

DIN EN 15512:2022-06 (E)

Steel static storage systems - Adjustable pallet racking systems - Principles for structural design (includes Amendment:2022)

Contents		Page
European foreword		10
0	Introduction	11
0.1	Racking	11
0.2	Requirement for EN Standards for racking in addition to the Eurocodes	11
0.3	Liaison	11
0.4	Racking and Work Equipment regulations	11
1	Scope	13
2	Normative references	13
3	Terms and definitions	14
4	Symbols	19
5	Assumptions and conventions	22
5.1	General	22
5.2	Verticality	22
5.3	Conventions for member axis	22
6	Basis of design	22
6.1	Requirements	22
6.1.1	Basic requirements	22
6.1.2	Design working life	22
6.1.3	Requirements for pallet racking	23
6.2	Principles of limit state design	23
6.2.1	General	23
6.2.2	Ultimate limit state	23
6.2.3	Serviceability limit state	23
6.3	Actions	23
6.3.1	General	23
6.3.2	Permanent actions	23
6.3.3	Variable actions	24
6.3.4	Accidental actions	31
6.4	Combination of actions	32
6.4.1	General	32
6.4.2	Ultimate limit state	32
6.4.3	Serviceability limit states	33
6.5	Partial factors	33
6.5.1	Load factors	33
6.5.2	Material factors	34
7	Materials	35
7.1	Steel	35
7.1.1	General	35
7.1.2	Material properties	35
7.1.3	Steels with no guaranteed mechanical properties	36
7.1.4	Untested steels	36
7.1.5	Average yield strength of sections	36
7.1.6	Special selection of production material	37

7.1.7	Fracture toughness	37
7.1.8	Dimensional tolerances	37
7.2	Floor materials	38
7.2.1	Concrete floors	38
7.2.2	Bituminous floors	38
7.2.3	Other floor materials	38
8	Durability	38
9	Structural analysis	39
9.1	Structural modelling for analysis	39
9.1.1	Structural modelling for analysis and basic assumption	39
9.1.2	Joint modelling	39
9.1.3	Ground-structure interaction	42
9.1.4	Racks braced against the building structure	45
9.2	Global analysis	45
9.2.1	Effects of deformed geometry of the structure	45
9.2.2	Method of analysis	46
9.2.3	Structural stability of frames	47
9.3	Imperfections	53
9.3.1	General	53
9.3.2	Global imperfections	53
9.3.3	Local bracing imperfections	55
9.3.4	Member imperfections	56
10	Ultimate limit states	57
10.1	Resistance of cross-sections and members	57
10.1.1	General	57
10.1.2	Section properties	57
10.1.3	Compression members	58
10.1.4	Bending members	60
10.1.5	Tension members	60
10.2	Design of beams	62
10.2.1	General	62
10.2.2	Effects of interaction between unit load and beam	62
10.2.3	Correction for looseness	63
10.2.4	Plastic design resistance	63
10.2.5	Buckling length of beams in braced pallet racks	63
10.2.6	Beams subject to bending and torsion	64
10.2.7	Beams affected by distortion	65
10.3	Design of uprights	65
10.3.1	General	65
10.3.2	Buckling curves	65
10.3.3	Flexural buckling length	66
10.3.4	Torsional buckling length	68
10.4	Design of frame bracing	71
10.4.1	General	71
10.4.2	Robustness	71
10.4.3	Buckling length of frame bracing	71
10.5	Design of run spacers	73
11	Serviceability limit states	74
11.1	General	74
11.2	Beams	74
11.3	Beams in walkways or rack supported floors	74
12	Design of joints	74
12.1	General	74
12.2	Design of beam end connectors	74
12.2.1	Design resistance of moment and shear	74
12.2.2	Combination of moment and shear	74
12.2.3	Reversed moment	74

12.3	Design of beam connector locks	75
12.4	Design of splices	75
12.5	Design of base plates	75
12.5.1	General	75
12.5.2	Compression	76
12.5.3	Tension	77
12.6	Design of anchorages	77
12.6.1	General	77
12.6.2	Robustness	77
13	Design assisted by testing	77
13.1	General	77
13.2	Requirements for tests	78
13.2.1	Equipment	78
13.2.2	Support conditions	78
13.2.3	Application of the load	78
13.2.4	Increments of the test load	79
13.2.5	Test materials	79
13.2.6	Assembly of test specimens	79
13.2.7	Test reports	79
13.3	Interpretation of test results	80
13.3.1	Definition of failure load	80
13.3.2	Adjustment of test results	80
13.3.3	Derivation of characteristic values	82
13.3.4	Characteristic values for a family of tests	83
13.3.5	Interpolation between test results	84
14	Marking and labelling - Identification of performance of rack installations	84
Annex A (normative) Testing		85
A.1	Materials tests	85
A.1.1	Tensile tests	85
A.1.1.1	General	85
A.1.1.2	Tensile test from beam end connector	85
A.1.2	Bend tests	85
A.2	Tests on components	86
A.2.1	Stub column compression test	86
A.2.1.1	Purpose of the test	86
A.2.1.2	Test arrangement and method	86
A.2.1.3	Corrections to the observations	87
A.2.1.4	Derivation of the results	88
A.2.2	Compression tests on uprights - Checks for the effects of distortional buckling	88
A.2.2.1	Purpose of the test	88
A.2.2.2	Test arrangement and method	88
A.2.2.3	Corrections to the observations	89
A.2.2.4	Derivation of the test results	89
A.2.3	Compression tests on uprights - Determination of buckling curves	90
A.2.3.1	Purpose of the test	90
A.2.3.2	Test arrangement	91
A.2.3.3	Test method	92
A.2.3.4	Corrections to the observations	92
A.2.3.5	Derivation of the column curve	93
A.2.4	Frame shear stiffness tests	94
A.2.4.1	Purpose of the tests	94
A.2.4.2	Method A, loading the frame in the longitudinal direction	94
A.2.4.2.1	Test arrangement	94
A.2.4.2.2	Test method	96
A.2.4.2.3	Corrections to the observations	96
A.2.4.2.4	Derivation of results	96
A.2.4.3	Alternative method B using a cross-aisle reversible shear load on a frame	97
A.2.4.3.1	General	97

A.2.4.3.2	Test arrangement	97
A.2.4.3.3	Test method	98
A.2.4.3.4	Corrections to the observations	99
A.2.4.3.5	Derivation of results	99
A.2.5	Bending tests on upright sections	100
A.2.5.1	Purpose of the test	100
A.2.5.2	Test arrangement	100
A.2.5.3	Test method	102
A.2.5.4	Corrections to the observations	102
A.2.5.5	Derivation of results	102
A.2.6	Bending tests on beams	102
A.2.6.1	Purpose of the test	102
A.2.6.2	Test arrangement	102
A.2.6.3	Test method	104
A.2.6.4	Corrections to the observations	104
A.2.6.5	Derivation of the results	104
A.3	Tests on connections	105
A.3.1	Bending tests on beam end connectors	105
A.3.1.1	Purpose of the test	105
A.3.1.2	Test arrangements	105
A.3.1.3	Test procedure	107
A.3.1.4	Corrections to the observations	107
A.3.1.5	Derivation of the results and procedure to define curves	108
A.3.1.5.1	Procedure 1:	108
A.3.1.5.2	Procedure 2:	108
A.3.1.5.3	General	108
A.3.1.5.4	Procedure to derive a bi-linear curve	109
A.3.1.5.5	Procedure to derive a multilinear curve	109
A.3.2	Looseness tests on beam end connectors	111
A.3.2.1	Purpose of the test	111
A.3.2.2	Alternative 'A' Test arrangement using a double acting jack	111
A.3.2.2.1	General	111
A.3.2.2.2	Test Method	111
A.3.2.2.3	Corrections to the observations	112
A.3.2.2.4	Derivation of results	112
A.3.2.3	Alternative 'B' using two cantilever beams and a central upright	112
A.3.2.3.1	Test arrangement	112
A.3.2.3.2	Test Method	114
A.3.2.3.3	Corrections to the observations	114
A.3.2.3.4	Derivation of results	114
A.3.3	Shear tests on beam end connectors and connector locks	114
A.3.3.1	Purpose of the test	114
A.3.3.2	Test arrangement	114
A.3.3.3	Test method	116
A.3.3.4	Corrections to the observations	116
A.3.3.5	Derivation of results	116
A.3.4	Moment-shear interaction test of beam end connectors	116
A.3.4.1	Purpose of the test	116
A.3.4.2	Test arrangement	116
A.3.4.3	Test procedure	116
A.3.4.4	Corrections to the observations	116
A.3.4.5	Derivation of the bending and shear resistance	116
A.3.4.6	Derivation of the moment-shear interaction curve	117
A.3.4.7	Generalized moment-shear relationship	117
A.3.5	Floor connections test	117
A.3.5.1	Purpose of the test	117
A.3.5.2	Reuse of concrete blocks	118
A.3.5.3	Alternative 'A' using two lengths of upright with a central concrete block	118
A.3.5.3.1	Test arrangement	118
A.3.5.3.2	Test method	120
A.3.5.4	Alternative 'B' using a single length of upright with an end concrete block	121
A.3.5.4.1	Test arrangement	121

A.3.5.4.2	Test Method	123
A.3.5.5	Corrections to the observations	123
A.3.5.6	Derivation of the Results	123
A.3.6	Upright splices test	124
A.3.6.1	Purpose of the test	124
A.3.6.2	Test arrangement	124
A.3.6.3	Test method	125
A.3.6.4	Corrections to observations	125
A.3.6.5	Derivation of results	125
Annex B (informative) Approximate method		126
B.1	General	126
B.2	Approximate down-aisle stability analysis - Amplified sway method	126
B.2.1	General	126
B.2.2	Amplification factor	128
B.2.3	Linear elastic analysis	128
B.2.4	Elastic critical value	128
B.3	Approximate down-aisle analysis of a regular storage rack	128
B.3.1	Approximate equation for regular construction	128
B.3.2	Additional bending moments due to pattern loading	131
B.3.3	Design Moments	131
B.3.4	Design loads in outer columns	132
B.4	Approximate cross-aisle stability analysis	133
B.4.1	General	133
B.4.2	Global buckling of upright frames	133
B.4.3	Shear stiffness of upright frame	133
B.4.4	Amplification factor	134
B.5	Approximate design for symmetrically loaded beams	137
B.5.1	Mid-span bending moment	137
B.5.2	Deflection	138
B.5.3	Shear force	138
B.5.4	Beam end connector	139
B.5.5	Equivalent beam loads	139
Annex C (informative) Correction of beam moments and deflection due to looseness		141
Annex D (informative) Frame looseness		143
D.1	General	143
D.2	Frame bracing types	143
D.3	Looseness	144
Annex E (normative) Resistance of compression member according to EN 1993-1-1 and -3		146
E.1	Cross-sectional verification	146
E.2	Design strength with respect to flexural buckling	146
E.2.1	General	146
E.2.2	Buckling curves	147
E.3	Design strength with respect to torsional and torsional-flexural buckling	148
E.4	Combined bending and axial loading	149
E.4.1	General	149
E.4.2	Bending and axial compression - resistance of cross-section	149
E.4.3	Bending and axial compression - buckling resistance of member	150
E.4.4	Bending and tension	153
Annex F (informative) Guidance to the determination of the critical length for the distortional buckling test		154
F.1	Introduction	154
F.2	Length in relation to the end conditions in the test set-up	154
F.3	Method for the determination of the critical distortional buckling length	155

F.3.1	Step 1	155
F.3.2	Step 2	155
F.3.3	Step 3	157
F.3.4	Step 4	157
F.3.5	Step 5	157
F.3.6	Step 6	157
Annex G (informative) Equivalent section properties		159
Annex H (informative) Guidance to modelling spine bracing in braced pallet racking		162
Annex I (informative) Cold-reduced steel		170
Annex J (informative) Systems with random storage		171
Annex K (informative) Position inaccuracies		172
Annex L (informative) Beam stability - comprising interlocking `C' sections		173
L.1	General	173
L.2	Approximate limit values	173
Annex M (informative) Factory production control (FPC)		175
M.1	General	175
M.2	Frequency of tests	175
M.3	Bending tests on beam end connectors	175
M.4	Bend tests	175
Annex N (informative) A-deviations		176
N.1	"Dutch national legislative deviations"	176
Annex O (informative) Bituminous floors		178
Annex P (informative) Typical loading pattern for a regular rack layout		179
Bibliography		181