value of the effect due to the design action
E_{D1}	design spectrum modification factor
E_{D2}	pallet weight modification factor
E_{D3}	design spectrum modification factor
E_{Edx}	effect due to the application of the seismic action along the horizontal axis x
E_{Edy}	effect due to the application of the seismic action along the horizontal axis y
E_{Edz}	effect due to the application of the seismic action along the vertical axis z
θ	inter-storey drift sensitivity coefficient
θ_i	inter-storey drift sensitivity coefficient between levels i and i+1
θ_p	rotation capacity of the beam-end connector
$F_{b,Rd}$	bearing strength of bolted connection
f_k	characteristic strength of the material
$F_{E,i}$	horizontal force at level i of the rack
$F_{v,Rd}$	bolt's shear strength
Φ_k	rotation at Mk, both positive and negative
G_i	permanent load
$G_{k,i}$	characteristic value of the permanent action

g	gravity acceleration
γ_I	importance factor
γ_M	material’s factor
γ_f	load factor
η	damping correction factor
H	height of the frame bracing pitch or the distance from floor to first horizontal
H/b	height to minimum width ratio of an unit load
h_i	inter-storey height above the storey i
H_i	horizontal action on the unit load at level i
I	moment of inertia of the upright
k_S	coefficient related to number of tests
K	buckling length factor
K_D	effective spectrum modification factor
L	beam’s length
λ	seismic shear force calculation coefficient in LFMA
$\overline{\lambda}$	adimensional slenderness (EN 15512 and EN 1993-1)
M_k	characteristic bending strength obtained from monotonic tests, both positive and negative
μ_m	mean value of the unit load-beam friction coefficient obtained from tests
$\mu_{n,i}$	individual test result of the unit load-beam friction coefficient
N_{Rd}	axial strength of a member
ΔN_{base}	additional vertical force at the base of the uprights
ΔN_i	additional vertical action at beam-upright intersection
μ_S	unit load-beam friction coefficient
P_c	constant downward load in the bending test
$P_{cr,E}$	Euler critical load
P_E	total gravity load in the seismic design situation
$P_{E,i}$	total gravity load at and above the considered storey i, in the seismic design situation
$P_{E,prod}$	total product weight on the rack
q	behaviour factor
q_d	displacement behaviour factor
q_{rack}	behavior factor of the rack

$Q_{k,i}$ characteristic value of a variable action

$Q_{P;max}$ specified weight of the unit load (see EN 15629, 6.7.1)

$Q_{P;rated}$ specified value of the weight of unit loads for the compartment, upright frame or global down aisle design (see EN 15512) as specified by the Specifier (see also EN 15629:2008, 6.7.1).

$Q_{p,rated,i}$ specified weight of the product stored at the level i in the seismic condition

R_d design resistance of the element

R_F rack filling grade reduction factor

s standard deviation of a number of tests results

S soil parameter

S_a seismic coefficient specified in EN 1998-1:2004, 4.3.5.2 for the analysis of non structural components

$S_d(T)$ ordinate of the design spectrum (normalized by g)

$S_{d,mod}(T)$ ordinate of the modified design spectrum for racks (normalized by g)

$S_e(T)$ ordinate of the elastic spectrum (normalized by g)

T period of vibration

T_1 fundamental period of vibration

T_B, T_C limits of the constant spectral acceleration branch

T_D period value defining the beginning of the spectrum constant displacement range

V_E seismic base shear force

$V_{E,i}$ total seismic storey shear at the considered storey i

W_E weight of the seismic mass considered in the analysis

$W_{E,G}$ weight of permanent loads

$W_{E,Q}$ weight of the variable loads

$W_{E,tot}$ total weight of the seismic mass of the rack

$W_{E,UL}$ seismic design weight of the unit load to be considered in the seismic analysis

$\psi_{2,i}$ combination factor for variable actions

Z distance from the ground level to the fixing level of the rack

4.2 Abbreviations

LFMA Lateral Force Method of Analysis

MRSA Modal Response Spectrum Analysis

LDMA Large Displacement Method of Analysis

5 Performance requirements and compliance criteria

5.1 Applicability

Non-seismic design shall comply with EN 15512. The reference to the tests and quality control of components and materials is based on EN 15512.

In case of very low seismicity conditions, the racking structures need not to be designed for earthquake (see also EN 1998-1:2004, 3.2.1, (5)P).

National Regulations shall be followed to define general conditions of applicability of the seismic design.

It is recommended to consider as very low seismicity cases either those in which the design ground acceleration on type A ground, $\gamma_I \, a_{gR}$, is not greater than 0,04 g, or those where the product $\gamma_I \, a_{gR} \, S$ is not greater than 0,05 g.

5.2 Performance requirements

5.2.1 No collapse requirement

The racking structure shall be designed and constructed to withstand the design seismic action without local or general collapse, retaining its structural integrity and a residual load bearing capacity after the seismic event.

Ultimate limit states are those associated with the collapse, or with other forms of structural failure, that may endanger the safety of people.

The structural system shall be verified as having the specified resistance and ductility.

5.2.2 Damage limitation requirement

No specific design requirement is prescribed in this European Standard. The movement of the stored unit loads does not constitute damage.

NOTE Reference is made to Annex J (normative) for integrity controls after a seismic event.

5.2.3 Movement of unit loads

Movement of unit loads shall be considered in the design when appropriate.

NOTE 1 Seismic accelerations can cause sliding of the pallets on the supporting beams, when the inertial horizontal forces on the pallet exceed the static friction force between pallet and beam.

This effect has been demonstrated by full scale tests to occur for small values of ground accelerations (low intensity earthquakes) with wooden or plastic pallets on painted or zinc coated steel beams, because of the structural amplification of the seismic forces at the highest storage levels.

The consequences of these phenomena are the reduction of the seismic action on the rack, due to the energy dissipation and the limitation of the horizontal action that can be transferred from the pallet to the rack structure, and the risk of unit loads falling, that can cause local or global collapse of the rack, or injury to people.

NOTE 2 The modification of the seismic response of the structure is considered in this European Standard by means of three coefficients that estimate the effects of typical phenomena of racking structures, such as energy dissipation due to the pallet-beam friction, damping due to the movement of the stored products, pallet flexibility, and others:

— E_{D1} and E_{D3} is the design spectrum modification factors,