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