ANSI MH16.1: 2012
(a revision of MH16.1: 2008)

Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks

Abstract:

The standard applies to industrial pallet racks, movable shelf racks, and stacker racks made of cold-formed or hot-rolled steel structural members. It does not apply to other types of racks, such as drive-in or drive-through racks, cantilever racks, portable racks, etc. or to racks made of material other than steel.

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V12a

American National Standard

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Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks

Rack Manufacturers Institute (RMI)

An Affiliated Trade Association of Material Handling Industry of America (MHIA),
MHIA is a Division of Material Handling Industry

Approved January 13, 2012

American National Standards Institute, Inc.

Disclaimer

FOREWORD. This Standard, approved by ANSI on January 13, 2012, was developed under Material Handling Industry's (MHI) ANSI approved procedures, and represents suggested design practices and operational requirements for Industrial Steel Storage Racks. It was developed by the Rack Manufacturers Institute (RMI), and is intended to provide useful information and guidance for owners, users, designers, purchasers and/or specifiers of material handling equipment or systems. It is advisory only and should only be regarded as a simple tool that its intended audience may or may not choose to follow, adopt, modify, or reject. The following information does not constitute a comprehensive safety program, cannot guard against pitfalls in operating, selecting and purchasing such a system, and should not be relied upon as such. Such a program should be developed, and an independent adviser should be consulted in doing so.

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Foreword (This foreword is not part of American National Standard MH16.1:2012)

RACK MANUFACTURERS INSTITUTE

The Rack Manufacturers Institute (RMI) is an independent incorporated trade association affiliated with the Material Handling Industry. The membership of RMI is made up of companies which produce the preponderance of industrial steel storage racks and Welded Wire Rack Decking used in the USA.

RMI maintains a public website at www.MHIA.org/RMI that has information about storage racks and the RMI members including ordering information for literature and a section for frequently asked questions. All inquiries concerning the Specification should be directed in writing to the RMI Engineering Committee, 8720 Red Oak Boulevard, Suite 201, Charlotte, NC 28217.

MATERIAL HANDLING INDUSTRY

The Material Handling Industry (MHI) provides RMI with certain services and, in connection with this Specification, arranges for its production and distribution. Neither the Material Handling Industry nor its officers, directors, or employees have any other participation in the development and preparation of the information contained in the Specification.

SPECIFICATION - HISTORY

In the interest of improved uniformity of rack performance and enhanced public safety, the RMI published in 1964 its first “Minimum Engineering Standards for Industrial Storage Racks”, and now publishes this Specification. It was developed and promulgated by the RMI with the sole intent of offering information to the parties engaged in the engineering, manufacturing, marketing, purchasing, installation, inspection, permitting or use of such racks.

Since 1964, mechanized storage systems have grown very rapidly both in size and height with new and modified types of racks having been developed. To reflect this rapid development and to assure adequate safety and performance of modern rack structures, the RMI decided early in 1971 to replace its original standards by a more detailed and comprehensive specification. Professors George Winter and Teoman Pekoz of Cornell University were retained to assist the Rack Standard Development Project Committee in producing such a document. The members of the Material Handling Institute, Inc. were the sponsors.

In 1972, the “Interim Specification for the Design, Testing and Utilization of Industrial Steel Storage Racks” was adopted by the Rack Manufacturers Institute at their annual fall meeting. The specification was then submitted to the American National Standards Institute for their review and acceptance. In 1974, the Interim Specification with minor changes was accepted as American National Standard ANSI MH 16.1-1974.

The Rack Manufacturers Institute together with its sponsors from the Material Handling Institute, Inc., retained Professors Winter and Pekoz to continue testing rack components plus perform full scale tests on typical storage rack structures. A number of the test results have been analyzed, and it was considered necessary to rewrite the 1972 Interim Specification to include the knowledge gained from the analysis of those tests. The 1972 Interim Specification was rewritten by the Rack Standards Subcommittee with the assistance of Professors Winter and Pekoz. Design parameters relating to drive-in and drive-through racks have been removed from the Specification until drive-in and drive-through rack test results could be analyzed more thoroughly; perhaps more testing would be required. Movable-shelf racks were added to the Specification.

As a result of additional testing and analytical research, the RMI revised the 1972 Specification. The ANSI MH 16.1-1974 was withdrawn in deference to the 1979 Specification. More additions and revisions prompted the RMI to publish the 1985 Specification.

Subsequent testing and research by Dr. Pekoz was the basis of the changes resulting in the 1990 Specification.

From 1990 to 1997, due to continuing changes, specifically as they relate to seismic analysis and other model building code issues, the Specification Advisory Committee, the Seismology Committee and the RMI Engineering Committee working again with Dr. Pekoz and several highly regarded members of the code community and various other members of similar groups throughout the world, conducted extensive testing and parametric analysis. Findings resulted in the 1997 Specification.

In addition to the state-of-the-art benefit from the ongoing testing and analysis, the 1997 Specification was expanded to include complete treatment of seismic design considerations so that the Specification could be more easily incorporated by reference into various model building and design codes.

In 1999, the Membership of RMI acted to create a Voluntary Certification Program known as the R-MARK. The R-Mark is a license earned by a manufacturer following a rigorous review by independent professional engineers of tests and load capacity calculations performed by the manufacturer consistent with the RMI/ANSI Specification.

Continued testing and parametric studies resulted in the 2002 Specification. In 2004 the 2002 RMI Specification and Commentary were adopted as American National Standard ANSI MH 16.1-2004.

The 2008 RMI Specification (ANSI MH 16.1-2008) incorporated the results from the FEMA 460 document, which was published in September, 2005. In addition, the symbol and nomenclature tables were added. The seismic section was updated going from the old A_a and A_v values to the current S_s and S_1 values utilized by the USGS. A section on Connection Rotational Capacity was added. The Column Base Plate section was updated. A section on shims was added. A section on Pick Modules and Rack Supported Platforms was added. The section on Automated and Manual Storage and Retrieval Systems was taken out of the appendix and incorporated into the Specification. A section for Cyclic Testing of Beam-to-Column Connections was added.

SPECIFICATION - 2012 EDITION

The use of this Specification is permissive, not mandatory. Voluntary use is within the control and discretion of the user and is not intended to, and does not in any way limit the ingenuity, responsibility or prerogative of individual manufacturers to design or produce industrial steel storage racks that do not comply with this Specification. The RMI has no legal authority to require or enforce compliance with the Specification. This advisory Specification provides technical guidelines to the user for his specific application. Following the Specification does not assure compliance with applicable federal, state, or local regulations and codes. This Specification is not binding on any person and does not have the effect of law.

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In the interest of safety, all users of storage racks are advised to regularly inspect and properly maintain the structural integrity of their storage rack systems by assuring proper operational, housekeeping and maintenance procedures.

Users of the Specification must rely on competent advice to specify, test and/or design the storage rack system for their particular application. This Specification is offered as a guideline. If a user refers to, or otherwise employs, all or any part of the Specification, the user is agreeing to follow the terms of indemnity, warranty disclaimer, and disclaimer of liability.

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SYMBOLS

SYMBOL	DEFINITION	FIRST APPEARS IN SECTION
A	Sum of the minimum net area ($A_{net\ min.}$) of the columns of the upright frame	6.4
A_b	Cross-sectional area of a horizontal brace	6.4
A_d	Cross-sectional area of a diagonal brace	6.4
A_e	Effective area at the stress F_n	4.1.3.1
$A_{net\ min}$	Minimum cross-sectional area obtained by passing a plane through the column normal to the axis of the column	9.2.2
C_d	Deflection amplification factor	2.6.4
C_s	Seismic response coefficient	2.6.2
C_w	Torsional warping constant	4.1.3.1
D	Dead load	2.1
E	Earthquake (seismic) Load	2.1
E	Modulus of elasticity of steel	6.4
F	Joint spring constant	C5.2
F_1	Lateral force at the first shelf level	2.6.7
F_a	Site coefficient defined in Table 2.6.3.2 (2).	2.6.3.2
F_c	Critical buckling stress	4.1.2
F_i	Portion of base shear induced at level i	2.6.8
F_n	Nominal buckling stress	4.1.3.1
F'_p	Maximum allowable bearing stress	7.2.1
F_v	Site coefficient defined in Table 2.6.3.2 (3).	2.6.3.2
F_x	Lateral force at any level	2.6.7
F_y	Yield point used for design	9.2.2
H	Total lateral force above shelf elevation being evaluated	C2.6.3
H	Horizontal load per beam	C9.4.2.3
I	Impact loading on a shelf	2.1
I	Minimum net moment of inertia of the columns about the gravity axis of the upright frame perpendicular to the plane of the upright frame	6.4
I_b	The beam moment of inertia	C5.2

I_{br}	Moment of inertia of the horizontal brace about its own axis perpendicular to the plane of the upright frame	6.4
I_c	Minimum net moment of inertia of one column about its own major axis perpendicular to the plane of the upright frame	6.4
I_p	System importance factor	2.6.2
I_x	Column moment of inertia about the x-axis	C2.6.3
K	Effective length factor	6.3.1.2
K_b	Base rotational stiffness	7.1.3
K_t	Effective length factor for torsional buckling	6.3.3.2
K_x	Effective length factor for story buckling in the down-aisle direction	C2.6.4
L	Live load other than the pallets or products stored on the racks	2.1
L	Column span length	C2.6.3
L	Span of the beam	C5.2
L	Clear span between shelf beams	C5.5
L	Distance between the centroid of the two columns parallel with the shelf beam	C9.4.2.3
L_b	Actual span of the pallet beams	C6.3.1.1
L_{c1}	Distance from the floor to the first beam level	C6.3.1.1
L_{c2}	Distance from the first beam level to the second beam level	C6.3.1.1
L_r	Roof live load	2.1
L_{short} **and** L_{long}	Distance between column brace points	6.3.2.2
L_x, L_y **and** L_t	Unbraced lengths for column design, for bending about x- and y-axes and for torsion	6.3
M_b	Base moment	7.1.3
M_e	Beam end moment	C5.2
N	Effective length of the base plate in the down-aisle direction	7.1.2.3
N_b	Number of base plate connections	C2.6.4
N_c	Number of beam-to-column connections	C2.6.4
P	Maximum load from pallets or products stored on the racks	2.1
$P_{Average}$	Maximum total weight of product expected on all beam levels in any row divided by the number of	2.6.2

	beam levels in that row	
$P_{Maximum}$	Maximum weight of product that will be placed on any one beam level in a row	2.6.2
P_{rf}	Product load reduction factor ($P_{Average}$ / $P_{Maximum}$)	2.6.2
P_{app}	Portion of pallet or product load that is used to compute the seismic base shear	2.1
P_{cr}	Critical elastic buckling load	6.4
P_n	Nominal axial strength	4.2
Q	Capacity reduction factor for compressive members	9.2.2
R	Load from rain including ponding	2.1
R	Seismic response modification factor	2.6.3
R.F.	Reduction Factor	C9.4.2.3
S	Snow load	2.1
S_{D1}	Design spectral response acceleration parameter for 1second period, (2/3) S_{M1}	2.6.3
S_{DS}	Design spectral response acceleration parameter for a 0.2 second (short) period, (2/3) S_{MS}	2.6.3
S_{M1}	Maximum considered earthquake spectral response accelerations for 1second period	2.6.3.1
S_{MS}	Maximum considered earthquake spectral response accelerations for a 0.2 second (short) period	2.6.3.1
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S_e	Elastic section modulus of the net section for the extreme compression fiber times (0.5+Q/2)	4.1.2
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S_1	Mapped spectral accelerations for a 1-second period as determined by the USGS	2.6.3.2
T	Fundamental period of the rack structure in each direction under consideration	2.6.3
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V_x	Seismic design shear at any level	2.6.8
W	Wind load	2.1
W	Total load on each beam	C5.2
W	Unit Load divided by the number of pallet supports under load	C5.5

W_i	Loads on each level of the structure that are used to compute the period, D + (0.67xP) + (0.25xL)	C2.6.3
W_{pi}	The weight on the rack that amplifies the drift	C2.6.4
W_s	Loads on the structure that are used to compute the horizontal base shear, D + (0.67xP_{rf}xP) + (0.25xL)	2.6.2
a	Vertical distance between the horizontal brace axes	6.4
b	Horizontal distance between neutral axes of the columns	6.4
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d	Depth of the column (perpendicular to the flexure axis)	C6.3.1.1
ec	Center of gravity of the load closest to the pallet support	C5.5
f '$_c$	Minimum 28-day compression strength of the concrete floor	7.1.1
g	Acceleration due to gravity	C2.6.3
h	Distance from the floor to the top of the beam	C9.4.2.3
h_i or h_x	Height from the base to level i or x	2.6.7
h_{total}	Height of the top shelf level	2.6.4
k	Upright frame stability coefficient based on location of the center of load	6.4
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k_{be}	Beam end rotational stiffness	C2.6.4
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k_{ce}	Bottom column end rotational stiffness	C2.6.4
l	Total height of the upright frame	6.4
w_i or w_x	Portion of the total gravity load of the rack, located or assigned to the bottom shelf level, level i or x	2.6.7
β	Seismic Product Load Coefficient	2.1
δ	Sway deflection corresponding to a lateral load of 2H	C9.4.2.3
Δ_i	Total lateral displacement at level, i	C2.6.3
$\Delta_{i,1}$	Primary deflection just below the level being evaluated	C2.6.3

Δ_p	Primary story drift	C2.6.3
Δ_s	Seismic displacement at height of the top shelf	2.6.4
$\boldsymbol{\theta_D}$	Rotational seismic demand of the beam-to-column connection	2.6.4
$\boldsymbol{\theta_{Max}}$	Maximum rotation sustained by the beam-to-column connection over at least 2 cycles during testing	2.6.4
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$\boldsymbol{\phi P_p}$	Design bearing load	7.1.1
$\boldsymbol{\Omega}$	Factor of safety for ASD	C2.1
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α_s	Second-order amplification factor calculated using W_{pi} as the vertical load.	2.6.4
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ρ	redundancy factor for earthquake loading	2.1

NOMENCLATURE

Note: Terms designated with † are common with AISI-AISC terms that are coordinated between the standards developers.

Automated Storage and Retrieval Systems - A rack structure in which loading and unloading of the racks is accomplished by a stacker crane, or similar vehicle, without the aid of an on-board operator.

Allowable Strength† - Nominal strength divided by the safety factor.

Allowable Strength Design (ASD)† - Method of proportioning structural components such that the allowable strength equals or exceeds the required strength of the component under the action of the ASD load combinations.

Allowable Stress. - Allowable strength divided by the appropriate section property, such as section modulus or cross-sectional area.

Applicable Code† - Code (enforced by the local building department) under which the structure is designed.

ASD Load Combination† - Load combination in the applicable building code intended for allowable strength design (allowable stress design).

Beam – Typically, a horizontal structural member that has the primary function of resisting bending moments.

Beam Locking Device - A pin, bolt, or other mechanism that resists disengagement of the beam connector from the column.

Braced Frame† - An essentially vertical truss system that provides resistance to lateral forces and provides stability for the structural system.

Bracing Towers - A bracing system consisting of two vertical plane bracings parallel to main aisle and joined at each load elevation with plan bracing. One of the vertical braces is located at the front column vertical plane and the second at the rear column vertical plane.

Buckling - Limit state of sudden change in the geometry of a structure or any of its elements under a critical loading condition.

Buckling Strength - Nominal strength for buckling or instability limit states.

Cantilever Rack - A rack structure comprised primarily of vertical columns, extended bases, horizontal arms projecting from the face of the columns, and down-aisle bracing between columns. There can be shelf beams between arms depending on the product being stored. Cantilever columns may be free-standing or overhead tied.

Cantilever Test - A test designed and conducted to determine the connection moment-resisting capacity and the rotational rigidity, F, of a beam-to-column connection. The test set-up employs one column segment and one beam segment connected to one another with a beam-to-column connector, with a load applied downwardly in the plane of the frame at the cantilever end of the beam segment.

Case-Flow Rack - A specialized pallet rack structure in which either the horizontal shelf beams support case-flow lanes or case-flow shelf assemblies are supported by the

upright frames. The case-flow lanes or shelves are installed at a slight pitch permitting multiple-depth case or box storage with loading from one service aisle and unloading or picking from another service aisle.

Cladding - Exterior covering of structure.

Cold-Formed Steel Structural Member† - Shape manufactured by press-braking blanks sheared from sheets, cut lengths of coils or plates, or by roll forming cold- or hot-rolled coils or sheets; both forming operations being performed at ambient room temperature; that is, without manifest addition of heat, such as would be required for hot forming.

Column - Structural member that has the primary function of resisting axial force.

Concrete Crushing - Limit state of compressive failure in concrete having reached the ultimate strain.

Concurrent Forces - Two or more forces acting in conjunction with one another at a single location.

Connection† - Combination of structural elements and joints used to transmit forces between two or more members.

Cross-Aisle – One of the two principal directions of the storage rack, corresponding to the direction perpendicular to the principal handling equipment aisle. This is also referred to as the transverse direction.

Cyclic Tests - A test designed and conducted to determine the connection's earthquake loading moment-resisting and inelastic rotational capacity and its rotational stiffness, along with energy-dissipation properties, of beam-to-column connections when those connections are subjected to cyclic loading conditions. The test set-up employs one column segment and two beam segments connected to one another, using two beam-to-column connectors, as a double cantilever. Two parallel loads are applied, in opposing reversing cyclic fashion, in the plane of the frame at the ends of, and normal to, the cantilevered beam elements.

Design Load† - Applied load determined in accordance with either LRFD load combinations or ASD load combinations, whichever is applicable.

Design Strength† - Resistance factor multiplied by the nominal strength, ΦR_n.

Design Stress - Design strength divided by the appropriate section property, such as section modulus or cross-sectional area.

Diagonal Bracing - Inclined structural member carrying primarily axial force in a braced frame.

Distortional Buckling - A mode of buckling involving change in cross-sectional shape, excluding local buckling.

Double-Stacking - When a shelf is loaded with loads stacked one on top of another in a pallet position.

Down-Aisle – One of the two principal directions of the storage rack, corresponding to the direction of the principal handling equipment aisle. This is also referred to as the longitudinal direction.

Drive-In Rack - A rack structure comprised primarily of vertical upright frames, horizontal support arms, and horizontal load rails typically used for one-wide by multiple-depth storage. This structure includes an 'anchor section' with horizontal beams supporting the load rails. Loading and unloading within a bay must be done from the same aisle. A two-way drive-in rack is a special case where back-to-back rows of drive-in racks are combined into a single entity with a common rear post.

Drive-Through Rack - A rack structure comprised primarily of vertical upright frames, horizontal support arms, and horizontal load rails typically used for one-wide by multiple-depth storage. This structure lacks the 'anchor section' found in drive-in racks; therefore, loading and unloading from can be accomplished from both ends of a bay.

Effective Length - Length of an otherwise identical column with the same strength when analyzed with pinned-end conditions.

Effective Length Factor - Ratio between the effective length and the unbraced length of the member.

Effective Section Modulus - Section modulus reduced to account for buckling of slender compression elements.

Effective Width - Reduced width of a plate or slab with an assumed uniform stress distribution which produces the same effect on the behavior of a structural member as the actual plate or slab width with its non-uniform stress distribution.

Factored Load† - Product of a load factor and the nominal load.

Flexural Buckling - Buckling mode in which a compression member deflects laterally without twist or change in cross-sectional shape.

Flexural-Torsional Buckling† - Buckling mode in which a compression member bends and twists simultaneously without change in cross-sectional shape.

Force - Resultant of distribution of stress over a prescribed area.

Frame – See Upright Frame

Guardrails - Members that are installed on an elevated rack supported platform or pick module walkway whose purpose is to provide fall protection for the occupants of the structure. Guardrails consist of a top rail, an intermediate rail and posts.

Gravity Load - Load such as that produced by product, dead and live loads, acting in the downward direction.

Handrail – Smooth, continuous railing that runs up a stairway assembly to provide added balance and safety for the occupants as they walk up or down the stairway assembly.

Kick-Plate (Toeboard) – A vertical plate (angle or barrier) that is installed at the edge of an elevated floor that is intended to prevent loose items from sliding off the edge of the floor.

Load Factor† - Factor that accounts for deviations of the nominal load from the actual load, for uncertainties in the analysis that transforms the load into a load effect, and for the probability that more than one extreme load will occur simultaneously.

Load and Resistance Factor Design (LRFD)† - Method of proportioning structural components such that the design strength equals or exceeds the required strength of the component under the action of the LRFD load combinations.

Local Buckling - Limit state of buckling of a compression element within a cross-section.

LRFD Load Combination† - Load combination in the applicable building code intended for strength design (load and resistance factor design).

Movable-Shelf Rack - A rack structure comprised primarily of vertical upright frames and horizontal shelf beams and typically used for one-deep pallet or hand-stack storage. Typically, the locations of a couple of shelf levels are 'fixed' with the location of the in-fill shelves being flexible.

Net Area - Gross area reduced to account for removed material.

Nominal Strength† - Strength of a structure or component (without the resistance factor or safety factor applied) to resist load effects, as determined in accordance with this Specification.

Out-Of-Plumb Ratio - Maximum horizontal distance (inches or mm) from the centerline of the column at the floor to a plumb line that extends downward from the centerline of the column at the top shelf elevation divided by the vertical distance (feet or m) from the floor to the top shelf elevation.

Out-Of-Straight Ratio – Maximum horizontal distance (inches or mm) from the centerline at any point on the column to a plumb line from any other point on the column divided by the vertical distance (feet or m) between the two points.

Overturning Moment - An applied force that causes a structure to turn over.

Pallet Beam - The front and back shelf members that bear the weight of the load and transfer the load to the upright frames.

Pallet-Flow Rack - A specialized pallet rack structure in which the horizontal shelf beams support pallet-flow lanes. The pallet-flow lanes are typically installed on a slight pitch permitting multiple-depth pallet storage with loading from one service aisle and unloading from another service aisle.

Pallet-Load Support Member - Any load bearing member with the long axis on the horizontal plane and intended for use as support of unit loads in direct contact. (pallet and shelf supports and beams, not bracing).

Pallet Rack - A rack structure comprised primarily of vertical upright frames and horizontal shelf beams and typically used for one and two-deep pallet storage.

Pallet Support – A member that extends between the shelf beams at a given level underneath the stored load that aids in the support of that load.

Pick Modules - A rack structure comprised primarily of vertical frames and horizontal beams, typically having one or more platform levels of selective, case-flow, or pallet-flow bays feeding into a central pick aisle(s) [work platform(s)] supported by the rack structure.

Plan and Back Bracing - A bracing system including bracing parallel to the main aisle of the rack located at the back of the rack row and horizontal bracing from the aisle column to the rear braced points.

Plaque – Signage permanently and prominently displayed depicting the permissible loading of the rack.

Portable Rack (Stacking Frames) - An assembly, typically with four corner columns, that permits stacking of one assembly on top of another without applying any additional load to the product being stored on each assembly.

Portal Test - A test designed and conducted to determine the connection moment-resisting capacity and the rotational rigidity, F, of a beam-to-column connection. The test set-up employs two column segments and one beam segment connected to one another using two beam-to-column connectors forming a portal frame, with the load applied laterally in the plane of, and to the corner of, the portal frame in the direction parallel to the beam segment.

Product Load - The weight of the item(s) placed on the rack.

Push-Back Rack - A specialized pallet rack structure in which the horizontal shelf beams support push-back lanes comprised of tracks and carts. The push-back lanes are installed on a slight pitch permitting multiple-depth pallet storage. Loading and unloading are done from the same service aisle by pushing the pallets back.

Rack-Supported Platforms - A decked working surface supported by the rack structure.

Rack-Supported Structure - A rack structure similar to other rack structures; however, this structure also includes wall girts and roof purlins or equivalent components used to support wall and roof cladding. This structure is designed to withstand wind and snow or rain loads in addition to the normal storage rack loads.

Redundancy Factor – Factor that accounts for the potential of structural distress when the system has lost the carrying capacity of one seismic load carrying element.

Resistance Factor† - Factor that accounts for unavoidable deviations of the nominal strength from the actual strength and for the manner and consequences of failure.

Risk Category – Classification of structures based on the nature of their use.

Safety Factor† - Factor that accounts for deviations of the actual strength from the nominal strength, deviations of the actual load from the nominal load, uncertainties in the analysis that transforms the load into a load effect, and for the manner and consequences of failure.
The nominal load divided by the safety factor results in the allowable load for an Allowable Strength Design.

Safety Flooring - A surface that is provided in areas where order picking personnel may need to step off the normal walking area or pick module walkway to dislodge loads that may not have properly flowed to their correct position.

Seismic Design Category – A classification assigned to a structure based on its Risk Category and the severity of the design earthquake ground motion at the site.

Seismic Response Modification Coefficient - Factor that reduces seismic load effects to strength level.

Sidesway Buckling - Buckling mode where there is translation of the top of the column with respect to the bottom of the column. This mode is also referred to as story buckling and is a buckling mode for the unbraced direction of a pallet rack row.

Simple Lip – Single plate elements used to stiffen a compression flange.

Site Class Definition - A classification assigned to a location based on the types of soils present.

Stability - Condition reached in the loading of a structural component, frame or structure in which a slight disturbance in the loads or geometry does not produce large displacements.

Stacking Rack – See Portable rack

Stacker Rack - A rack structure similar to one of the other rack structures that is serviced by an automated storage and retrieval machine.

Stiffness - Resistance to deformation of a member or structure, measured by the ratio of the applied force (or moment) to the corresponding displacement (or rotation).

Stress - Force per unit area caused by axial force, moment, shear, or torsion.

Structural System - An assemblage of load-carrying components that are joined together to provide interaction or interdependence.

Stub-Column Test – Concentric compression testing of members, not affected by column buckling, used to determine the column effectiveness.

Torsional Buckling - Buckling mode in which a compression member twists about its shear center axis.

Torsional-Flexural Buckling. - Buckling mode in which compression members bend and twist simultaneously without change in cross sectional shape.

Trussed-Braced Upright Frame – Upright frames having two columns similar to the chords of a truss and diagonal and horizontal bracing attached to and located between the columns. The diagonals and horizontals become the web members of the truss. (It is referred to as a vertical truss.)

Unbraced Length - Distance between braced points of a member, measured between the centers of gravity of the bracing members.

Unit-Load - The total weight expected to be positioned in the rack consisting of the product load and pallet weight.

Upright Frame – A structural assembly that transfers the vertical and horizontal loads to the floor. It is usually made up of two columns and bracing members between the columns. The beams of the rack are attached to the columns of the frames and transfer the loads to the columns.

Vertical Impact Load - Additional downward force added to the beams produced during loading of the rack.

Welded-Wire Rack Deck – A decking system used on pallet rack shelves. Wire decking is fabricated from welded-wire mesh and generally has reinforcements in the form of channels or support wires. Its purpose is to provide additional support for stored material, as well as, becoming a safety net for unstable loads.

Yield Point† - First stress in a material at which an increase in strain occurs without an increase in stress as defined by ASTM.

Yield Strength† - Stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain as defined by ASTM.

SPECIFICATION FOR THE DESIGN, TESTING AND UTILIZATION OF INDUSTRIAL STEEL STORAGE RACKS

1. GENERAL

1.1 SCOPE

This Specification and companion Commentary (hereinafter referred to as the Specification) applies to industrial steel storage racks, movable-shelf racks, rack-supported systems and automated storage and retrieval systems (stacker racks) made of cold-formed or hot-rolled steel structural members. Such rack types also include push-back rack, pallet-flow rack, case-flow rack, pick modules, and rack-supported platforms. This Specification is intended to be applied to the design of the storage rack portion of any rack structure that acts as support for the exterior walls and roof, except as noted. It does not apply to other types of racks, such as drive-in or drive-through racks, cantilever racks, portable racks, or to racks made of material other than steel.

1.2 MATERIALS

This Specification assumes the use of steel of structural quality as defined by the specifications of the American Society for Testing and Materials (ASTM) that are listed in the American Iron and Steel Institute (AISI) North American Specification for the Design of Cold-Formed Steel Structural Members [1][1], and the American Institute of Steel Construction (AISC) Specification for Structural Steel Buildings [2].

Steels not listed in the above specifications are not excluded provided they (a) conform to the chemical and mechanical requirements of either reference [1] or [2] or other published specifications, which establish their properties and structural suitability and (b) are subjected either by the producer or the purchaser to analyses, tests, and other controls in the manner prescribed by either reference [1] or [2] as applicable.

1.3 APPLICABLE DESIGN SPECIFICATIONS

Except as modified or supplemented in this Specification, the AISI [1] shall be used for the design of cold-formed members and the AISC [2] shall be used for the design of hot-rolled members. These specifications shall be used to determine the available strength and stiffness of industrial steel storage racks.

1.4 INTEGRITY OF RACK INSTALLATIONS

1.4.1 Owner Maintenance

The owner shall maintain the structural integrity of the installed rack system by assuring proper operational, housekeeping, and maintenance procedures including, but not limited to, the following:

[1] Numbers in brackets refer to corresponding numbers in Section 10, References to the Text.