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Racking Design Code for Steel Static Storage Systems

立体仓库货架系统设计规范

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Racking Design Code for Steel Static Storage Systems

1 Scope

This Standard specifies the terms, materials, loads and load combinations, racking design and test methods for steel static storage systems.

This Standard is applicable to steel static storage systems made of cold-formed steel or hot-rolled steel components, and mainly subjected to static loads.

2 Normative References

The following documents are indispensable to the application of this document. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 228.1 Metallic Materials - Tensile Testing - Part 1: Method of Test at Room Temperature

GB/T 232 Metallic Materials - Bend Test

GB/T 700 Carbon Structural Steels

GB/T 1591 High Strength Low Alloy Structural Steels

GB/T 2518 Continuously Hot-dip Zinc and Zinc Alloy Coated Steel Sheet and Strip

GB 4053.3 Safety Requirements for Fixed Steel Ladders and Platforms - Part 3: Industrial Guardrails and Steel Platform

GB/T 18354 Logistics Terminology

GB/T 28576-2012 Calculation of Industrial Rack Design

GB 50009 Load Code for the Design of Building Structures

GB 50011 Code for Seismic Design of Buildings

GB 50018-2002 Technical Code of Cold-formed Thin-wall Steel Structures

JB/T 9018 Automated Storage and Retrieval System - Design Rules

JB/T 11270 Assembled Steel Rack Structure for High-bay Warehouse - Technical Requirements

comply with the requirements of 4.1.1 and 4.1.2.

4.2 Connectors

The strength design value of the connectors, such as: welds and bolts, shall comply with the stipulations of GB 50018. For the bolts, Grade-8.8 or higher should be adopted.

5 Loads and Load Combinations

5.1 Classification

The loads on the rack structure can be divided into dead load, live load, vertical impact load, horizontal load and possible wind load, snow load, roof live load and seismic action, etc. If there are other types of loads, they shall comply with the stipulations of GB 50009.

5.2 Dead Load P_{DL}

Dead load refers to the self-weight of the racking system. The dead load of the rack-clad building shall also include the self-weight of the structures, such as: the roof and wall. The dead load is composed of the weight of all permanent structures, including the racks and auxiliary facilities connected to the racks, such as: fire sprinklers, heating ventilation and air conditioning systems, etc., as well as other fixed auxiliary equipment that needs to be supported by the rack members, and their masses shall all be included in the dead load.

5.3 Live Load P_{PL}

Live load generally refers to the weight of the goods and carriers placed on the rack structure. In addition, the floor slab and aisle loads in 5.7 shall also be included.

5.4 Vertical Impact Load P_{IL}

5.4.1 The vertical impact load refers to the additional impact force generated on the beam when the goods are stored, and usually, only loaded once at the most unfavorable position. When designing beams, (if designed) brackets and hanging pieces, the load can be calculated in accordance with the following situations:

- a) When placing goods through mechanical equipment (automation), it shall be equal to 50% of the maximum unit load;
- b) When manually placing goods (non-automation), it shall be equal to the maximum unit load.

5.4.2 The vertical impact load is used to inspect local components (beams, hanging pieces and brackets, etc.). When designing the overall structure of the racks, the influence of the vertical impact load is not considered.

5.5 Horizontal Load P_{HL}

5.5.1 The horizontal load acting on the combined rack structure refers to the horizontal force generated by the defects caused by the initial bending of the rack structure members, the installation deviation and load eccentricity, etc., as well as the normal operation of the handling equipment.

5.5.2 The horizontal load generated by the defects described in 5.5.1 respectively acts on the connection node of the beam and the column along the longitudinal and transverse main directions of the combined rack structure. The horizontal load may be taken as 0.4% of the sum of the total dead load and the maximum live load transmitted from the beam to the node.

5.5.3 For racks with handling equipment, the horizontal load shall be determined in accordance with the relevant information provided by the manufacturer of the handling equipment.

5.6 Seismic Action P_{EL}

5.6.1 The seismic action and structural seismic checking calculation shall comply with the relevant stipulations of GB 50011.

5.6.2 For rack structures with a height of not more than 40 m, mainly shear deformation, and relatively uniform distribution of mass and stiffness along the height, simplified methods, for example, the bottom shear force method can be adopted. For the rack structures other than this type, the mode decomposition response spectrum method should be adopted.

5.6.3 For the seismic checking calculation of the cross-section of the members, the design value of the seismic bearing capacity shall take $R/0.75$; the design value of the bearing capacity stability shall take $R/0.8$; R is the design value of the bearing capacity of the structural member.

5.7 Floor Slab and Aisle Loads

For the load acting on the floor slab or aisle, in accordance with the actual demands, calculate the uniformly distributed load or concentrated load, which shall not be lower than 300 kg/m². The other situations shall comply with the relevant stipulations of GB 4053.3.

5.8 Thrust on the Railing

The railings of stairs and floor slabs shall be designed to be able to withstand a thrust of no more than 0.7 kN/m acting in any direction above the railings. The other situations shall comply with the relevant stipulations of GB 4053.3.

5.9 Wind Load P_{WL}

The wind load checking calculation of the rack-clad building shall comply with the relevant stipulations of GB 50009.

5.10 Snow Load P_{SL} and Roof Live Load P_{RL}

The snow load and roof live load checking calculation of the rack-clad building shall comply with the relevant stipulations of GB 50009.

0.9;

ψ_{cW} ---the combined value coefficient of wind load, which shall take 0.6;

ψ_{cR} ---the combined value coefficient of snow load and roof live load, which shall take 0.7.

When designing the racks in accordance with the limit states of normal application, the partial factors for the various loads may refer to the combination of Formula (1) ~ Formula (6), and all the numerical partial factors can be changed to 1. The loads and load combinations of other circumstances shall comply with the relevant requirements of GB 50009.

6 Rack Design

6.1 General Design Requirements

6.1.1 This Standard adopts the limit state design method based on the probability theory and calculates with the design expressions of the partial factors. The combined conditions, in which, the horizontal load and wind load play a dominant role, and the seismic action condition shall be subjected to the second-order analysis of the structure.

6.1.2 The load-bearing members of the rack structure shall be designed in accordance with the limit states of the bearing capacity; the non-load-bearing members shall be designed in accordance with the structural requirements. The limit states of the bearing capacity include: strength failure of components and connectors, fatigue failure, and structural failure due to loss of stability of structures and components. For the design that is controlled by stiffness, such as: the overall displacement of the racks and the deflection of the beam, it shall be performed in accordance with the limit states of normal application.

6.1.3 The overall stiffness requirements for the racks shall comply with the requirements of Chapter 8 in GB/T 28576-2012. The mode shown in Figure 1 can enhance the overall stiffness of the racks.

Key:

a---horizontal tie beams of the racks;

b---torsion members between the racks.

Figure 1 (continued from previous page)

6.1.4 For the racks that require seismic resistance design or wind resistance design, vertical pull rods should be added to maintain the overall stability of the racks.

6.1.5 All formulas in the Standard shall adopt the International System of Units, unless it is otherwise stated.

6.1.6 For the design and verification contents not covered in the Standard, such as: bolted connection and welded seam connection, GB 50018 shall be taken as a reference.

6.2 Design of Columns and Rack Pieces

6.2.1 For non-porous parts, the average design strength f_{ya} can be determined in accordance with Formula (9). If the cross-sectional area A_{eff} of the non-porous parts is determined through the method of 7.3 and used for calculation, then, this clause does not apply.

$$f_{ya} = f_y + \left(\frac{C_f N t^2}{A_g} \right) (f_u - f_y) \leq 0.5(f_u + f_y) \quad \dots\dots\dots (9)$$

Where,

f_y ---the nominal yield strength of the material;

f_u ---the nominal ultimate tensile strength of the material;

t ---the design thickness of the material (before cold forming);

A_g ---the gross cross-sectional area;

C_f ---the coefficient related to the forming type:

for the material formed through the cold-bend method, $C_f = 5$;

for the material formed through other forming methods: $C_f = 7$;

N ---the number of 90° bending angles in the section, and the bending radius is not greater than $5t$.

6.2.2 For the design of the columns, generally only the load condition on the structure shown in Figure 2a) is considered, that is, except for one beam near the middle part of the lowermost layer of the structure, which is no-load, all other beams are fully loaded. For racks with vertical pull rods, another loading mode that causes single bending of the column shall also be

Key:

a---rolling direction.

Figure 8 -- Bent Test Piece of Transverse Bend Test

If it is determined through visual inspection that there is no crack on the outer surface of the test piece after bending by 180° from the bottom, then, it shall be deemed that this test piece satisfies the standard requirements. If there is a local crack at the bend, but the crack does not extend by more than 1 mm from the edge of the test piece, then, it is still allowed to be used.

7.3 Acquisition of Calculated Cross-sectional Area A_{eff} of the Column**7.3.1 Test purpose**

The calculated cross-section area A_{eff} of the column is divided into effective cross-sectional area A_e and effective net cross-sectional area A_{en} , both of which can be obtained through the short column test. In addition, the influence of punching, local (longitudinal) buckling and other factors on the compressive strength of the short columns can also be observed.

7.3.2 Test scheme

The test specimen is shown in Figure 9. The length of the specimen shall be greater than 3 times the maximum size of the cross-section (ignoring the bending in the middle), and at least 5 groups of regular punching holes shall be included. The cutting of the specimen shall be performed between the 2 groups of perforations, and along the direction perpendicular to the longitudinal axis.

The combined column foot or bottom plate is fixed to both ends of the short column through the mode of bolts or welding, then, the short column specimen is fixed on the corresponding position of the pressure plate with a thickness of greater than 30 mm. The thick pressure plate should have a small, drilled indent to accommodate a steel ball, as it is shown in Figure 9.

In accordance with the method of 7.5.4, process the data, without considering the data correction. Thus, the design value of the column foot stiffness k_u can be obtained. k_u can take the average value k_m of k_{ni} .

8 Overall Test of Combined Racking Unit

8.1 The purpose of the test is to simulate the actual working conditions of the combined racking structure, so as to determine its bearing capacity and rated load. The test rack is composed of three rack pieces connected with no less than two-layer unit cargo beams. The structural combination of the bottom beam and the rack pieces is the same as that of the actual racks. The structural combination of the top-layer beam and its rack piece is strengthened compared with the actual racks, so that it can bear the test load higher than the failure load of the whole frame. The base of the rack piece is laid flat on the concrete floor. The test device is shown in Figure 16.

8.2 The overall test of the combined racking unit adopts the pallet to apply the vertical load and the jack, or the rope and pulley that hang heavy objects to apply the horizontal load. The load shall be applied in accordance with different combinations of loads and through the following three modes:

- a) On each layer of pallet beams, apply a vertical load to 1.5 times the design load, then, at the connection nodes between each layer of beams and columns, along the direction of the beam, apply a horizontal load, which is 1.5% of the total vertical load of the layer. Afterwards, respectively and step-by-step increase the vertical load and the corresponding horizontal load only on the top pallet beam and its node level, until the combined racking unit is destroyed as a whole.
- b) Merely apply a vertical load equivalent to 1.5 times the design load of the beam and the corresponding horizontal load on the pallet of one cargo compartment on the bottom layer. Then, in accordance with the mode of a), step-by-step apply the vertical load and the corresponding horizontal load only on the top beam, until the combined racking unit is destroyed as a whole.
- c) As described in a), apply the load, but change the direction of the horizontal load (perpendicular to the roadway) to be in the plane of the rack piece; the loading mode, sequence, magnitude and proportion are the same as those in a).

8.3 The overall ultimate load of the combined racking unit shall take the minimum value among the corresponding failure loads of the three loading modes listed in 8.2. The overall rated load of the combined racking unit shall take 1/2 of the ultimate load.

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