European Rack Project Structural Design Certification Template

This certification document is issued by Shanghai Wesafe Rack Safety Inspection Technology Co., Ltd. It reviews and verifies the load-bearing performance, scheme selection and material selection of rack structures for projects in Europe, in compliance with the requirements of standard EN 15512-2020. This report bears the CNAS accreditation mark and is signed and confirmed by a professionally registered European Structural Engineer.

CONTENT

1. Certificate of Qualified European Professional Engineer

Engineering Council

Established for the promotion and development of the knowledge and good practice of engineering

This is to certify that

[redacted]

in membership of the

Institution of Structural Engineers

has been registered by the Engineering Council and is hereby authorised to use the style or title of

Chartered Engineer

Chairman

Chief Executive Officer

Registered 18 December 2018

*Registration No.*6

Date of Issue 23 December 2018

This Certificate is the property of the Engineering Council and is returnable on request. It is valid only for so long as the holder remains on the Engineering Council's Register.

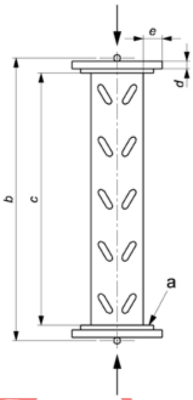
2. Report on Key Structural Design Parameters & Test Photos

2.1 Stub column test

1 Stub column test

1.1 Test Objective

Test Objective: To determine the effect of perforations and local buckling on the axial capacity of columns.



Schematic of the stub column testing apparatus

The stub column test specimens and test methods shall comply with the relevant provisions of BS EN15512:2020+A1:2022.

1.2 Test data

Stub column tests were repeated three times for each group. The test results were corrected in accordance with the relevant provisions of BS EN15512:2020+A1:2022. Detailed data are shown in the table below:

Stub column test data corrections

t	t_t	f_y	f_t	Rti(kN)	C	α	β	Rni(kN)	Rm	Rk(kN)	Aeff, Ib(mm^2)
2.00	2.04	460	520	302.06	0.885	1	2	256.83	252.85	241.25	524.45
2.00	2.03	460	520	292.09	0.885	1	2	250.81			
2.00	2.03	460	520	292.23	0.885	1	2	250.93			

Conclusion: The corrected effective area of the 100962.0 stub column, based on three tests, is 524.45 mm².

1.3 Testing/destroy photograph

Photographs of Stub column tests

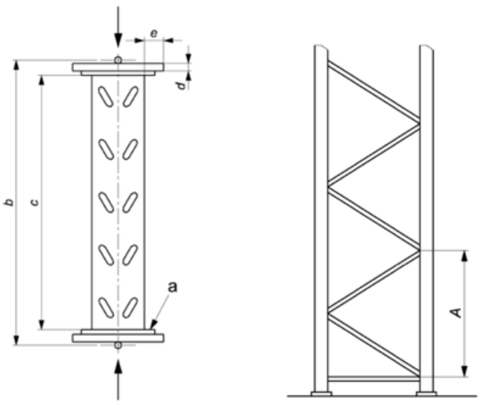
2.2 Medium column test

上海稳图货架安全检测技术有限公司（报告编号：WSZ2026XXXX-XX）

2 Medium column test

2.1 Test objective

Test objective: To determine the effect of distortional buckling on the axial load capacity of columns.



Schematic of the medium column testing apparatus

The medium column test specimens and test methods shall comply with the relevant provisions of BS EN15512:2020+A1:2022.

2.2 Test data

Each group of medium columns was tested in triplicate. The test results were corrected in accordance with the relevant provisions of BS EN15512:2020+A1:2022. Detailed data are presented in the table below:

Medium column test data corrections

t	t_t	f_y	f_t	Rti(kN)	C	α	β	Rni(kN)	Rm	Rk(kN)
2.00	2.03	460	556	263.20	0.827	1	2	211.37	208.97	201.55
2.00	2.04	460	556	262.17	0.827	1	2	208.48		
2.00	2.02	460	556	255.28	0.827	1	2	207.04		

Conclusion: The corrected failure load of the 100*96*2.0 medium column from the

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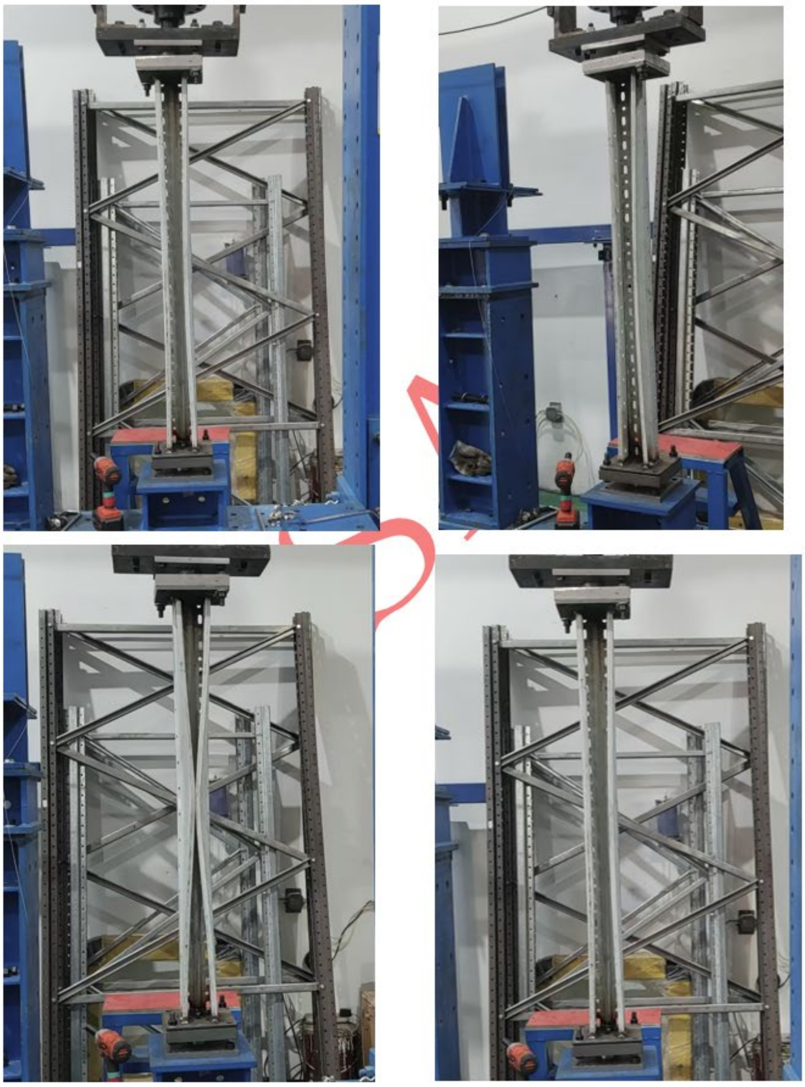
three tests in this project is 201.55 kN. Calculations indicate that the effect of distortional buckling does not need to be considered for the columns in this project.

2.3 Testing/destroy photograph



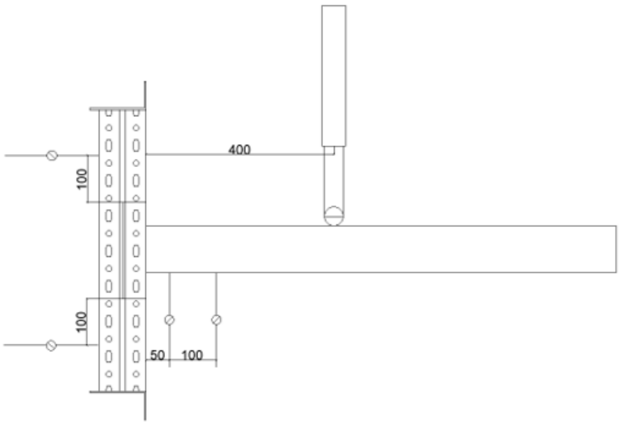
Photographs of medium column tests

2.3 Beam end connector bending test

3 Beam end connector bending test

3.1 Test objective

Test objective: to determine the rotational stiffness and moment capacity of beam end connecters.



Schematic diagram of the beam end end connector bending test setup

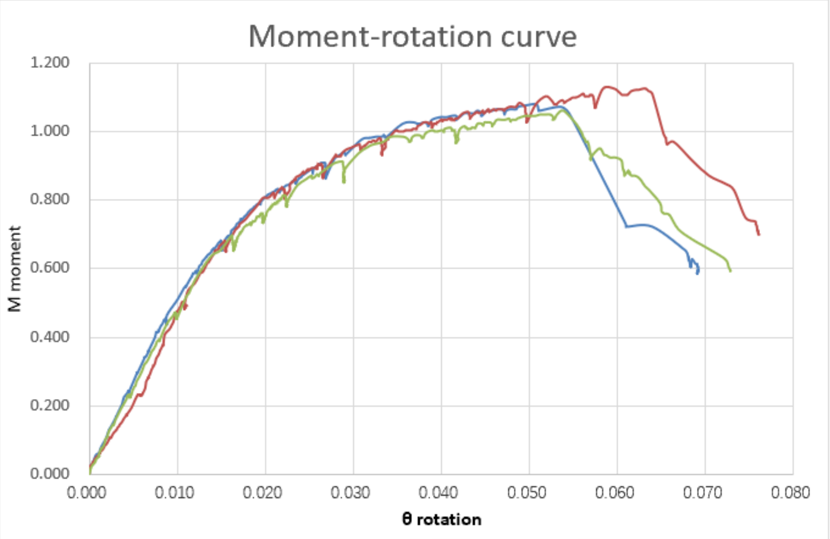
The test specimens and testing methods for the beam connector bending test shall comply with the relevant provisions of BS EN15512:2020+A1:2022.

3.2 Test data

Each beam end connecter assembly was tested in triplicate. The stiffness and maximum moment capacity of the connections were corrected and calculated in accordance with BS EN15512:2020+A1:2022. Detailed data are presented in the table below and the moment-rotation curves:

Statistical data table of beam end connecters

Mni (kN*m)	Mm (kN*m)	s	Mk (kN*m)	MRd (kN*m)	ki (kN*m/rad)	kd (kN*m/rad)
1.08	1.09	0.036	0.97	0.88	40.48	38.96
1.13					37.48	
1.06					38.920	

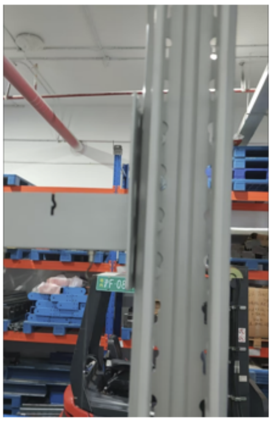


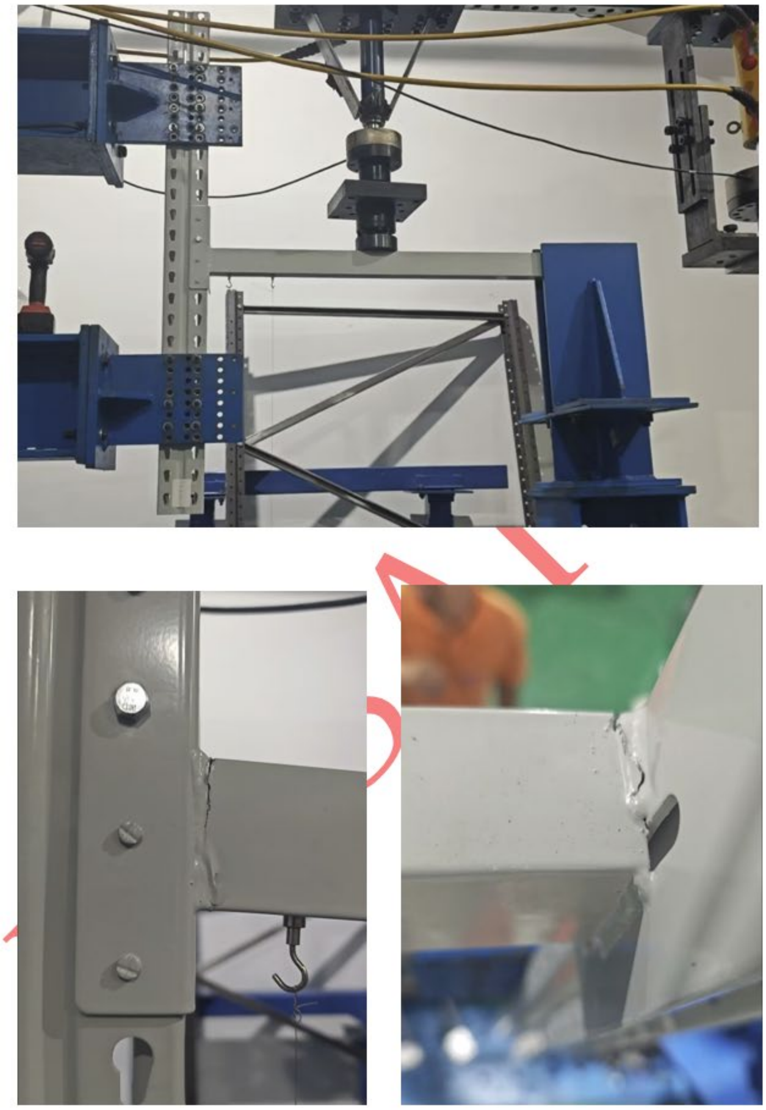
Moment-rotation curve

Conclusion:

The corrected bending stiffness of three tests (100*60*2.0 upright+ 60*40 beam+1 bolt) is 92.24 kN*m/rad, and the corrected moment capacity of three tests is 1.862 kN*m.

3.3 Testing/destroy photograph





Photographs of beam end connecter bending test

3. Rack Structure Design Review Report

Rack Structure Design Review Report

Order Number: WSZ2026XXXX-XX

Project Name: XXXX

Client: XXXX

Inspection type: Commission

Inspected by：Shanghai Wesafe Rack Safety Inspection Technology Co., Ltd.

Engineering Council

A N Othername
BSc CEng MIET
Chartered Engineer
Registrant 000000 of the Engineering Council

CONTENT

1 Calculation Assumptions

(1) The frequency of loading and unloading goods on the racks is low, and fatigue effects are not considered.

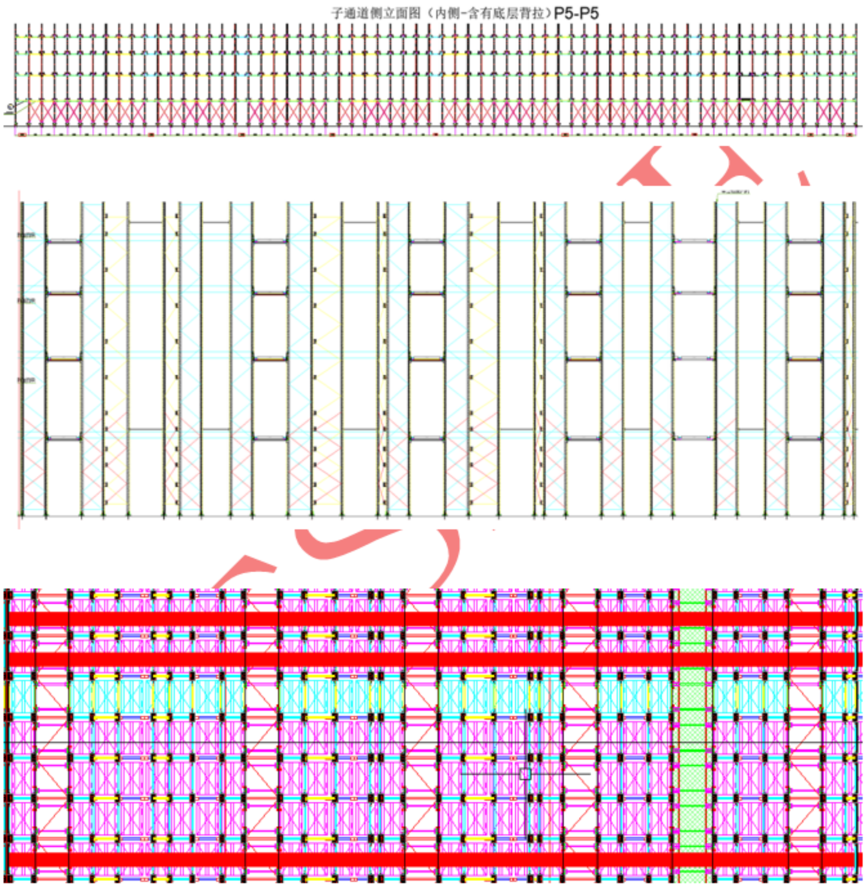
(2) The racks are installed on concrete slabs, which are designed to withstand the concentrated forces induced by the columns.

(3) The ground where the racks are installed can be considered as a rigid foundation, and no deformation of the ground will cause additional forces on the racks.

(4) Warehouse management ensures that the full load rate of the racks does not exceed the specified values in the table below.

2 System Overview

The racking arrangement follows the designated zones and specifications provided by the client, as illustrated below.



Racking Arrangement

3 Material Properties

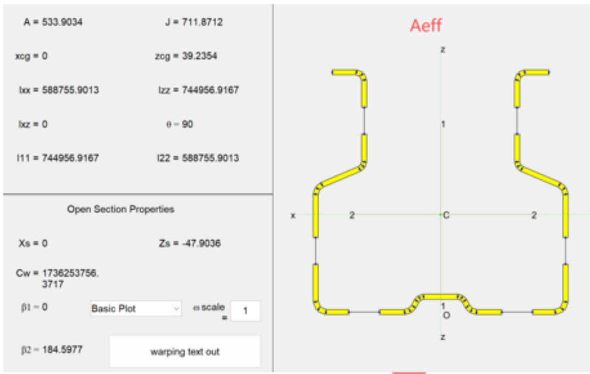
3.1 Materials

Steel properties

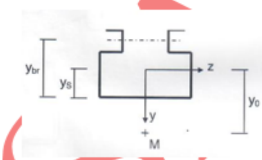
Modulus of elasticity	E	=	206000N/mm^2
Shear modulus	G	=	79231N/mm^2
Density	ρ	=	7850kg/m^3
Q235	f_y	=	235N/mm^2
Q355	f_y	=	355N/mm^2
Q460	f_y	=	460N/mm^2

4 Section of member and Joint Characteristics

4.1 Lower upright（100*96*2.0）



Effective Cross-sectional Details of upright

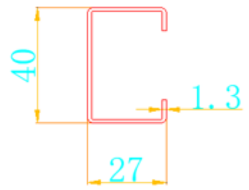


Upright section

Upright section properties

Name	Value	Description
fy	460.000	Steel Yield Strength
E	206000.000	Elastic Modulus
G	79231.000	Shear Modulus
Aeq	602.000	Equivalent Cross-sectional Area
Aeff	520.000	Effective Cross-sectional Area
Iy,eq	847159.000	Equivalent Moment of Inertia about y-axis (Symmetry Axis)
Iz,eq	651238.000	Equivalent Moment of Inertia about z-axis
It,eq	744.000	Equivalent Torsional Constant (Free Torsion)
Iw,eq	2013800510.000	Equivalent Warping Constant
y0,eq	86.970	Distance between Centroid and Shear Center
Wy,eff	14899.000	Effective Section Modulus about y-axis (Symmetry Axis)
Wz,eff,min	10373.000	Minor Effective Section Modulus about z-axis
Wz,eff,max	15004.000	Major Effective Section Modulus about z-axis

4.2 Brace（40*27*1.3）



Brace section

Brace section properties

Name	Value	Description
fy	355.000	Steel Yield Strength[EN]
fu	470.000	Steel Tensile Strength [EN]
E	206000.000	Elastic Modulus [EN]
G	79231.000	Shear Modulus [EN]
An	119.000	Minimum Net Cross-sectional Area [EN]
A	133.000	Gross Cross-sectional Area [EN][CH]
Aeff	119.000	Effective Cross-sectional Area [EN][CH]
Iy	34963.000	Gross Moment of Inertia about y-axis (Symmetry Axis) [EN][CH]
Iz	13448.000	Gross Moment of Inertia about z-axis [EN][CH]
It	69.000	Gross Torsional Constant (Free Torsion) [EN][CH]
Iw	4175449.000	Gross Warping Constant [EN][CH]
y0	22.870	Distance between Centroid and Shear Center [EN][CH]
Wz,eff	815.000	Minor Effective Section Modulus about z-axis [EN]

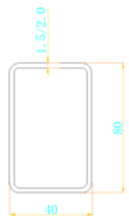
4.3 Support beam（80*40*2.0）

Support beam section

80*40*2.0 Support beam section properties

Name	Value	Description
fy	355.000	Steel Yield Strength [EN][CH][ANSI][AS]
MRd,y	2967082.000	Moment Resistance about Major Axis [EN][CH]
MRd,z	2027228.000	Moment Resistance about Minor Axis [EN]

4.4 Support beam（80*40*1.5）



Bearing beam section

80*40*1.5 Support beam section properties

Name	Value	Description
fy	355.000	Steel Yield Strength [EN][CH][ANSI][AS]
MRd,y	2287313.000	Moment Resistance about Major Axis [EN][CH]
MRd,z	1577039.000	Moment Resistance about Minor Axis [EN]

4.5 Cross Bracing（ϕ32*1.5）

Cross bracing section properties

Name	Value	Description
fy	235.000	Steel Yield Strength [EN][CH][ANSI][AS]
An	119.000	Minimum Net Cross-sectional Area [EN][CH]

4.6 Joint Characteristics

Joint characteristics

节点特性	k kNm/rad
Beam end connector	109.00
Brace end connnector	0
Cross bracing end connnector	0
Upright foot joint	Down-aisle: 60.00
	Cross-aisle: 0

5 Load

5.1 Dead load D

In the finite element model, the software automatically generates the dead load of the rack member.

5.2 5.2 Unit loads L

Pallet loads are applied onto track plates; the track plates are treated as beams subjected to uniformly distributed line loads, with the rated load of each pallet equal to 1000 kg.

As specified by the client, uniformly distributed line load q=5.55N/mm shall be adopted for the second floor to account for fire load; for all other floors, the uniformly distributed line load is taken as q=5.45N/mm.

5.2.1 Load Ratio

Static Load Case: 100%。

5.3 Placement load

5.3.1 Horizontal placement load

Racking height: 11840mm.

Down-aisle direction: $2Q_{ph}$=0.5kN, H=0.5/4=0.125kN(per tier beam).

Cross-aisle direction: 0.25 kN acting on the top-tier beam.

5.3.2 Vertical placement load

As specified by the client, the vertically applied load is taken as 50 kg and positioned at the most unfavorable location (mid-span of a single supporting beam).

5.4 Global imperfections Imp

Down-aisle direction:

Ultimate Limit State:

Φ_0=3/2x1/500=0.003

α_h=1

n_{da}=10

$\alpha_{da}=(0.5(1+1/10))^{0.5}=0.742$

$\Phi_{l,BEC}=0$

$\Phi_0\alpha_h\alpha_{da}$=0.003x1x0.742=0.0022>1/500

Φ_{ULS}=0.0022+0=0.0022

Serviceability limit state:

Φ_{SLS}=1/500+0=0.002

Cross-aisle direction:

(Ultimate limit state:

Φ_0=3/2x1/500=0.003

α_h=1

n_{ca}=10

$\alpha_{ca}=(0.5(1+1/10))^{0.5}=0.742$

$\Phi_{l,fr}$=0.00163

$\Phi_0\alpha_h\alpha_{da}$=0.003x1x0.742=0.0022

Φ_{ULS}=0.0022+0.0016=0.0038>1/500

Serviceability limit state:

Φ_{SLS}=1/500+0.0016=0.0036

6 Loading combination

6.1 Global analysis

Load combinations

Group-1：ULS with only PL	
G1-LC01	1.3D+1.40PL+1.4ImpX
G1-LC02	1.3D+1.40PL+1.4ImpY
Group-2：ULS with PL+PHL	
G2-LC01	1.3D+1.26PL+1.26PHL-X+1.26ImpX
G2-LC02	1.3D+1.26PL+1.26PHL-X+1.26ImpY
Group-3：ULS with PL+A	
G3-LC01	1.0D+1.0PL+1.0AX+1.0ImpX
G3-LC02	1.0D+1.0PL+1.0AY+1.0ImpY
Group-4：SLS with only PL	
G4-LC01	1.0D+1.0PL+1.0ImpX
G4-LC02	1.0D+1.0PL+1.0ImpY
Group-5：SLS with PL+PHL	
G5-LC01	1.0D+0.9PL+0.9PHL-X+0.9ImpX
G5-LC02	1.0D+0.9PL+0.9PHL-X+0.9ImpY

Where,

ULS stands for ultimate limit state,

SLS tands for serviceability limit state,

ImpX stands for global imperfection in down-aisle direction,

ImpY stands for global imperfection in cross-aisle direction,

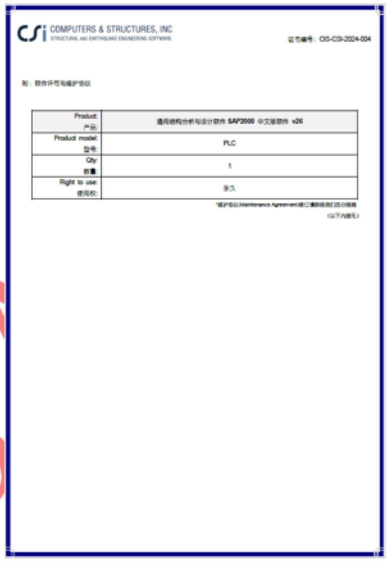
HPL-X stands for horizontal placement load in down-aisle direction,

HPL-Y stands for horizontal placement load in cross-aisle direction.

7 Global structural analysis

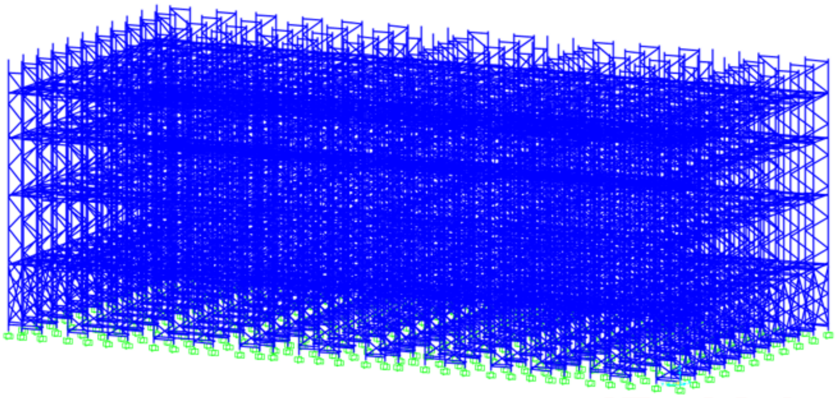
7.1 Software information

The structural computing software used in this calculation is SAP2000. SAP2000 is a rich and powerful finite element computing software, such as modeling function, editing function, analysis function, load function, custom function and design function.



7.2 Finite element modal

A finite element model was established based on the structural layout of the designated racking area, as shown in the figure below. Characteristics such as end releases of members and joint stiffness were considered in the model and are not elaborated upon herein. Unfavorable load arrangements for storage unit loads were taken into account, as illustrated in the following figures. Other load models are not discussed in detail.

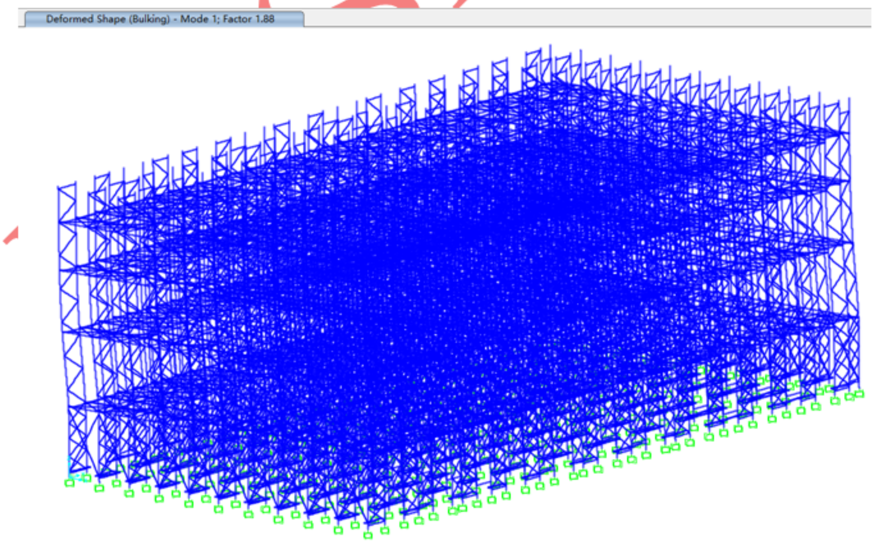


Finite element model

7.2.1 Buckling analysis

Firstly, the elastic buckling analysis was carried out, and the load condition was considered as 1.3D+1.4 PL.

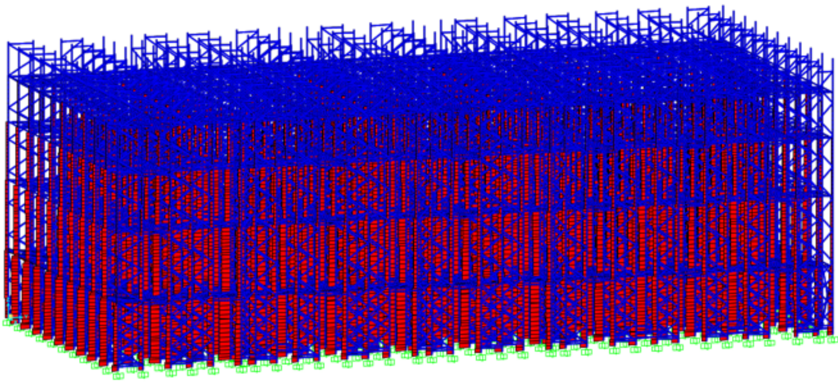
The down-aisle lowest order global buckling modes is shown in the figure below, and the corresponding buckling coefficient is 1.88 < 3.33. The second-order effects shall be taken into account directly in the global analysis of the structure.

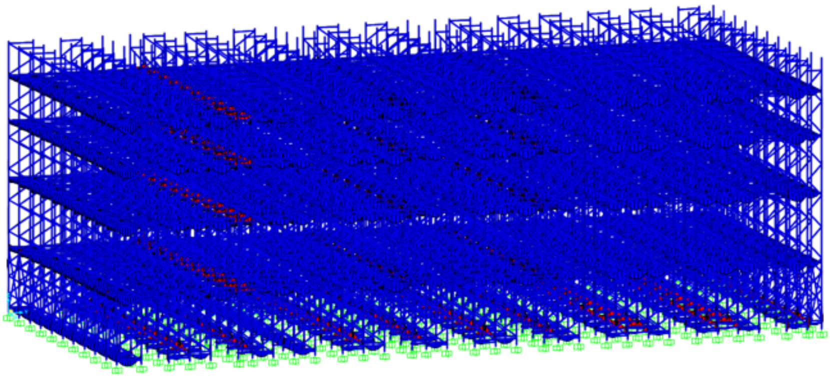


Down-aisle buckling mode

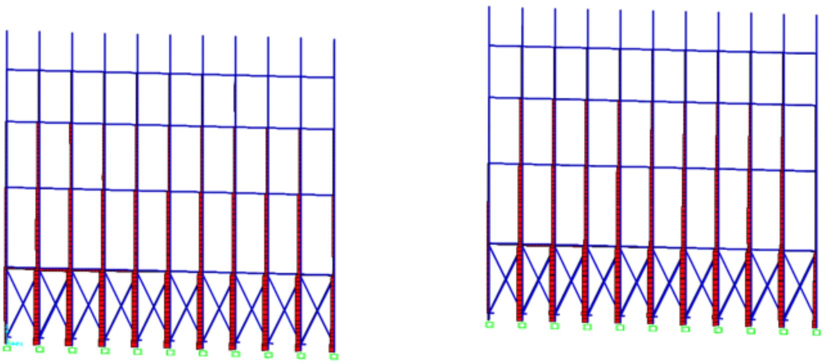
7.3 Finite element model – Internal forces of overall structure

Axial force diagram of overall structure for finite element model

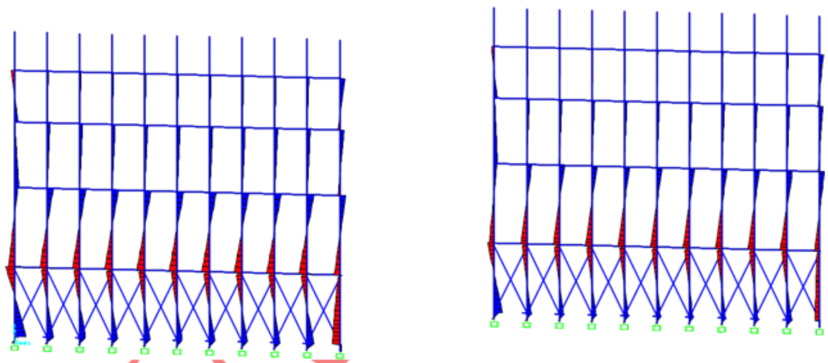




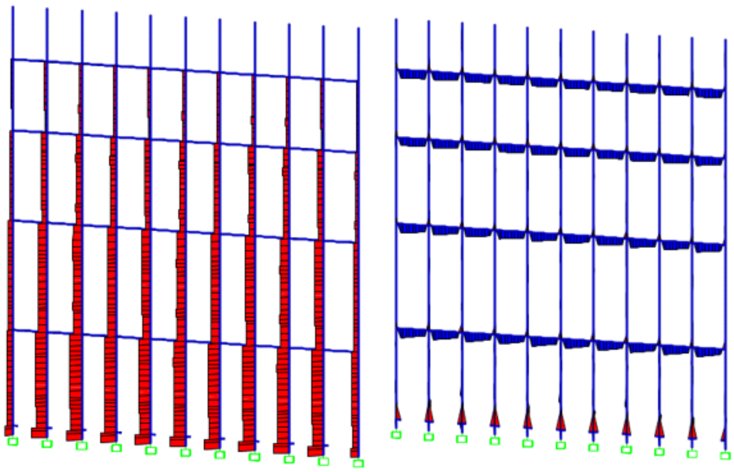
Bending moment diagram of overall structure for finite element model M3



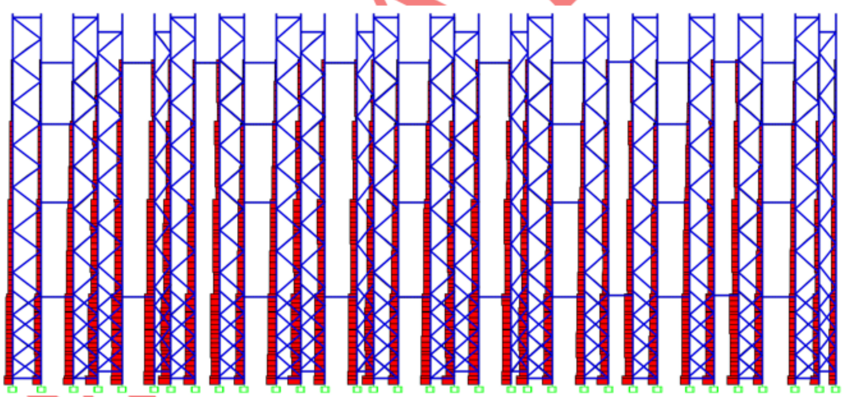
Axial force diagram of cross brace



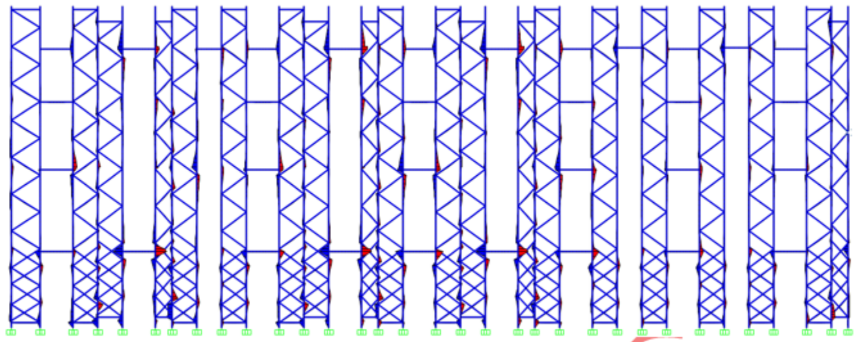
Bending Moment Diagram of cross brace



Internal Force Diagram of Frame without corss brace



Axial force diagram of cross-aisle direction



Bending moment diagram of cross-aisle direction

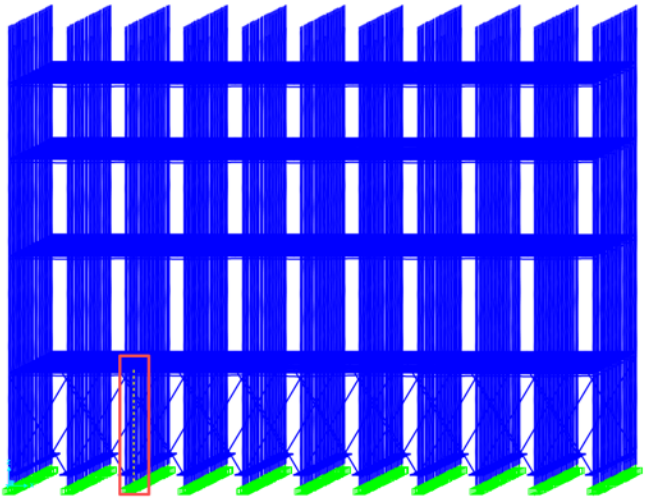
7.4 Analytical method

- Linear elasticity of material
- Geometric nonlinearity
- Consider the global imperfection
- P-Δ Analysis

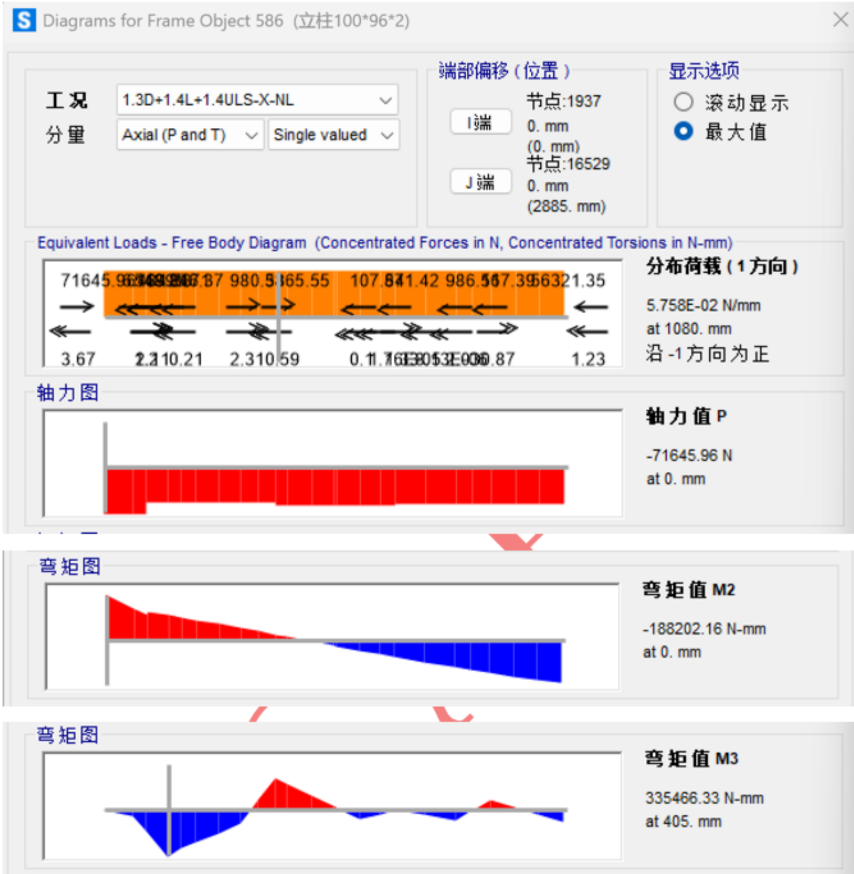
8 Structural member check

8.1 Upright（100*96*2.0）

All upright sections are checked for structural compliance, with the critical upright sections located at the bottom upright base. The detailed verification procedure is presented below:



Critical upright location



Internal force diagram of member 586 (upright)

Member	586	
Load case	1.3D+1.4L+1.4ULS-X-NL	
Name	Value	Description
fy	460.000	Steel Yield Strength [EN][CH][ANSI][AS]
ϒ M0	1.100	Partial material factor
E	206000.000	Elastic Modulus [EN][ANSI][AS]
G	79231.000	Shear Modulus [EN][ANSI][AS]
Aeq	602.000	Equivalent Cross-sectional Area [EN]
Aeff	520.000	Effective Cross-sectional Area [EN]
Iy,eq	847159.000	Equivalent Moment of Inertia about y-axis (Symmetry Axis) [EN]
Iz,eq	651238.000	Equivalent Moment of Inertia about z-axis [EN]
It,eq	744.000	Equivalent Torsional Constant (Free Torsion) [EN]

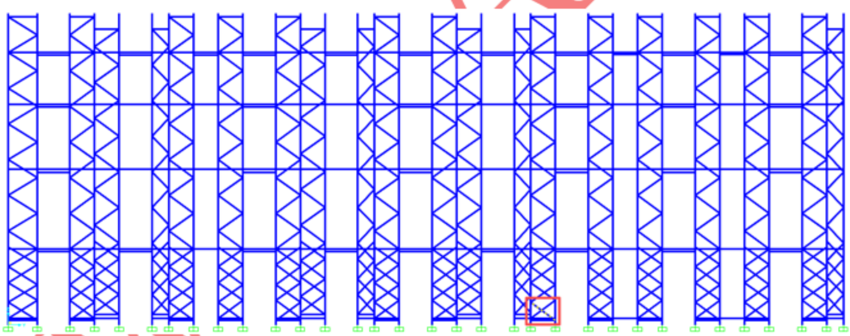
Iw,eq	2013800510.000	Equivalent Warping Constant [EN]
y0,eq	86.970	Distance between Centroid and Shear Center [EN]
Wy,eff	14899.000	Effective Section Modulus about y-axis (Symmetry Axis) [EN]
Wz,eff,min	10373.000	Minor Effective Section Modulus about z-axis [EN]
Wz,eff,max	15004.000	Major Effective Section Modulus about z-axis [EN]
Ly	2885.000	mm
Lz	1086.000	Lateral Unbraced Length (mm)
Lt	675.000	Torsional Unbraced Length (mm)
Ky	1.000	
Kz	1.000	
Kt	1.000	
α y	0.340	
α z	0.340	
α LT	0.340	
Nc,Rd	217454.545	N
My,Rd	6230490.909	Nmm
Mz,Rd,min	4337800.000	Nmm
Mz,Rd,max	6274400.000	Nmm
iy	37.513	mm
iz	32.891	mm
i0	100.264	mm
λ y	76.906	
Ncr,y	206938.006	N
λ y,rel	1.075	
Φ y	1.227	
χ y	0.550	
Nby,Rd	119648.812	N
λ z	33.019	
Ncr,z	1122657	N
λ z,rel	0.462	
Φ z	0.651	
χ z	0.901	
Nbz,Rd	195893	N
β	0.248	
Ncr,T	899762.477	N
Ncr,TF	175103.020	N
λ TF,rel	1.169	
Φ TF	1.348	
χ TF	0.495	
NFT,Rd	107716.900	N
λ T,rel	0.516	
Φ T	0.687	
χ T	0.877	
NT,Rd	190759.383	N
LOC1 静力		
N	71645.955	N

My	188202.157	Nmm
Mz	335466.329	Nmm
α β δ y	0.850	
α β δ z	0.901	
(NEd/χ Nc,Rd) α y	0.707	
（My,Ed/χ LTMy,Rd) β y	0.051	
(Mz,Ed/Mz,Rd) δ y	0.114	
DCR1	0.872	
(NEd/χ zNc,Rd) α z	0.404	
（My,Ed/χ LTMy,Rd) β z	0.043	
(Mz,Ed/Mz,Rd) δ z	0.100	
DCR2	0.547	

According to the calculation, the maximum DCR of the upright under the most critical condition is 0.742 (<1.0). Meet the requirements.

8.2 Brace (40*27*1.3)

Member checks were performed on all brace sections. The verification process for the most critically loaded section is as follows:



The most critical brace location

Internal force diagram of member 5822 (Brace)

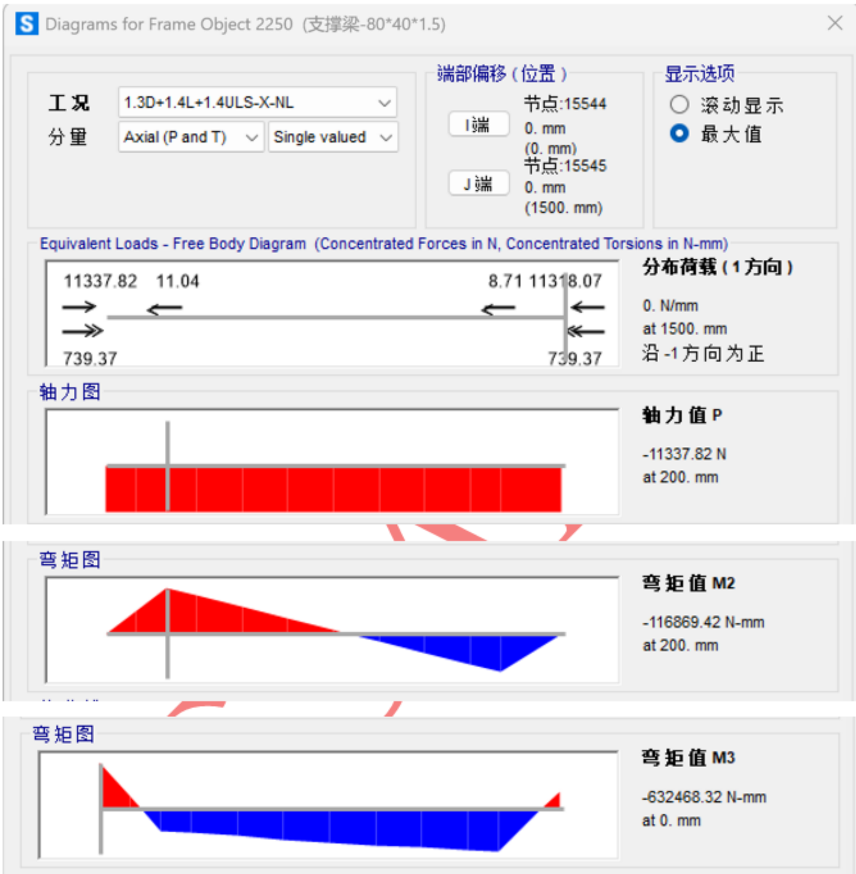
Member	5822	
Load case	1.3D+1.4L+1.4ULS-Y-NL	
Name	Value	Description
NEd	4258.962	N
fy	355.000	Steel Yield Strength[EN]
fu	350.000	Steel Tensile Strength [EN]
ϒ M0	1.100	Member Material Factor
ϒ M2	1.250	Joint Material Factor
E	206000.000	Shear Modulus [EN]
G	79231.000	Minimum Net Cross-sectional Area [EN]
An	119.000	Gross Cross-sectional Area [EN][CH]
A	133.000	Effective Cross-sectional Area [EN][CH]
Aeff	119.000	Gross Moment of Inertia about y-axis (Symmetry Axis) [EN][CH]
Iy	34963.000	Gross Moment of Inertia about z-axis [EN][CH]
Iz	13448.000	Gross Torsional Constant (Free Torsion) [EN][CH]
It	69.000	Gross Warping Constant [EN][CH]
Iw	4175449.000	Distance between Centroid and Shear Center [EN][CH]
y0	22.870	Minor Effective Section Modulus about z-axis [EN]
Wz,eff	815.000	Shear Modulus [EN]
Ly	1153.191	mm
Lz	1153.191	mm
Lt	1153.191	mm
Ky	1.000	

Kz	1.000	
Kt	1.000	
α y	0.490	
α z	0.490	
α LT	0.490	
Nc,Rd	38404.545	N
Mz,Rd	263022.727	
iy	16.214	mm
iz	10.055	mm
i0	29.783	mm
λ y	71.125	
Ncr,y	53453.112	N
λ y,rel	0.889	
Φ y	1.064	
χ y	0.607	
Nby,Rd	23296.436	N
λ z	114.683	
Ncr,z	20559.948	N
λ z,rel	1.433	
Φ z	1.830	
χ z	0.337	
Nbz,Rd	12946.297	N
β	0.410	
Ncr,T	13359.835	N
Ncr,TF	11500.778	N
λ TF,rel	1.917	
Φ TF	2.757	
χ TF	0.211	
NFT,Rd	8103.441	N
λ T,rel	1.778	
Φ T	2.468	
χ T	0.239	
NT,Rd	9190.535	N
ey	0.000	Eccentricity
MRd.z.eff	270250.000	Nmm
η	1.261	
MEd.Z	0.000	Nmm
α y	0.850	
α z	0.850	
DCR1	0.579	
DCR2	0.389	
DCR3	0.128	Net Section

The calculations indicate that the maximum stress ratio of the brace members under the most unfavorable static load case is less than 1.0. Meets the requirements.

8.3 Support Beam (80*40*1.5)

Member checks were performed on all support beam sections. The verification process for the most critically loaded section is as follows:



Internal force diagram of critical beam

Name	Value	Units
f_y	355	N/mm²
γ_{M0}	1.1	Material safety factor
E	206000	N/mm²
G	79231	N/mm²
A_{eq}	341	mm²
A_{eff}	341	mm²
$I_{y,eq}$	283498	mm⁴
$I_{z,eq}$	97732	mm⁴
$I_{t,eq}$	234205	mm⁴

$y_{0,eq}$	0	mm
$W_{y,eff}$	7087	mm³
$W_{z,eff,min}$	4887	mm³
L_y	1500	mm
L_z	1500	Horizontal unsupported length (mm)
L_t	1500	Torsional unsupported length (mm)
K_y	1.00	
K_z	1.00	
K_t	1.00	
α_y	0.34	
α_z	0.34	
α_{LT}	0.34	
$N_{c,Rd}$	110050	N
$M_{y,Rd}$	2287168	Nmm
$M_{z,Rd}$	1577168	Nmm
i_y	28.83	mm
i_z	16.93	mm
i_0	33.44	mm
λ_y	52.02	
$N_{cr,y}$	256174	N
$\lambda_{y,rel}$	0.687	
Φ_y	0.819	
χ_y	0.791	
$N_{by,Rd}$	87024	N
λ_z	88.603	
$N_{cr,z}$	88312	N
$\lambda_{z,rel}$	1.171	
Φ_z	1.350	
χ_z	0.494	
$N_{bz,Rd}$	54390	N
1.3D+1.4L+1.4ULS-Y-NL		
N	**11265**	N
M_y	**0.9*（632468+262500）**	Nmm
M_z	**0.9*（116869+131250）**	Nmm
$\alpha\beta\delta_y$	0.850	
$\alpha\beta\delta_z$	0.850	
$(N_{Ed}/\chi N_{c,Rd})^{\alpha y}$	0.007	
$(M_{y,Ed}/\chi_{LT}M_{y,Rd})^{\beta y}$	0.412	
$(M_{z,Ed}/M_{z,Rd})^{\delta y}$	0.190	
DCR1	0.609	
$(N_{Ed}/\chi_z N_{c,Rd})^{\alpha z}$	0.264	

$(M_{y,Ed}/\chi_{LT}M_{y,Rd})^{\beta z}$	0.412	
$(M_{z,Ed}/M_{z,Rd})^{\delta z}$	0.190	
DCR2	0.865	

According to the relevant provisions of EN15512, the beam verification must also account for the additional bending moments caused by horizontal and vertical placement loads. The horizontal placement load is Qph = 250 N, and the vertical placement load is Qpv = 500 N. These are applied as concentrated loads at the mid-span of two beams. The resulting additional bending moments on a single beam are calculated as follows:

MED, y = 1.4 * (Qpv / 2 * L / 2) = 1.4 * (500 / 2 * 1500 / 2) = 262500 Nmm

MED, z = 1.4 * (Qph / 2 * L / 2) = 1.4 * (250 / 2 * 1500 / 2) = 131250 Nmm

The above additional bending moments have already been superimposed into the beam verification table. Additionally, it should be noted that in accordance with EN15512, a combination factor of 0.9 is required when considering both placement loads and pallet loads simultaneously; this has also been taken into account in the aforementioned table.

Based on the calculations, the maximum stress ratio of the support beam under the most unfavorable static load condition is less than 1.0, which satisfies the load-bearing requirements.

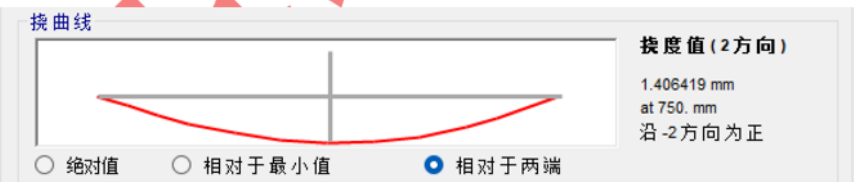
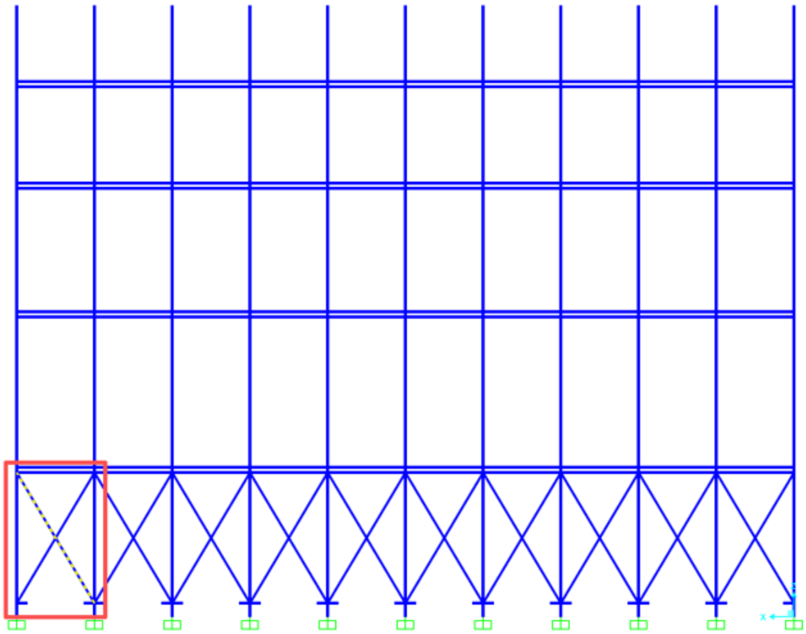


Diagram of beam deflection

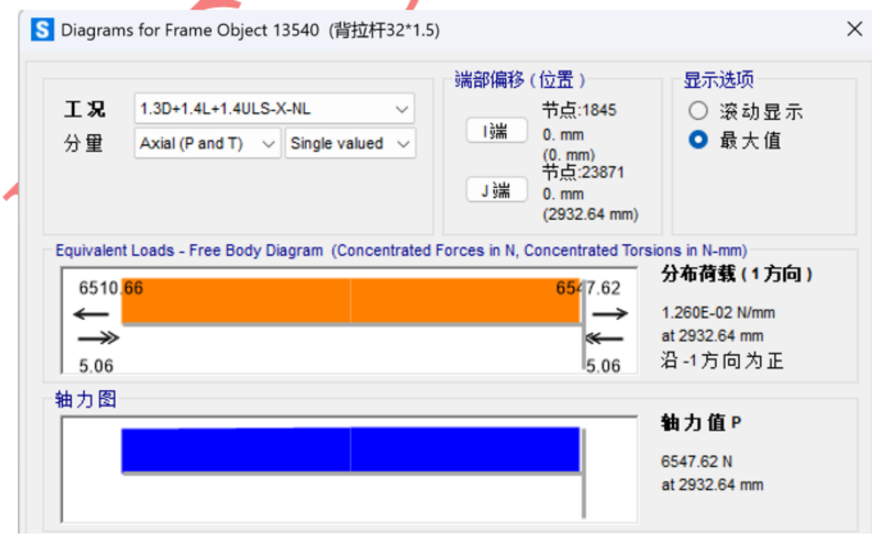
The finite element analysis shows that, the maximum deflection of the beam under the normal service limit state is 1.406 mm, which is less than the deflection limit L/200=7.50 mm; it meets the deformation requirements.

8.4 Cross Bracing (Φ32*1.5)

Member checks were performed on all cross bracing sections. The verification process for the most critically loaded section is as follows:



Critical corss brace location



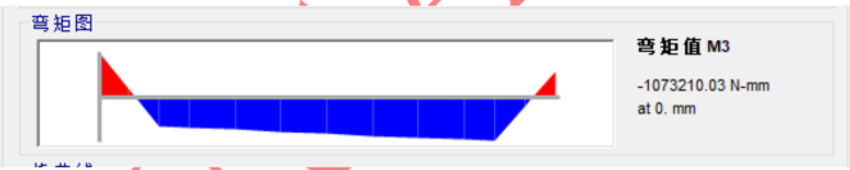
Internal force diagram of critical cross brace

ID	13540	
Laod combinations	1.3D+1.4L+1.4ULS-X-NL	
Name	Value	Describe
γ_{M2}	1.250	Material safety factor
fu	370.000	Tensile strength of steel
Nmax	6547.620	N
An	119.000	Minimum net area
DCR1	0.258	

The calculations indicate that the maximum stress ratio of the crossing bracing members under the most unfavorable static load case is less than 1.0. Meets the requirements.

8.5 Beam end connector

Based on beam end connector joint test data, the flexural capacity of the bracket at the beam end is 3.25 kN·m. According to the finite element model, the maximum design bending moment at the beam end is 1.07 kN·m. Therefore, the beam end connector joint satisfies the load-bearing requirement.



Maximum Design Bending Moment at Beam End

8.6 Brace end connector

All brace end connector joints are verified. The verification procedure for the critical brace end connector joint under self-weight is detailed below:

	Name	Value	Units
N	Sv	4258.96	N
N	Sc	4258.96	N
gama_M2	γ_{M2}	1.25	Joint Material safety factor
nv	nv	1	Number of cutting surfaces
e1	e1	20	Distance to the component(mm)
d	d	10	Diameter of bolt(mm)
t	t	1.3	Bar thickness(mm)
fu	fu	470	Tensile strength of steel (N/mm2)

ab	ab	0.667	
kt	kt	1	
As	As	58	Stress area of the bolt (mm2)
fub	fub	800	Tensile strength of the bolt (N/mm2)
Gd	Gd	8.8	Bolt level (x.x)
Co	Co	0.6	
DCR1	DCR1	0.191	Shear
DCR2	DCR2	0.523	Compressive

It is calculated that the maximum stress ratio of the brace end connector joint under the most unfavorable static condition is less than 1.0. Meet the requirements.

8.7 Cross brace end connector

All cross brace end connector joints are verified. The verification procedure for the critical brace end connector joint under self-weight is detailed below:

17	Name	Value	Units
N	Sv	6547.62	N
N	Sc	6547.62	N
gama_M2	γ_{M2}	1.25	Joint Material safety factor
nv	nv	1	Number of cutting surfaces
e1	e1	20	Distance to the component(mm)
d	d	10	Diameter of bolt(mm)
t	t	2	Bar thickness(mm)
fu	fu	470	Tensile strength of steel (N/mm2)
ab	ab	0.667	
kt	kt	1	
As	As	58	Stress area of the bolt (mm2)
fub	fub	800	Tensile strength of the bolt (N/mm2)
Gd	Gd	8.8	Bolt level (x.x)
Co	Co	0.6	
DCR1	DCR1	0.294	Shear
DCR2	DCR2	0.522	Compressive

It is calculated that the maximum stress ratio of the cross brace end connector joint under the most unfavorable static condition is less than 1.0. Meet the requirements.。

8.8 Upright foot joint

8.8.1 Bearing capacity of base plate

All base plates of upright bases are checked. The verification for the critical base plate is detailed as follows:

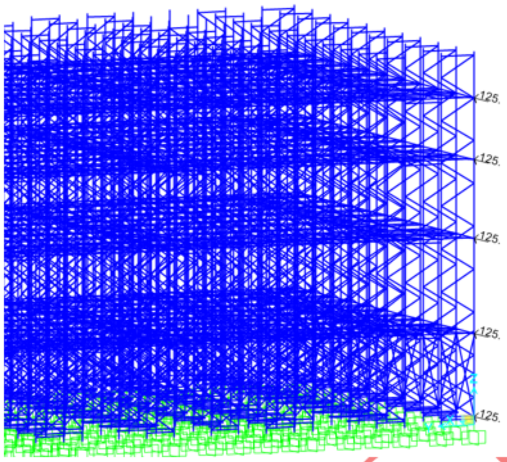
13	Name	Value	Units
t_b	t_b	16.0	Thickness (mm)
f_y	f_y	235.0	Yield Strength (N/mm²)
gama_M0	γ_{M0}	1.10	Material safety factor
f_ck	f_{ck}	20.1	Characteristic cylinder compressive strength of concrete (N/mm²)
β_j	β_j	0.667	
gama_c	γ_c	1.5	
f_j	f_j	8.9	N/mm²
c	c	45.2	mm
A_bas	A_{bas}	25486.00	Effective compressive area of base plate (mm²)
f_j_Abas	f_jA_{bas}	227788.771	N
N	N	71645.955	N
DCR1	**DCR1**	**0.315**	

Calculation results show that the maximum stress ratio of the column base plate under critical static loads is less than 1.0, complying with load-bearing requirements.

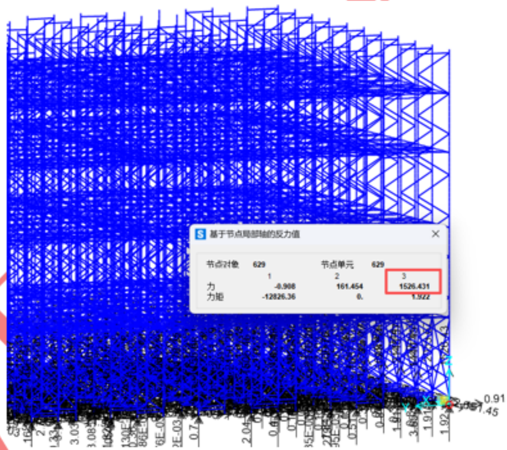
8.8.2 Anchor Bolt Uplift Resistance

When the rack is unloaded with lateral horizontal load applied at the top, overturning occurs and uplift force is induced at column bases.

The above overturning load case is included in the finite element model, defined as 1.3D+1.4Qph (Qph denotes horizontal load along the aisle direction, specified in Section 5.3 of this report). The maximum uplift force obtained under this load combination is 1714 N. Refer to the figure below for model load setup and column base internal forces.:



Load Setup Diagram for Load Combination 1.3D+1.4Q_p



Upright Base Uplift Force

The two column-base anchor bolts adopted for this project shall satisfy the above uplift force requirement.

8.8.3 Base plate bending capacity

The upright base plate is sized 280×150×16 mm, with a spacing of 200 mm between anchor bolts on both sides and a 50 mm distance from each anchor bolt to the adjacent upright flange. Subjected to uplift force, the base plate is simplified as a simplysupported beam under two concentrated loads; detailed verification is listed in the table below.

Bending Verification Table of Column Base Plate

Name	Value	Unit
F	1526.431	N
D	50	mm
M=F/2*50	38160.775	Nmm
M_{Rd}	1367273	Nmm
DCR	0.028	-

Where:

F stands for Maximum uplift force at column base;

D stands for Distance from anchor bolt to column edge;

M stands for Maximum bending moment acting on base plate;

M_{Rd} stands for Design flexural resistance of base plate.

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4. Contact Us

Wesafe is able to conduct the above structural certifications in compliance with design standards including EN 15512 (Europe), ANSI MH16.1 (USA), AS 4084 (Australia) and GB/T 39681 (China).

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