Steel storage racking

Part 1: Design

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Australian Standard®

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Section 1 Scope and general

1.1 Scope

This document sets out minimum requirements for the analysis, design and test methods associated with steel storage racking in the limit states method.

This document applies to adjustable static pallet racking made of cold-formed or hot-rolled steel structural members. It covers racking installed within a building, outside a building, and racking that forms part of the frame of the building.

This document does not cover the following:

(a) Drive-in and drive-through racking.

(b) Cantilever racking.

(c) Standalone hand loaded shelving systems up to 3.0 metres high where the unit load does not exceed 25 kg.

(d) Mobile racking.

(e) Racking made of materials other than steel.

NOTE 1 Refer to FEM 10.2.07 for guidance for the design of drive-in and drive-through racking. Refer to FEM 10.2.09 for guidance for the design of cantilever racking. Refer to FEM 10.2.06 for guidance for the design of standalone hand loaded shelving systems up to 3.0 metres high where the unit load does not exceed 25 kg.

NOTE 2 Refer to AS 4084.2 for details associated with operation and maintenance, dimensions and tolerances of steel storage racking.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents referenced for informative purposes are listed in the Bibliography.

AS 1170.4, *Structural design actions, Part 4: Earthquake actions in Australia*

AS 1391, *Metallic materials — Tensile testing — Method of test at room temperature*

AS 1657, *Fixed platforms, walkways, stairways and ladders—Design, construction and installation*

AS 4100, *Steel structures*

AS 5216, *Design of post-installed and cast-in fastenings in concrete*

AS/NZS 1170.0, *Structural design actions, Part 0: General principles*

AS/NZS 1170.1, *Structural design actions, Part 1: Permanent, imposed and other actions*

AS/NZS 1170.2, *Structural design actions, Part 2: Wind actions*

AS/NZS 4600, *Cold-formed steel structures*

ϕ_V = capacity factor for shear

ϕ_X = global imperfection acting in the down-aisle direction

ϕ_Z = global imperfection acting in the cross-aisle direction

ρ = true load amplification factor, equal to the ratio of the action on the beam arising from pallets placed with maximum misalignment, to the corresponding action on the beam arising from pallets placed in the perfect position

Ψ_A = average unit load factor for global static design (1.0 if unknown)

Ψ_M = rigid mass factor for seismic weight calculation

Ψ_{EX} = occupancy factor for global down-aisle design

Ψ_{EZ} = occupancy factor for global cross-aisle design

ω_{max} = maximum value of sectorial coordinate

1.5 Use of alternative materials or methods

This document assumes the use of steel of structural quality as specified in AS/NZS 4600 for the design of cold-formed steel structural members and AS 4100 for the design of hot-rolled steel structural members. This document does not prevent the use of materials, methods of assembly, procedures and the like that do not conform with the specific requirements of this document, or are not mentioned in it, provided the minimum dimensional and performance requirements specified herein are met.

1.6 Localized fires

If the sprinkler system within a rack is activated for a localized fire at the the base of an upright, the uprights shall be designed according to AS/NZS 4600:2018 Section 9 for a maximum temperature of 200 °C for the fire limit state load case combination defined in AS/NZS 1170.0.

1.7 End frame extensions

End frame extensions shall be installed where the end frame is adjacent to a trafficable aisle (trafficable by pedestrians, fork lift trucks or any other vehicles). Where required, an end frame extension shall be at least 50 % of the height of the unit loads to be stored on the uppermost pallet beam. If the usage of an aisle adjacent to an end frame changes so that it becomes trafficable, end frame extensions shall be installed.

1.8 Retrospectivity and upgrading

The requirements of this document do not apply retrospectively to racking installations designed, fabricated and installed in accordance with the previous edition of AS 4084:2012. However, if an existing racking installation has its components modified or substituted with an alternative product, has its geometry modified, has the magnitude or location of unit loads modified, or is moved from one site to another, then such racking installations shall be upgraded to the current edition of AS 4084.

values shall be used. The concentrated actions applied by upright frames directly supported by a flooring system shall be accounted for.

Where moving equipment applies dynamic forces to the structure, these effects shall be taken into account as quasi-static actions. In order to distinguish between the effective vertical wheel actions of the different types of trucks, the relevant static forces shall be multiplied by the dynamic factors given in Table 2.3.6.

Table 2.3.6 — Dynamic factor

Truck type	Dynamic factor
Pedestrian controlled truck with velocity less than 5.0 km/h	1.2
Ride-on truck with a velocity less than 7.5 km/h	1.4
Ride-on truck with a velocity less than 10.0 km/h	2.0

When repeated cycles of rolling loads are involved, fatigue design shall be taken into account.

The effects of horizontal forces applied by the equipment shall be accommodated by the structure.

2.3.7 Actions arising from installation or repair

When the installation method requires the installers to use safety harnesses, anchorage points capable of arresting an accidental fall shall be provided.

NOTE Residual deformation of the members can occur in the event of a fall.

2.4 Accidental actions

2.4.1 General

Accidental actions are defined as impact actions which are more severe than those which occur under ordinary "good practice" operating conditions.

Provision shall be made in the structural design for uses and actions that involve unusual vibration or dynamic forces.

The minimum requirements for the protection of corner uprights shall be as follows:

(a) An upright protector with a height of not less than 400 mm shall be positioned at the end upright of each run of racking between cross-aisles.

(b) An upright protector shall be positioned at all those uprights positioned at aisle and gangway intersections.

(c) The upright protector shall be designed for an energy absorption of not less than 400 Nm in any direction at any height between 0.1 m and 0.4 m.

(d) The upright protector shall be positioned in such a way that, after its deformation by absorbing an impact, the upright will not be damaged.

NOTE 1 Uprights other than corner uprights may be protected in a direction normal to the aisle, depending on the preference of the user.

NOTE 2 The protection of uprights of racking served by mechanically guided handling equipment may not be necessary.

NOTE 3 As an alternative to the use of upright protectors, the installation may be designed to survive the complete removal of a section at the bottom of an upright.

4.2.4 Design based on GMNIAs structural analysis

For the strength limit state, the following shall be satisfied:

(a) For the ultimate limit state, the members shall be required to support the factored limit states actions multiplied by $1/\phi$, where $\phi = 0.9$.

(b) The connections shall satisfy the requirements of AS/NZS 4600:2018 Section 5, or the design actions shall be limited to —

  (i) the moment and shear capacities of the connections determined by testing in accordance with Clauses 7.5.1 and 7.5.4, respectively, and Clause 7.9 for base plate connections; and

  (ii) the combined moment and shear capacity in accordance with Clause 4.2.3(b) .

4.2.5 Serviceability criteria

In determinations of serviceability, the fully loaded racking with the actions arising from the imperfections as specified in Clauses 3.3.2.1 and 3.3.2.2 shall be taken into account. Placement or accidental actions need not be taken into account. It shall be verified that under these actions the sway of the racking is less than $h/200$, where h is the total height of the racking.

Where required by frame classification in accordance with Clause 3.3.8, this analysis shall take second-order effects into account.

NOTE Sway is the horizontal movement in addition to any initial out-of-plumb.

In the serviceability limit state, pallet beam deflections shall not exceed 1/180 of the span measured relative to the ends of the beam.

The serviceability limit state requirements for tolerance grade III racking may exceed the minimum criteria specified above depending on the requirements of the storage and retrieval equipment used.

Section 6 Connections and base plates

6.1 General

Adequate strength of connections to withstand the calculated resultant forces and moments, and adequate rigidity where required, shall be established by test or, where possible, by calculation. Test procedures for various connections are specified in Section 7.

6.2 Pallet beam connections

Pallet beams shall have connection locking devices (or bolts) capable of withstanding an accidental upward force of 5 kN per connection without failure or disengagement. This requirement is met if a Grade 4.6 M6 bolt is installed.

The strength, rigidity and looseness of the connection shall be determined by testing. Alternatively, the initial rigidity of the connection may be determined by calculation as specified in Appendix E.

6.3 Base plates

6.3.1 General

The design of base plates specified in Clause 6.3.2 applies to concrete floor slabs only. For further information on other types of floors, refer to EN 15512.

The floor slab and its supporting foundation (e.g. soil and subsoil or structural framework) shall be designed to safely support the imposed loads from racking uprights with levels of vertical settlement or deflection which either satisfy quasi rigid requirements as specified in Table 6.3.1 or that agreed to during the design stage.

Table 6.3.1 — References for allowable floor deformations

Installation type	Reference
(a) Tolerance Grade I and II installations	EN 15620
(b) Tolerance Grade III installations	
(i) Single and double deep systems	FEM 9.831-1
(ii) Automatic small parts warehouses	FEM 9.832
(iii) Storage systems with rail dependent storage	FEM 9.841

A plan view of the rack anchoring layout (footprint) indicating the rack upright dimensions, the point loads applied to the slab, and the base plate thickness and perimeter shall be provided for the purpose of the structural assessment of the floor.

6.3.2 Design of base plates

6.3.2.1 General

The bottom of all uprights shall be furnished with base plates to transfer upright actions and moments (as required) into the floor. These forces and moments shall be consistent in magnitude and direction with the racking analysis.

In every upright frame, the base plates shall be fixed squarely to the uprights and secured to the floor through using packing material or grouting necessary to ensure that the uprights are solidly supported under the whole area of the base plate. The packing material shall be steel and prevented from shifting relative to the base plate.

Alternatively, appropriate tests may be used to determine the minimum thickness of the base plate.

$$= \frac{M^*}{d_1} \quad 6.3.2.5(2)$$

l_2 = overall depth of the unlipped channel

d_1 = distance from the anchor bolt in tension to the unlipped channel flange in compression

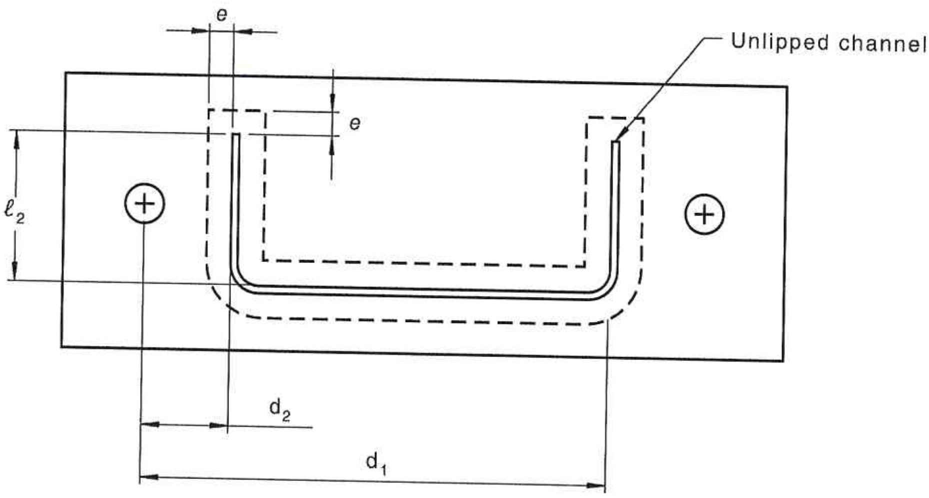

Figure 6.3.2.5 — Effective area

The base plate design shall satisfy the following:

$$A_{\mathrm{eff}} f_{\mathrm{cb}} \geq N^* + F_{\mathrm{t}}^* \quad 6.3.2.5(3)$$

For base plates supporting uprights with more complex profiles than the simple unlipped channel shown in Figure 6.3.2.5, a similar approach to the design of the base plate may be made, with the distance (d_1) measured from the centre of the effective area of the base plate adjacent to the compression flange. Alternatively, appropriate tests may be used to determine the minimum thickness of the base plate.

6.4 Design of base plate anchorage

6.4.1 General

The design actions in the floor fixings shall be calculated for the most onerous action combination at the ultimate limit state resulting from relevant actions as specified in Section 2. It shall also be verified that the empty racking is stable when subjected to appropriate horizontal placement actions as specified in Clause 2.3.4.

NOTE Only the racking self-weight may be considered as resisting action.

In addition, the floor fixings shall be designed to carry the tensile forces necessary to maintain stability against overturning in accordance with Clause 2.7.7.

On racking serviced by mechanical equipment, a minimum of two anchors per base plate shall be used. Each base plate (see Clause 1.3.3) shall be able to transfer design ultimate actions of 5 kN in tension and 8 kN in shear applied separately.

The supporting slab shall have sufficient strength to withstand the design anchor forces.

6.4.2 Design of anchors

Anchor bolts used to fasten base plates to concrete foundations shall be designed in accordance with the provisions of AS 5216.

6.5 Design of frame spacers

In double entry racking, at least two frame spacers [see Figures 1.3.1(a) and 1.3.2(a)] shall be provided between each adjacent pair of upright frames. The frame spacers shall be located near the node points of the upright frames and spaced as widely apart as practicable. The lowest spacer should be positioned at the level of the first bracing node above the floor.

Each frame spacer shall have a capacity greater than or equal to the horizontal placement action and the horizontal accidental action.

6.6 Upright splices

In general, splices in an upright frame should be avoided. A splice should not be allowed below the lowest beam level or below 1.5 m. No more than one splice should be located between any two adjacent beam levels.

Splices shall be designed either by calculation or by testing in accordance with Clause 7.8.

Splices shall have, as a minimum, the strength of the weaker of the connected members or shall be designed for a concentric compressive force (N^*) and a bending moment (M^*).

Splices and connections shall be designed in such a way that actions (axial force, shear force and bending moment) can be transmitted to the effective portions of the cross-section.

If it can be shown by test (see Clause 7.8) that the stiffness and the moment resistance of the two uprights connected by the splice are greater than or equal to those of the upright in one piece and with the same length, it shall be permissible to ignore the presence of the splice in the global analysis.

If the construction details at the ends of a member are such that there is doubt regarding the line of action of the action, a suitable bending moment due to eccentricity (M^*_{ecc}) shall be incorporated into the design.

If a hinged splice is assumed in the global model, then only the axial strength and the shear strength may be checked; the stiffness need not be checked.

The splice joint shall be designed as follows:

$$\frac{N^*}{\phi A_{sp} f_y} + \frac{M^*_{ecc} + M^*}{M_{sp}} \leq 1 \qquad 6.6$$

where

N^*	=	concentric compressive force
A_{sp}	=	net cross-sectional area of the splice
ϕ	=	0.9
M^*_{ecc}	=	moment due to eccentricities
M^*	=	amplified internal bending moment of the splice
M_{sp}	=	design moment of resistance of the splice