Project:	**Wall with openings according to EN**
Project no:	**Project - 08/16/2021**
Author:	**Jason Smith**

Project data

Project name	Wall with openings according to EN
Project number	Project - 08/16/2021
Author	Jason Smith
Description	Wall with openings solved by CSFM (Compatible stress field method)
Date	8/16/2021
Design code	EN

Materials

Concrete

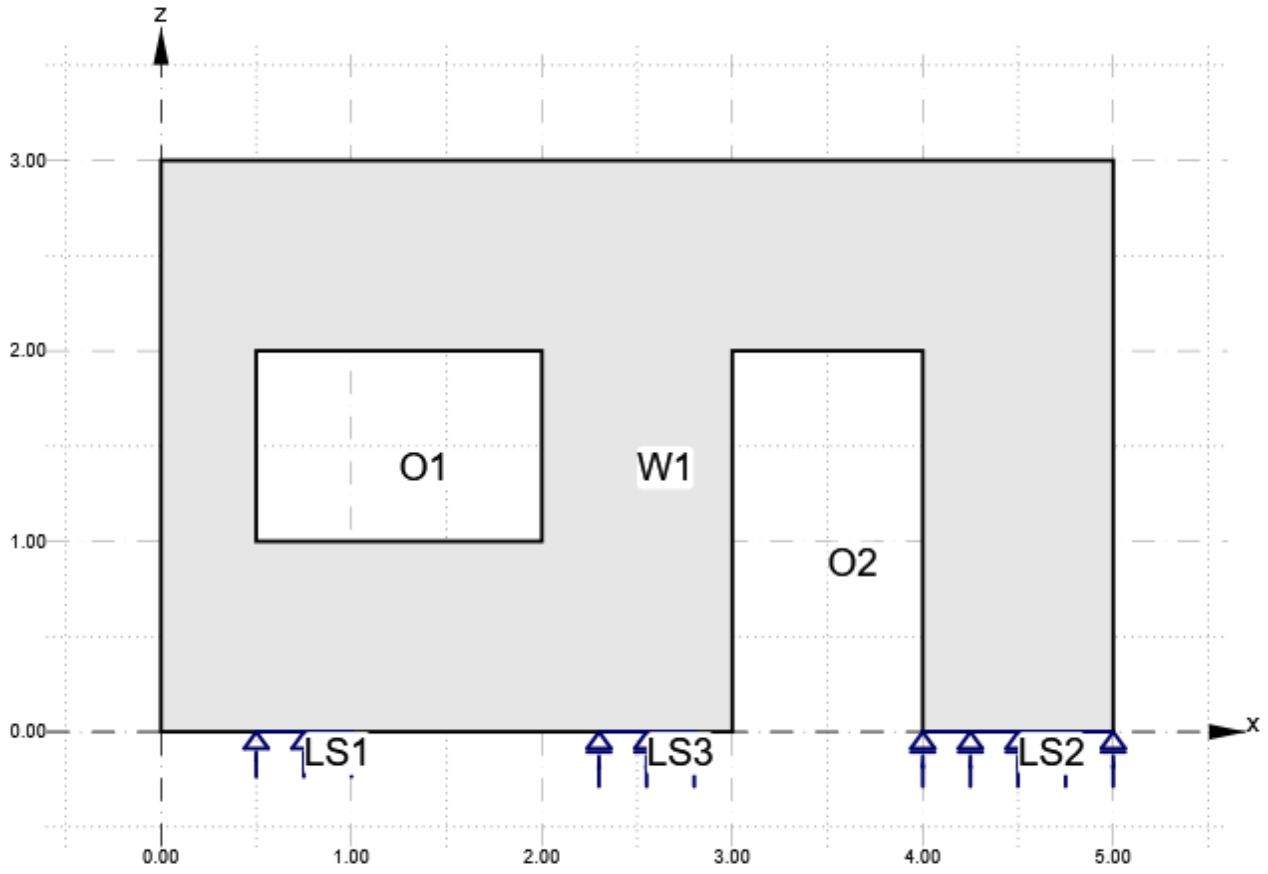
Name	f_{ck} [MPa]	$f_{ctk,0.05}$ [MPa]	f_{ctm} [MPa]	E_{cm} [MPa]
C30/37	30.0	2.0	2.9	32836.6
	ε_{c2} = 20.0 1e-4, ε_{cu2} = 500.0 1e-4, Diagram type: Parabolic Creep coefficient: 2.50			

Reinforcement

Name	f_{yk} [MPa]	k [-]	E_s [MPa]	Unit mass [kg/m^3]	ε_{uk} [1e-4]	Surface
B 500B	500.0	1.08	200000.0	7850	500.0	Ribbed
	ε_{st} = 500.0 1e-4, ε_{sc} = 500.0 1e-4,					

DRM1

Geometry

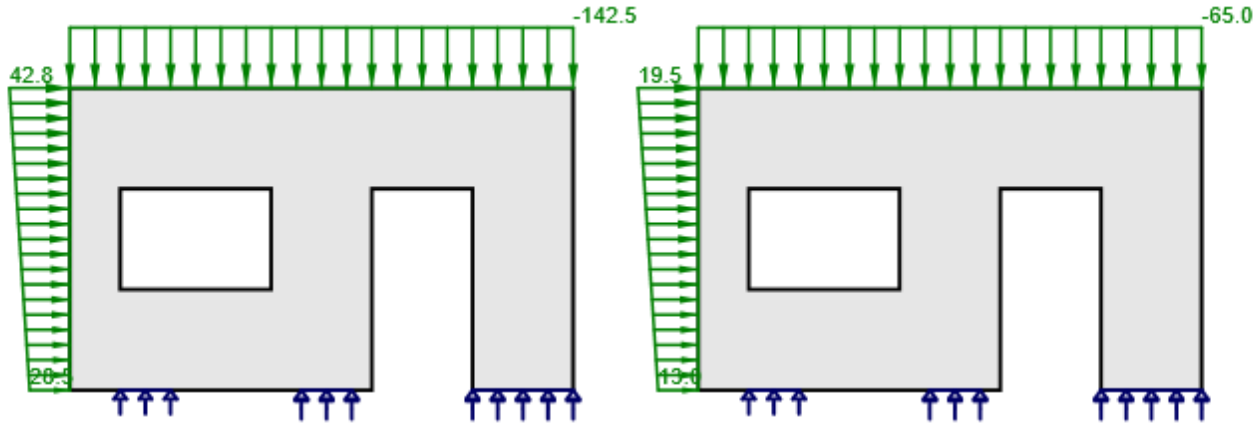


Overview table

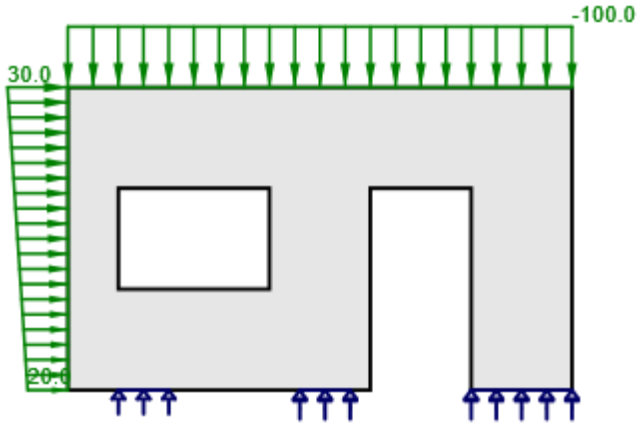
Name	Type	Properties	Position
W1	Wall	Rectangular; W: 5.00 m; H: 3.00 m; T: 0.20 m; Material: C30/37	
O1	Opening	Rectangular; W: 1.50 m; H: 1.00 m	M: W1; IP: 1; MP: 1; X: 0.50 m; Z: 1.00 m
O2	Opening	Rectangular; W: 1.00 m; H: 2.00 m	M: W1; IP: 2; MP: 2
LS1	Line support	X; Z (Pressure only); Local; L: 0.50 m	M: W1, Edge 1; Part of edge; From beginning; X: 0.50 m
LS2	Line support	Z (Pressure only); Local; L: 1.00 m	M: W1, Edge 1; Part of edge; From end; X: 0.00 m
LS3	Line support	Z (Pressure only); Local; L: 0.50 m	M: W1, Edge 1; Part of edge; From end; X: 2.20 m

Loads

C1, C2



C3

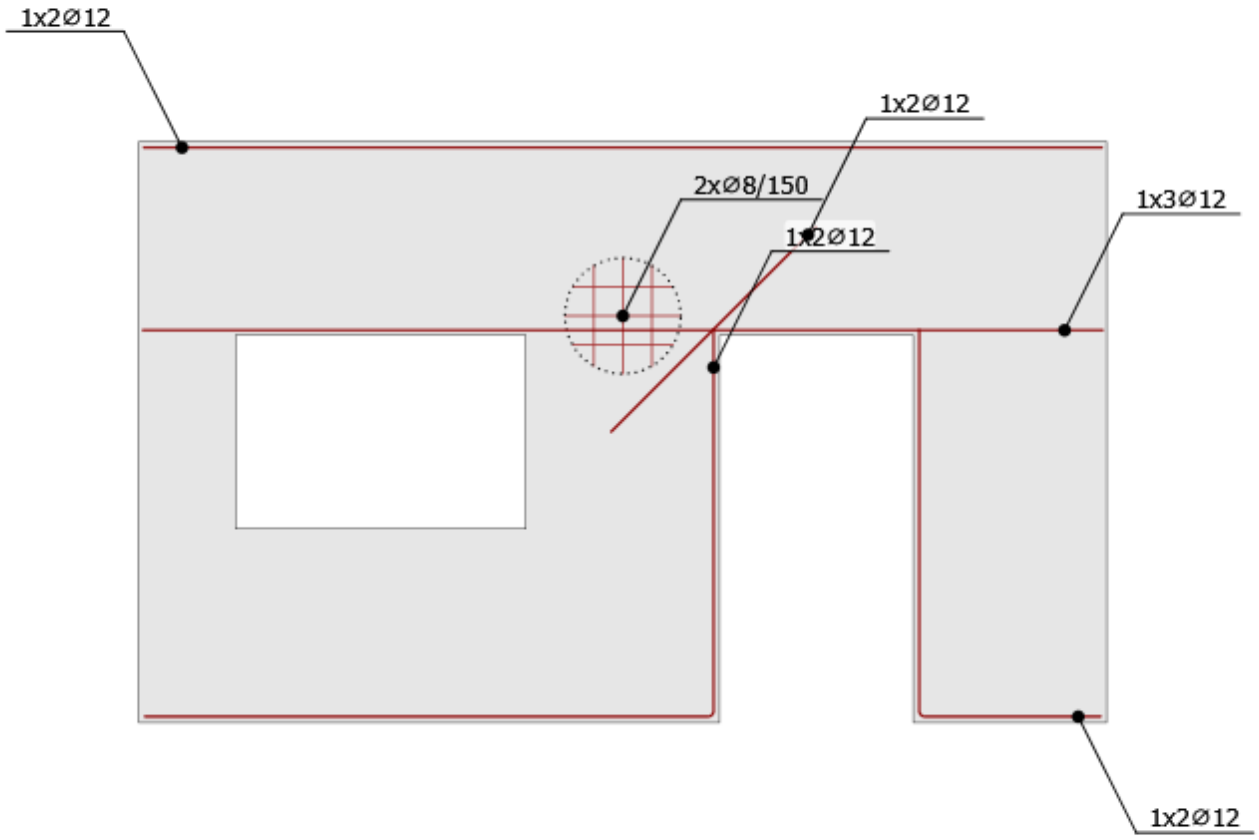


Combination

Name	Type	Content
C1	ULS	1.35*LC1 + 1.50*LC2
C2	SLS - Quasi-permanent	LC1 + 0.30*LC2
C3	SLS - Characteristic	LC1 + LC2

Reinforcement

Scheme of reinforcement



Concrete: C30/37; Steel: B 500B

Results

Summary

Overview table

Check item	Combination	Increment	Item	
ULS	C1	P100.0%, V100.0%	Strength of reinforcement	✓

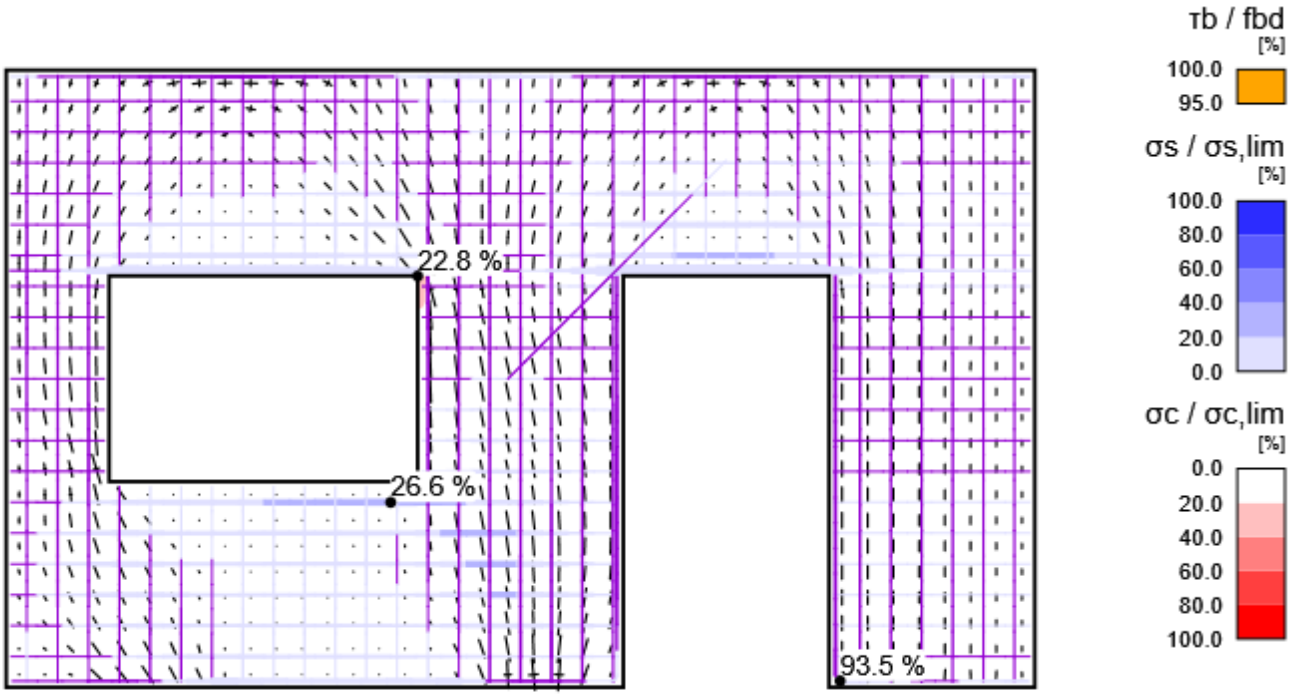
Check item	Item	Utilization	
Strength of concrete	W1	σc/σc,lim: 22.8%	✓
Strength of reinforcement	WF1	εs/εs,lim: 0.8%, σs/σs,lim: 26.6%	✓
Anchorage length	GB3	τb/fbd: 93.5%	✓

SLS	C3 (LT)	P100.0%, V100.0%	Stress limitation ✓

Check item	Combination	Increment	Critical check	Item	Utilization	
Stress limitation	C3 (LT)	P100.0%, V100.0%	7.2(5)	WF1	22.4%	✓
Crack width	C2 (LT)	P100.0%, V100.0%	w/wlim	WF1	3.2%	✓

ULS - Summary

Stress flow



Above yield	Compression	Explanation
		Thickness proportional to force

Summary of reactions and applied loads: C1, Load increment: P100.0%, V100.0%

Type	F_x [kN]	F_z [kNm]	M_y [kNm]
Summary of reactions	-75.0	500.0	1370.0
Summary of applied load	75.0	-500.0	-1370.0
Check of equilibrium	0.0	0.0	0.0

ULS - Strength

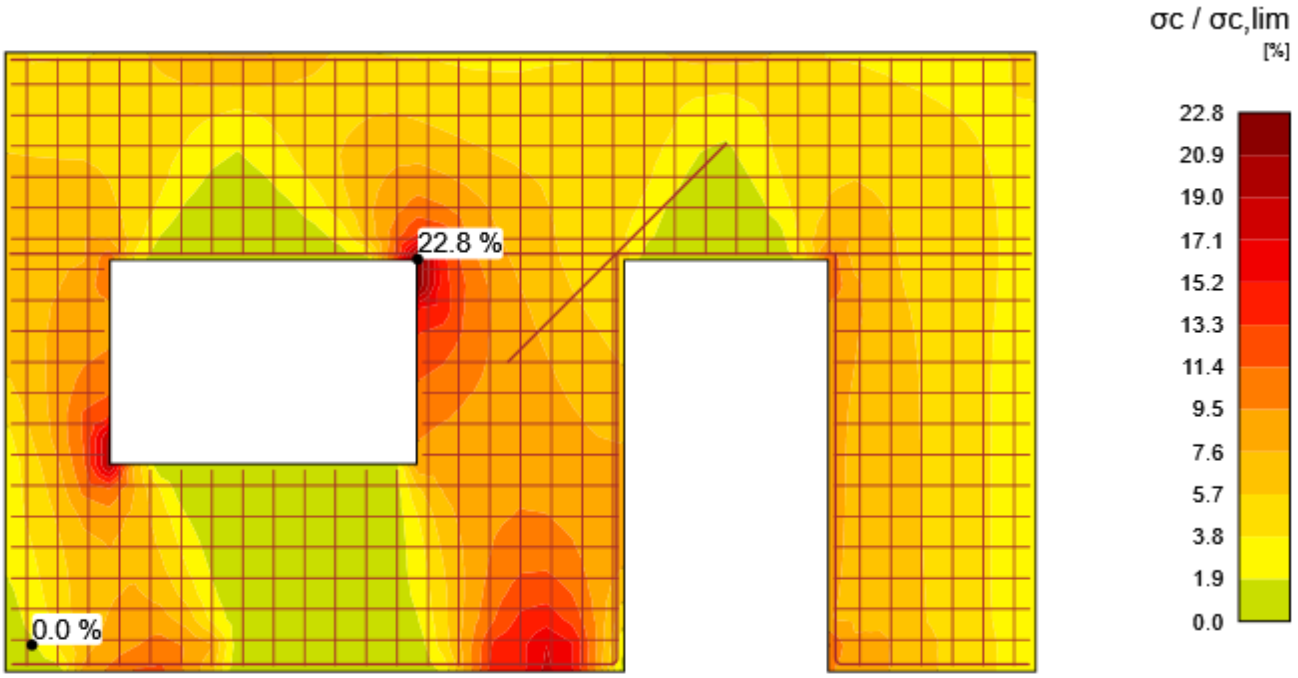
Detailed concrete strength results: C1, Load increment: P100.0%, V100.0%

Member	X [m]	Z [m]	σ_c [MPa]	ε_c [1e-4]	k_{c2} [-]	$\sigma_c/\sigma_{c,lim}$ [%]	
W1	2.00	2.00	-4.6	-2.4	1.00	22.8	OK
W1	4.00	1.88	-1.7	-0.9	1.00	8.6	OK

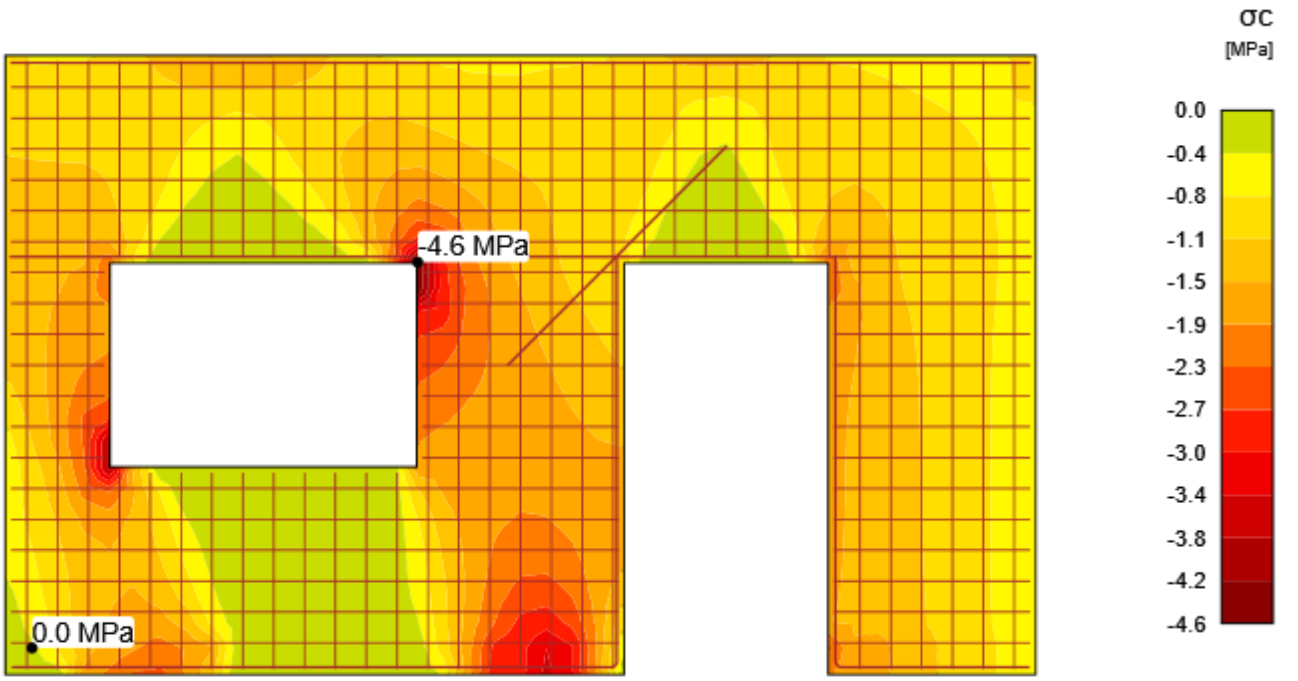
Detailed reinforcement strength results: C1, Load increment: P100.0%, V100.0%

Member	X [m]	Z [m]	σ_s [MPa]	ε_s [1e-4]	$\sigma_s/\sigma_{s,lim}$ [%]	$\varepsilon_s/\varepsilon_{s,lim}$ [%]	
WF1	1.87	0.90	125.0	0.6	26.6	0.8	OK
WF1	3.00	2.10	85.4	0.9	18.2	0.7	OK
GB4	3.00	2.03	70.7	1.3	15.0	0.7	OK
GB2	1.00	0.03	51.1	0.9	10.9	0.4	OK
GB3	4.03	0.18	-20.3	-1.0	4.3	0.2	OK
GB1	1.26	2.97	-15.5	-0.8	3.3	0.2	OK
GB3	4.06	0.03	41.9	0.4	8.9	0.2	OK
GB1	2.38	2.97	30.3	0.2	6.5	0.1	OK
IB1	2.52	1.58	-4.5	-0.2	1.0	0.0	OK
IB1	3.42	2.48	0.7	0.0	0.1	0.0	OK

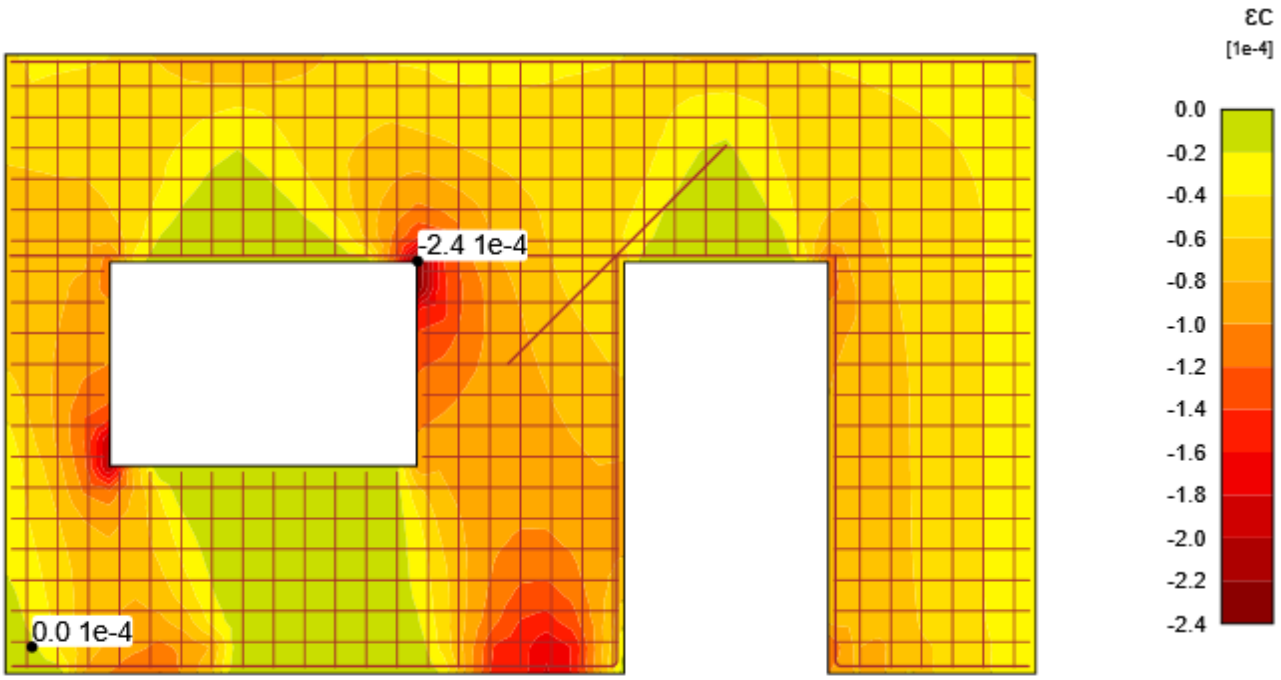
Concrete stress/strength ratio



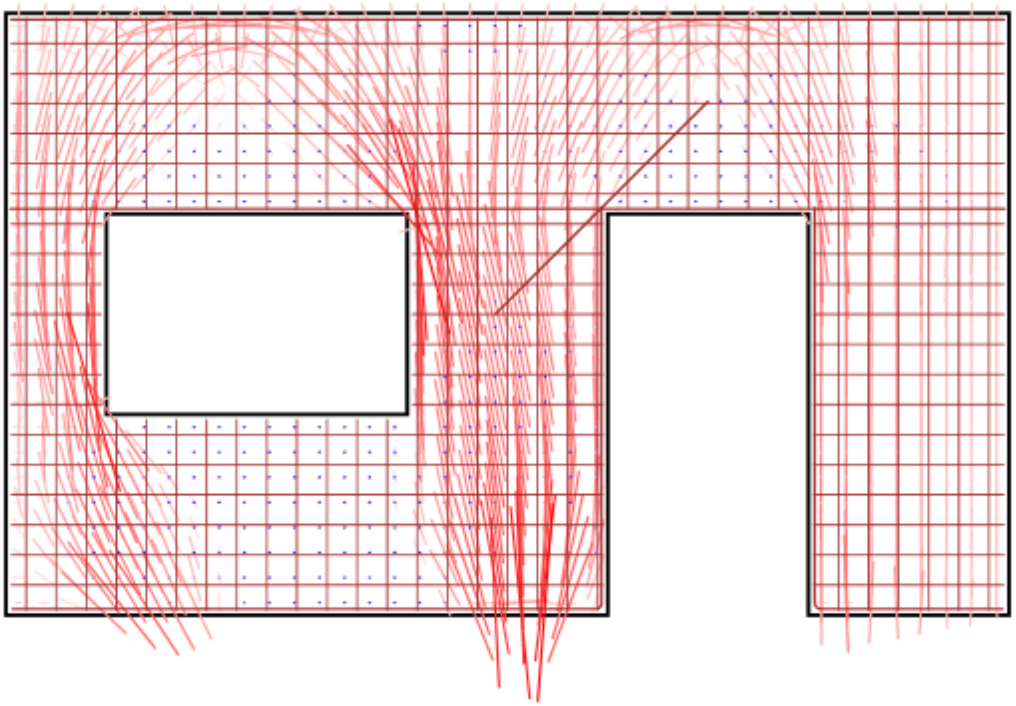
Concrete principal stress σ_c



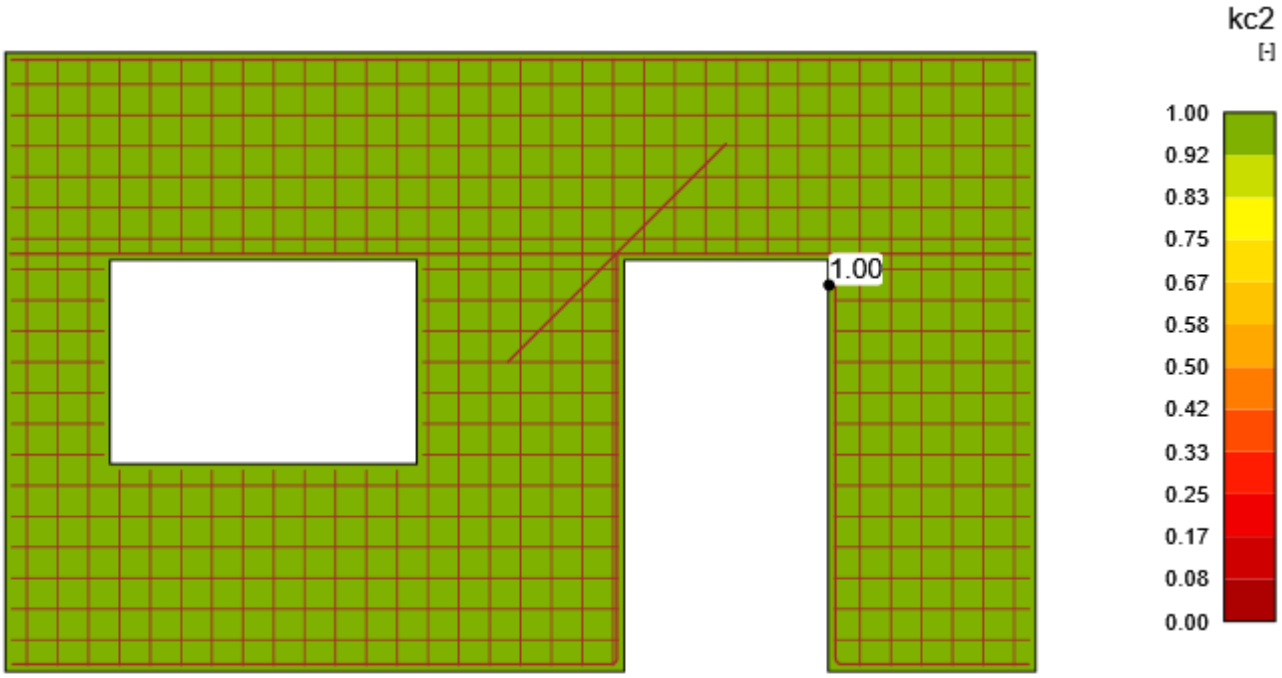
Concrete principal strain ε_c



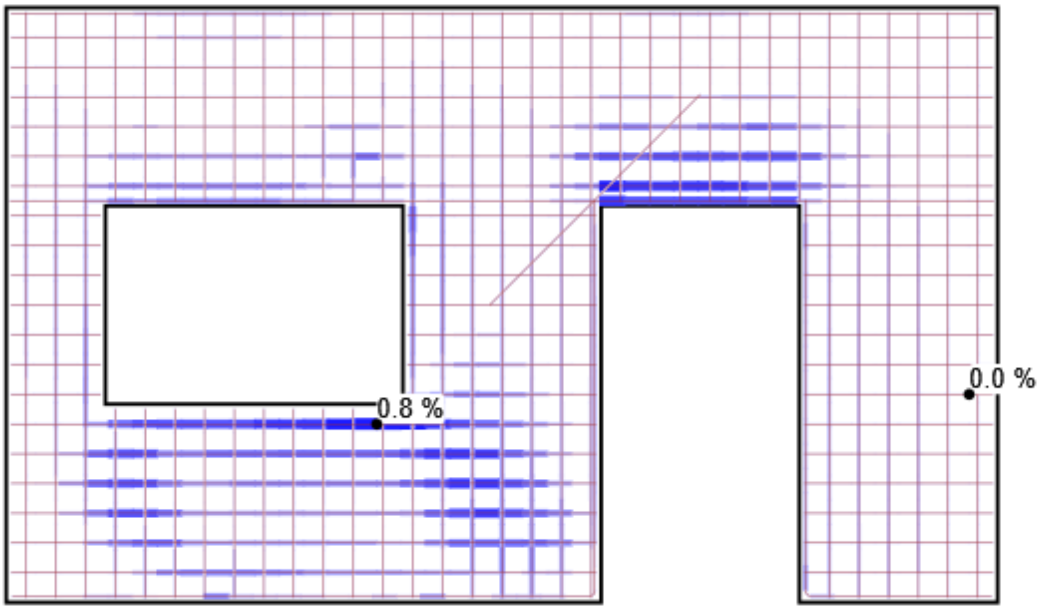
Directions of principal stresses



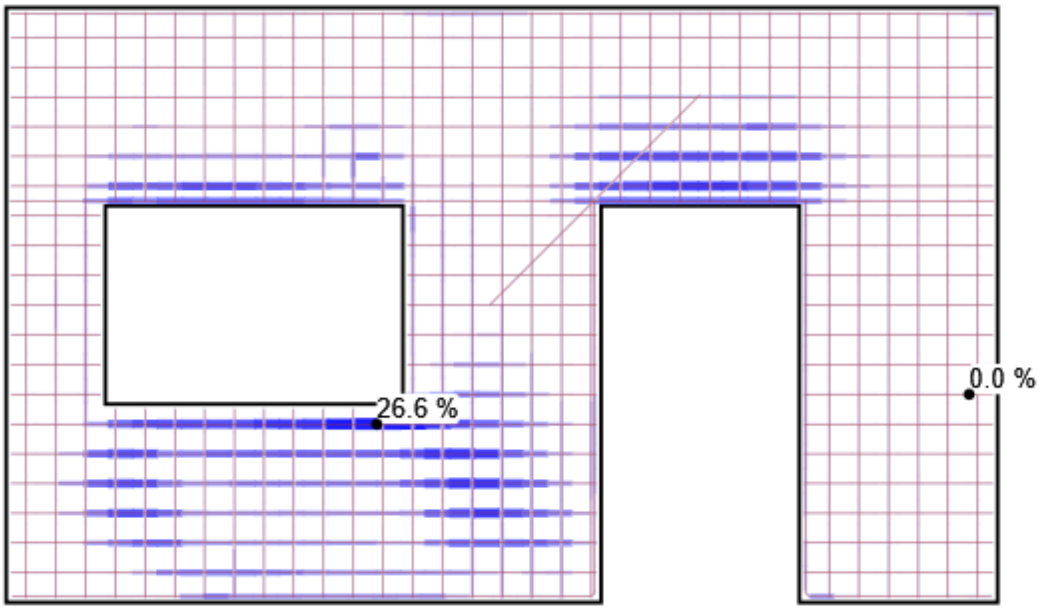
Compressive strength reduction factor kc2



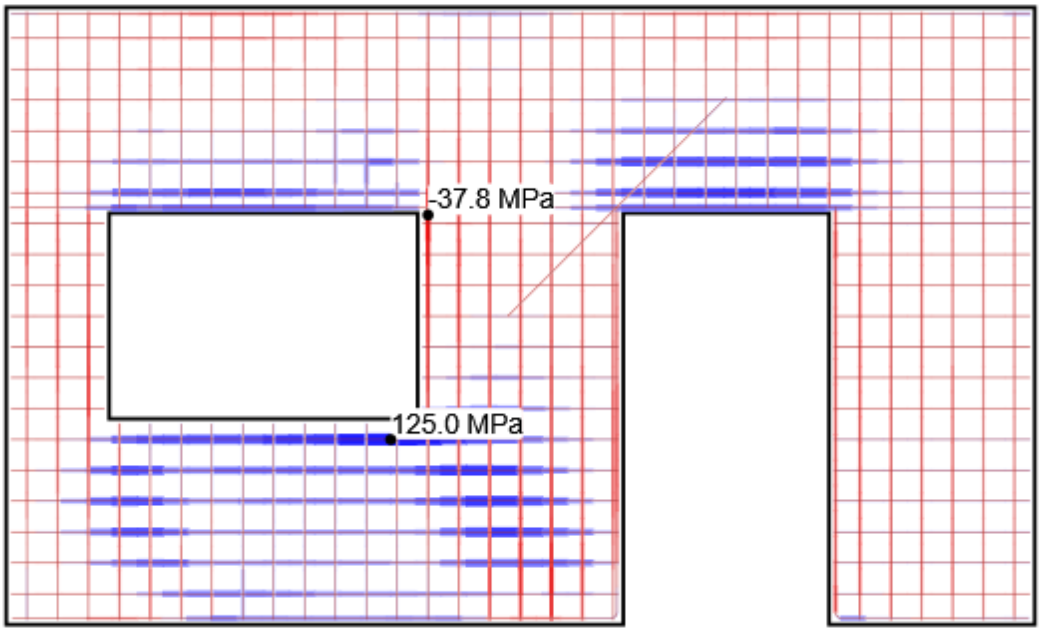
Reinforcement strain/limit strain ratio - $\varepsilon_s/\varepsilon_{s,lim}$ [%]



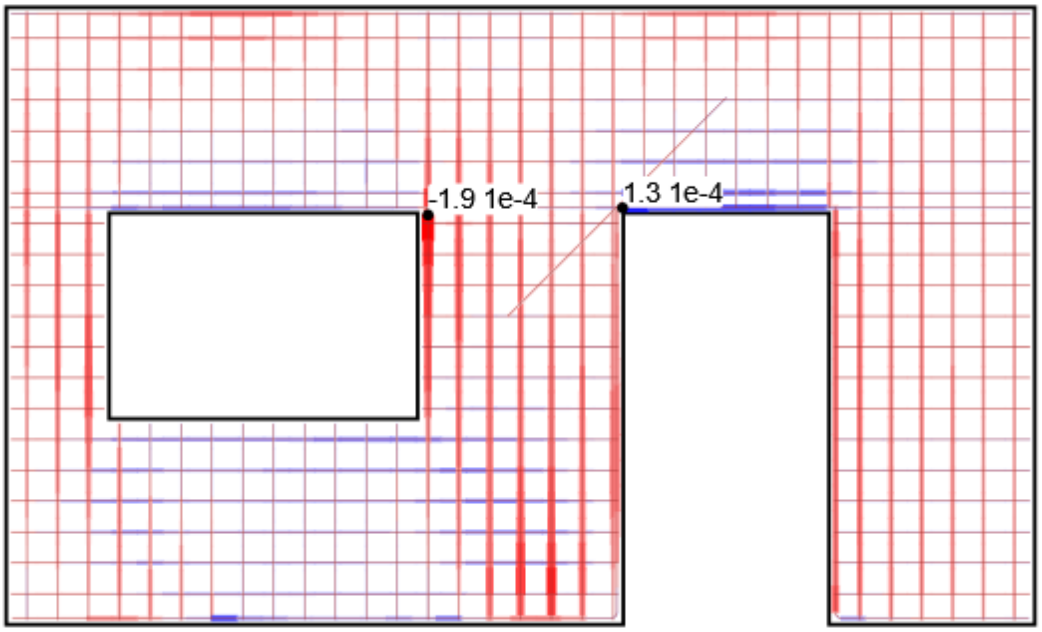
Reinforcement stress/strength ratio - $\sigma_s/\sigma_{s,lim}$ [%]



Reinforcement stress - σ_s [MPa]



Reinforcement strain - ε_s [1e-4]

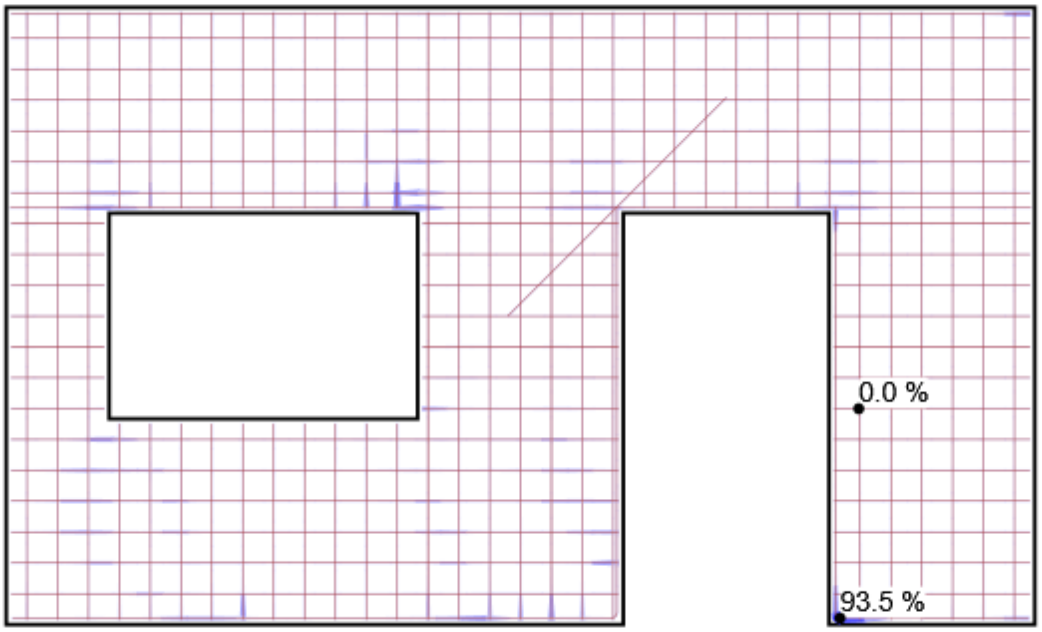


ULS - Anchorage

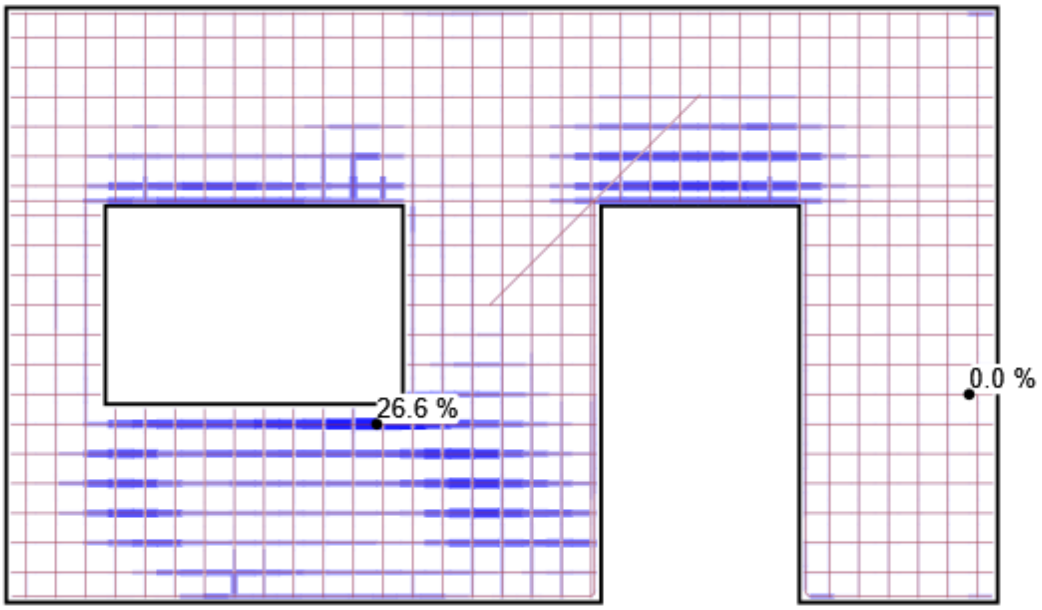
Detailed anchorage results: C1, Load increment: P100.0%, V100.0%

Member	X [m]	Z [m]	τ_b [MPa]	F_a [kN]	F_{tot} [kN]	F_{tot}/F_{lim} [%]	τ_b/f_{bd} [%]	
GB3	4.05	0.03	2.8	2.0	5.0	4.7	93.5	OK
GB3	4.17	0.03	-1.6	2.0	9.5	8.9	52.7	OK
GB3	4.06	0.03	2.1	2.0	9.5	8.9	70.1	OK
GB3	4.03	0.18	-0.4	2.0	-4.6	4.3	13.4	OK
WF1	1.90	2.03	-1.5	0.0	2.1	11.9	50.5	OK
WF1	2.65	0.02	1.4	0.0	-2.6	5.4	44.8	OK
WF1	1.87	0.90	0.1	0.0	12.6	26.6	3.3	OK
WF1	2.05	1.99	-0.4	0.0	-3.8	8.0	11.8	OK
GB4	2.00	2.03	-1.3	0.1	12.3	7.7	43.9	OK
GB4	0.52	2.03	0.9	0.1	12.2	7.7	29.5	OK
GB4	3.00	2.03	0.4	0.1	24.0	15.0	13.9	OK
GB4	2.13	2.03	0.2	0.1	-1.8	1.1	5.7	OK
GB2	2.33	0.03	-1.0	0.0	5.8	5.5	33.5	OK
GB2	0.88	0.03	0.7	0.0	1.9	1.8	22.9	OK
GB2	1.00	0.03	0.6	0.0	11.6	10.9	20.0	OK
GB2	2.97	0.68	0.0	0.0	-3.8	3.6	0.6	OK
GB1	4.98	2.97	0.9	2.7	4.5	7.5	28.7	OK
GB1	4.85	2.97	-0.6	2.7	4.5	7.5	18.7	OK
GB1	2.38	2.97	0.1	2.7	6.9	6.5	2.6	OK
GB1	1.26	2.97	0.0	2.7	-3.5	3.3	0.8	OK
IB1	2.44	1.50	-0.3	0.1	-0.8	0.7	9.2	OK
IB1	3.01	2.07	0.1	0.1	-0.6	0.6	2.4	OK
IB1	3.42	2.48	0.0	0.1	0.2	0.3	0.4	OK
IB1	2.52	1.58	0.0	0.1	-1.0	1.0	1.0	OK

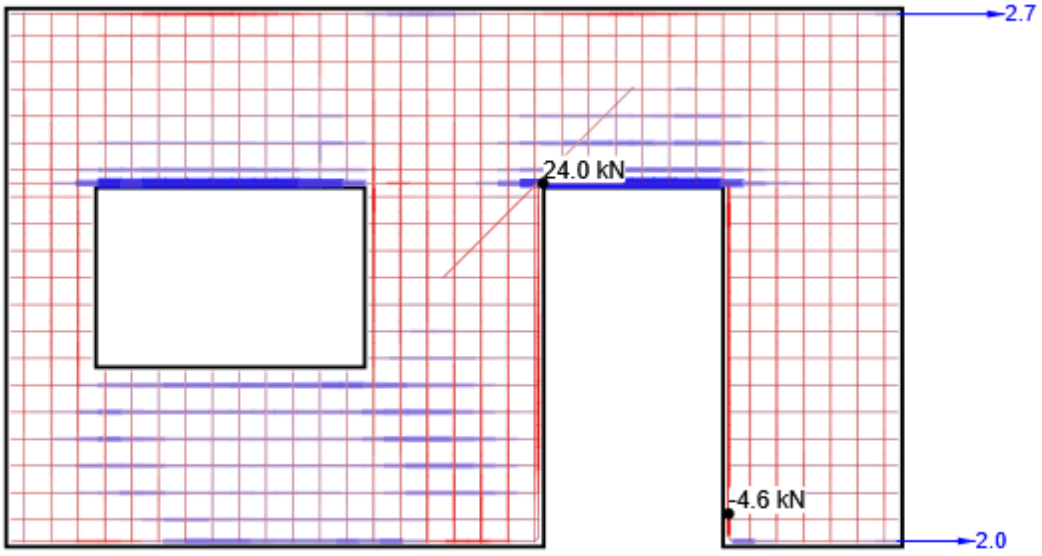
Bond stress check value - τ_b/f_{bd} [%]



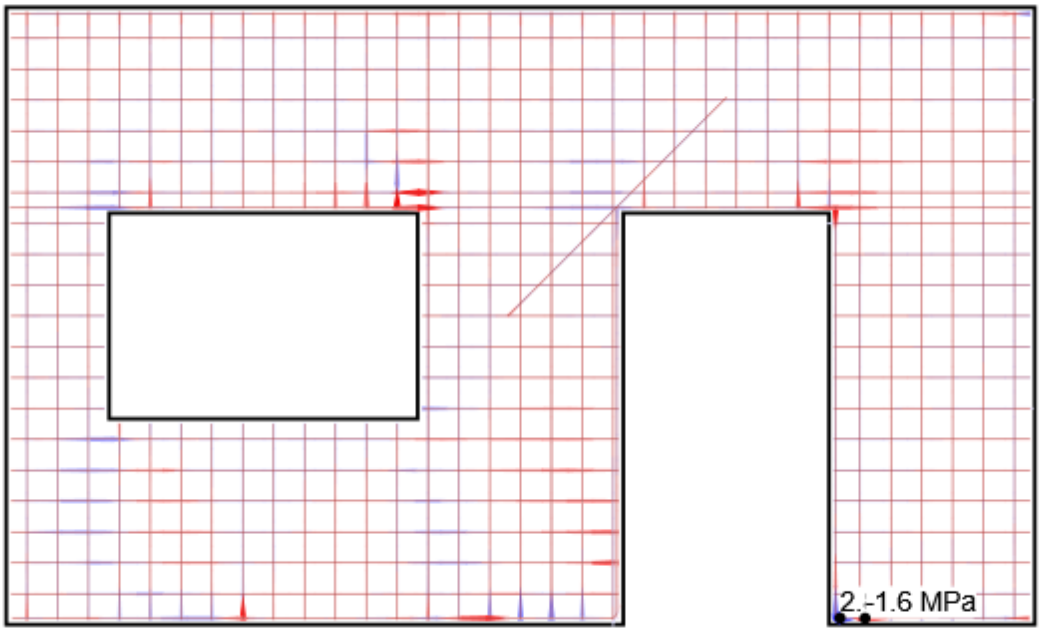
Force check value - F_{tot}/F_{lim} [%]



Total force in the bar - F_{tot} [kN]



Bond stress - τ_b [MPa]



Settings

Creep coefficient

Type of input	Creep coefficient
Input by user	2.5

SLS - Stress

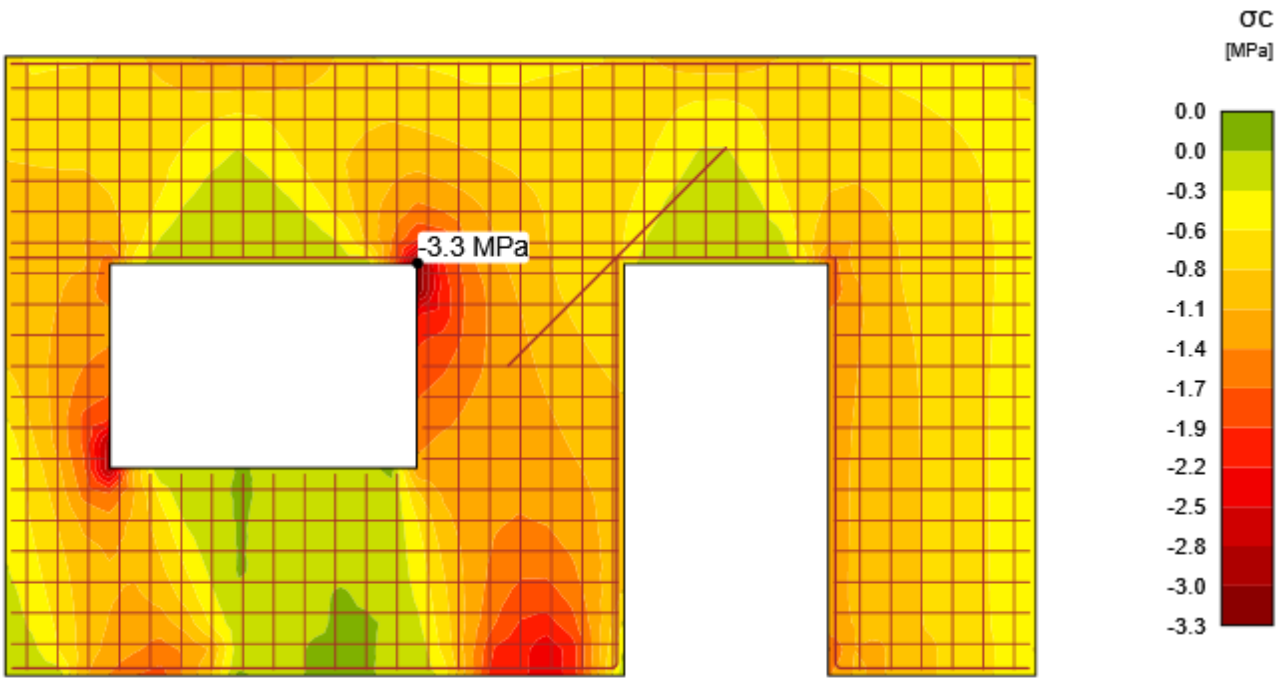
Detailed concrete stress results: C3, Load increment: P100.0%, V100.0%

Member	X [m]	Z [m]	Critical check	σ_c [MPa]	σ_{lim} [MPa]	σ_c/σ_{lim} [%]	
W1	2.00	2.00	7.2(2)	-3.3	18.0	18.4	OK

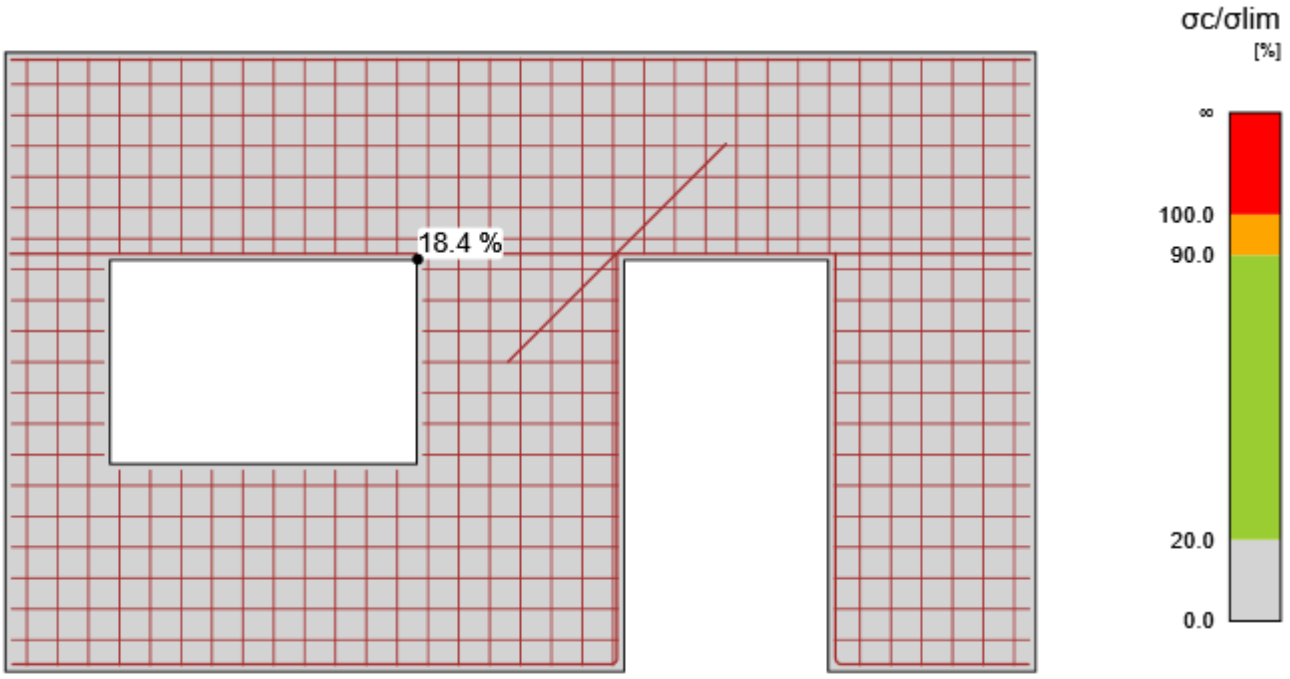
Detailed reinforcement stress results: C3, Load increment: P100.0%, V100.0%

Reinforcement	X [m]	Z [m]	Critical check	σ_s [MPa]	σ_{lim} [MPa]	σ_s/σ_{lim} [%]	
WF1	1.87	0.90	7.2(5)	89.7	400.0	22.4	OK
GB1	4.98	2.97	7.2(5)	16.1	400.0	4.0	OK
GB2	1.00	0.03	7.2(5)	48.4	400.0	12.1	OK
GB3	4.05	0.03	7.2(5)	56.7	400.0	14.2	OK
GB4	3.62	2.03	7.2(5)	63.1	400.0	15.8	OK
IB1	2.44	1.50	7.2(5)	-3.9	400.0	0.0	OK

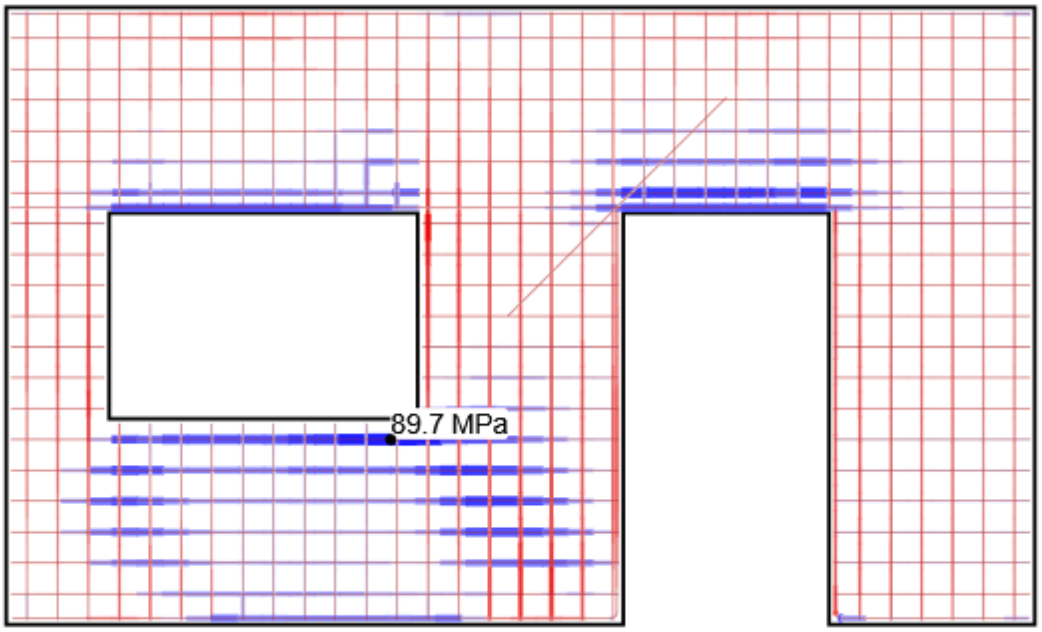
Concrete stress



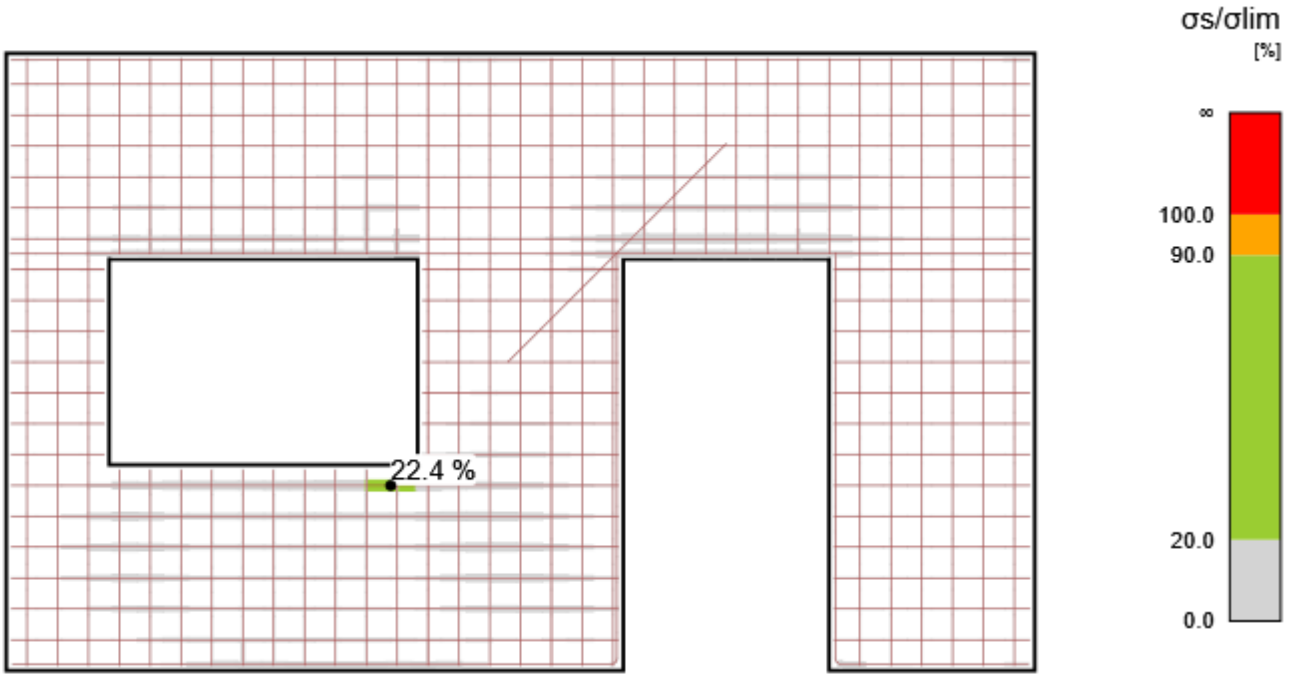
Concrete stress check



Reinforcement stress - σ_s [MPa]



Reinforcement stress check



SLS - Crack

Detailed crack results: C2, Load increment: P100.0%, V100.0%, w_{lim}=0.300 mm

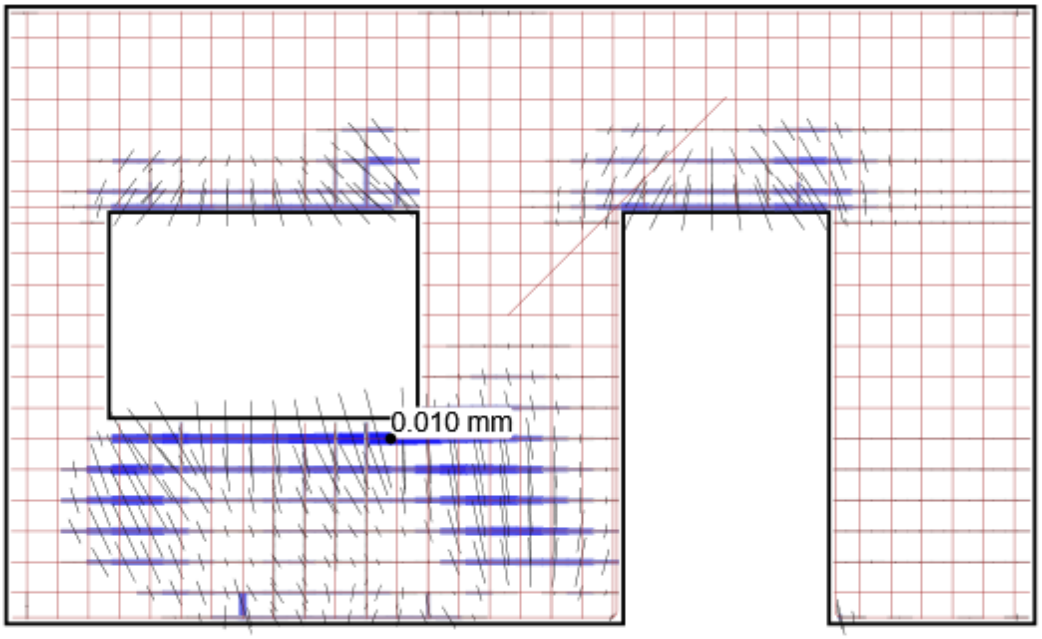
Member	X [m]	Z [m]	w [mm]	w/w_{lim} [%]	
WF1	1.87	0.90	0.010	3.2	OK
WF1	1.75	0.90	0.010	3.2	OK
GB4	3.00	2.03	0.005	1.8	OK
GB4	3.74	2.03	0.005	1.7	OK
GB3	4.05	0.03	0.003	1.1	OK
GB2	2.09	0.03	0.002	0.8	OK
GB1	4.98	2.97	0.001	0.2	OK
IB1	2.44	1.50	0.000	0.0	OK

Intermediate crack results

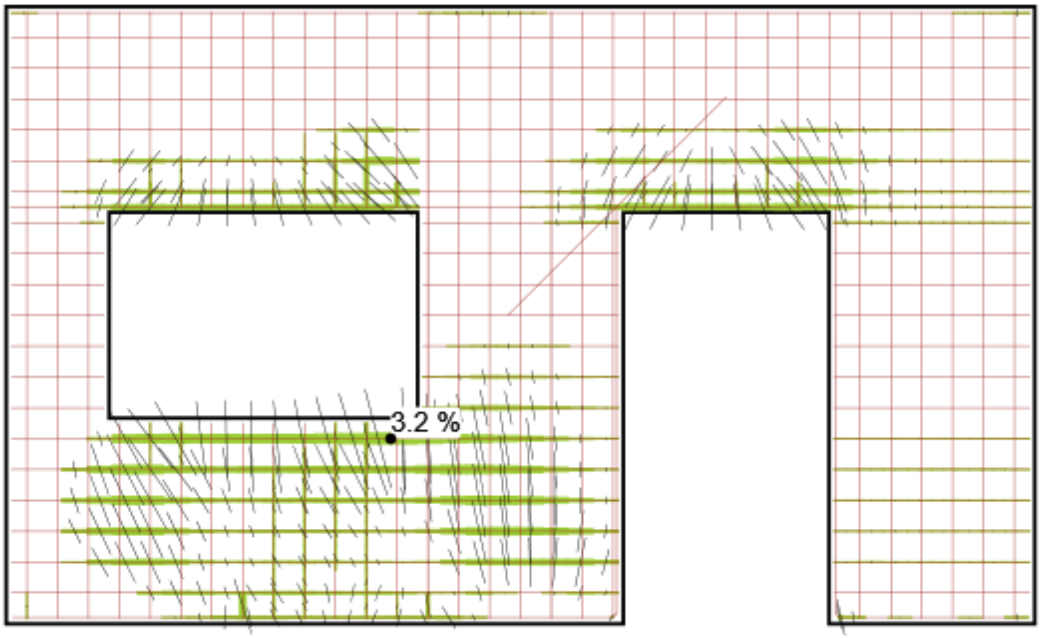
Member	ε_{cm} [1e-4]	ε_m [1e-4]	s_r [mm]	Φ [mm]	ρ_{eff} [%]	w_b [mm]	θ_r [-]	θ_b [-]
WF1	0.0	0.3	297	8	0.67	0.010	1.60	0.00
WF1	0.0	0.3	297	8	0.67	0.009	1.83	0.00
GB4	0.0	0.4	137	12	2.15	0.005	1.14	0.00
GB4	0.0	0.3	166	12	1.77	0.004	2.18	0.00
GB3	0.0	0.2	154	12	1.91	0.003	1.79	-0.13
GB2	0.0	0.2	120	12	2.44	0.002	2.11	0.00
GB1	0.0	0.1	120	12	2.44	0.001	1.69	0.00
IB1	0.0	0.0	0	0	0.00	0.000	0.00	0.00

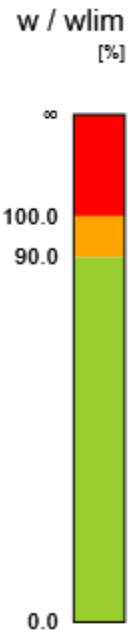
Note: There are TCM intermediate values displayed in the table above. Adequate POM values are not available in current version of the program.

Crack width - w [mm]



Crack width check



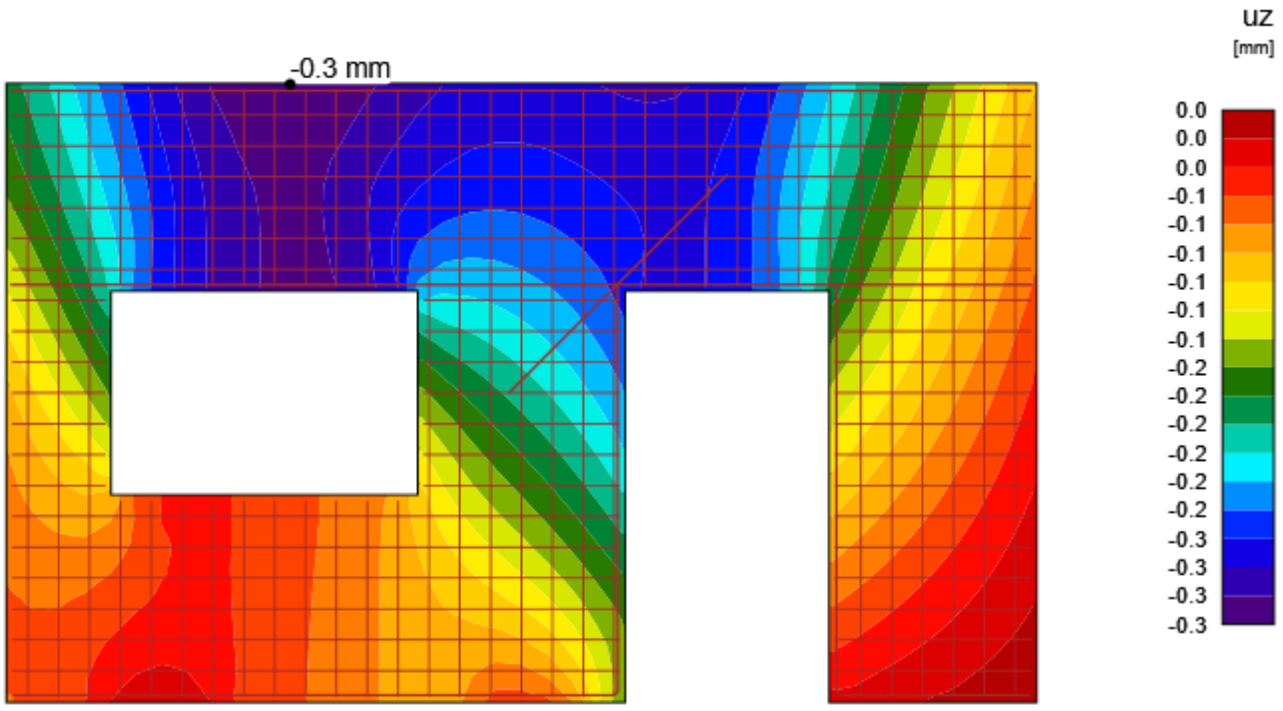


SLS - Deflection

Detailed deflection results: C3, Load increment: P100.0%, V100.0%

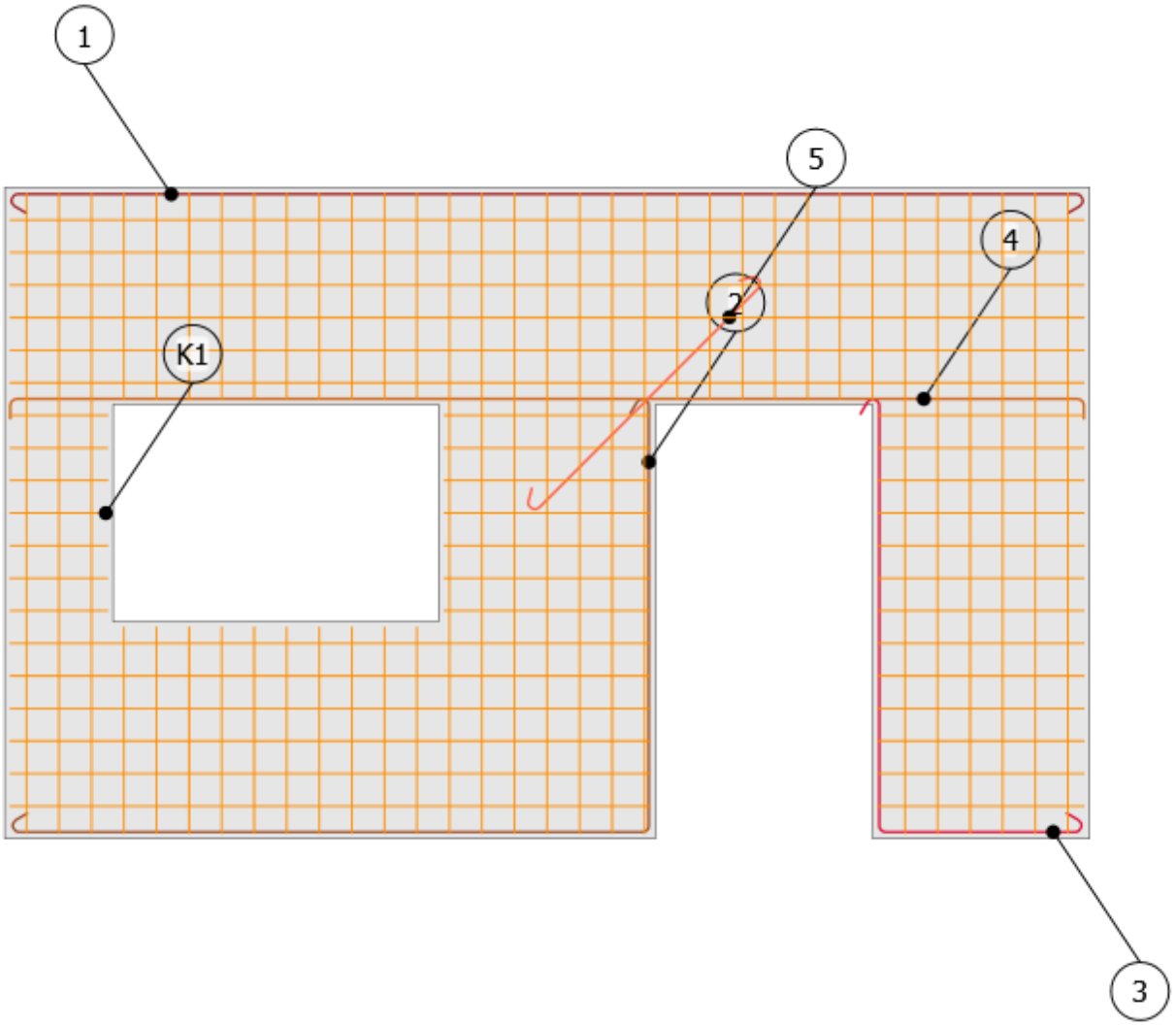
Member	X [m]	Z [m]	$u_{z,st}$ [mm]	$u_{z,lt}$ [mm]	Δu_z [mm]	u_z [mm]	
W1	1.38	3.00	-0.2	-0.2	-0.1	-0.3	OK
W1	3.25	3.00	-0.2	-0.2	-0.1	-0.3	OK

Deflection



Bill of material

Items numbering



Fabric reinforcement tables

Parameter	Value
Index	K1
Φ X/Y [mm]	8 / 8
Material	B 500B
Number of items	2
Total area [m2]	15.00
Bar spacing X/Y [mm]	150 / 150
Weight of one item [kg]	79
Assigned to wall	-all-

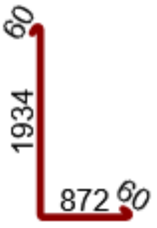
Brief reinforcement bar table

Index	Φ [mm]	Material	Items	Length [mm]	Weight [kg]	Total length [m]
1	12	B 500B	2	5155	5	10.31
2	12	B 500B	2	5130	5	10.26
3	12	B 500B	2	3130	3	6.26
4	12	B 500B	3	5102	5	15.31
5	12	B 500B	2	1705	2	3.41

Detailed reinforcement bar tables

Parameter	Value	Shape
Index	1	
Φ [mm]	12	
Material	B 500B	
Number of items	2	
Length [mm]	5155	
Weight [kg]	5	
Total length [m]	10.31	

Parameter	Value	Shape
Index	2	
Φ [mm]	12	
Material	B 500B	
Number of items	2	
Length [mm]	5130	
Weight [kg]	5	
Total length [m]	10.26	

Parameter	Value	Shape
Index	3	
Φ [mm]	12	
Material	B 500B	
Number of items	2	
Length [mm]	3130	
Weight [kg]	3	
Total length [m]	6.26	

Parameter	Value	Shape
Index	4	
Φ [mm]	12	
Material	B 500B	
Number of items	3	
Length [mm]	5102	
Weight [kg]	5	
Total length [m]	15.31	

Parameter	Value	Shape
Index	5	
Φ [mm]	12	
Material	B 500B	
Number of items	2	
Length [mm]	1705	
Weight [kg]	2	
Total length [m]	3.41	

Overview table

Φ [mm]	12
Total length of Φ [m]	45.55
Weight per meter of Φ [kg/m]	1
Total weight of Φ [kg]	40
Total weight of bars [kg]	40
Total weight of fabric reinforcement [kg]	158
Total weight [kg]	198
Volume of concrete [m3]	2.30
Reinforcement weight per volume unit of concrete [kg/m3]	86

Explanation

Symbol	Explanation
f_{ck}	Characteristic compressive cylinder strength of concrete at 28 days
$f_{ctk,0.05}$	Characteristic axial tensile strength of concrete 5% quantile
f_{ctm}	Mean value of axial tensile strength of concrete
E_{cm}	Secant modulus of elasticity of concrete
ε_c	Compressive strain in the concrete at the peak stress fc
ε_{cu}	Ultimate compressive strain in the concrete
f_{yk}	Characteristic yield strength of reinforcement
E_s	Modulus of elasticity of reinforcement steel
ε_{uk}	Characteristic strain of reinforcement or prestressing steel at maximum load
Properties	W - Width; H - Height; T - Thickness; L - Length; r - Radius; α - Inclination
Position	M - Master; MP - Master point; IP - Insert point
σ_c	The extreme value of compressive stress σc of concrete of selected subregion.
k_{c2}	Compressive strength reduction factor kc2
$\sigma_c/\sigma_{c,lim}$	The ratio of concrete stress and concrete strength. It presents the level of material utilization with respect to concrete strength.
σ_s	Maximum stress along the length of reinforcement bar.
ε_s	Maximum strain along the length of reinforcement bar.
$\sigma_s/\sigma_{s,lim}$	The ratio of stress and strength of the reinforcement. It presents the level of material utilization with respect to reinforcement strength.
$\varepsilon_s/\varepsilon_{s,lim}$	The ratio of strain and limit strain of the reinforcement. It presents the level of material utilization with respect to limit strain
τ_b	Bond stress on the surface of reinforcement bar.

Symbol	Explanation
F_a	The anchorage force. It is developed at the ends of the bars due to hooked anchorage.
F_{tot}	Total force developed along the length of the bar. It consists of the anchorage force due to hooked anchorage and bond force, which integrates bond stresses acting on the surface of the bar.
F_{tot}/F_{lim}	The ratio of total force in the bar and limit value of the force. It presents the level of utilization of the rebar. The limit value of the force is calculated as the minimum of two values: (a) the force calculated as the sum of ultimate anchorage force and the force developed from the end of the bar to the point of interest assuming ultimate bond strength, (b) the ultimate strength of the bar.
τ_b/f_{bd}	The ratio of bond stress and ultimate bond strength for selected (group of) bars and applied portion of the load. It shows the level of utilization with respect to ultimate bond strength between the rebar and adjacent concrete.
Creep coefficient	Final value of creep coefficient at time interval (t0 = 28 days, tinf = design working life)
w	Total crack width including effect of creep.
ε_{cm}	the mean strain in the concrete between cracks
ε_m	the mean strain in the reinforcement under relevant combination of loads, including the effect of imposed deformations and taking into account the effects of tension stiffening. Only the additional tensile strain beyond the state of zero strain of the concrete at the same level is considered
s_r	mean value of axial tensile strength of concrete
Φ	diameter of reinforcing bar
ρ_{eff}	effective reinforcement ratio
w_b	calculated crack width
θ_r	inclination of the cracks (the angle between the global coordinate system and the crack direction)
θ_b	bar inclination (the angle between the global coordinate system and the axis of reinforcement bar)
$u_{z,st}$	Immediate deflection caused by total load, calculated with short-term stiffnesses.
$u_{z,lt}$	Long-term effects of long-term load.
Δu_z	Deflection increment caused by variable load.
u_z	Total deflection including effect of creep.

Code settings

Clause	Name	Value	Description
2.4.2.4 (1)	γ_c	1.50	Partial factor for concrete.
2.4.2.4 (1)	γ_s	1.15	Partial factor for reinforcement
3.1.6 (1)	α_{cc}	1.00	Coefficient taking into account the long term effect on the compressive strength and the unfavourable from the way the load is applied
3.2.7 (2)	$\varepsilon_{ud}/\varepsilon_{uk}$	0.90	Ratio of design and characteristic strain limit.
8.3(2)	Φ m,min - Φs <= 16mm (4.00 Φs)	4.00	Minimum mandrel diameter of stirrups as multiple of stirrups diameter.
8.3(2)	Φ m,min - Φs > 16mm (7.00 Φs)	7.00	Minimum mandrel diameter of stirrups as multiple of stirrups diameter.
7.2(2)	k1	0.60	Coefficient for calculation of the maximum compressive stress in concrete under SLS characteristic combination
7.2(3)	k2	0.45	Coefficient for calculation of the stress in the concrete under the SLS quasi-permanent combination
7.2(5)	k3	0.80	Coefficient for calculation of maximal tensile stress in the reinforcement under SLS characteristic combination

Calculation presumptions

- Minimum amount of reinforcement resisting at least the tensile stresses prior cracking has to be provided in cracked zones.

- It is assumed that a transverse rebar or adequate overlap is provided to enable full anchorage of the stirrups.
- The analysis and code checks are performed for support conditions as specified in the project. No change of supports in construction/service stages is considered.
- The crack width is checked in the vicinity of the reinforcement only. No control of cracking is performed in non-reinforced zones.
- The presentation of crack spacing is schematic only. It does not represent the crack spacing computed for the calculations.