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AREA VI - Risorse Strumentali - Uffici Tecnici

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DREAMERS

Design REsearch, implementation And Monitoring of Emerging technologies for a new generation of Resilient Steel buildings

REALIZZAZIONE EDIFICIO C3 - Campus di Fisciano

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Luogo: Fisciano
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RELAZIONE	DESCRIZIONE ELABORATO
R 15.2	RELAZIONE DI CALCOLO DELLE STRUTTURE – CORPO SCALA

REV. N	DATA	MOTIVO DELLA EMISSIONE	ELABORATO DA:

RIF. PRATICA:	VERIFICA PROGETTO (art. 26 D.Lgs. 50/2016)
	UNITA' DI VERIFICA: Ing. Pantaleone Aufiero Geom. Giovanni Soldà
DATA: Febbraio 2023	

Università degli Studi di Napoli Federico II · LIÈGE université · tiarstudio · Universidade de Coimbra · Mott MacDonald · KNAUF · ArcelorMittal · Dreamers

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Certificato CSQ n. 0783.2020-6 scadenza 27/07/2023 per l'attività di verifiche sulla progettazione delle opere, ai fini della validazione, su progetti relativi alla propria stazione appaltante

STRUTTURE DEL CORPO SCALA-ASCENSORE

RELAZIONE DI CALCOLO

1. DESCRIZIONE DELLA STRUTTURA

La presente relazione di calcolo riguarda la struttura in acciaio del corpo scala-ascensore dell'edificio C3 nel Campus Universitario di Fisciano.

La struttura del corpo scala-ascensore è concepita in maniera tale da risultare strutturalmente indipendente dalla struttura dell'edificio C3. In particolare, essa è costituita da un castelletto in acciaio controventato. Il castelletto presenta quattro colonne costituite da una coppia di profili IPE240 disposti a croce in composizione saldata. Il castelletto ha sei livelli di cui tre risultano coincidenti con le quote degli impalcati dell'edificio C3. Le travi sono realizzate in profilo IPE240. I controventi sono realizzati in profilo tubolare tondo CHS 76.1x3.2. Tutte le membrature sono in acciaio S355.

Le rampe delle scale ed i pianerottoli sono realizzati mediante una soletta in cemento armato, pieghettata secondo lo sviluppo dei gradini, che poggia su delle travi a mensola in profilo IPE240, collegate al castelletto.

I collegamenti trave colonna sono bullonati di tipo flangiato. I collegamenti delle diagonali di controvento sono realizzate mediante un sistema bullonato del tipo fazzoletto e forcella. I collegamenti colonna fondazione sono realizzati mediante una piastra di base con tirafondi di ancoraggio, annegata nel getto di calcestruzzo per un tratto di lunghezza pari alla dimensione delle anime delle travi rovesce di fondazione. Pertanto, il collegamento colonna-fondazione può essere considerato rigido.

La Figura 1 mostra il modello strutturale agli elementi finiti. Le membrature in acciaio sono modellate mediante elementi finiti del tipo “beam-column”. La soletta è discretizzata mediante elementi finiti bidimensionali del tipo “plate”.

STAIRCASE-ELEVATOR BODY STRUCTURES

CALCULATION REPORT

1. DESCRIPTION OF THE STRUCTURE

This calculation report concerns the steel structure of the stair-elevator body of the C3 building on the Fisciano University Campus.

The structure of the stair-elevator body is designed in such a way as to be structurally independent of the structure of the C3 building. In particular, it consists of a braced steel castle structure. The castle has four columns made up of a pair of IPE240 profiles arranged in a cross in a welded composition. The castle has six levels, three of which coincide with the levels of the decks of building C3. The beams are made of IPE240 profiles. The braces are made of CHS 76.1x3.2 round tubular profiles. All members are in S355 steel.

The flights of stairs and the landings are made using a reinforced concrete slab, folded according to the development of the steps, which rests on cantilever beams made of IPE240 profiles, connected to the castle.

The beam-to-column connections are bolted according to the flanged type. The connections of the bracing diagonals are made using a bolted system of the gusset and fork type. The foundation-column connections are made using a base plate with anchor bolts, embedded in the concrete casting for a length equal to the size of the webs of the foundation beams. Therefore, the column-foundation connection can be considered rigid.

Figure 1 shows the structural finite element model. The steel members are modelled using finite elements of the "beam-column" type. The slab is discretized using two-dimensional finite elements of the "plate" type.

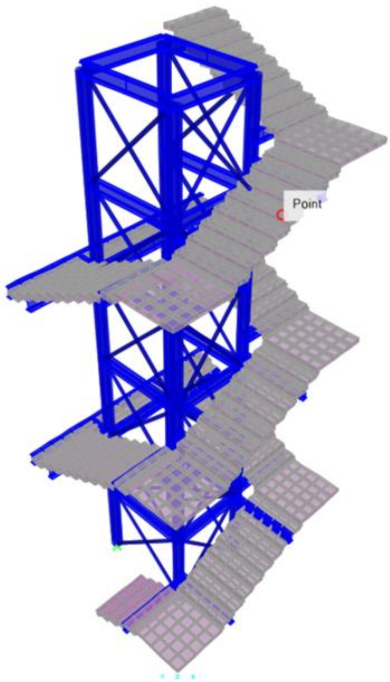


Figura 1: Modello strutturale

Figure 1: Structural model

2. NORME DI RIFERIMENTO

[1] NORME TECNICHE PER LE COSTRUZIONI di cui al D.M. 17/01/2018 - G.U. 42 del 20 febbraio 2018
[2] Circolare 21 gennaio 2019 n.7 “Istruzioni per l’applicazione dell’«Aggiornamento delle “Norme tecniche per le costruzioni”» di cui al decreto ministeriale 17 gennaio 2018″
[3] UNI EN 13670 - Esecuzione di strutture di calcestruzzo
[4] UNI EN 1992-1-1: 2005 – Eurocodice 2. Progettazione delle strutture di calcestruzzo Parte 1-1: Regole generali e regole per gli edifici
[5] UNI EN 1993-1-1:2014 - Eurocodice 3 - Progettazione delle strutture di acciaio - Parte 1-1: Regole generali e regole per gli edifici
[6] UNI EN 10027-1:2016 - Sistemi di designazione degli acciai - Parte 1: Designazione simbolica
[7] UNI EN 10025-1 - Prodotti laminati a caldo di acciai per impieghi strutturali - Parte 1: Condizioni tecniche generali di fornitura
[8] UNI EN 10025-2:2005 - Prodotti laminati a caldo di acciai per impieghi strutturali - Parte 2: Condizioni tecniche di fornitura di acciai non legati per impieghi strutturali

2. REFERENCE STANDARDS

[1] TECHNICAL STANDARDS FOR BUILDINGS as per D.M. 17/01/2018 - Official Journal 42 of 20 February 2018 (in Italian)
[2] Circular no. 7 of 21 January 2019 "Instructions for the application of the “Update of the “Technical standards for construction" referred to in the ministerial decree of 17 January 2018″ (in Italian)
[3] UNI EN 13670 - Execution of concrete structures
[4] UNI EN 1992-1-1: 2005 – Eurocode 2. Design of concrete structures Part 1-1: General rules and rules for buildings
[5] UNI EN 1993-1-1:2014 - Eurocode 3 - Design of steel structures - Part 1-1: General rules and rules for buildings
[6] UNI EN 10027-1:2016 - Steel designation systems - Part 1: Symbolic designation
[7] UNI EN 10025-1 - Hot rolled steel products for structural uses - Part 1: General technical supply conditions
[8] UNI EN 10025-2:2005 - Hot rolled steel products for structural uses - Part 2: Technical conditions for the supply of non-alloy steels for structural uses.

3. AZIONI DI PROGETTO

Le azioni considerate ai fini del progetto della struttura sono:

- i carichi permanenti strutturali G_{k1}, che nel caso in esame risultano costituiti dal solo peso proprio delle membrature in acciaio e dal peso della soletta di calcestruzzo costituente le rampe e i pianerottoli;
- i carichi permanenti non strutturali G_{k2}, che nel caso specifico risultano costituiti rivestimento delle scale e dal peso della cabina dell’ascensore.
- i carichi variabili dovuti alla destinazione d’uso della struttura.
- le azioni sismiche.

La struttura del corpo scala-ascensore non risulta soggetta ad azioni da vento, in quanto tutta interna al corpo dell’edificio C3. Inoltre, gli effetti delle variazioni termiche risultano trascurabili.

3. PROJECT ACTIONS

The actions considered for the structure design are:

- permanent structural loads G_{k1}, which in the case in question are constituted only by the weight of the steel members and by the weight of the concrete slab constituting the ramps and landings;
- non-structural permanent loads G_{k2}, which in the specific case are made up of the stairs' slab and the elevator car's weight.
- variable loads due to the intended use of the structure.
- seismic actions.

The structure of the stair-elevator body is not subject to wind actions, as it is entirely inside the body of the C3 building. Furthermore, the effects of thermal variations are negligible.

3.1 Carichi permanenti strutturali

I carichi permanenti strutturali sono costituiti da:

3.1 Structural permanent loads

The structural permanent loads consist of:

Lista dei materiali/materials’ list		
Sezione/Section	**Lunghezza totale/Total length**	**Peso totale/Total Weight**
	m	Kg
2XIPE240	46,4	2694,51
IPE240	81	2485,87
TUBO-D76.1X3.2	100,3192	577,09

La soletta dei pianerottoli e della rampe ha un peso pari a 25 kN/m^3.

The slab of the landings and ramps weighs 25 kN/m^3.

3.2 Carichi permanenti non strutturali

I carichi permanenti non strutturali sono costituiti dal rivestimento delle scale e del vano ascensore per complessivi 1.81 kN/m^2.

3.3 Carichi variabili

I carichi variabili, in accordo a quanto previsto dalla normativa, sono assunti pari 4.0 kN/m^2.

3.4 Azioni sismiche

Con riferimento alla cittadina di Fisciano, i parametri per la determinazione degli spettri elastici di progetto che definiscono l'azione sismica per i diversi stati limite previsti dalla normativa sono riportati nel prospetto seguente:

3.2 Permanent non-structural loads

The non-structural permanent loads consist of the finishes of the stairs and the lift shaft for a total of 1.81 kN/m^2.

3.3 Variable loads

The variable loads, by the provisions of the legislation, are assumed to be equal to 4.0 kN/m^2.

3.4 Seismic actions

Concerning the town of Fisciano, the parameters for the determination of the design elastic spectra that define the seismic action for the various limit states envisaged by the legislation are shown in the following table:

STATO LIMITE/LIMIT STATE	T_R [anni]	a_g [g]	F_o [-]	T_C^* [s]
SLO	45	0,053	2,361	0,313
SLD	75	0,065	2,405	0,338
SLV	712	0,148	2,527	0,431
SLC	1462	0,182	2,591	0,448

I suddetti parametri si riferiscono alla Categoria d'Uso III per la quale risulta C_u=1.50.
Con tali valori dei parametri che definiscono la pericolosità sismica del sito, gli spettri elastici di progetto per sito di riferimento (suolo rigido e piano di campagna orizzontale) sono riportati nella figura seguente:

The aforementioned parameters refer to Category of Use III for which C_u=1.50.
With these values of the parameters that define the seismic hazard of the site, the design elastic spectra for the reference site (rigid ground and horizontal countryside plane) are shown in the following figure:

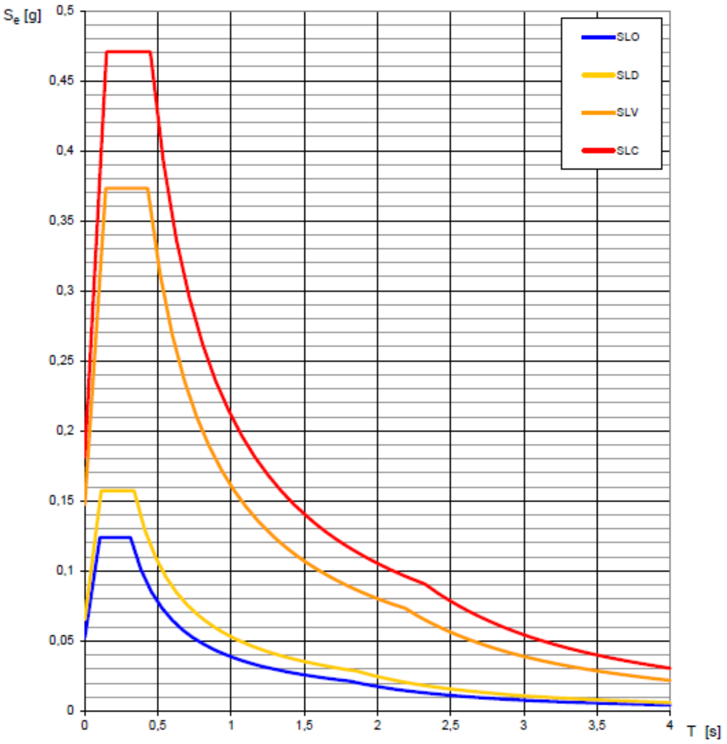
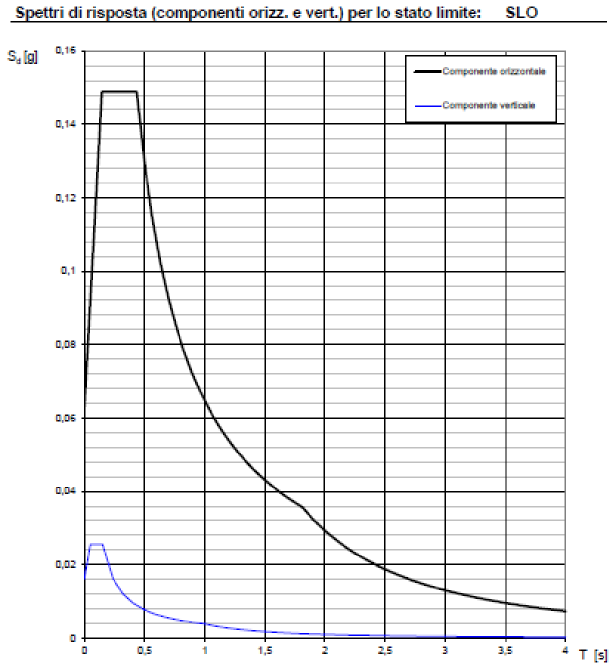


Figura 2: sismicità del sito

Figure 2: site sismicity

Dalle prove eseguite in sito, come risulta dalla relazione geologica, la colonna stratigrafica rientra nel caso di suolo tipo B.
La progettazione sismo-resistente della struttura è stata effettuata con l'obiettivo di garantire che la struttura rimanga in campo elastico per un valore dell'azione sismica pari a quella più gravosa definita come la massima derivante dallo spettro SLO e dallo spettro SLV. A vantaggio di statica lo spettro di progetto allo stato limite SLV è stato determinato considerando fattore di struttura q=4. In particolare, tale scelta del fattore di struttura risulta inferiore al valore previsto dalla normativa per le strutture intelaiate e pari quello previsto per le strutture con controventi concentrici ad X.
Gli spettri di progetto per gli stati limite SLO ed SLV, determinati come precisato, sono riportati di seguito.

From the tests carried out on-site, as shown by the geological report, the stratigraphic column falls within the case of soil type B.
The seismic-resistant design of the structure was carried out to ensure that the structure remains in the elastic range for a value of the seismic action equal to the heaviest one defined as the maximum deriving from the SLO spectrum and the SLV spectrum. For the benefit of statics, the design spectrum at the limit state SLV was determined by considering the structure factor q=4. In particular, this choice of the structure factor is lower than the value set by the law for framed structures and equal to that set for structures with concentric X-bracings.
The design spectra for the SLO and SLV limit states, determined as specified, are given below.



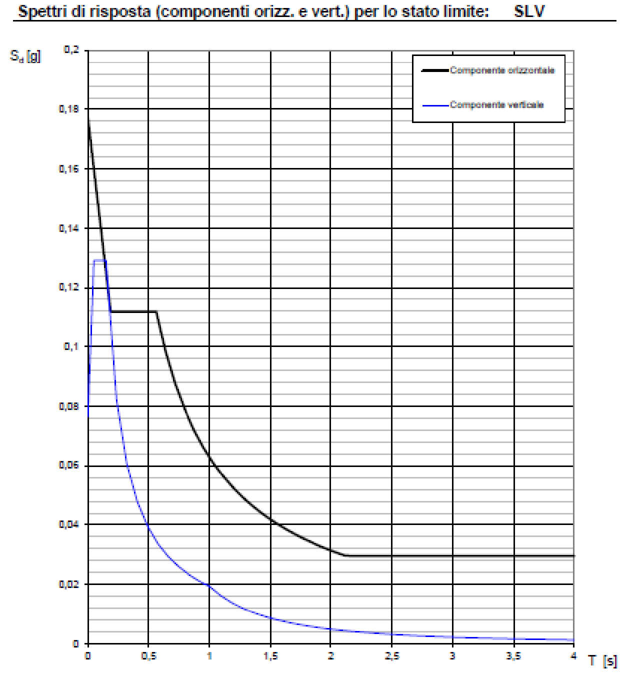


Figura 3: Spettri di Progetto allo SLO (sinistra) e spettri di progetto allo SLV (destra)

Figure 3: Design spectra at SLO (left) and design spectra at SLV (right)

L'analisi sismica della struttura è stata effettuata mediante l'analisi modale per spettro di risposta. La tecnica di combinazione modale impiegata è la CQC.

L'analisi è stata effettuata considerata i primi 12 modi di vibrazione che garantiscono una partecipazione modale delle masse superiore al 98% sia per sisma in direzione x che per sisma in direzione y.
I periodi di vibrazione dei 18 modi di vibrare considerati sono riportati nel prospetto seguente:

The seismic analysis of the structure was performed using the modal response spectrum analysis. The modal combination technique employed is the CQC.

The analysis was carried out considering the first 12 vibration modes which guarantee modal participation of the masses greater than 98% for both an earthquake in the x direction and for an earthquake in the y direction.
The periods of vibration of the 18 modes of vibration considered are shown in the following table:

Coefficienti di partecipazione modale delle masse Modal Participating Mass Ratios					
Modo/Mode	**Periodo/Period**	**UX**	**UY**	**SumUX**	**SumUY**
Unitless	Sec				
1	0,4981	0,4243	0,0065	0,4243	0,0065
2	0,3569	0,2585	0,0548	0,6828	0,0613
3	0,3088	0,0060	0,6177	0,6888	0,6790
4	0,1690	0,0965	0,0035	0,7853	0,6825
5	0,1470	0,0451	0,0001	0,8304	0,6827
6	0,1283	0,0046	0,0362	0,8350	0,7188
7	0,1248	0,0140	0,0538	0,8489	0,7726
8	0,1215	0,0091	0,0016	0,8581	0,7742
9	0,1184	0,0001	0,0015	0,8582	0,7757
10	0,1081	0,0019	0,0015	0,8601	0,7772
11	0,1077	0,0024	0,0000	0,8625	0,7772
12	0,1051	0,0003	0,0000	0,8629	0,7772
13	0,1013	0,0019	0,0346	0,8647	0,8118
14	0,0989	0,0061	0,0002	0,8708	0,8120
15	0,0984	0,0022	0,0060	0,8729	0,8180
16	0,0972	0,0005	0,0111	0,8734	0,8292
17	0,0952	0,0002	0,0050	0,8736	0,8342
18	0,0885	0,0197	0,0152	0,8933	0,8493

4. COEFFICIENTI PARZIALI DI SICUREZZA E COMBINAZIONI DI CARICO

Secondo quanto prescritto dalle NTC 2018, le combinazioni di carico di progetto sono state determinate tenendo conto dei seguenti coefficienti parziali di sicurezza.

4. PARTIAL SAFETY FACTORS AND LOAD COMBINATIONS

As prescribed by the NTC 2018, the design load combinations have been determined taking into account the following partial safety factors.

	Simbolo / symbol	**se favorevoli / if favourable**	**se non favorevoli / if unfavourable**
Carichi permanenti strutturali / permanent structural loads	G1	1.00	1.30
Carichi permanenti non strutturali / permanent non structural loads	G2	0.80	1.50
Carichi variabili / variable loads	Q	0	1.50
Azioni sismiche allo SLO / Seismic actions for SLO limit state	SISMA-SLO	0	1.00
Azioni sismiche allo SLV / Seismic actions for SLV limit state	SISMA-SLU	0	1.00

In particolare, il carico variabile è stato disposto su tutte le rampe (condizione di carico Q), solo sulla rampa sinistra (condizione di carico QS), solo sulla rampa destra (condizione di carico QD) oppure solo sulla rampa parallela al pianerottolo di arrivo (condizione di carico QB). In altri termini, sono state investigate anche le condizioni di carico gravitazionale che massimizzano la

In particular, the variable load was placed on all ramps (load condition Q), only on the left ramp (load condition QS), only on the right ramp (load condition QD) or only on the ramp parallel to the arrival landing (load condition QB). In other words, the gravitational load conditions that maximize the flexure of the frame in the longitudinal direction or the transversal direction were also investigated.

flessione del castelletto in direzione longitudinale o in direzione trasversale.
Pertanto sono state considerate le seguenti combinazioni di carico:

1) 1.30 G1 + 1.50 G2
2) 1.30 G1 + 1.50 G2 + 1.50 Q
3) 1.30 G1 + 1.50 G2 + 1.50 QS
4) 1.30 G1 + 1.50 G2 + 1.50 QD
5) 1.30 G1 + 1.50 G2 + 1.50 QB
6) G1 + G2 + 0.60 Q + SISMA-SLO-U1 + 0.30 SISMA-SLO-U2
7) G1 + G2 + 0.60 Q + 0.30 SISMA-SLO-U1 + SISMA-SLO-U2
8) G1 + G2 + 0.60 Q + SISMA-SLU-U1 + 0.30 SISMA-SLU-U2
9) G1 + G2 + 0.60 Q + 0.30 SISMA-SLU-U1 + SISMA-SLU-U2

dove U1 denota il sisma in direzione x ed U2 il sisma in direzione y.

5. SINTESI DEI RISULTATI DI CALCOLO E DELLE VERIFICHE

Dai tabulati di calcolo e delle verifiche di resistenza e di stabilità delle membrature, risulta che tutte le verifiche sono soddisfatte.
La Figura 4 seguente riporta i tassi di lavoro delle membrature (ossia il rapporto tra la sollecitazione di progetto e la resistenza di progetto). Un valore inferiore a 1.0 indica che il punto rappresentativo dello stato di sollecitazione è interno al dominio di resistenza della membratura.

Therefore the following load combinations have been considered:

1) 1.30 G1 + 1.50 G2
2) 1.30 G1 + 1.50 G2 + 1.50 Q
3) 1.30 G1 + 1.50 G2 + 1.50 QS
4) 1.30 G1 + 1.50 G2 + 1.50 QD
5) 1.30 G1 + 1.50 G2 + 1.50 QB
6) G1 + G2 + 0.60 Q + SISMA-SLO-U1 + 0.30 SISMA-SLO-U2
7) G1 + G2 + 0.60 Q + 0.30 SISMA-SLO-U1 + SISMA-SLO-U2
8) G1 + G2 + 0.60 Q + SISMA-SLU-U1 + 0.30 SISMA-SLU-U2
9) G1 + G2 + 0.60 Q + 0.30 SISMA-SLU-U1 + SISMA-SLU-U2

where U1 denotes the earthquake in the x direction and U2 is the earthquake in the y direction.

5. SUMMARY OF CALCULATION RESULTS AND VERIFICATIONS

From the calculation tables and the resistance and stability checks of the members, it appears that all the checks are satisfied.
The following Figure 4 shows the work rates of the members (i.e. the ratio between the design stress and the design strength). A value less than 1.0 indicates that the representative stress state point is within the strength domain of the member.

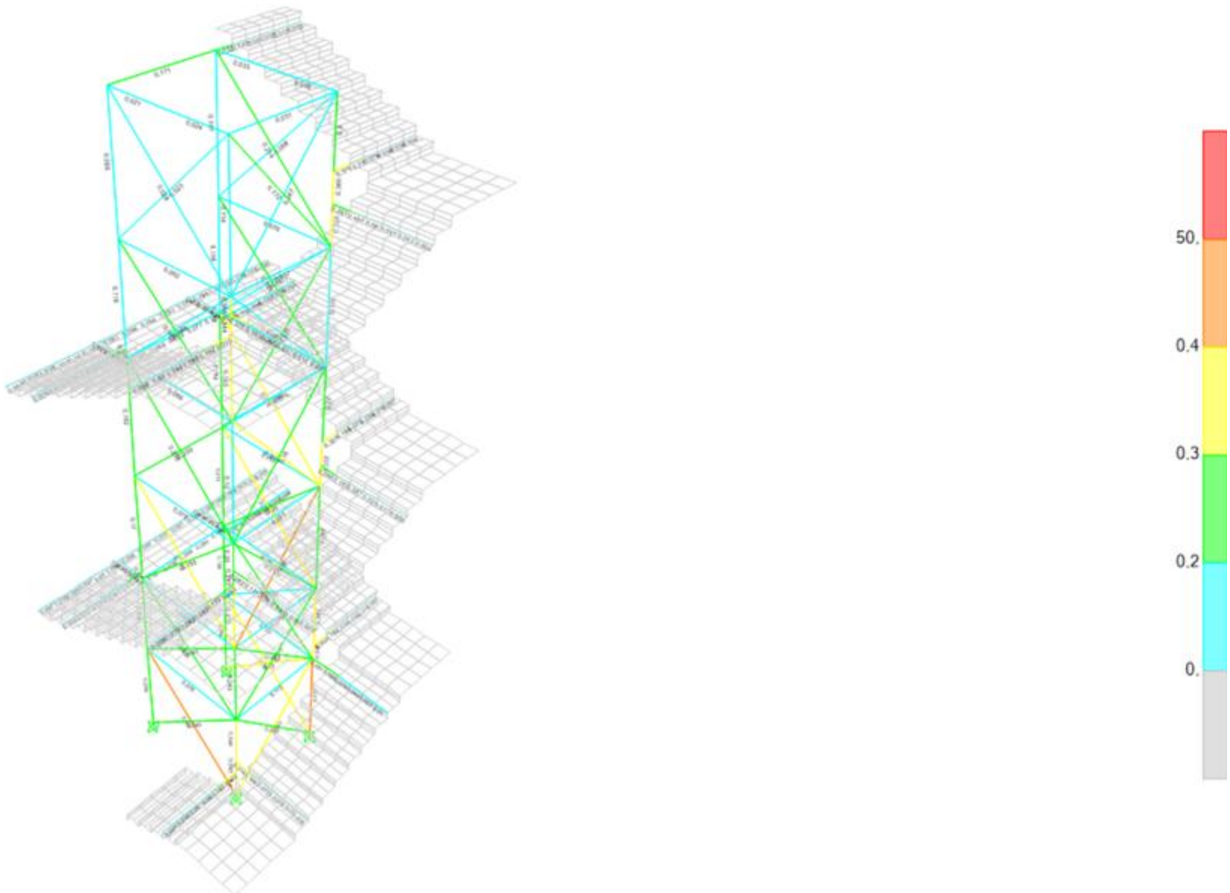


Figura 4: Tassi di lavoro massimi delle membrature

Figure 4: Maximum member work rates

In particolare, i tassi di lavoro massimi delle membrature strutturali risultano i seguenti:

In particular, the maximum working rates of the structural members are as follows:

Colonne: 42.7%
Diagonali: 40.8%
Travi del castelletto: 23.9%
Travi a mensola: 34.2%

I tabulati seguenti riportano le verifiche dei collegamenti.

Columns: 42.7%
Diagonals: 40.8%
Castle beams: 23.9%
Cantilever beams: 34.2%

The following tables show the checks on the connections.

Project data

Project name: CORPO SCALA COLLEGAMENTO DI BASE	
Project number	
Author Description Date	
Design code	
	12/01/2023
	EN

Material

Steel	S 355, S 275
Concrete	C25/30

Project item CON1

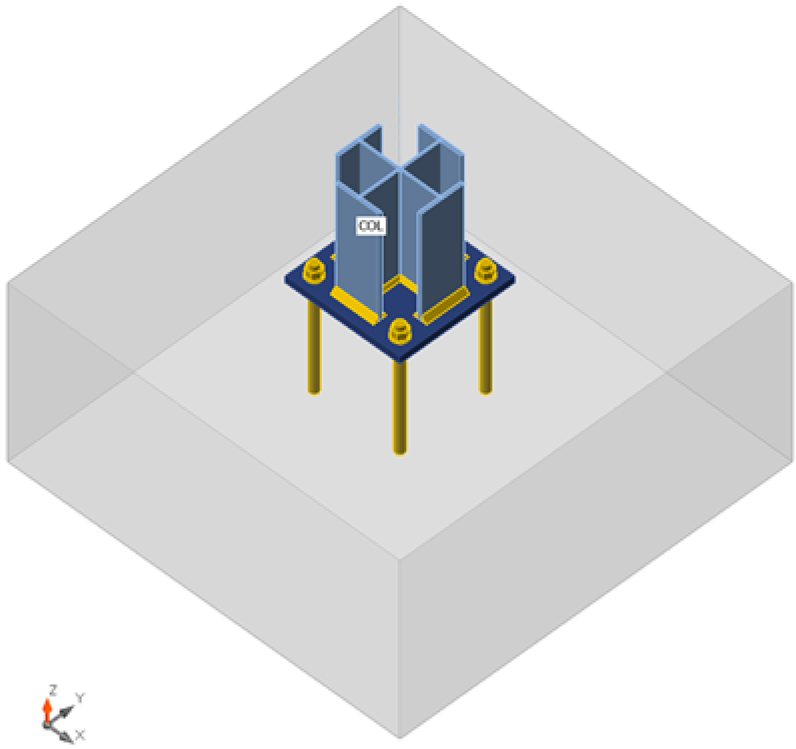
Design

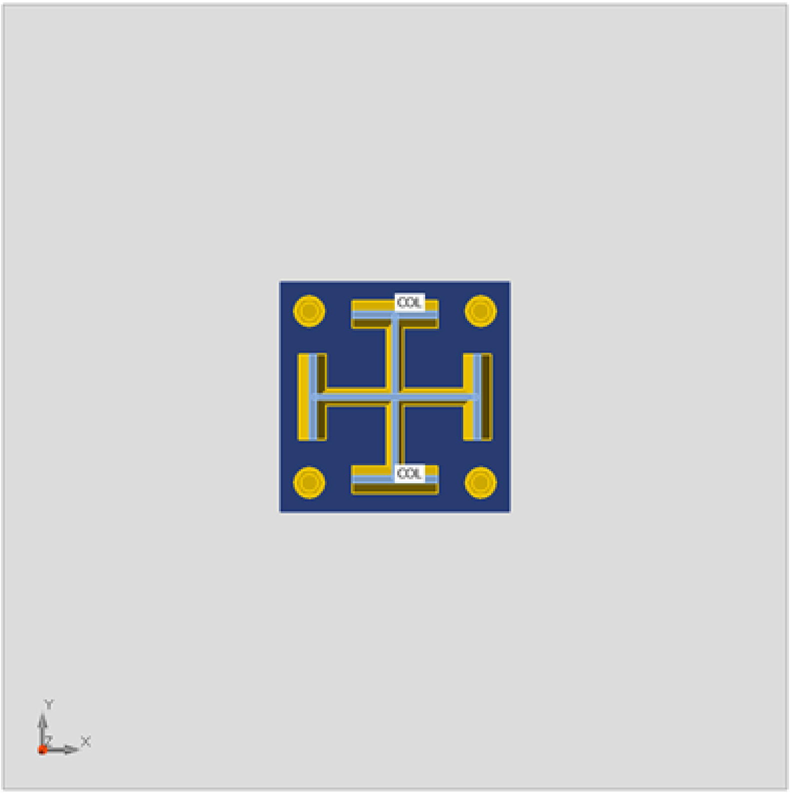
Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

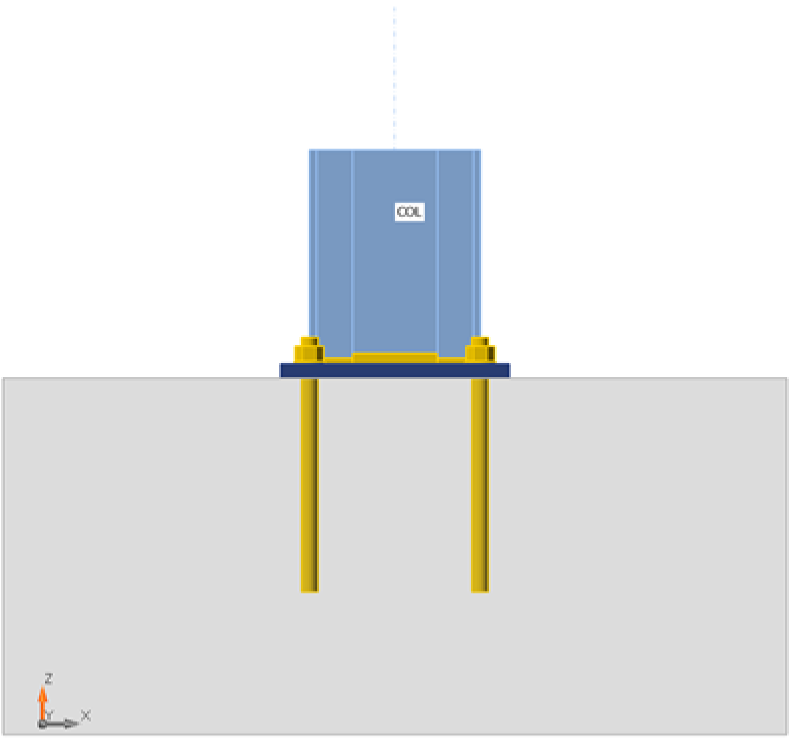
Members

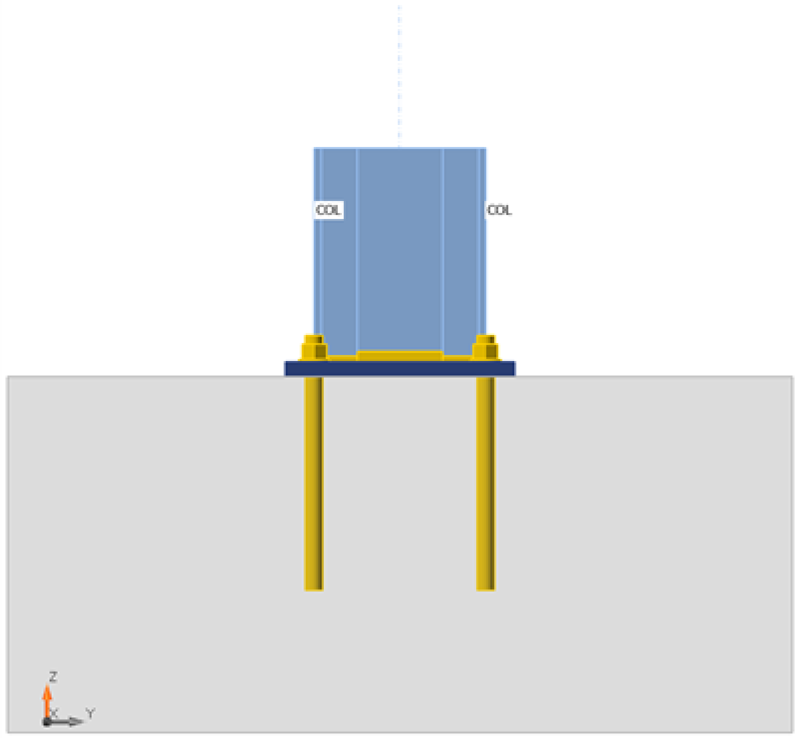
Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
COL	4 - General	0.0	-90.0	0.0	0	0	0	Position	1100




COL
COL
Y
X

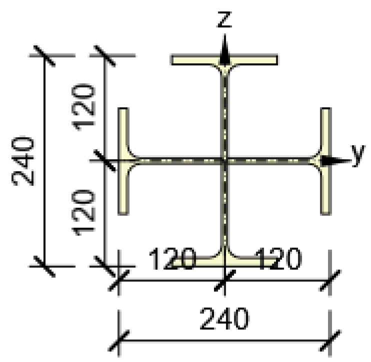

COL
Z
X



Cross-sections

Name	Material
4 - General	S 275, S 275, S 275

Cross-sections

Name	Material	Drawing
4 - General	S 275, S 275, S 275	

Anchors

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M24 8.8	M24 8.8	24	800.0	452

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	COL	-169.1	-2.6	-3.0	0.0	-0.7	3.2
LE2	COL	-319.5	-5.6	-6.4	0.0	-1.3	6.2
LE3	COL	-114.0	-1.7	-1.9	0.0	-0.4	2.1
LE4	COL	-223.4	-3.8	-4.4	0.0	-0.9	4.3
LE5	COL	-291.7	13.3	16.2	0.0	5.7	8.4
LE6	COL	-14.7	-18.2	-21.8	0.0	-6.9	-2.5
LE7	COL	-262.4	6.6	14.6	0.0	4.9	6.1
LE8	COL	-44.0	-11.5	-20.2	0.0	-6.1	-0.3
LE9	COL	-327.6	17.8	21.3	0.0	7.4	9.9
LE10	COL	21.2	-22.7	-26.9	0.0	-8.6	-4.1
LE11	COL	-295.9	9.4	20.1	0.0	6.6	7.1
LE12	COL	-10.5	-14.3	-25.7	0.0	-7.8	-1.3
LE13	COL	-133.0	-0.7	-2.3	0.0	-1.5	3.3
LE14	COL	-305.2	-9.8	-2.1	0.0	-1.1	6.1
LE15	COL	-285.5	-2.6	-10.9	0.0	-0.5	4.2
LE16	COL	-26.0	-2.3	4.5	0.0	-1.8	-3.5
LE17	COL	-35.2	-4.5	9.4	0.0	-3.7	-6.9
LE18	COL	-19.0	-1.5	2.9	0.0	-1.2	-2.3
LE19	COL	-25.7	-3.1	6.5	0.0	-2.6	-4.8
LE20	COL	-72.4	1.9	16.3	0.0	1.6	4.5
LE21	COL	29.6	-6.1	-7.9	0.0	-5.0	-10.9
LE22	COL	-108.2	-0.1	19.1	0.0	2.3	0.5
LE23	COL	65.3	-4.1	-10.8	0.0	-5.7	-6.9
LE24	COL	-89.6	2.8	19.9	0.0	2.5	6.3
LE25	COL	46.8	-7.0	-11.5	0.0	-5.9	-12.7
LE26	COL	-137.4	0.4	24.0	0.0	3.6	1.5
LE27	COL	94.6	-4.7	-15.6	0.0	-7.0	-7.9
LE28	COL	0.1	-4.2	6.1	0.0	-2.0	-7.3
LE29	COL	-74.2	-3.3	4.0	0.0	-2.4	-4.3
LE30	COL	7.0	-1.9	11.4	0.0	-4.0	-2.8
LE31	COL	-176.7	3.9	0.3	0.0	2.1	3.3
LE32	COL	-334.9	8.1	0.1	0.0	4.2	6.6
LE33	COL	-119.0	2.5	0.3	0.0	1.4	2.2
LE34	COL	-234.0	5.6	0.1	0.0	2.9	4.6
LE35	COL	-305.4	16.4	17.9	0.0	7.3	6.7
LE36	COL	-15.0	-9.2	-17.5	0.0	-3.4	-0.6
LE37	COL	-268.5	11.5	12.6	0.0	5.6	5.1
LE38	COL	-51.9	-4.3	-12.2	0.0	-1.7	1.0
LE39	COL	-341.2	19.8	22.6	0.0	8.7	7.7
LE40	COL	20.8	-12.6	-22.2	0.0	-4.9	-1.6
LE41	COL	-300.8	13.9	16.2	0.0	6.6	5.7

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE42	COL	-19.6	-6.7	-15.8	0.0	-2.8	0.4
LE43	COL	-315.1	3.9	1.2	0.0	3.2	4.2
LE44	COL	-144.3	11.5	-0.7	0.0	2.3	6.3
LE45	COL	-291.3	3.1	-0.5	0.0	3.9	4.4
LE46	COL	-50.8	1.0	-1.8	0.0	-0.8	0.3
LE47	COL	-84.0	2.0	-3.1	0.0	-1.6	0.6
LE48	COL	-35.5	0.7	-1.3	0.0	-0.5	0.2
LE49	COL	-59.6	1.4	-2.2	0.0	-1.1	0.4
LE50	COL	-116.7	5.2	14.6	0.0	3.6	8.3
LE51	COL	28.4	-3.4	-17.7	0.0	-5.1	-7.8
LE52	COL	-124.6	3.0	10.9	0.0	2.7	4.1
LE53	COL	36.3	-1.2	-14.1	0.0	-4.2	-3.6
LE54	COL	-140.8	6.2	19.3	0.0	4.8	10.2
LE55	COL	52.5	-4.4	-22.5	0.0	-6.3	-9.7
LE56	COL	-151.6	3.6	14.7	0.0	3.7	5.1
LE57	COL	63.3	-1.8	-17.9	0.0	-5.2	-4.6
LE58	COL	-117.5	1.0	-5.0	0.0	-1.0	-1.3
LE59	COL	-30.1	1.7	-1.2	0.0	-0.8	1.5
LE60	COL	-17.7	1.4	-0.1	0.0	-2.0	1.0

Foundation block

Item	Value	Unit
CB 1		
Dimensions	1100 x 1100	mm
Depth	500	mm
Anchor	M24 8.8	
Anchoring length	300	mm
Shear force transfer	Anchors	

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.2 < 5.0%	OK
Anchors	67.4 < 100%	OK
Welds	85.7 < 100%	OK
Concrete block	26.2 < 100%	OK
Buckling	Not calculated	

Plates

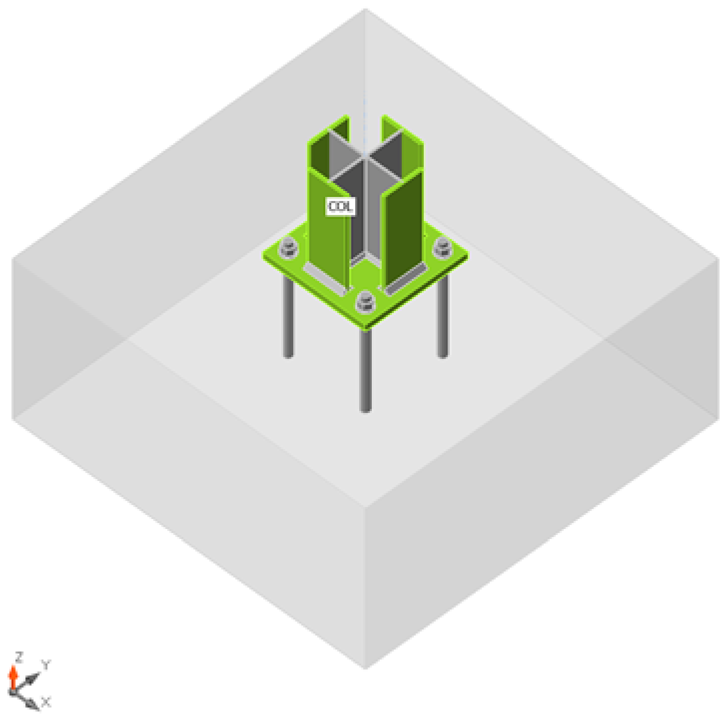
Name	Material	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
COL-bfl 1	S 275	9.8	LE10	199.5	0.0	0.0	OK
COL-tfl 1	S 275	9.8	LE10	258.1	0.2	0.0	OK
COL-w 1	S 275	6.2	LE26	92.0	0.0	0.0	OK
COL-tfl 2	S 275	9.8	LE10	222.2	0.0	0.0	OK
COL-w 2	S 275	6.2	LE10	94.1	0.0	0.0	OK
COL-tfl 3	S 275	9.8	LE10	254.6	0.2	0.0	OK
COL-w 3	S 275	6.2	LE39	127.3	0.0	0.0	OK
BP1	S 355	20.0	LE10	345.6	0.0	0.0	OK

Design data

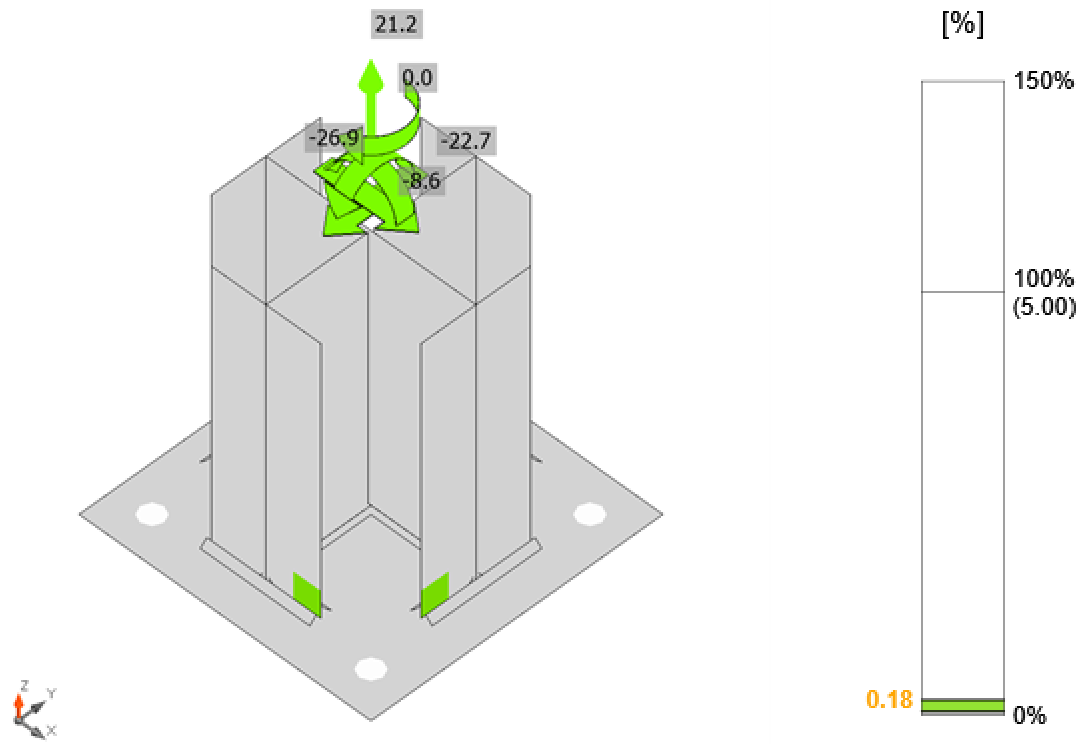
Material	f_y [MPa]	ε_{lim} [%]
S 275	275.0	5.0
S 355	355.0	5.0

Symbol explanation

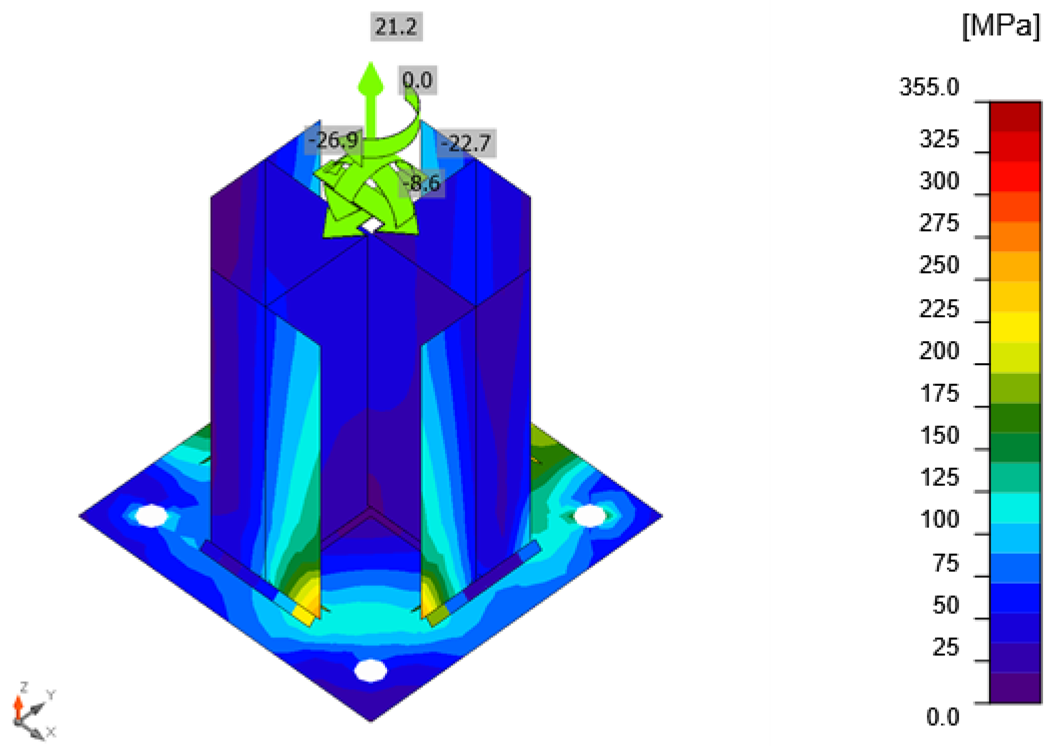
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE10

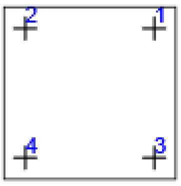


Strain check, LE10



Equivalent stress, LE10

Anchors

Shape	Item	Loads	N_{Ed} [kN]	V_{Ed} [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Status
	A1	LE10	107.9	10.3	67.4	9.1	46.3	OK
	A2	LE55	37.0	5.4	23.1	4.8	5.6	OK
	A3	LE10	49.4	7.7	30.9	6.9	10.0	OK
	A4	LE24	37.7	5.3	23.6	4.7	5.8	OK

Design data

Grade	$N_{Rd,s}$ [kN]	$V_{Rd,s}$ [kN]
M24 8.8 - 1	160.0	113.0

Symbol explanation

N_{Ed}	Tension force
V_{Ed}	Resultant of bolt shear forces Vy and Vz in shear planes
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Utilization in tension and shear
$N_{Rd,s}$	Design tensile resistance of a fastener in case of steel failure - EN1992-4 - Cl. 7.2.1.3
$V_{Rd,s}$	Design shear resistance in case of steel failure - EN1992-4 - Cl.7.2.2.3.1

Detailed result for A1

Anchor tensile resistance (EN1992-4 - Cl. 7.2.1.3)

$$N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}} = 160.0 \text{ kN} \geq N_{Ed} = 107.9 \text{ kN}$$

$$N_{Rk,s} = c \cdot A_s \cdot f_{uk} = 240.0 \text{ kN}$$

Where:

$c = 0.85$ – reduction factor for cut thread

$A_s = 353 \text{ mm}^2$ – tensile stress area

$f_{uk} = 800.0 \text{ MPa}$ – minimum tensile strength of the bolt

$\gamma_{Ms} = 1.50$ – safety factor for steel

- $\gamma_{Ms} = 1.2 \cdot \frac{f_{uk}}{f_{yk}} \geq 1.4$, where:
  - $f_{yk} = 640.0$ MPa – minimum yield strength of the bolt

Shear resistance (EN1992-4 - Cl.7.2.2.3.1)

$V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}} =$ 113.0 kN ≥ $V_{Ed} =$ 10.3 kN

$V_{Rk,s} = k_7 \cdot V_{Rk,s}^0 =$ 141.2 kN

Where:

$k_7 = 1.00$ – coefficient for anchor steel ductility

- $k_7 = \begin{cases} 0.8, & A < 0.08 \\ 1.0, & A \geq 0.08 \end{cases}$, where:
  - $A =$ 0.12 – bolt grade elongation at rupture

$V_{Rk,s}^0 = 141.2$ kN – the characteristic shear strength

- $V_{Rk,s}^0 = k_6 \cdot A_s \cdot f_{uk}$, where:
  - $k_6 =$ 0.50 – coefficient for anchor resistance in shear
  - $A_s =$ 353 mm^2 – tensile stress area
  - $f_{uk} =$ 800.0 MPa – specified ultimate strength of anchor steel

$\gamma_{Ms} = 1.25$ – safety factor for steel

Interaction of tensile and shear forces in steel (EN 1992-4 - Table 7.3)

$\left(\frac{N_{Ed}}{N_{Rd,s}}\right)^2 + \left(\frac{V_{Ed}}{V_{Rd,s}}\right)^2 =$ 0.46 ≤ 1.0

Where:

$N_{Ed} = 107.9$ kN – design tension force

$N_{Rd,s} = 160.0$ kN – fastener tensile strength

$V_{Ed} = 10.3$ kN – design shear force

$V_{Rd,s} = 113.0$ kN – fastener shear strength

Interaction of tensile and shear forces in concrete (EN 1992-4 - Table 7.3)

$(\frac{N_{Ed}}{N_{Rd,i}})^{1.5} + (\frac{V_{Ed}}{V_{Rd,i}})^{1.5} =$ 0.00 ≤ 1.0

Where:

$\frac{N_{Ed}}{N_{Rd,i}}$ – the largest utilization value for tension failure modes

$\frac{V_{Ed}}{V_{Rd,i}}$ – the largest utilization value for shear failure modes

$\frac{N_{Ed,g}}{N_{Rd,c}} = 0\%$ – concrete breakout failure of anchor in tension

$\frac{N_{Ed}}{N_{Rd,p}} = 0\%$ – concrete pullout failure

$\frac{N_{Ed}}{N_{Rd,cb}} = 0\%$ – concrete blowout failure

$\frac{V_{Ed}}{V_{Rd,c}} = 0\%$ – concrete edge failure

$\frac{V_{Ed}}{V_{Rd,cb}} = 0\%$ – concrete pryout failure

Supplementary reinforcement (EN 1992-4 - Cl. 7.2.1.9; EN 1992-4 - Cl. 7.2.2.6)

Supplementary reinforcement should resist force of 191.5 kN in tension and 35.2 kN in shear.

Welds

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
BP1	COL-bfl 1	◢ 10.0 ◣	120	LE30	171.7	0.0	41.9	74.4	60.9	42.4	19.9	OK
		◢ 10.0 ◣	120	LE30	201.1	0.0	63.9	-100.5	-45.0	49.7	18.2	OK
BP1	COL-tfl 1	◢ 10.0 ◣	120	LE10	347.0	0.0	96.2	187.4	43.8	85.7	31.0	OK
		◢ 10.0 ◣	120	LE10	287.6	0.0	54.7	-122.9	-107.1	71.1	36.3	OK
BP1	COL-w 1	◢ 6.0 ◣	230	LE10	54.1	0.0	20.1	-26.9	-10.9	13.4	8.4	OK
		◢ 6.0 ◣	230	LE10	65.7	0.0	10.0	27.0	-26.0	16.2	6.9	OK
BP1	COL-tfl 2	◢ 10.0 ◣	120	LE10	213.7	0.0	-88.5	92.5	-63.7	52.8	20.2	OK
		◢ 10.0 ◣	120	LE10	184.4	0.0	-57.4	-59.1	82.2	45.6	22.1	OK
BP1	COL-w 2	◢ 6.0 ◣	112	LE10	75.4	0.0	-0.9	-40.5	15.9	18.6	6.3	OK
		◢ 6.0 ◣	112	LE10	46.2	0.0	2.5	-26.2	-5.0	11.4	9.0	OK
BP1	COL-tfl 3	◢ 10.0 ◣	120	LE10	346.1	0.0	103.3	-183.4	52.2	85.5	33.9	OK
		◢ 10.0 ◣	120	LE10	292.9	0.0	63.3	119.1	-114.4	72.4	36.6	OK
BP1	COL-w 3	◢ 6.0 ◣	112	LE39	65.9	0.0	-20.5	-32.4	-16.1	16.3	12.5	OK
		◢ 6.0 ◣	112	LE39	68.9	0.0	-16.7	32.3	21.1	17.0	11.8	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.85	404.7	309.6

Symbol explanation

◢	Fillet weld
ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Detailed result for BP1 COL-tfl 1

Weld resistance check (EN 1993-1-8 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 404.7 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 347.0 MPa

$\sigma_{\perp,Rd} = 0.9\ f_u\ /\ \gamma_{M2} =$ 309.6 MPa ≥ $|\sigma_\perp| =$ 96.2 MPa

where:

$f_u =$ 430.0 MPa – Ultimate strength

$\beta_w =$ 0.85 – appropriate correlation factor taken from Table 4.1

$\gamma_{M2} =$ 1.25 – Safety factor

Stress utilization

$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 85.7 %

Concrete block

Item	Loads	c [mm]	A_{eff} [mm^2]	σ [MPa]	k_j [-]	F_{jd} [MPa]	Ut [%]	Status
CB 1	LE10	38	19904	8.8	3.00	33.5	26.2	OK

Symbol explanation

c	Bearing width
A_{eff}	Effective area
σ	Average stress in concrete
k_j	Concentration factor
F_{jd}	The ultimate bearing strength of the concrete block
Ut	Utilization

Detailed result for CB 1

Concrete block compressive resistance check (EN 1993-1-8 6.2.5)

$\sigma = \frac{N}{A_{eff}} =$ 8.8 MPa

$F_{jd} = \alpha_{cc} \beta_j k_j f_{ck} / \gamma_c =$ 33.5 MPa

where:

N = 174.9 kN	– Design normal force
A_{eff} = 19904 mm^2	– Effective area, on which the column force N is distributed
α_{cc} = 1.00	– Long-term effects on Fcd
β_j = 0.67	– Joint coefficient βj
k_j = 3.00	– Concentration factor
f_{ck} = 25.0 MPa	– Characteristic compressive concrete strength
γ_c = 1.50	– Safety factor

Stress utilization

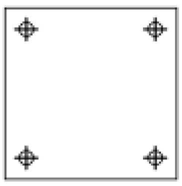
$U_t = \frac{\sigma}{F_{jd}} =$ 26.2 %

Buckling

Buckling analysis was not calculated.

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
BP1	P20.0x320.0-320.0 (S 355)		1	Double fillet: a = 10.0 Double fillet: a = 6.0	480.0 454.4	M24 8.8	4

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Double fillet	S 355	10.0	14.1	480.0
Double fillet	S 355	6.0	8.5	454.4

Anchors

Name	Length [mm]	Drill length [mm]	Count
M24 8.8	320	300	4

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	None		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name: CORPO SCALA - COLLEGAMENTO DIAGONALE COLONNA - COMPLETO RIPRISTINO
Project number
Author Description Date
Design code

12/01/2023
EN

Material

Steel	S 355, S 275
Concrete	C25/30

Project item CON1

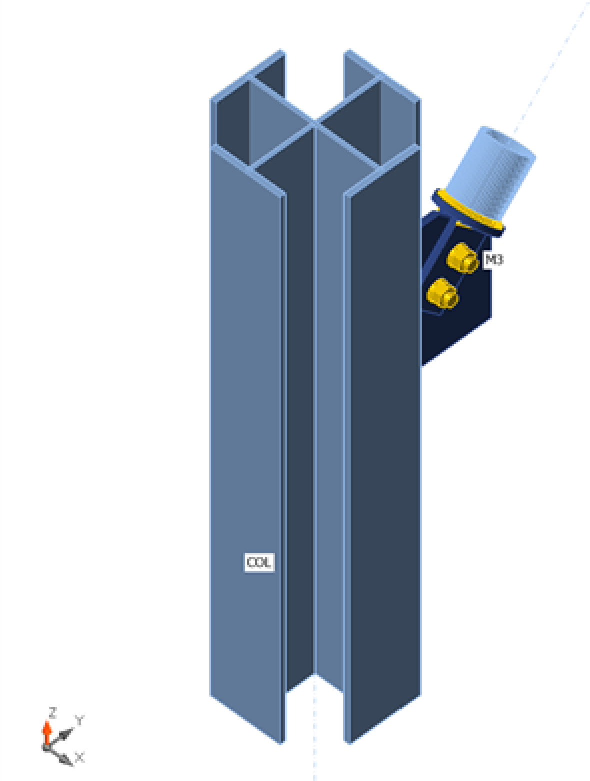
Design

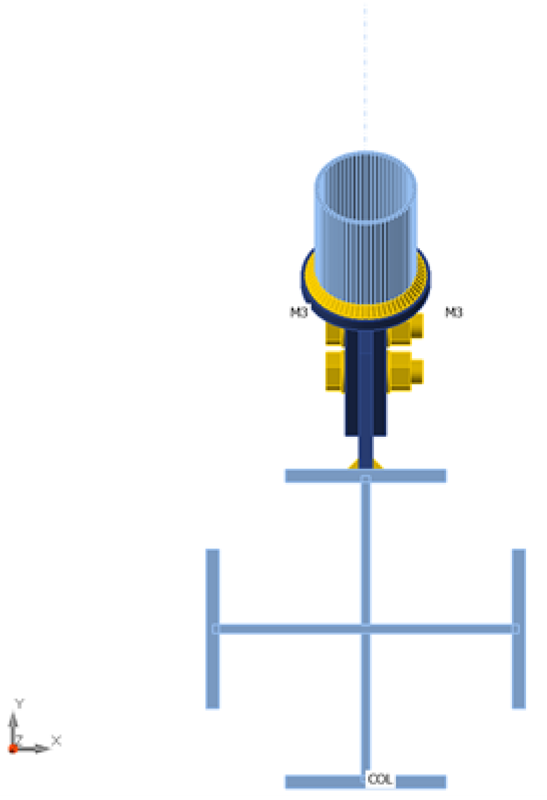
Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

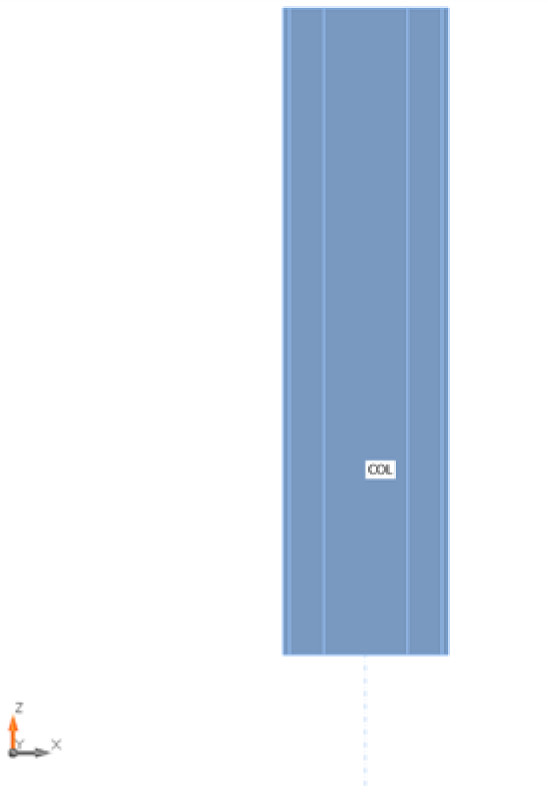
Members

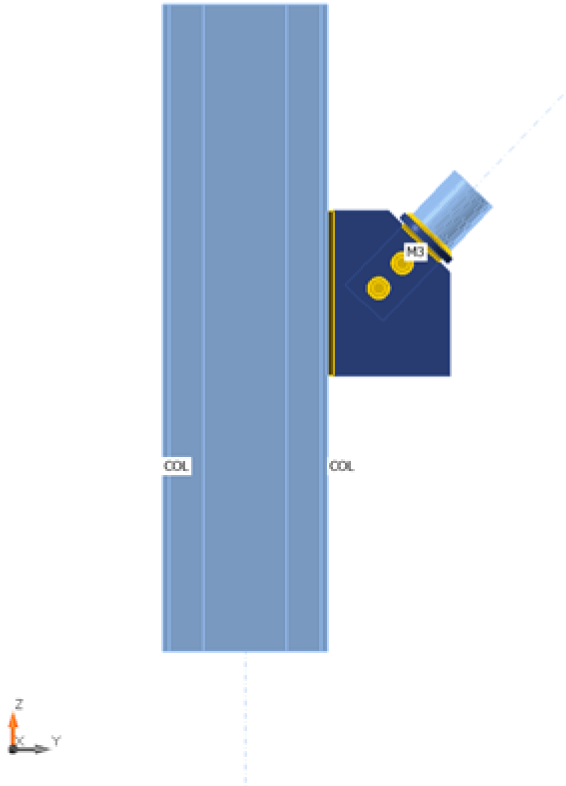
Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
COL	4 - General	0.0	-90.0	0.0	0	0	0	Position	1100
M3	2 - CHS76.1/3.2	90.0	-46.3	0.0	0	0	-100	Position	0




M3
M3
COL
Y
X
COL

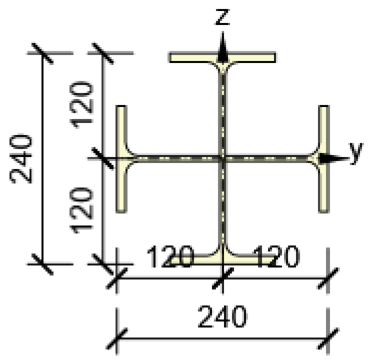
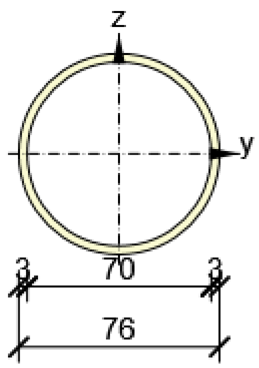

Z
X



Cross-sections

Name	Material
4 - General	S 275, S 275, S 275
2 - CHS76.1/3.2	S 355

Cross-sections

Name	Material	Drawing
4 - General	S 275, S 275, S 275	
2 - CHS76.1/3.2	S 355	

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M18 8.8	M18 8.8	18	800.0	254

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	M3	190.0	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.4 < 5.0%	OK
Bolts	92.3 < 100%	OK
Welds	99.0 < 100%	OK
Buckling	Not calculated	

Plates

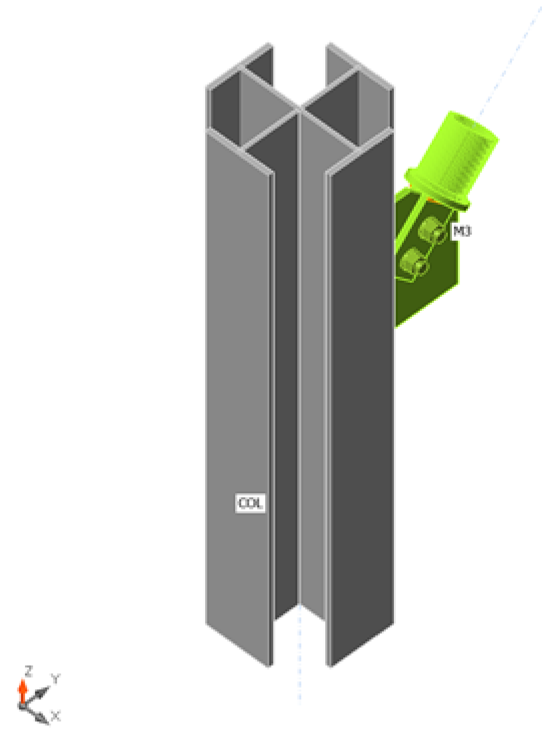
Name	Material	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
COL-bfl 1	S 275	9.8	LE1	45.3	0.0	0.0	OK
COL-tfl 1	S 275	9.8	LE1	45.3	0.0	0.0	OK
COL-w 1	S 275	6.2	LE1	82.5	0.0	0.0	OK
COL-tfl 2	S 275	9.8	LE1	137.1	0.0	0.0	OK
COL-w 2	S 275	6.2	LE1	118.4	0.0	0.0	OK
COL-tfl 3	S 275	9.8	LE1	243.5	0.0	0.0	OK
COL-w 3	S 275	6.2	LE1	222.9	0.0	0.0	OK
M3	S 355	3.2	LE1	355.8	0.4	0.0	OK
SP1	S 355	10.0	LE1	355.4	0.2	23.6	OK
CPL3a	S 355	10.0	LE1	355.5	0.2	0.0	OK
CPL3b	S 355	10.0	LE1	284.9	0.0	23.6	OK
CPL3c	S 355	10.0	LE1	285.0	0.0	23.6	OK

Design data

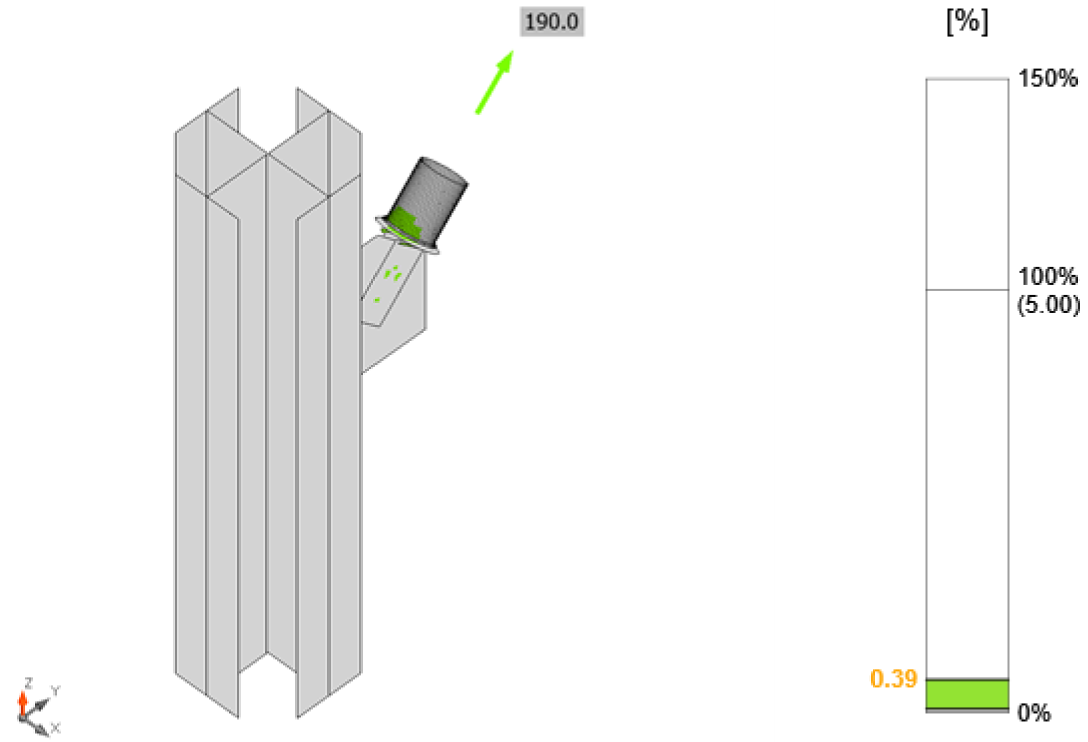
Material	f_y [MPa]	ε_{lim} [%]
S 275	275.0	5.0
S 355	355.0	5.0

Symbol explanation

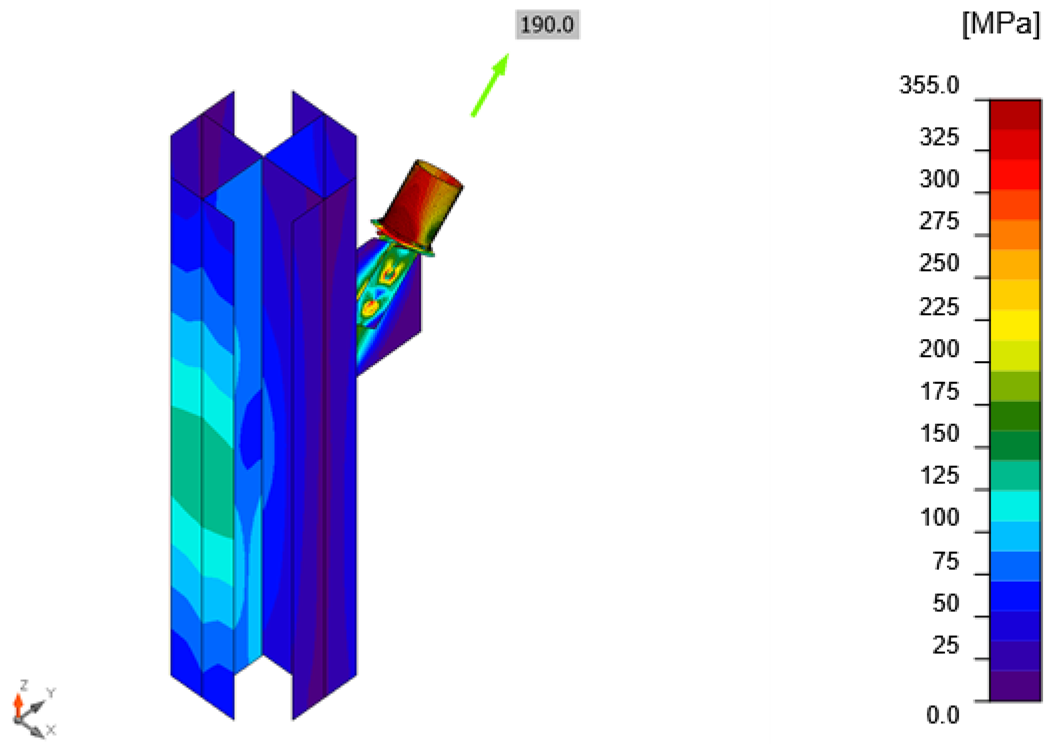
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1

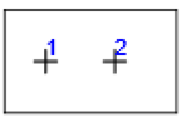


Strain check, LE1



Equivalent stress, LE1

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE1	11.6	47.5	10.5	102.9	92.3	56.2	OK
	B2	LE1	1.2	47.5	1.1	115.4	82.3	49.5	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M18 8.8 - 1	110.6	211.1	97.5

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Detailed result for B1

Tension resistance check (EN 1993-1-8 tab 3.4)

$$F_{t,Rd} = \frac{k_2 \, f_{ub} \, A_s}{\gamma_{M2}} = \quad 110.6 \quad \text{kN} \quad \geq \quad F_t = \quad 11.6 \quad \text{kN}$$

where:

$k_2 = 0.90$	– Factor
$f_{ub} = 800.0$ MPa	– Ultimate tensile strength of the bolt
$A_s = 192$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Punching resistance check (EN 1993-1-8 tab 3.4)

$$B_{p,Rd} = \frac{0.6 \, \pi \, d_m \, t_p \, f_u}{\gamma_{M2}} = \quad 211.1 \quad \text{kN} \quad \geq \quad F_t = \quad 11.6 \quad \text{kN}$$

where:

$d_m = 29$ mm	– The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller
$t_p = 10$ mm	– Thickness
$f_u = 490.0$ MPa	– Ultimate strength
$\gamma_{M2} = 1.25$	– Safety factor

Shear resistance check (EN 1993-1-8 tab 3.4)

$$F_{v,Rd} = \frac{\beta_p \, \alpha_v \, f_{ub} A}{\gamma_{M2}} = \quad 97.5 \quad \text{kN} \quad \geq \quad V = \quad 47.5 \quad \text{kN}$$

where:

$\beta_p = 1.00$	– Reducing factor
$\alpha_v = 0.60$	– Reducing factor
$f_{ub} = 800.0$ MPa	– Ultimate tensile strength of the bolt
$A = 254$ mm^2	– Gross cross-section area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Bearing resistance check (EN 1993-1-8 tab 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 102.9 kN ≥ $V =$ 95.0 kN

where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50 – Factor for edge distance and bolt spacing perpendicular to the direction of load transfer

$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.58 – Factor for end distance and bolt spacing in direction of load transfer

$e_2 =$ 93 mm – Distance to the plate edge perpendicular to the shear force

$p_2 =$ ∞ mm – Distance between bolts perpendicular to the shear force

$d_0 =$ 20 mm – Bolt hole diameter

$e_1 =$ 89 mm – Distance to the plate edge in the direction of the shear force

$p_1 =$ 50 mm – Distance between bolts in the direction of the shear force

$f_{ub} =$ 800.0 MPa – Ultimate tensile strength of the bolt

$f_u =$ 490.0 MPa – Ultimate strength

$d =$ 18 mm – Nominal diameter of the fastener

$t =$ 10 mm – Thickness of the plate

$\gamma_{M2} =$ 1.25 – Safety factor

Interaction of tension and shear (EN 1993-1-8 tab 3.4)

$U_{tts} = \frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4 \ F_{t,Rd}} =$ 56.2 %

Utilization in tension

$U_{tt} = \frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 10.5 %

Utilization in shear

$U_{ts} = \frac{V_{Ed}}{\min(F_{v,Rd}; F_{b,Rd})} =$ 92.3 %

Welds

Item	Edge	Material	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\|\|}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
CPL3a	M3	S 355	◢ 5.0	229	LE1	344.9	0.0	155.8	2.7	-177.6	79.2	58.4	OK
CPL3a	CPL3b	S 355	◢ 5.0	75	LE1	431.3	2.6	203.5	68.2	208.7	99.0	91.2	OK
CPL3a	CPL3c	S 355	◢ 5.0	75	LE1	431.3	2.6	203.6	-67.4	-209.0	99.0	91.7	OK
COL-tfl 3	SP1	S 275	◢ 6.0 ◣	240	LE1	396.9	0.2	155.4	-142.6	-155.3	98.1	31.5	OK
		S 275	◢ 6.0 ◣	240	LE1	396.9	0.2	155.3	142.5	155.4	98.1	31.5	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.90	435.6	352.8
S 275	0.85	404.7	309.6

Symbol explanation

◢	Fillet weld
ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Detailed result for CPL3a CPL3c

Weld resistance check (EN 1993-1-8 4.5.3.2)

$$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) = \quad 435.6 \quad \text{MPa} \quad \geq \quad \sigma_{w,Ed} = [\sigma_{\perp}^2 + 3(\tau_{\perp}^2 + \tau_{\parallel}^2)]^{0.5} = \quad 431.3 \quad \text{MPa}$$

$$\sigma_{\perp,Rd} = 0.9\, f_u \,/\, \gamma_{M2} \; = \quad 352.8 \quad \text{MPa} \quad \geq \quad |\sigma_{\perp}| = \quad 203.6 \quad \text{MPa}$$

where:

f_u = 490.0 MPa – Ultimate strength

β_w = 0.90 – appropriate correlation factor taken from Table 4.1

γ_{M2} = 1.25 – Safety factor

Stress utilization

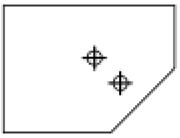
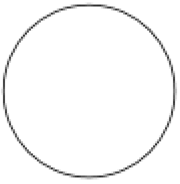
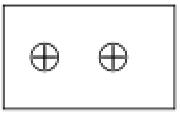
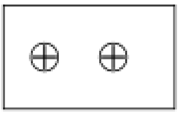
$$U_t = \max\left(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}} \; ; \; \frac{|\sigma_{\perp}|}{\sigma_{\perp,Rd}}\right) = \quad 99.0 \quad \%$$

Buckling

Buckling analysis was not calculated.

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
SP1	P10.0x240.0-176.9 (S 355)		1			M18 8.8	2
CPL3	P10.0x96.1-0.0 (S 355)		1	Fillet: a = 5.0 Fillet: a = 5.0	75.0 303.9	M18 8.8	2
	P10.0x125.0-75.0 (S 355)		1				
	P10.0x125.0-75.0 (S 355)		1				

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Fillet	S 355	5.0	7.1	75.0
Fillet	S 355	5.0	7.1	303.9
Double fillet	S 275	6.0	8.5	240.0

Bolts

Name	Grip length [mm]	Count
M18 8.8	30	2

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	None		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name: CORPO SCALA - COLLEGAMENTO TRAVE-COLONNA-DIAGONALE DI CONTROVENTO	
Project number	
Author Description	
Date	
Design code	13/01/2023
	EN

Material

Steel	S 355

Project item CON1

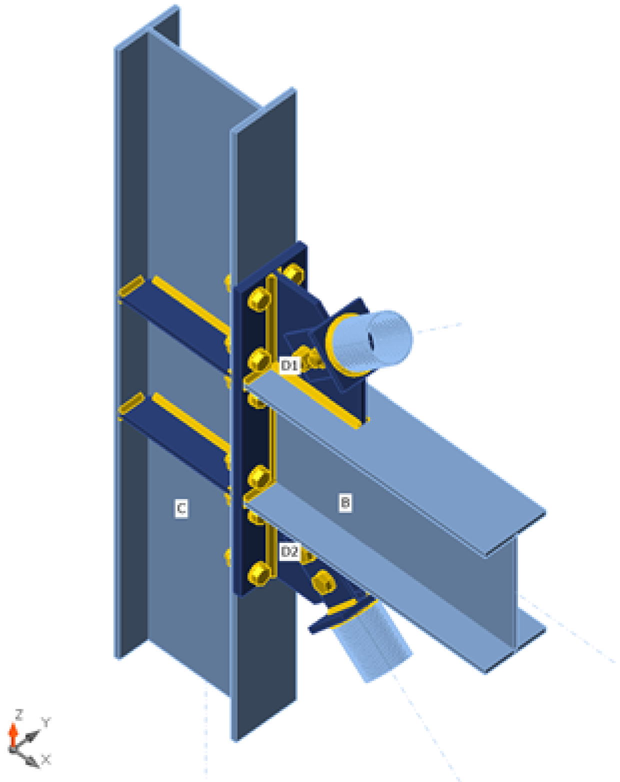
Design

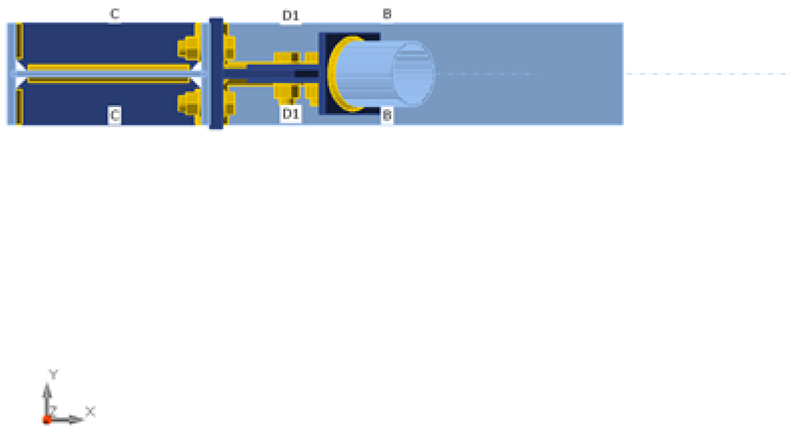
Name	CON1
Description	
Analysis	Stress, strain/ simplified loading

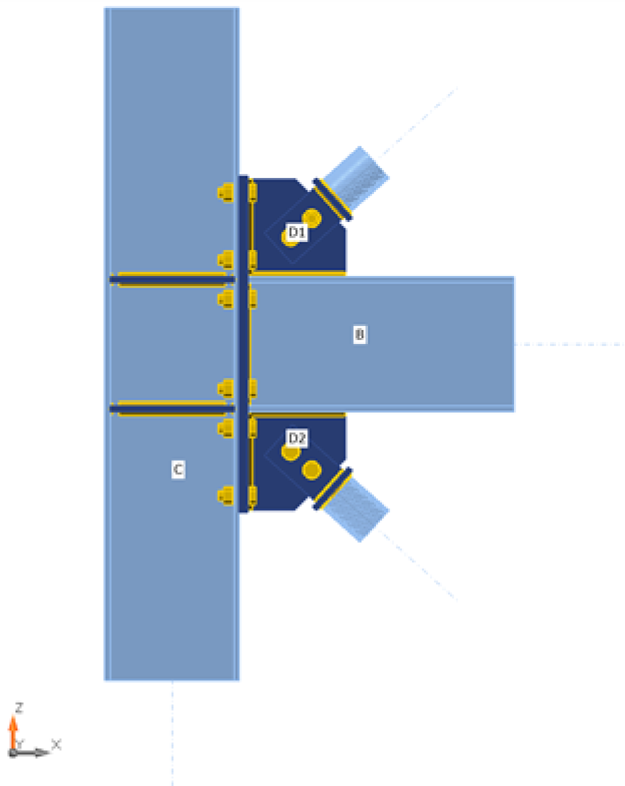
Members

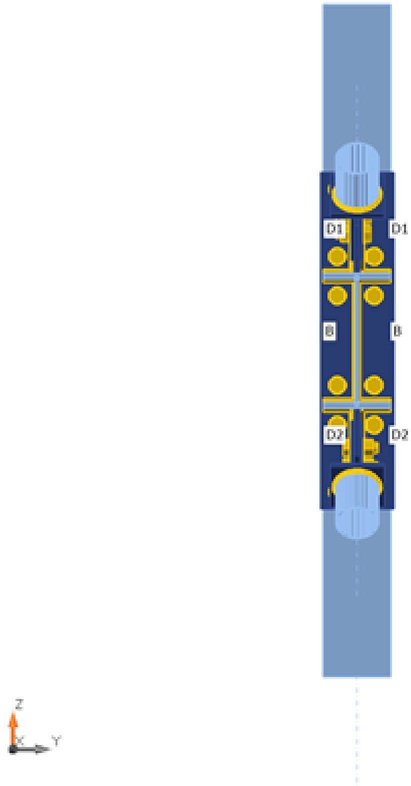
Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
C	1 - CON1(IPE240)	0.0	-90.0	0.0	0	0	0	Node
B	1 - CON1(IPE240)	0.0	0.0	0.0	0	0	0	Node
D1	4 - CHS76.1/3.2	0.0	-42.0	0.0	0	0	0	Node
D2	4 - CHS76.1/3.2	0.0	42.0	0.0	0	0	0	Node




C
D1
B
C
D1
B
Y
X


D1
B
D2
C
Z
X



Cross-sections

Name	Material
1 - CON1(IPE240)	S 355
4 - CHS76.1/3.2	S 355

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M18 8.8	M18 8.8	18	800.0	254

Load effects (equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B	0.0	0.0	0.0	0.0	-10.0	0.0
	D1	100.0	0.0	0.0	0.0	0.0	0.0
	D2	-100.0	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	57.8 < 100%	OK
Welds	98.1 < 100%	OK
Buckling	Not calculated	

Plates

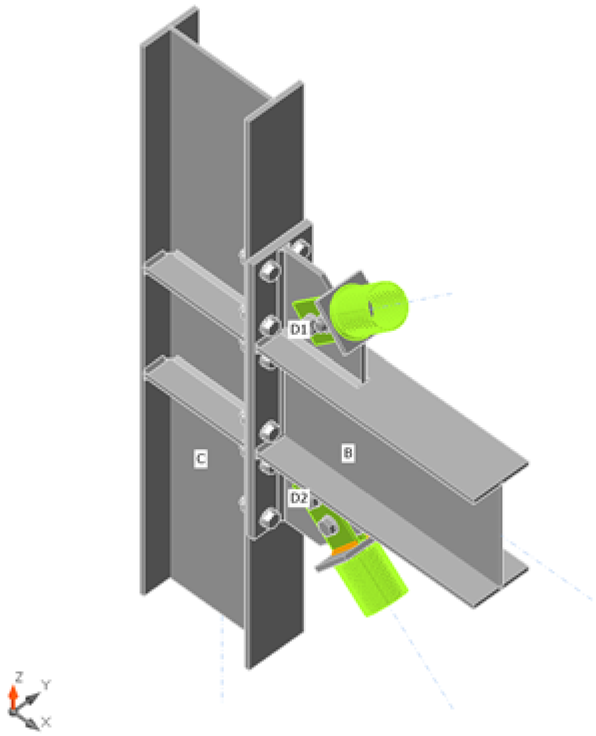
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
C-bfl 1	9.8	LE1	73.3	0.0	4.6	OK
C-tfl 1	9.8	LE1	10.5	0.0	0.0	OK
C-w 1	6.2	LE1	38.1	0.0	0.0	OK
B-bfl 1	9.8	LE1	36.7	0.0	0.0	OK
B-tfl 1	9.8	LE1	37.7	0.0	0.0	OK
B-w 1	6.2	LE1	54.2	0.0	0.0	OK
D1	3.2	LE1	338.5	0.0	0.0	OK
D2	3.2	LE1	339.0	0.0	0.0	OK
EP1	15.0	LE1	44.2	0.0	4.6	OK
STIFF1a	10.0	LE1	16.3	0.0	0.0	OK
STIFF1b	10.0	LE1	14.2	0.0	0.0	OK
STIFF1c	10.0	LE1	25.4	0.0	0.0	OK
STIFF1d	10.0	LE1	21.3	0.0	0.0	OK
WID1a	10.0	LE1	250.9	0.0	20.8	OK
WID1b	10.0	LE1	242.6	0.0	16.9	OK
CPL1a	10.0	LE1	223.1	0.0	0.0	OK
CPL1b	5.0	LE1	250.2	0.0	20.8	OK
CPL1c	5.0	LE1	250.3	0.0	20.8	OK
CPL2a	10.0	LE1	224.6	0.0	0.0	OK
CPL2b	5.0	LE1	244.4	0.0	16.9	OK
CPL2c	5.0	LE1	244.1	0.0	16.9	OK

Design data

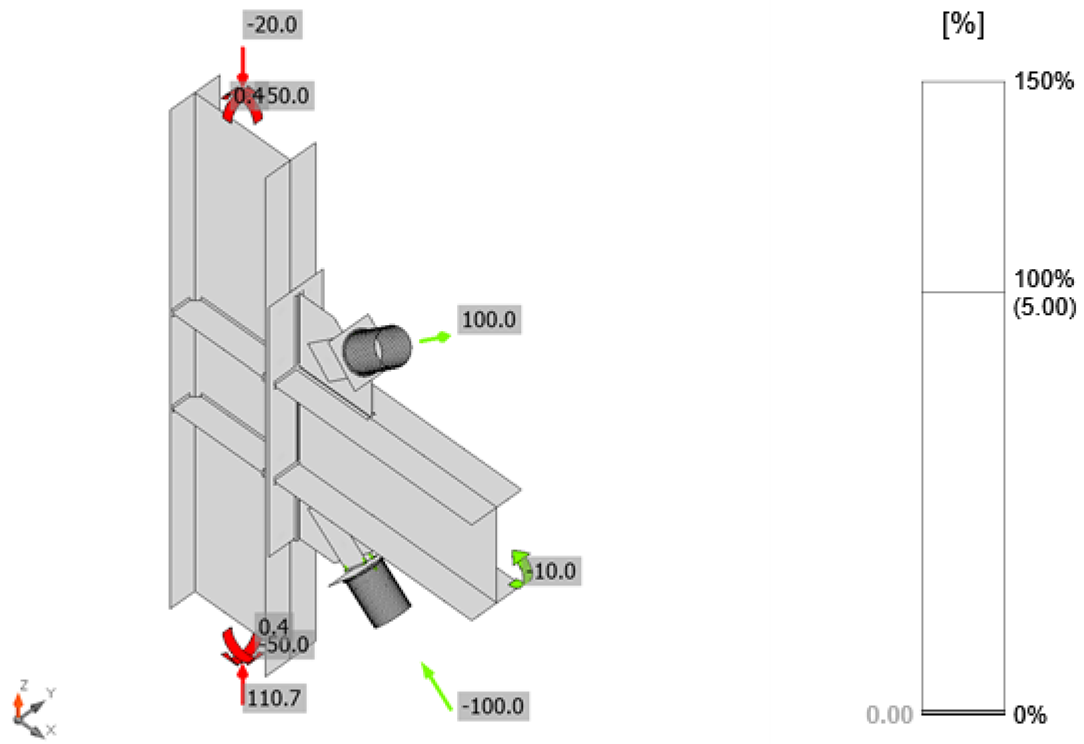
Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

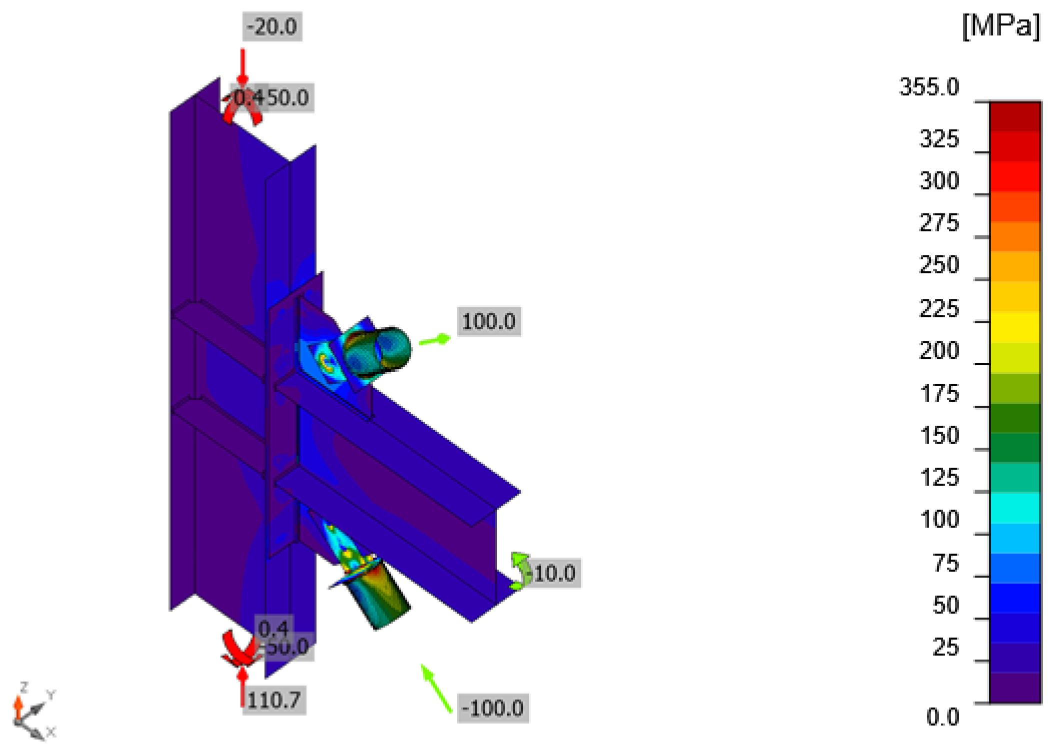
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1

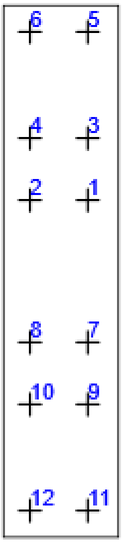
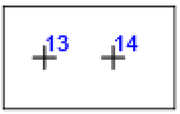
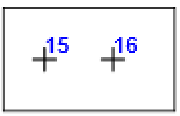


Strain check, LE1



Equivalent stress, LE1

Bolts

	Name	Grade	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	M18 8.8 - 1	LE1	3.2	11.0	2.9	158.5	14.9	17.0	OK
	B2	M18 8.8 - 1	LE1	2.9	10.9	2.6	114.1	14.8	16.6	OK
	B3	M18 8.8 - 1	LE1	5.0	11.4	4.5	172.9	15.4	18.7	OK
	B4	M18 8.8 - 1	LE1	4.7	11.2	4.2	124.5	15.2	18.2	OK
	B5	M18 8.8 - 1	LE1	4.1	11.5	3.7	172.9	15.6	18.2	OK
	B6	M18 8.8 - 1	LE1	3.6	11.3	3.3	124.5	15.3	17.6	OK
	B7	M18 8.8 - 1	LE1	1.3	11.1	1.2	172.9	15.0	15.9	OK
	B8	M18 8.8 - 1	LE1	1.4	10.9	1.3	124.5	14.8	15.7	OK
	B9	M18 8.8 - 1	LE1	0.5	11.3	0.4	158.5	15.3	15.6	OK
	B10	M18 8.8 - 1	LE1	0.5	11.1	0.4	114.1	15.1	15.4	OK
	B11	M18 8.8 - 1	LE1	0.8	11.2	0.7	132.3	15.2	15.7	OK
	B12	M18 8.8 - 1	LE1	0.6	11.0	0.5	124.5	14.9	15.3	OK
	B13	M18 8.8 - 2	LE1	7.2	24.9	6.8	44.1	56.4	38.4	OK
	B14	M18 8.8 - 2	LE1	3.6	25.2	3.4	87.1	57.8	36.5	OK
	B15	M18 8.8 - 2	LE1	3.6	24.8	3.4	51.5	48.3	36.0	OK
	B16	M18 8.8 - 2	LE1	4.6	25.2	4.3	102.9	48.9	37.1	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M18 8.8 - 1	110.6	206.9	73.7
M18 8.8 - 2	110.6	105.6	73.7

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Detailed result for B14

Tension resistance check (EN 1993-1-8 tab 3.4)

$$F_{t,Rd} = \frac{k_2 \ f_{ub} \ A_s}{\gamma_{M2}} = \quad 110.6 \quad \text{kN} \quad \geq \quad F_t = \quad 3.6 \quad \text{kN}$$

where:

$k_2 = 0.90$	– Factor
$f_{ub} = 800.0$ MPa	– Ultimate tensile strength of the bolt
$A_s = 192$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Punching resistance check (EN 1993-1-8 tab 3.4)

$$B_{p,Rd} = \frac{0.6 \ \pi \ d_m \ t_p \ f_u}{\gamma_{M2}} = \quad 105.6 \quad \text{kN} \quad \geq \quad F_t = \quad 3.6 \quad \text{kN}$$

where:

$d_m = 29$ mm	– The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller
$t_p = 5$ mm	– Thickness
$f_u = 490.0$ MPa	– Ultimate strength
$\gamma_{M2} = 1.25$	– Safety factor

Shear resistance check (EN 1993-1-8 tab 3.4)

$$F_{v,Rd} = \frac{\beta_p \ \alpha_v \ f_{ub} \ A}{\gamma_{M2}} = \quad 73.7 \quad \text{kN} \quad \geq \quad V = \quad 25.2 \quad \text{kN}$$

where:

$\beta_p = 1.00$	– Reducing factor
$\alpha_v = 0.60$	– Reducing factor
$f_{ub} = 800.0$ MPa	– Ultimate tensile strength of the bolt
$A = 192$ mm^2	– Tensile stress area of the bolt
$\gamma_{M2} = 1.25$	– Safety factor

Bearing resistance check (EN 1993-1-8 tab 3.4)

$F_{b,Rd} = \frac{k_1 \alpha_b f_u dt}{\gamma_{M2}} =$ 87.1 kN ≥ $V =$ 50.3 kN

where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.49	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 64 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ ∞ mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 20 mm	– Bolt hole diameter
$e_1 =$ 30 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ ∞ mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 800.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength
$d =$ 18 mm	– Nominal diameter of the fastener
$t =$ 10 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Interaction of tension and shear (EN 1993-1-8 tab 3.4)

$U_{tts} = \frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4\, F_{t,Rd}} =$ 36.5 %

Utilization in tension

$U_{tt} = \frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 3.4 %

Utilization in shear

$U_{ts} = \frac{V_{Ed}}{\min(F_{v,Rd}; F_{b,Rd})} =$ 57.8 %

Welds

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
CPL1a	D1	◢ 4.0	229	LE1	388.2	0.0	136.5	-127.5	-166.6	89.1	39.4	OK
CPL2a	D2	◢ 4.0	229	LE1	388.4	0.0	-136.2	-127.6	166.8	89.2	39.4	OK
EP1	B-bfl 1	◢ 5.0 ◣	120	LE1	16.6	0.0	-8.2	-8.3	-0.5	3.8	2.7	OK
		◢ 5.0 ◣	120	LE1	14.5	0.0	11.1	-2.5	-4.8	3.3	3.2	OK
EP1	B-tfl 1	◢ 5.0 ◣	120	LE1	14.7	0.0	-12.2	-1.6	-4.5	3.5	2.5	OK
		◢ 5.0 ◣	120	LE1	14.3	0.0	6.5	-7.2	1.1	3.3	3.2	OK
EP1	B-w 1	◢ 3.0 ◣	230	LE1	74.2	0.0	-1.5	42.8	-0.8	17.0	11.1	OK
		◢ 3.0 ◣	230	LE1	73.6	0.0	-0.8	-42.5	1.5	16.9	10.9	OK
C-bfl 1	STIFF1a	◢ 5.0 ◣	42	LE1	5.6	0.0	2.8	1.2	-2.5	1.3	1.1	OK
		◢ 5.0 ◣	42	LE1	16.3	0.0	-11.8	0.7	6.4	3.7	2.6	OK
C-w 1	STIFF1a	◢ 5.0 ◣	190	LE1	5.4	0.0	-4.0	1.2	-1.7	1.2	0.6	OK
		◢ 5.0 ◣	190	LE1	5.8	0.0	3.7	-2.2	-1.4	1.3	0.6	OK
C-tfl 1	STIFF1a	◢ 5.0 ◣	42	LE1	5.0	0.0	-2.5	1.8	-1.7	1.1	0.8	OK
		◢ 5.0 ◣	42	LE1	2.9	0.0	0.5	-1.6	0.4	0.7	0.5	OK
C-bfl 1	STIFF1b	◢ 5.0 ◣	42	LE1	16.2	0.0	-11.8	-2.0	-6.1	3.7	2.6	OK
		◢ 5.0 ◣	42	LE1	8.3	0.0	1.2	-1.7	4.4	1.9	1.7	OK
C-w 1	STIFF1b	◢ 5.0 ◣	190	LE1	5.2	0.0	3.5	1.7	1.4	1.2	0.6	OK
		◢ 5.0 ◣	190	LE1	5.7	0.0	-4.1	-1.2	2.0	1.3	0.5	OK
C-tfl 1	STIFF1b	◢ 5.0 ◣	42	LE1	2.8	0.0	0.5	1.6	-0.4	0.7	0.5	OK
		◢ 5.0 ◣	42	LE1	4.9	0.0	-2.5	-1.8	1.6	1.1	0.8	OK
C-bfl 1	STIFF1c	◢ 5.0 ◣	42	LE1	26.0	0.0	16.9	-1.2	11.3	6.0	4.4	OK
		◢ 5.0 ◣	42	LE1	12.4	0.0	1.0	2.6	-6.6	2.8	1.7	OK
C-w 1	STIFF1c	◢ 5.0 ◣	190	LE1	4.8	0.0	-3.8	1.1	-1.2	1.1	0.8	OK
		◢ 5.0 ◣	190	LE1	7.8	0.0	5.2	-2.2	-2.5	1.8	0.8	OK
C-tfl 1	STIFF1c	◢ 5.0 ◣	42	LE1	3.6	0.0	-0.1	-2.0	0.6	0.8	0.6	OK
		◢ 5.0 ◣	42	LE1	5.5	0.0	2.5	2.2	-1.7	1.3	0.8	OK
C-bfl 1	STIFF1d	◢ 5.0 ◣	42	LE1	15.3	0.0	4.7	0.6	8.4	3.5	2.6	OK
		◢ 5.0 ◣	42	LE1	27.6	0.0	16.4	-1.5	-12.7	6.3	4.7	OK
C-w 1	STIFF1d	◢ 5.0 ◣	190	LE1	8.6	0.0	5.4	2.2	3.1	2.0	0.9	OK
		◢ 5.0 ◣	190	LE1	4.5	0.0	1.3	-2.5	-0.5	1.0	0.8	OK
C-tfl 1	STIFF1d	◢ 5.0 ◣	42	LE1	5.2	0.0	2.4	-2.1	1.7	1.2	0.8	OK
		◢ 5.0 ◣	42	LE1	3.4	0.0	-0.1	1.9	-0.6	0.8	0.6	OK
EP1	WID1a	◢ 6.0 ◣	175	LE1	77.4	0.0	13.2	41.9	13.4	17.8	10.0	OK
		◢ 6.0 ◣	175	LE1	76.1	0.0	13.4	-41.2	-13.1	17.5	9.7	OK
B-tfl 1	WID1a	◢ 6.0 ◣	175	LE1	68.6	0.0	7.0	-38.7	7.1	15.7	11.4	OK
		◢ 6.0 ◣	175	LE1	68.2	0.0	7.1	38.5	-7.0	15.6	11.3	OK
EP1	WID1b	◢ 6.0 ◣	175	LE1	73.7	0.0	-17.3	-37.5	-17.5	16.9	9.5	OK
		◢ 6.0 ◣	175	LE1	74.4	0.0	-17.5	38.0	17.4	17.1	9.6	OK
B-bfl 1	WID1b	◢ 6.0 ◣	175	LE1	66.8	0.0	-7.9	37.5	-7.9	15.3	10.6	OK

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_\perp$ [MPa]	$\tau_{\|\|}$ [MPa]	$\tau_\perp$ [MPa]	Ut [%]	Ut_c [%]	Status
		◢ 6.0 ◣	175	LE1	67.2	0.0	-7.9	-37.7	8.0	15.4	10.6	OK
CPL1a	CPL1b	◢ 4.0	75	LE1	427.1	0.2	186.3	110.2	192.6	98.1	58.2	OK
CPL1a	CPL1c	◢ 4.0	75	LE1	427.1	0.2	186.3	-110.1	-192.7	98.1	58.3	OK
CPL2a	CPL2b	◢ 4.0	75	LE1	427.1	0.2	-182.3	-117.5	-189.5	98.1	59.4	OK
CPL2a	CPL2c	◢ 4.0	75	LE1	427.1	0.2	-182.4	117.5	189.5	98.1	59.4	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.90	435.6	352.8

Symbol explanation

◢	Fillet weld
ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_\perp$	Perpendicular stress
$\tau_{\|\|}$	Shear stress parallel to weld axis
$\tau_\perp$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Detailed result for CPL1a CPL1c

Weld resistance check (EN 1993-1-8 4.5.3.2)

$$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) = 435.6 \text{ MPa} \geq \sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_{||}^2)]^{0.5} = 427.1 \text{ MPa}$$

$$\sigma_{\perp,Rd} = 0.9\ f_u\ /\ \gamma_{M2} = 352.8 \text{ MPa} \geq |\sigma_\perp| = 186.3 \text{ MPa}$$

where:

$f_u = 490.0$ MPa – Ultimate strength

$\beta_w = 0.90$ – appropriate correlation factor taken from Table 4.1

$\gamma_{M2} = 1.25$ – Safety factor

Stress utilization

$$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}} ; \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) = 98.1 \%$$

Buckling

Buckling analysis was not calculated.

Bill of material

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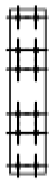
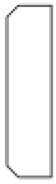
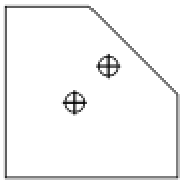
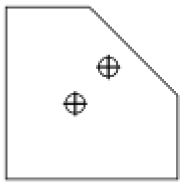
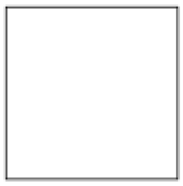
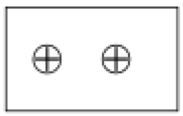
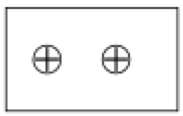
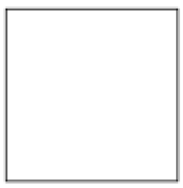
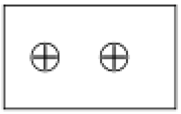
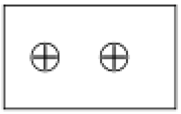
Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
EP1	P15.0x130.0-600.0 (S 355)		1	Double fillet: a = 5.0 Double fillet: a = 3.0	240.0 230.2	M18 8.8	12
STIFF1	P10.0x56.9-220.4 (S 355)		4	Double fillet: a = 5.0	1096.8		
WID1	P10.0x175.0-175.0 (S 355)		1	Double fillet: a = 6.0	700.0	M18 8.8	4
	P10.0x175.0-175.0 (S 355)		1				
CPL1	P10.0x96.1-96.1 (S 355)		1	Fillet: a = 4.0 Fillet: a = 4.0	75.0 303.9	M18 8.8	2
	P5.0x125.0-75.0 (S 355)		1				
	P5.0x125.0-75.0 (S 355)		1				
CPL2	P10.0x96.1-96.1 (S 355)		1	Fillet: a = 4.0 Fillet: a = 4.0	75.0 303.9	M18 8.8	2

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
	P5.0x125.0-75.0 (S 355)		1				
	P5.0x125.0-75.0 (S 355)		1				

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Double fillet	S 355	5.0	7.1	1336.8
Double fillet	S 355	3.0	4.2	230.2
Double fillet	S 355	6.0	8.5	700.0
Fillet	S 355	4.0	5.7	150.0
Fillet	S 355	4.0	5.7	607.9

Bolts

Name	Grip length [mm]	Count
M18 8.8	25	12
M18 8.8	20	4

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	None		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name: CORPO SCALA - COLLEGAMENTO TRA LE DIAGONALI CON DISCO CENTRALE	
Project number	
Author	
Description	
Date	13/01/2023
Design code	EN

Material

Steel	S 355

Project item CON1

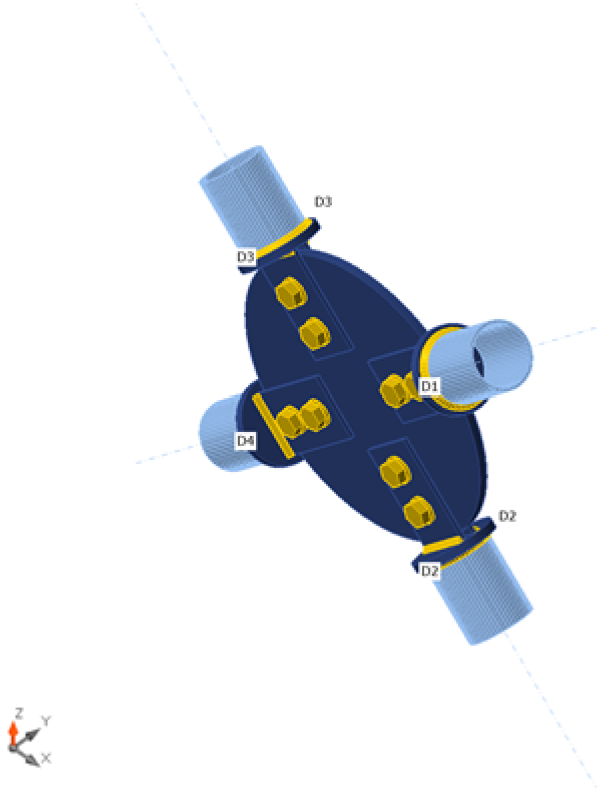
Design

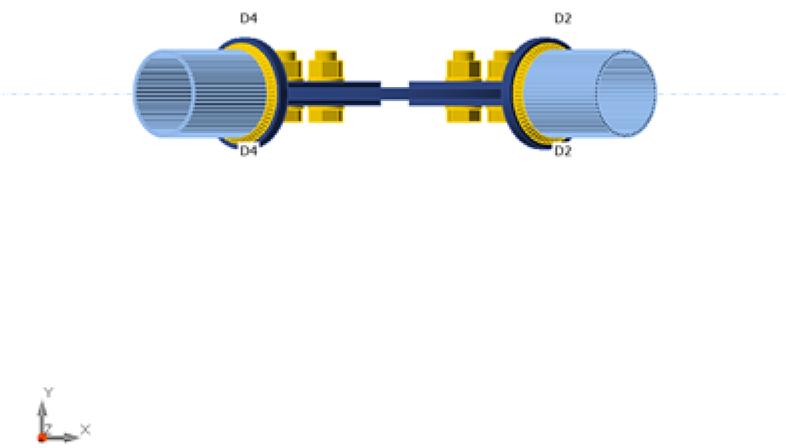
Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

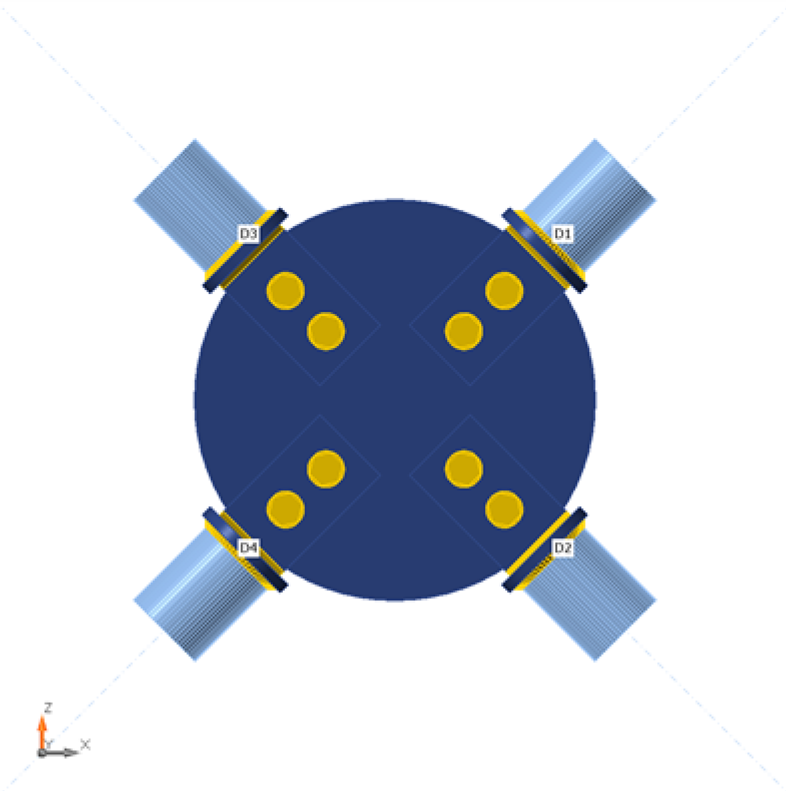
Members

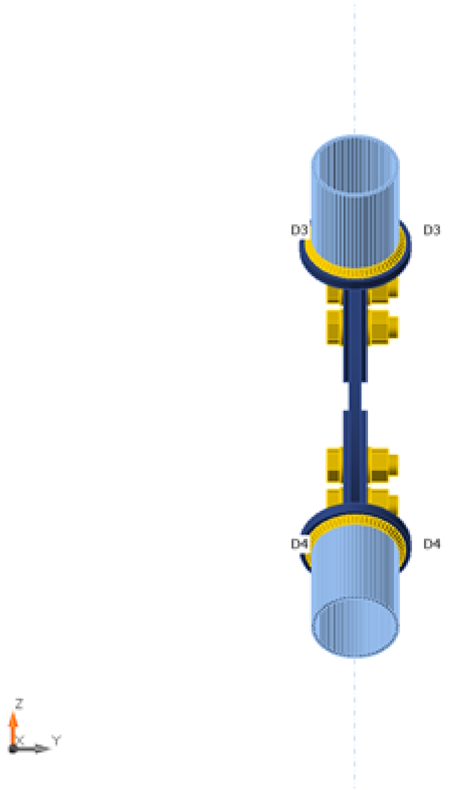
Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
D1	4 - CHS76.1/3.2	0.0	-45.0	0.0	0	0	0	Node
D2	4 - CHS76.1/3.2	0.0	45.0	0.0	0	0	0	Node
D3	4 - CHS76.1/3.2	180.0	-45.0	0.0	0	0	0	Node
D4	4 - CHS76.1/3.2	180.0	45.0	0.0	0	0	0	Node




D4
D2
D4
D2


D3
D1
D4
D2



Cross-sections

Name	Material
4 - CHS76.1/3.2	S 355

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M18 8.8	M18 8.8	18	800.0	254

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	D1	100.0	0.0	0.0	0.0	0.0	0.0
	D2	-100.0	0.0	0.0	0.0	0.0	0.0
	D3	-100.0	0.0	0.0	0.0	0.0	0.0
	D4	100.0	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Bolts	56.2 < 100%	OK
Welds	98.0 < 100%	OK
Buckling	Not calculated	
GMNA	Calculated	

Plates

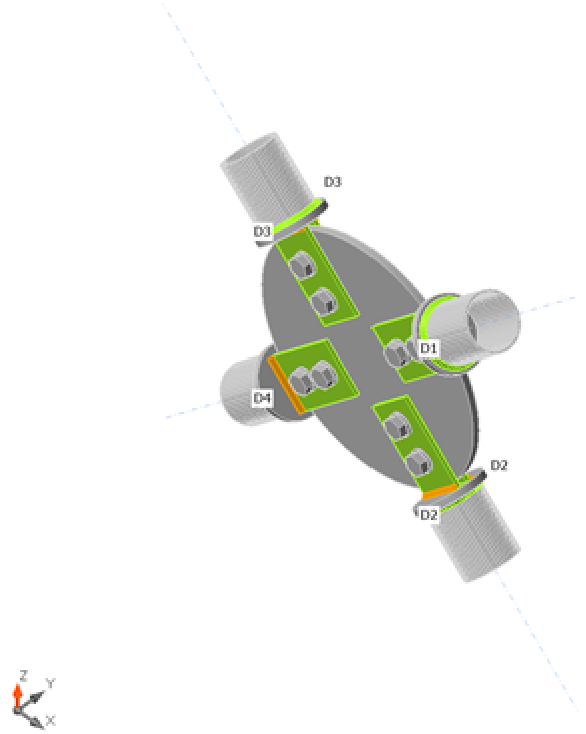
Name	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
D1	3.2	LE1	332.7	0.0	0.0	OK
D2	3.2	LE1	330.6	0.0	0.0	OK
D3	3.2	LE1	330.3	0.0	0.0	OK
D4	3.2	LE1	332.7	0.0	0.0	OK
SP1	10.0	LE1	267.3	0.0	20.1	OK
CPL1a	10.0	LE1	232.9	0.0	0.0	OK
CPL1b	5.0	LE1	256.4	0.0	20.1	OK
CPL1c	5.0	LE1	254.9	0.0	20.1	OK
CPL2a	10.0	LE1	227.2	0.0	0.0	OK
CPL2b	5.0	LE1	253.0	0.0	18.2	OK
CPL2c	5.0	LE1	251.5	0.0	18.2	OK
CPL3a	10.0	LE1	226.5	0.0	0.0	OK
CPL3b	5.0	LE1	253.9	0.0	18.2	OK
CPL3c	5.0	LE1	252.6	0.0	18.2	OK
CPL4a	10.0	LE1	232.5	0.0	0.0	OK
CPL4b	5.0	LE1	254.1	0.0	20.1	OK
CPL4c	5.0	LE1	255.4	0.0	20.1	OK

Design data

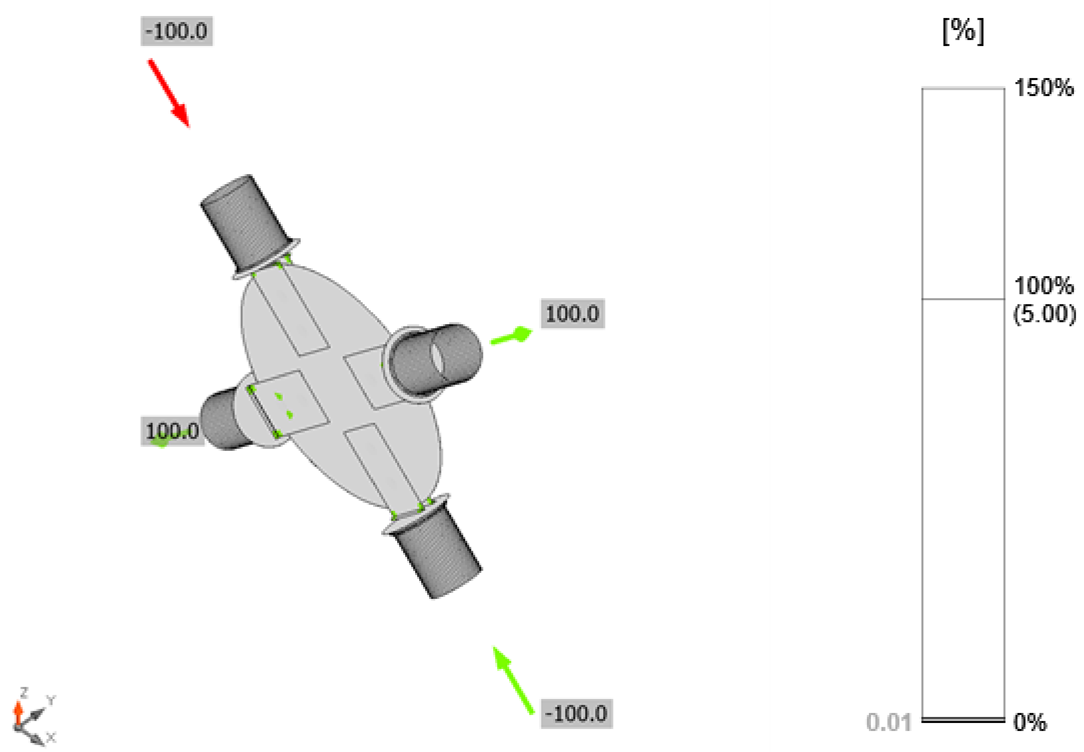
Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

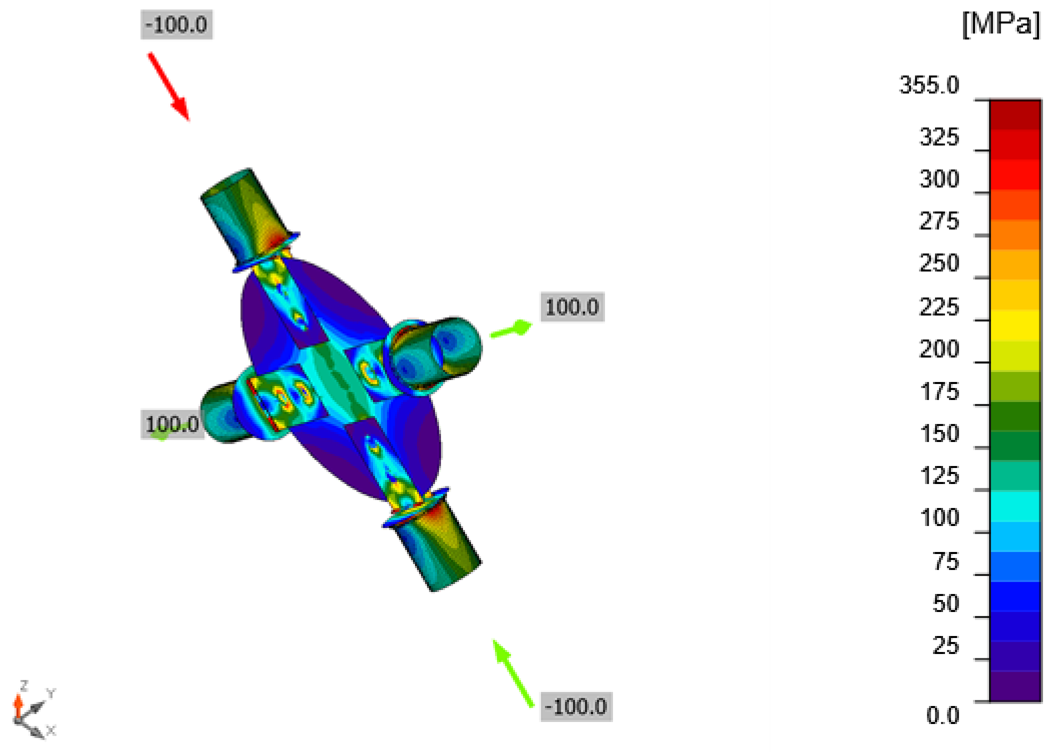
ε_{Pl}	Strain
σ_{Ed}	Eq. stress
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain



Overall check, LE1

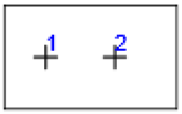
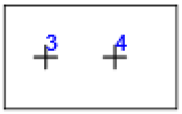
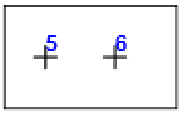
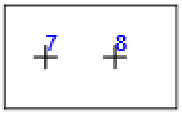


Strain check, LE1



Equivalent stress, LE1

Bolts

	Name	Loads	$F_{t,Ed}$ [kN]	V [kN]	Ut_t [%]	$F_{b,Rd}$ [kN]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	LE1	7.1	24.8	6.7	44.1	56.2	38.2	OK
	B2	LE1	3.6	25.2	3.4	51.5	49.0	36.5	OK
	B3	LE1	3.6	24.9	3.4	51.5	48.3	36.1	OK
	B4	LE1	5.4	25.1	5.1	102.9	48.9	37.6	OK
	B5	LE1	3.6	24.9	3.4	51.5	48.3	36.0	OK
	B6	LE1	5.4	25.1	5.1	102.9	48.9	37.6	OK
	B7	LE1	7.1	24.8	6.7	44.1	56.2	38.2	OK
	B8	LE1	3.6	25.2	3.4	51.5	49.0	36.5	OK

Design data

Name	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M18 8.8 - 1	110.6	105.6	73.7

Symbol explanation

$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 tab. 3.4
$F_{t,Ed}$	Tension force
$B_{p,Rd}$	Punching shear resistance
V	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{v,Rd}$	Bolt shear resistance EN_1993-1-8 table 3.4
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear

Detailed result for B7

Tension resistance check (EN 1993-1-8 tab 3.4)

$F_{t,Rd} = \frac{k_2 \, f_{ub} \, A_s}{\gamma_{M2}} =$ 110.6 kN ≥ $F_t =$ 7.1 kN

where:

$k_2 = 0.90$ – Factor

$f_{ub} = 800.0$ MPa – Ultimate tensile strength of the bolt

$A_s = 192$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Punching resistance check (EN 1993-1-8 tab 3.4)

$B_{p,Rd} = \frac{0.6 \, \pi \, d_m \, t_p \, f_u}{\gamma_{M2}} =$ 105.6 kN ≥ $F_t =$ 7.1 kN

where:

$d_m = 29$ mm – The mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller

$t_p = 5$ mm – Thickness

$f_u = 490.0$ MPa – Ultimate strength

$\gamma_{M2} = 1.25$ – Safety factor

Shear resistance check (EN 1993-1-8 tab 3.4)

$F_{v,Rd} = \frac{\beta_p \, \alpha_v \, f_{ub} \, A}{\gamma_{M2}} =$ 73.7 kN ≥ $V =$ 24.8 kN

where:

$\beta_p = 1.00$ – Reducing factor

$\alpha_v = 0.60$ – Reducing factor

$f_{ub} = 800.0$ MPa – Ultimate tensile strength of the bolt

$A = 192$ mm^2 – Tensile stress area of the bolt

$\gamma_{M2} = 1.25$ – Safety factor

Bearing resistance check (EN 1993-1-8 tab 3.4)

$F_{b,Rd} = \frac{k_1 \ \alpha_b \ f_u \ dt}{\gamma_{M2}} =$ 44.1 kN ≥ $V =$ 24.8 kN

where:

$k_1 = \min(2.8\frac{e_2}{d_0} - 1.7, 1.4\frac{p_2}{d_0} - 1.7, 2.5) =$ 2.50	– Factor for edge distance and bolt spacing perpendicular to the direction of load transfer
$\alpha_b = \min(\frac{e_1}{3d_0}, \frac{p_1}{3d_0} - \frac{1}{4}, \frac{f_{ub}}{f_u}, 1) =$ 0.50	– Factor for end distance and bolt spacing in direction of load transfer
$e_2 =$ 38 mm	– Distance to the plate edge perpendicular to the shear force
$p_2 =$ ∞ mm	– Distance between bolts perpendicular to the shear force
$d_0 =$ 20 mm	– Bolt hole diameter
$e_1 =$ 30 mm	– Distance to the plate edge in the direction of the shear force
$p_1 =$ ∞ mm	– Distance between bolts in the direction of the shear force
$f_{ub} =$ 800.0 MPa	– Ultimate tensile strength of the bolt
$f_u =$ 490.0 MPa	– Ultimate strength
$d =$ 18 mm	– Nominal diameter of the fastener
$t =$ 5 mm	– Thickness of the plate
$\gamma_{M2} =$ 1.25	– Safety factor

Interaction of tension and shear (EN 1993-1-8 tab 3.4)

$U_{tts} = \frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4 \ F_{t,Rd}} =$ 38.2 %

Utilization in tension

$U_{tt} = \frac{F_{t,Ed}}{\min(F_{t,Rd}; B_{p,Rd})} =$ 6.7 %

Utilization in shear

$U_{ts} = \frac{V_{Ed}}{\min(F_{v,Rd};F_{b,Rd})} =$ 56.2 %

Welds

Item	Edge	Throat th. [mm]	Length [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	$\tau_{\perp}$ [MPa]	Ut [%]	Ut_c [%]	Status
CPL1a	D1	◢ 4.0	229	LE1	328.6	0.0	140.1	-5.1	-171.5	75.4	38.9	OK
CPL2a	D2	◢ 4.0	229	LE1	327.2	0.0	-138.9	5.1	171.0	75.1	38.8	OK
CPL3a	D3	◢ 4.0	229	LE1	326.1	0.0	-138.7	-10.6	170.1	74.9	38.8	OK
CPL4a	D4	◢ 4.0	229	LE1	328.5	0.0	139.8	-5.2	-171.5	75.4	38.9	OK
CPL1a	CPL1b	◢ 4.0	75	LE1	427.0	0.1	191.1	100.8	196.1	98.0	58.7	OK
CPL1a	CPL1c	◢ 4.0	75	LE1	427.0	0.1	190.2	-102.9	-195.3	98.0	58.4	OK
CPL2a	CPL2b	◢ 4.0	75	LE1	427.0	0.1	-189.8	108.5	-192.4	98.0	58.8	OK
CPL2a	CPL2c	◢ 4.0	75	LE1	427.0	0.1	-185.7	109.6	193.1	98.0	58.6	OK
CPL3a	CPL3b	◢ 4.0	75	LE1	427.0	0.1	-185.2	-110.7	-192.6	98.0	58.7	OK
CPL3a	CPL3c	◢ 4.0	75	LE1	427.0	0.1	-186.1	109.0	193.3	98.0	58.8	OK
CPL4a	CPL4b	◢ 4.0	75	LE1	427.1	0.1	189.8	103.9	194.9	98.0	58.4	OK
CPL4a	CPL4c	◢ 4.0	75	LE1	427.0	0.1	190.7	-102.1	-195.6	98.0	58.7	OK

Design data

	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.90	435.6	352.8

Symbol explanation

◢	Fillet weld
ε_{Pl}	Strain
$\sigma_{w,Ed}$	Equivalent stress
$\sigma_{w,Rd}$	Equivalent stress resistance
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\parallel}$	Shear stress parallel to weld axis
$\tau_{\perp}$	Shear stress perpendicular to weld axis
0.9 σ	Perpendicular stress resistance - 0.9*fu/γM2
β_w	Corelation factor EN 1993-1-8 tab. 4.1
Ut	Utilization
Utc	Weld capacity utilization

Detailed result for CPL4a CPL4b

Weld resistance check (EN 1993-1-8 4.5.3.2)

$\sigma_{w,Rd} = f_u/(\beta_w \gamma_{M2}) =$ 435.6 MPa ≥ $\sigma_{w,Ed} = [\sigma_\perp^2 + 3(\tau_\perp^2 + \tau_\parallel^2)]^{0.5} =$ 427.1 MPa

$\sigma_{\perp,Rd} = 0.9\ f_u\ /\ \gamma_{M2}\ =$ 352.8 MPa ≥ $|\sigma_\perp| =$ 189.8 MPa

where:

$f_u =$ 490.0 MPa – Ultimate strength

$\beta_w =$ 0.90 – appropriate correlation factor taken from Table 4.1

$\gamma_{M2} =$ 1.25 – Safety factor

Stress utilization

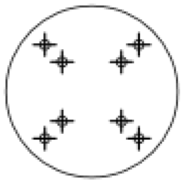
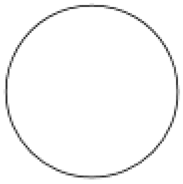
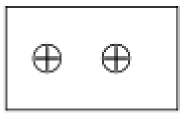
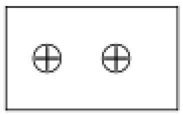
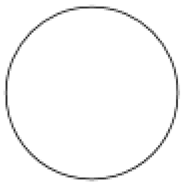
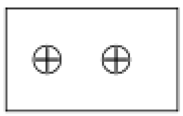
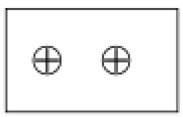
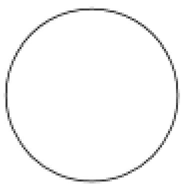
$U_t = \max(\frac{\sigma_{w,Ed}}{\sigma_{w,Rd}}\ ;\ \frac{|\sigma_\perp|}{\sigma_{\perp,Rd}}) =$ 98.0 %

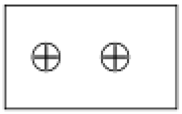
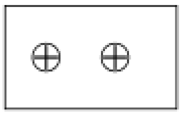
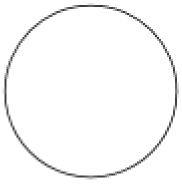
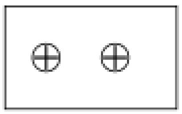
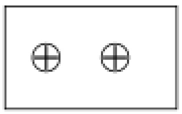
Buckling

Buckling analysis was not calculated.

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
SP1	P10.0x350.0-0.0 (S 355)		1			M18 8.8	8
CPL1	P10.0x96.1-0.0 (S 355)		1	Fillet: a = 4.0 Fillet: a = 4.0	75.0 303.9	M18 8.8	2
	P5.0x125.0-75.0 (S 355)		1				
	P5.0x125.0-75.0 (S 355)		1				
CPL2	P10.0x96.1-0.0 (S 355)		1	Fillet: a = 4.0 Fillet: a = 4.0	75.0 303.9	M18 8.8	2
	P5.0x125.0-75.0 (S 355)		1				
	P5.0x125.0-75.0 (S 355)		1				
CPL3	P10.0x96.1-0.0 (S 355)		1	Fillet: a = 4.0 Fillet: a = 4.0	75.0 303.9	M18 8.8	2

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
	P5.0x125.0-75.0 (S 355)		1				
	P5.0x125.0-75.0 (S 355)		1				
CPL4	P10.0x96.1-0.0 (S 355)		1	Fillet: a = 4.0 Fillet: a = 4.0	75.0 303.9	M18 8.8	2
	P5.0x125.0-75.0 (S 355)		1				
	P5.0x125.0-75.0 (S 355)		1				

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Fillet	S 355	4.0	5.7	300.0
Fillet	S 355	4.0	5.7	1215.7

Bolts

Name	Grip length [mm]	Count
M18 8.8	20	8

Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	None		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5

Project data

Project name: CORPO SCALA - COLLEGAMENTO FLANGIATO TRA COLONNE E MENSOLE DI APPOGGIO DELLE RAMPE

Project number	
Author	
Description	
Date	12/01/2023
Design code	EN

Material

Steel	S 355, S 275 H

Project item CON2

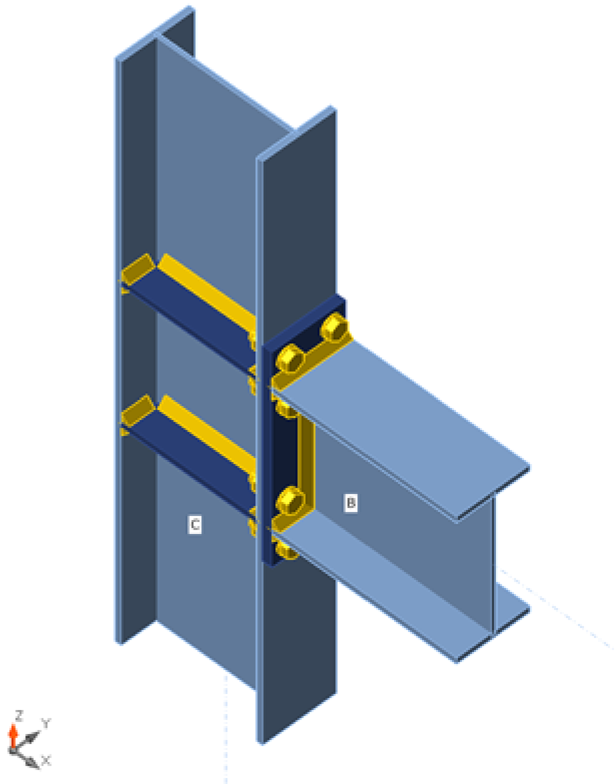
Design

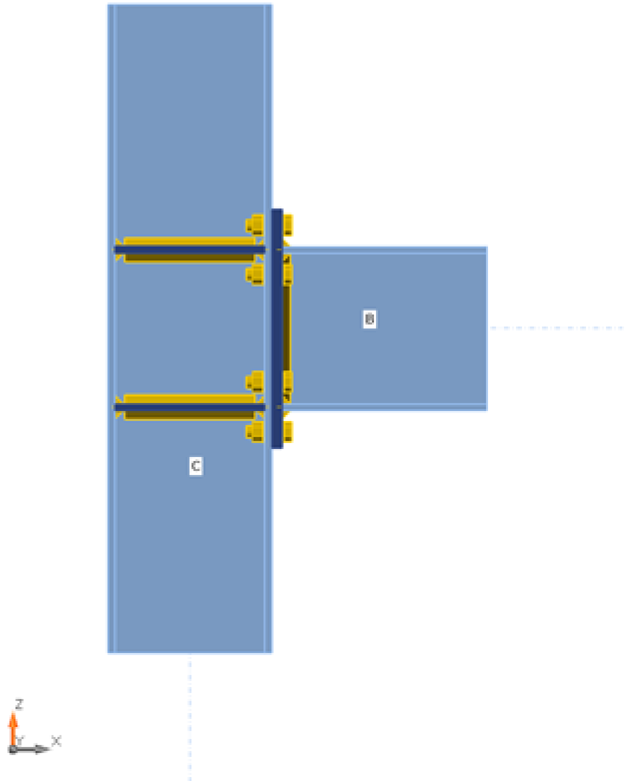
Name	CON2
Description	
Analysis	Stiffness

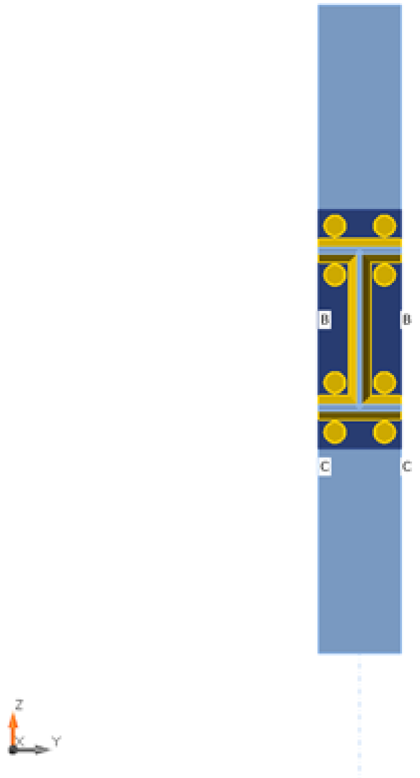
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in	X [mm]
C	7 - IPE240	0.0	-90.0	0.0	0	0	0	Node	0
B	7 - IPE240	0.0	0.0	0.0	0	0	0	Position	120





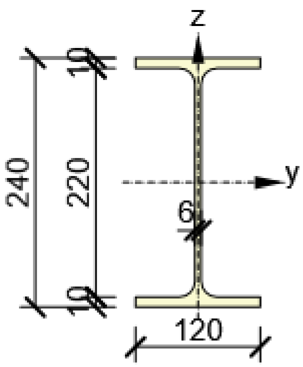


Cross-sections

Name	Material
7 - IPE240	S 275 H

Project:
Project no:
Author:

Cross-sections

Name	Material	Drawing
7 - IPE240	S 275 H	

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
M18 8.8	M18 8.8	18	800.0	254

Load effects

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B	0.0	0.0	-31.4	0.0	44.0	0.0

Check

Rotational stiffness

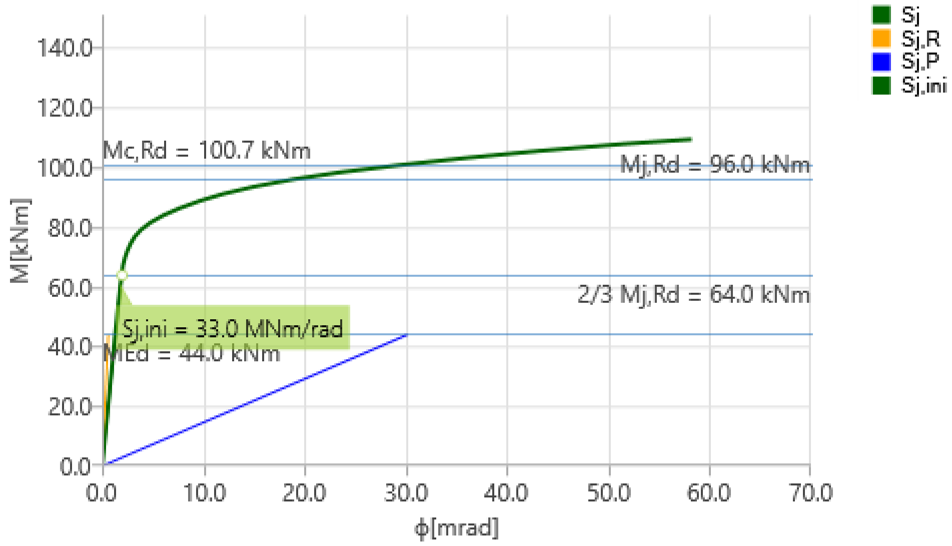
Name	Comp.	Loads	Mj,Rd [kNm]	Sj,ini [MNm/rad]	Φc [mrad]	L [m]	Sj,R [MNm/rad]	Sj,P [MNm/rad]	Class.
B	My	LE1	96.0	33.0	19.0	2.80	73.0	1.5	Semi-rigid

Secant rotational stiffness

Name	Comp.	Loads	M [kNm]	Sjs [MNm/rad]	Φ [mrad]
B	My	LE1	44.0	34.1	1.3

Symbol explanation

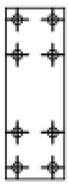
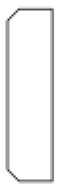
$M_{j,Rd}$	Bending resistance
$S_{j,ini}$	Initial rotational stiffness
$S_{j,s}$	Secant rotational stiffness
Φ	Rotational deformation
Φc	Rotational capacity
$S_{j,R}$	Limit value - rigid joint
$S_{j,P}$	Limit value - nominally pinned joint



Stiffness diagram My - ϕy, LE1

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
EP1	P15.0x120.0-350.0 (S 355)		1	Double fillet: a = 9.0	470.2	M18 8.8	8
STIFF1	P10.0x56.9-220.4 (S 355)		4	Double fillet: a = 9.0	1096.8		

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Double fillet	S 355	9.0	12.7	1567.0

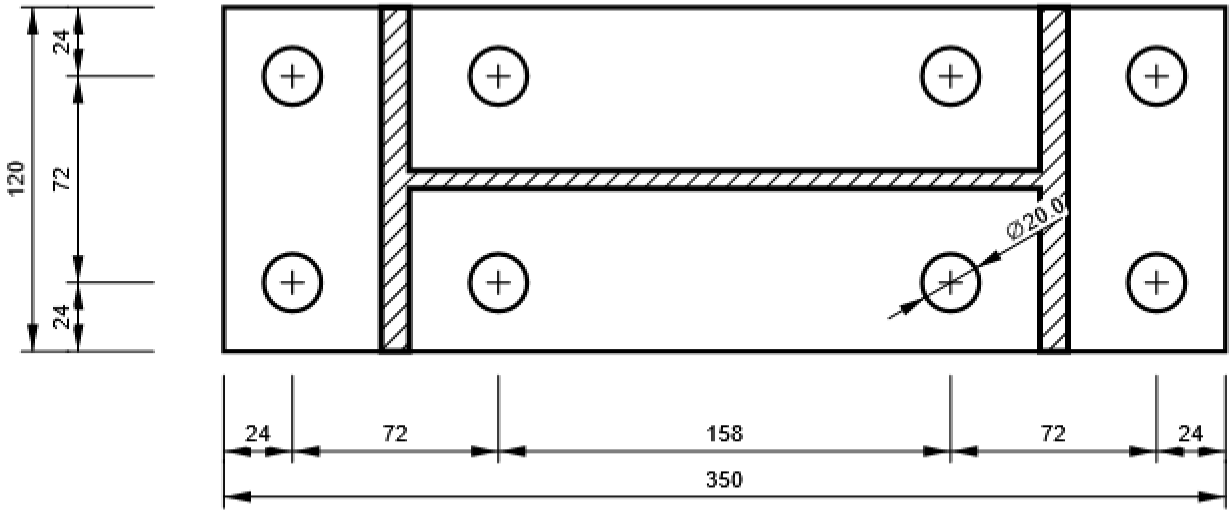
Bolts

Name	Grip length [mm]	Count
M18 8.8	25	8

Drawing

EP1

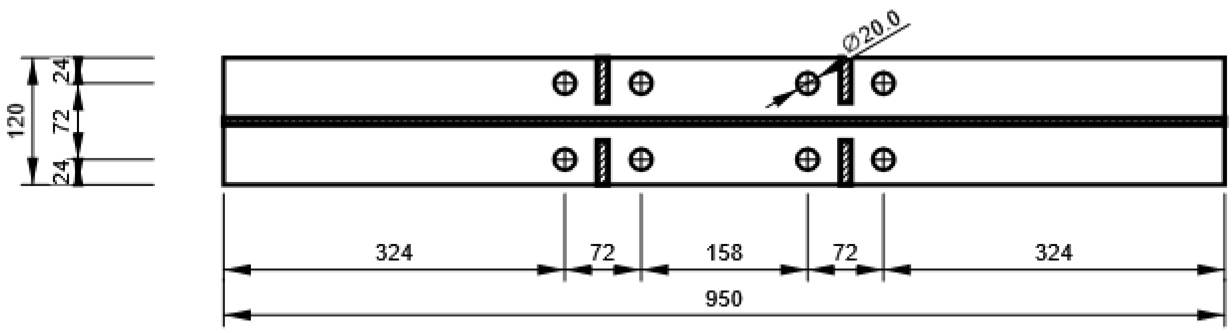
P15.0x350-120 (S 355)



STIFF1

P10.0x220-57 (S 355)

C, IPE240 - Bottom flange 1:



Code settings

Item	Value	Unit	Reference
γ_{M0}	1.00	-	EN 1993-1-1: 6.1
γ_{M1}	1.00	-	EN 1993-1-1: 6.1
γ_{M2}	1.25	-	EN 1993-1-1: 6.1
γ_{M3}	1.25	-	EN 1993-1-8: 2.2
γ_{C}	1.50	-	EN 1992-1-1: 2.4.2.4
γ_{Inst}	1.20	-	EN 1992-4: Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8: 6.2.5
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 tab 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d]	2.20	-	EN 1993-1-8: tab 3.3
Distance between bolts and edge [d]	1.20	-	EN 1993-1-8: tab 3.3
Concrete breakout resistance check	None		EN 1992-4: 7.2.1.4 and 7.2.2.5
Use calculated αb in bearing check.	Yes		EN 1993-1-8: tab 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		CIDECT DG 1, 3 - 1.1
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8: 5.2.2.5