Verification example – Concrete in compression

Type of connection: Base plate subjected to pure compression

Unit system: Metric

Designed acc. to: CSA S14-16 and CSA A23.3

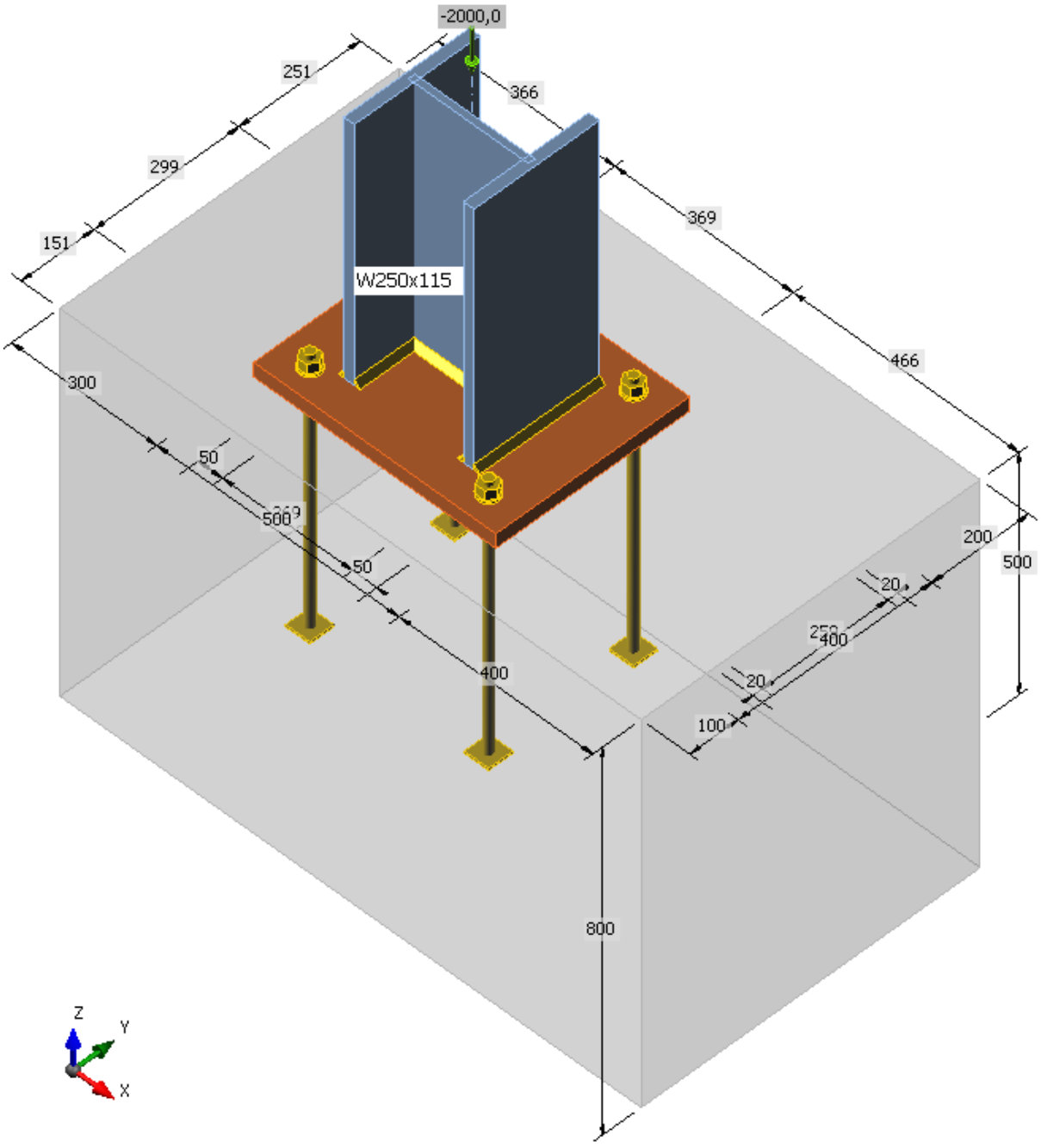
Investigated: Concrete in compression

Plate Materials: 350W

Base plate thickness: 30 mm

Anchor bolts: M20, grade A325, standard holes with diameter 22 mm

Geometry:



Applied forces:

N = −2000 kN

V = 0 kN

M = 0 kNm

Procedure:

The compressive resistance of concrete is determined in accordance with S16-14 – 25.3.1 and CSA A23.3 – 10.8. When the supported surface of the concrete is larger than the base plate the design bearing strength is defined as

$$f_{\mathrm{p(max)}} = 0.85\phi_{\mathrm{c}} f_{\mathrm{c}}' \sqrt{\frac{A_2}{A_1}} \leq 1.7\phi_{\mathrm{c}} f_{\mathrm{c}}'$$

where:

- $\phi_{\mathrm{c}} = 0.65$ – resistance factor for concrete,
- f_{c}' – the concrete compressive strength,
- A_1 – base plate area in contact with concrete surface (upper surface area of the frustum),
- A_2 – concrete supporting surface (geometrically similar lower area of the frustum having its slopes of 1 vertical to 2 horizontal).

The assessment of concrete in bearing is as follows

$$\sigma \leq f_{\mathrm{p(max)}}$$

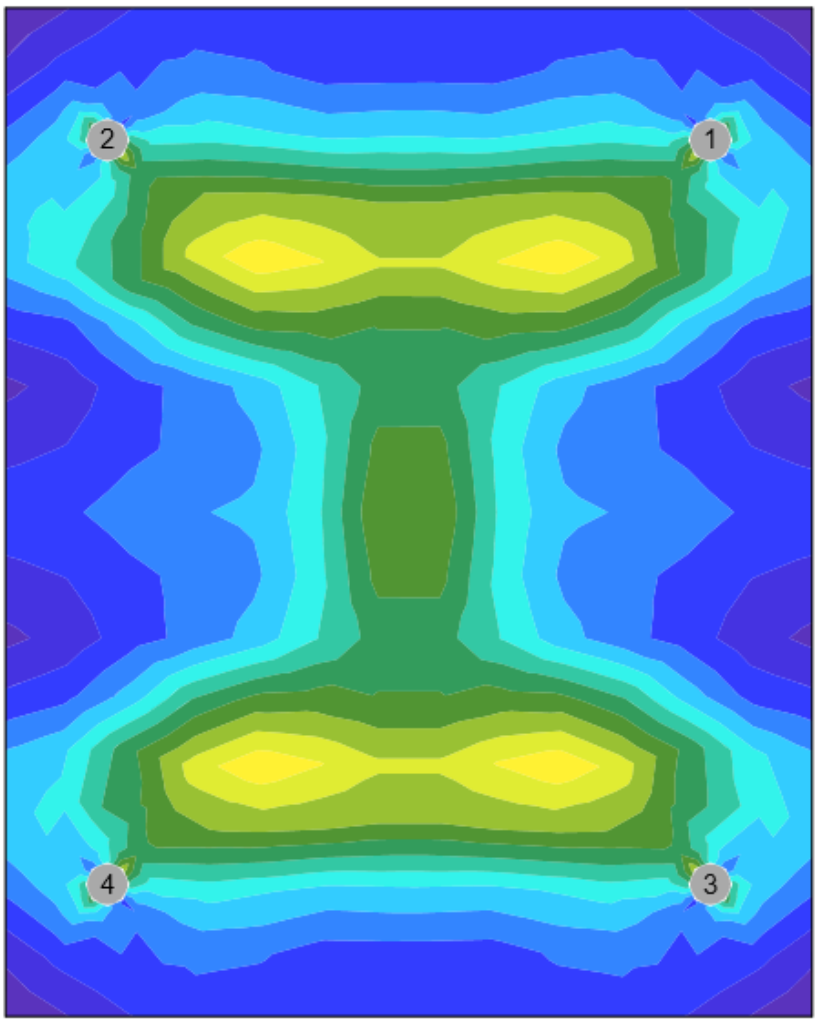
where:

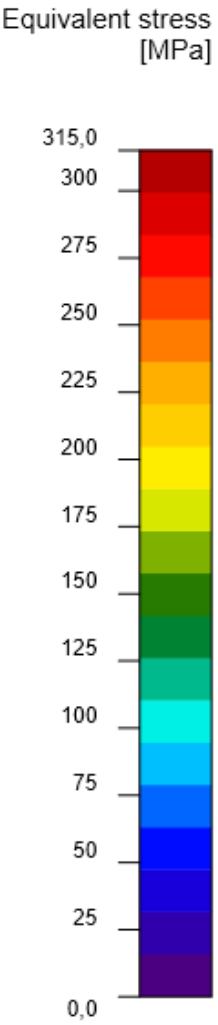
- σ is the average compressive stress under the base plate.

IDEA StatiCa uses a Winkler subsoil model for concrete foundation pad as simplification.

IDEA StatiCa Connection

According to Canadian customs, the base plate should not yield. From the following picture, it can be seen that the maximum stress on the base plate is 204.5 MPa so it is stiff enough.





Summary | Analysis | Plates | Welds | Anchors | Concrete block | Shear

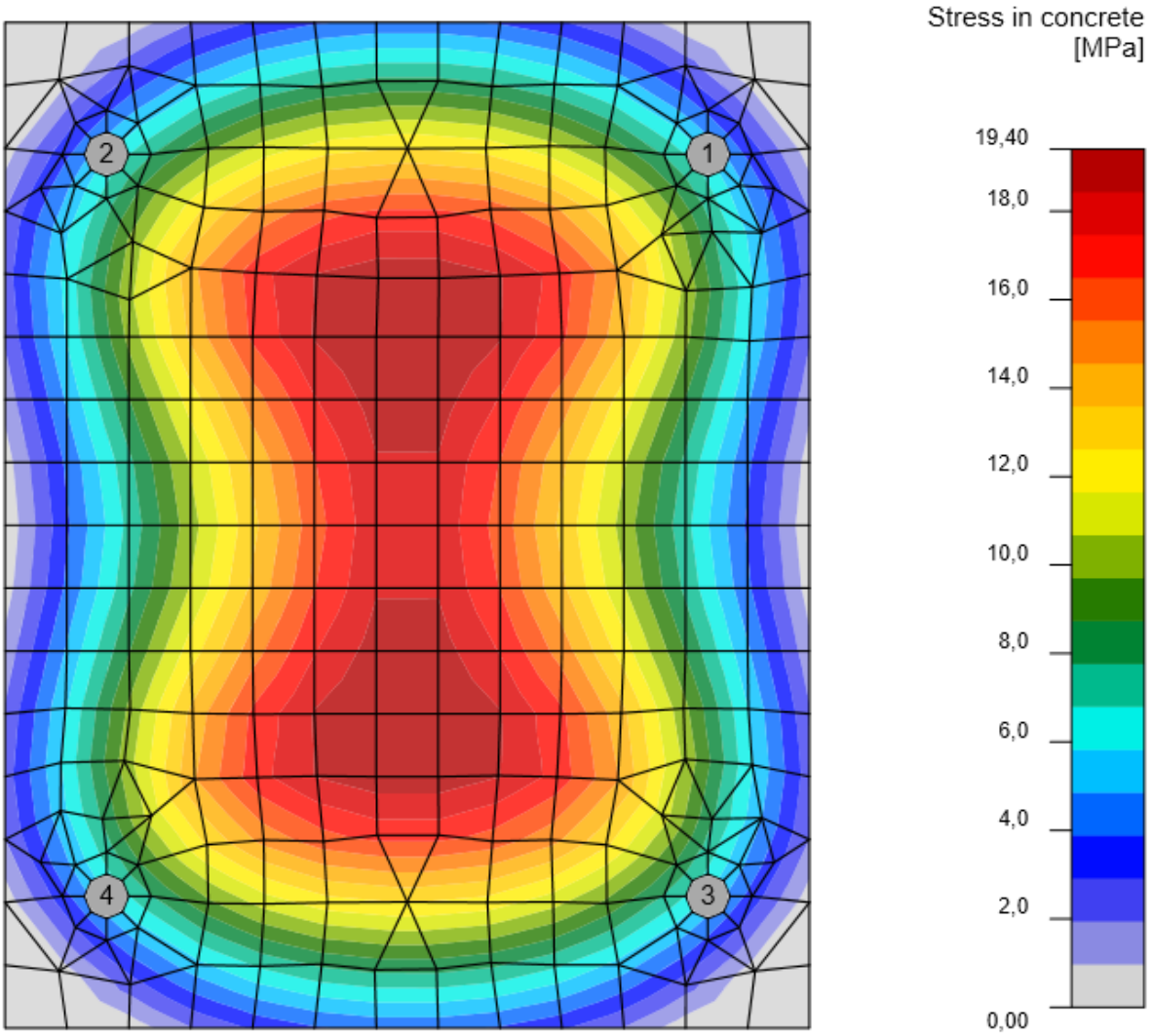
Check of members and steel plates for extreme load effect

	Item	Th [mm]	Loads	σ,Ed [MPa]	ε,Pl [%]	Status
	W250x115-bfl 1	22	LE1	200,2	0,0	✓
	W250x115-tfl 1	22	LE1	200,3	0,0	✓
	W250x115-w 1	14	LE1	151,0	0,0	✓
>	BP1	30	LE1	204,5	0,0	✓

Design data

	Material	Fy [MPa]	ε,lim [%]
>	350W	350,0	5,0

The maximum stress in concrete reaches 19.4 MPa but for the assessment, the average stress below the base plate is important. IDEA StatiCa calculates the average stress on the area under the base plate which is in compression so the method works for general loading, i.e. by combination of tension and bending moment. Corners of the base plate (grey area on the following picture) are not in contact with the concrete and therefore, the loaded area is slightly lower and the averaged stress is slightly higher than according to hand calculation.



Summary | Analysis | Plates | Welds | Anchors | Concrete block | Shear

Check of contact stress in concrete for extreme load effect

	Item	Loads	A1 [m2]	A2 [m2]	σ [MPa]	Fp [MPa]	Ut [%]	Status
⊞	CB 1	LE1	0,20	0,42	10,1	16,6	60,7	✓

CISC

IDEA StatiCa Connection CISC Verification Example

Concrete in compression

Material:

Material of concrete: $f'_c := 20.7\ \text{MPa}$

Resistance factor for concrete: $\phi_c := 0.65$

Geometry:

Width of the concrete pad supporting area: $a_c := 700\ \text{mm}$

Depth of the concrete pad supporting area: $b_c := 600\ \text{mm}$

Height of the concrete pad: $h_c := 800\ \text{mm}$

Width of the base plate: $a_{bp} := 400\ \text{mm}$

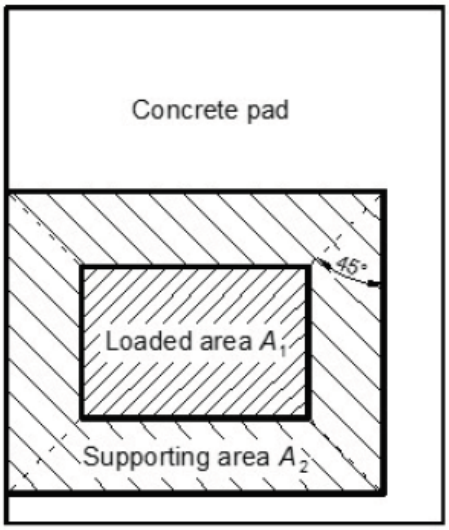
Depth of the base plate: $b_{bp} := 500\ \text{mm}$

Thickness of the base plate: $t_{bp} := 30\ \text{mm}$

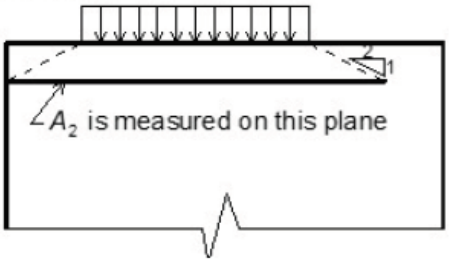
Loaded area: $A_1 := a_{bp} \cdot b_{bp} = 200000\ \text{mm}^2$

Supporting area: $A_2 := a_c \cdot b_c = 420000\ \text{mm}^2$

Plan



Elevation



Loading:

Normal compressive force: $N := 2000\ \text{kN}$

Concrete compressive strength:

$$f_{pmax1} := 0.85 \cdot \phi_c \cdot f'_c \cdot \sqrt{\frac{A_2}{A_1}} = 16.57\ \text{MPa}$$

$\leq$

$$f_{pmax2} := 1.7 \cdot \phi_c \cdot f'_c = 22.87\ \text{MPa}$$

Average compressive stress under the base plate: $\sigma := \frac{N}{a_{bp} \cdot b_{bp}} = 10\ \text{MPa}$

Utilization: $\frac{\sigma}{min\left(f_{pmax1}, f_{pmax2}\right)} = 60\%$

Comparison

CISC suggests using stiff base plate which ensures the contact between the base plate and the concrete foundation pad under pure compression. To be able to tackle general loading, IDEA StatiCa software uses a numerical analysis to determine the area which is in contact between the base plate and the foundation pad. There are very slight differences between manual assessment and IDEA StatiCa – 1 % in the presented example.