Project:
Project no:
Author:

Project data

Project name	
Project number	
Author	
Description	
Date	7/22/2025
Design code	ACI 318

Summary results

Check item	
Detail2	✓

Materials

Concrete

Name	f_c' [ksi]	E_c [ksi]	ν [-]
4000 psi	4.0	3606.5	0.15

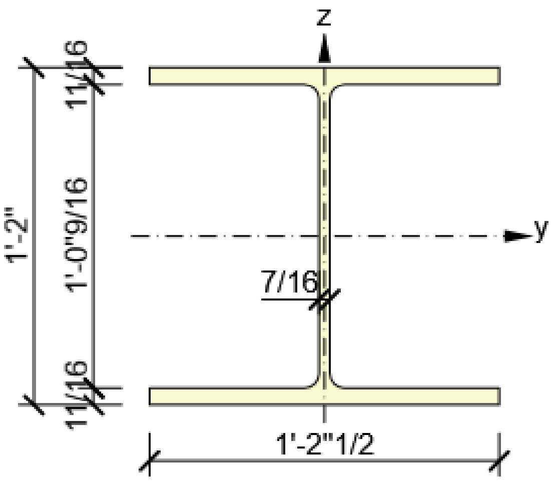
Reinforcement

Name	f_y [ksi]	E_s [ksi]	Unit mass [lb/ft^3]
Grade 60	60.0	29000.0	490
	ε_{st} = 1000.0 1e-4, ε_{sc} = 1000.0 1e-4,		

Steel

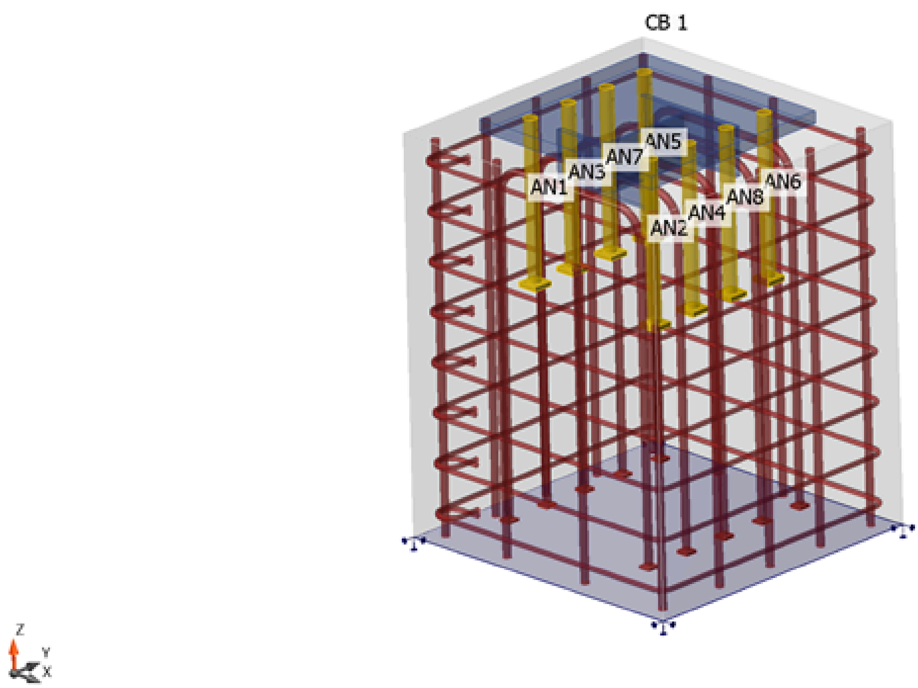
Name	E [ksi]
A36	29007.5

Cross-sections

Name	Material	Master	Picture
	A36	Detail2: BP1	

Detail2

Geometry



Overview table

Name	Type	Properties	Position
CB 1	Solid Block	Shape: General; H: 4'-0" ft; Material: 4000 psi	X: 0" ft; Y: 0" ft; Z: -4'-1"1/2 ft
BP1	Base plate	W: 11"13/16 ft; T: 1"1/2 ft; D: 11"13/16 ft; Material: A36; Shear force transfer: Shear lug; - Cross-section: 6; - Edge of base plate: 1; - X - position: 1'-1"1/4 ft; - Y - position: 1'-1" ft; - Length of shear lug: 6" ft; - Rotation of shear lug: 180.0 °	M: CB 1, Edge 1, Surface 6; X: 0" ft; Y: 0" ft
SS1	Surface support	X; Y; Z; Direction - Local	M: CB 1, Surface: 5; Geometry type: Whole surface
AN1	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 10" ft, Y: 10" ft
AN2	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 2'-4"1/2 ft, Y: 10" ft
AN3	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 10" ft, Y: 1'-4" ft
AN4	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 2'-4"1/2 ft, Y: 1'-4" ft
AN5	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 10" ft, Y: 2'-4" ft
AN6	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 2'-4"1/2 ft, Y: 2'-4" ft
AN7	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 10" ft, Y: 1'-10" ft
AN8	Anchorage - Load	L1: 1"1/2 ft; L2: 1'-6" ft; Φ: 1"11/16 in; Material: F1554 Gr.105; Anchor type: Cast-in place – Reinforcement; Anchorage type: Perfect bond	M: CB 1, Edge: 1, Surface: 6; X: 2'-4"1/2 ft, Y: 1'-10" ft

Loads

Load case 1056: (2) - Dead

Point loads

Name	Fx [kip]	Fy [kip]	Fz [kip]	Direction	Master	Position [X;Y;Z] [in]
PL2	0.00	0.00	103.31	Global		-
PL3	0.00	0.00	103.12	Global		-
PL4	0.00	0.00	65.52	Global		-
PL5	0.00	0.00	58.60	Global		-
PL6	0.00	0.00	0.00	Global		-
PL7	0.00	0.00	0.00	Global		-

Point loads

Name	Fx [kip]	Fy [kip]	Fz [kip]	Mx [kip.ft]	My [kip.ft]	Mz [kip.ft]	Direction	Master	Position [X;Z] [in]
FL1	-1.19	0.24	-1.99	-0.02	0.14	0.06	Global	BP1	1'-8"1/2;6"15/16
FL1	-0.99	1.78	-5.13	-0.06	-0.16	-0.04	Global	BP1	1'-7"5/16;6"15/16
FL1	1.00	-0.56	-4.02	-0.03	0.14	0.00	Global	BP1	1'-7"5/16;6"15/16
FL1	1.00	1.29	-3.64	-0.04	-0.12	-0.02	Global	BP1	1'-6"1/16;6"15/16
FL1	0.49	-1.04	-2.18	-0.01	0.09	0.00	Global	BP1	1'-6"1/16;6"15/16
FL1	0.49	1.17	-2.73	-0.04	-0.08	-0.01	Global	BP1	1'-4"7/8;6"15/16
FL1	0.69	-0.75	-2.29	-0.01	0.10	0.01	Global	BP1	1'-4"7/8;6"15/16
FL1	0.69	1.48	-3.51	-0.05	-0.09	-0.02	Global	BP1	1'-3"11/16;6"15/16
FL1	-0.07	-1.08	-1.93	-0.01	0.10	0.01	Global	BP1	1'-3"11/16;6"15/16
FL1	-0.07	1.35	-3.80	-0.05	-0.10	-0.01	Global	BP1	1'-2"7/16;6"15/16
FL1	1.29	2.81	-2.87	-0.05	0.13	0.14	Global	BP1	1'-2"7/16;6"15/16
FL1	1.12	4.83	-3.55	-0.08	-0.11	-0.16	Global	BP1	1'-1"1/4;6"15/16
FL1	-1.13	4.28	-2.73	-0.06	0.11	0.12	Global	BP1	1'-1"1/4;6"15/16
FL1	-1.24	1.35	-4.02	-0.05	-0.13	-0.10	Global	BP1	1'-0"1/16;6"15/16
FL1	-0.28	2.87	-3.23	-0.06	0.11	0.05	Global	BP1	1'-0"1/16;6"15/16
FL1	-0.28	-0.37	-3.53	-0.03	-0.12	-0.04	Global	BP1	10"13/16;6"15/16
FL1	-0.02	1.94	-3.56	-0.05	0.14	0.02	Global	BP1	10"13/16;6"15/16
FL1	-0.02	-0.85	-4.60	-0.03	-0.14	-0.02	Global	BP1	9"5/8;6"15/16
FL1	0.63	1.86	-4.00	-0.05	0.18	0.01	Global	BP1	9"5/8;6"15/16
FL1	0.56	-0.70	-5.45	-0.04	-0.17	-0.02	Global	BP1	8"7/16;6"15/16
FL1	0.36	1.04	-6.51	-0.07	0.22	0.02	Global	BP1	8"7/16;6"15/16
FL1	0.28	0.39	-6.63	-0.06	-0.22	-0.02	Global	BP1	7"3/16;6"15/16
FL1	2.86	0.33	-5.63	-0.05	0.20	-0.03	Global	BP1	7"3/16;6"15/16
FL1	3.73	-0.67	-3.55	-0.03	-0.14	-0.03	Global	BP1	6";6"15/16
FL1	-3.15	-0.05	-5.10	0.05	0.16	-0.01	Global	BP1	1'-8"1/2;5"13/16
FL1	-2.42	0.85	-5.87	0.05	-0.21	-0.04	Global	BP1	1'-7"5/16;5"13/16
FL1	-1.87	-0.30	-6.17	0.06	0.19	-0.01	Global	BP1	1'-7"5/16;5"13/16
FL1	-1.91	0.75	-6.10	0.05	-0.22	-0.02	Global	BP1	1'-6"1/16;5"13/16
FL1	-2.27	-0.52	-5.94	0.06	0.18	-0.02	Global	BP1	1'-6"1/16;5"13/16
FL1	-2.20	0.53	-6.00	0.05	-0.22	-0.02	Global	BP1	1'-4"7/8;5"13/16
FL1	-1.65	-0.30	-6.31	0.06	0.20	-0.01	Global	BP1	1'-4"7/8;5"13/16
FL1	-1.55	0.49	-6.35	0.05	-0.23	-0.02	Global	BP1	1'-3"11/16;5"13/16
FL1	-1.43	-0.28	-6.46	0.06	0.20	-0.01	Global	BP1	1'-3"11/16;5"13/16
FL1	-1.34	0.31	-6.50	0.06	-0.23	-0.01	Global	BP1	1'-2"7/16;5"13/16
FL1	-1.06	0.46	-6.63	0.06	0.21	0.01	Global	BP1	1'-2"7/16;5"13/16
FL1	-1.02	0.97	-6.60	0.05	-0.23	-0.03	Global	BP1	1'-1"1/4;5"13/16
FL1	1.09	0.75	-6.63	0.05	0.23	0.03	Global	BP1	1'-1"1/4;5"13/16
FL1	1.07	0.20	-6.68	0.06	-0.21	-0.01	Global	BP1	1'-0"1/16;5"13/16
FL1	1.03	0.41	-6.70	0.06	0.23	0.02	Global	BP1	1'-0"1/16;5"13/16
FL1	1.03	-0.05	-6.71	0.06	-0.22	0.00	Global	BP1	10"13/16;5"13/16
FL1	0.85	0.26	-6.76	0.06	0.23	0.01	Global	BP1	10"13/16;5"13/16
FL1	0.84	-0.11	-6.77	0.06	-0.22	0.01	Global	BP1	9"5/8;5"13/16
FL1	0.87	0.22	-6.80	0.06	0.24	0.01	Global	BP1	9"5/8;5"13/16

Project:
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Name	Fx [kip]	Fy [kip]	Fz [kip]	Mx [kip.ft]	My [kip.ft]	Mz [kip.ft]	Direction	Master	Position [X;Z] [in]
FL1	0.84	-0.12	-6.82	0.06	-0.22	0.01	Global	BP1	8"7/16;5"13/16
FL1	0.31	0.20	-6.91	0.06	0.23	0.01	Global	BP1	8"7/16;5"13/16
FL1	0.29	0.09	-6.94	0.06	-0.23	0.00	Global	BP1	7"3/16;5"13/16
FL1	2.13	0.17	-6.47	0.06	0.23	0.02	Global	BP1	7"3/16;5"13/16
FL1	2.55	-0.26	-6.12	0.06	-0.19	0.02	Global	BP1	6";5"13/16
FL1	4.16	0.07	5.80	0.05	-0.17	-0.03	Global	BP1	1'-8"1/2;1'-8"1/4
FL1	3.66	0.29	6.70	0.06	0.25	-0.04	Global	BP1	1'-7"5/16;1'-8"1/4
FL1	1.49	0.05	7.27	0.07	-0.23	-0.01	Global	BP1	1'-7"5/16;1'-8"1/4
FL1	1.67	0.37	7.08	0.06	0.26	-0.02	Global	BP1	1'-6"1/16;1'-8"1/4
FL1	2.18	-0.51	6.50	0.06	-0.19	-0.03	Global	BP1	1'-6"1/16;1'-8"1/4
FL1	2.51	-0.13	6.23	0.06	0.24	-0.01	Global	BP1	1'-4"7/8;1'-8"1/4
FL1	1.78	-0.19	6.39	0.06	-0.19	-0.02	Global	BP1	1'-4"7/8;1'-8"1/4
FL1	2.63	0.27	5.63	0.05	0.23	-0.02	Global	BP1	1'-3"11/16;1'-8"1/4
FL1	1.43	0.14	6.36	0.06	-0.20	0.00	Global	BP1	1'-3"11/16;1'-8"1/4
FL1	1.74	0.74	5.18	0.04	0.23	-0.03	Global	BP1	1'-2"7/16;1'-8"1/4
FL1	1.35	0.28	4.97	0.04	-0.14	0.01	Global	BP1	1'-2"7/16;1'-8"1/4
FL1	1.35	0.76	4.35	0.03	0.17	-0.03	Global	BP1	1'-1"1/4;1'-8"1/4
FL1	-1.72	1.43	5.13	0.03	-0.18	0.04	Global	BP1	1'-1"1/4;1'-8"1/4
FL1	-1.74	0.21	4.51	0.04	0.15	-0.01	Global	BP1	1'-0"1/16;1'-8"1/4
FL1	-2.60	0.95	3.92	0.03	-0.18	0.03	Global	BP1	1'-0"1/16;1'-8"1/4
FL1	-2.46	-0.23	5.08	0.05	0.13	0.01	Global	BP1	10"13/16;1'-8"1/4
FL1	-3.26	0.87	4.64	0.03	-0.22	0.03	Global	BP1	10"13/16;1'-8"1/4
FL1	-2.41	-0.18	5.91	0.06	0.17	0.02	Global	BP1	9"5/8;1'-8"1/4
FL1	-2.88	0.22	5.68	0.05	-0.23	0.02	Global	BP1	9"5/8;1'-8"1/4
FL1	-2.29	-0.39	6.24	0.06	0.18	0.03	Global	BP1	8"7/16;1'-8"1/4
FL1	-1.61	0.31	6.89	0.06	-0.25	0.02	Global	BP1	8"7/16;1'-8"1/4
FL1	-1.38	-0.02	7.10	0.06	0.22	0.01	Global	BP1	7"3/16;1'-8"1/4
FL1	-3.79	0.30	6.38	0.06	-0.24	0.04	Global	BP1	7"3/16;1'-8"1/4
FL1	-4.10	0.06	5.86	0.05	0.17	0.03	Global	BP1	6";1'-8"1/4
FL1	4.14	0.07	5.47	-0.05	-0.17	0.05	Global	BP1	1'-8"1/2;1'-7"1/16
FL1	3.55	0.33	6.52	-0.06	0.24	0.02	Global	BP1	1'-7"5/16;1'-7"1/16
FL1	0.99	0.06	7.24	-0.07	-0.23	0.02	Global	BP1	1'-7"5/16;1'-7"1/16
FL1	1.15	0.46	7.06	-0.07	0.25	0.00	Global	BP1	1'-6"1/16;1'-7"1/16
FL1	1.57	-0.62	6.65	-0.06	-0.21	0.00	Global	BP1	1'-6"1/16;1'-7"1/16
FL1	1.91	-0.15	6.44	-0.06	0.24	0.03	Global	BP1	1'-4"7/8;1'-7"1/16
FL1	1.39	-0.25	6.48	-0.06	-0.20	0.01	Global	BP1	1'-4"7/8;1'-7"1/16
FL1	2.59	0.58	4.81	-0.05	0.24	0.03	Global	BP1	1'-3"11/16;1'-7"1/16
FL1	0.33	0.14	4.90	-0.05	-0.13	0.02	Global	BP1	1'-3"11/16;1'-7"1/16
FL1	0.36	0.79	2.49	-0.03	0.14	-0.01	Global	BP1	1'-2"7/16;1'-7"1/16
FL1	0.24	0.28	2.32	-0.02	-0.06	0.02	Global	BP1	1'-2"7/16;1'-7"1/16
FL1	0.24	0.76	1.71	-0.02	0.07	-0.02	Global	BP1	1'-1"1/4;1'-7"1/16
FL1	1.15	1.46	2.52	-0.04	-0.06	0.04	Global	BP1	1'-1"1/4;1'-7"1/16
FL1	1.15	0.21	1.84	-0.02	0.08	-0.02	Global	BP1	1'-0"1/16;1'-7"1/16
FL1	0.34	0.95	1.18	-0.02	-0.06	0.01	Global	BP1	1'-0"1/16;1'-7"1/16

Name	Fx [kip]	Fy [kip]	Fz [kip]	Mx [kip.ft]	My [kip.ft]	Mz [kip.ft]	Direction	Master	Position [X;Z] [in]
FL1	0.34	-0.31	2.71	-0.02	0.07	-0.01	Global	BP1	10"13/16;1'-7"1/16
FL1	-1.54	1.44	2.11	-0.03	-0.20	0.00	Global	BP1	10"13/16;1'-7"1/16
FL1	-1.24	-0.21	5.84	-0.05	0.17	-0.02	Global	BP1	9"5/8;1'-7"1/16
FL1	-2.48	0.63	5.50	-0.06	-0.23	-0.03	Global	BP1	9"5/8;1'-7"1/16
FL1	-1.58	-0.57	6.44	-0.05	0.20	0.00	Global	BP1	8"7/16;1'-7"1/16
FL1	-1.14	0.42	6.86	-0.07	-0.24	-0.01	Global	BP1	8"7/16;1'-7"1/16
FL1	-0.92	-0.01	7.06	-0.06	0.22	-0.01	Global	BP1	7"3/16;1'-7"1/16
FL1	-3.76	0.35	6.10	-0.06	-0.23	-0.03	Global	BP1	7"3/16;1'-7"1/16
FL1	-4.13	0.07	5.47	-0.05	0.16	-0.04	Global	BP1	6";1'-7"1/16
FL1	-0.14	0.20	-5.41	0.16	0.05	0.00	Global	BP1	1'-1"11/16;6"3/8
FL1	-0.08	0.23	-2.82	-0.16	0.03	0.01	Global	BP1	1'-1"11/16;7"9/16
FL1	0.11	0.32	2.04	-0.05	-0.02	0.01	Global	BP1	1'-1"11/16;7"9/16
FL1	0.09	0.32	0.72	0.04	-0.01	0.00	Global	BP1	1'-1"11/16;8"3/4
FL1	-0.02	-0.39	0.65	-0.02	-0.01	0.00	Global	BP1	1'-1"11/16;8"3/4
FL1	0.05	-0.39	0.87	0.03	-0.01	0.00	Global	BP1	1'-1"11/16;10"
FL1	-0.04	0.62	0.56	-0.03	-0.01	0.01	Global	BP1	1'-1"11/16;10"
FL1	0.03	0.62	1.06	0.02	-0.01	0.01	Global	BP1	1'-1"11/16;11"3/16
FL1	0.03	-0.61	0.64	-0.02	-0.01	0.00	Global	BP1	1'-1"11/16;11"3/16
FL1	0.22	-0.61	0.97	0.03	-0.01	-0.01	Global	BP1	1'-1"11/16;1'-0"3/8
FL1	-0.15	-0.25	0.90	-0.03	-0.01	0.00	Global	BP1	1'-1"11/16;1'-0"3/8
FL1	0.18	-0.25	0.76	0.03	-0.01	0.00	Global	BP1	1'-1"11/16;1'-1"5/8
FL1	-0.13	-0.63	1.23	-0.03	-0.01	0.00	Global	BP1	1'-1"11/16;1'-1"5/8
FL1	0.27	-0.63	1.15	0.05	-0.01	-0.01	Global	BP1	1'-1"11/16;1'-2"13/16
FL1	-0.21	-0.81	0.65	-0.02	-0.01	-0.01	Global	BP1	1'-1"11/16;1'-2"13/16
FL1	0.30	-0.81	0.74	0.03	0.00	-0.01	Global	BP1	1'-1"11/16;1'-4"
FL1	-0.25	-0.22	0.69	-0.02	-0.01	0.00	Global	BP1	1'-1"11/16;1'-4"
FL1	0.35	-0.22	0.62	0.02	0.00	0.00	Global	BP1	1'-1"11/16;1'-5"1/4
FL1	-0.30	-0.67	0.50	0.00	-0.01	-0.01	Global	BP1	1'-1"11/16;1'-5"1/4
FL1	0.34	-0.67	-0.30	0.01	0.01	-0.01	Global	BP1	1'-1"11/16;1'-6"7/16
FL1	-0.43	0.33	2.03	-0.07	-0.02	-0.01	Global	BP1	1'-1"11/16;1'-6"7/16
FL1	-0.09	0.33	2.22	0.07	-0.02	0.01	Global	BP1	1'-1"11/16;1'-7"5/8
FL1	-0.13	0.32	-5.63	0.17	-0.05	-0.01	Global	BP1	1'-0"13/16;6"3/8
FL1	-0.08	0.36	-3.14	-0.18	-0.03	0.00	Global	BP1	1'-0"13/16;7"9/16
FL1	0.11	0.29	2.01	-0.05	0.02	0.00	Global	BP1	1'-0"13/16;7"9/16
FL1	0.09	0.29	0.69	0.04	0.01	-0.01	Global	BP1	1'-0"13/16;8"3/4
FL1	-0.02	-0.27	0.43	-0.02	0.00	0.00	Global	BP1	1'-0"13/16;8"3/4
FL1	0.05	-0.27	0.65	0.02	0.01	0.00	Global	BP1	1'-0"13/16;10"
FL1	-0.04	0.74	0.48	-0.03	0.00	-0.01	Global	BP1	1'-0"13/16;10"
FL1	0.03	0.74	0.98	0.02	0.01	-0.01	Global	BP1	1'-0"13/16;11"3/16
FL1	0.03	-0.31	0.47	-0.02	0.00	0.01	Global	BP1	1'-0"13/16;11"3/16
FL1	0.22	-0.31	0.80	0.02	0.01	0.00	Global	BP1	1'-0"13/16;1'-0"3/8
FL1	-0.15	0.29	0.84	-0.03	0.01	0.00	Global	BP1	1'-0"13/16;1'-0"3/8
FL1	0.18	0.29	0.70	0.02	0.01	0.00	Global	BP1	1'-0"13/16;1'-1"5/8
FL1	-0.13	0.04	1.02	-0.03	0.01	0.00	Global	BP1	1'-0"13/16;1'-1"5/8

Name	Fx [kip]	Fy [kip]	Fz [kip]	Mx [kip.ft]	My [kip.ft]	Mz [kip.ft]	Direction	Master	Position [X;Z] [in]
FL1	0.27	0.04	0.94	0.03	0.01	0.00	Global	BP1	1'-0"13/16;1'-2"13/16
FL1	-0.21	0.04	0.63	-0.02	0.00	0.00	Global	BP1	1'-0"13/16;1'-2"13/16
FL1	0.30	0.04	0.72	0.02	0.01	0.00	Global	BP1	1'-0"13/16;1'-4"
FL1	-0.25	0.77	0.40	-0.02	0.00	-0.01	Global	BP1	1'-0"13/16;1'-4"
FL1	0.35	0.77	0.33	0.01	0.01	-0.01	Global	BP1	1'-0"13/16;1'-5"1/4
FL1	-0.30	0.39	0.54	-0.01	0.00	0.00	Global	BP1	1'-0"13/16;1'-5"1/4
FL1	0.34	0.39	-0.27	0.00	0.00	0.00	Global	BP1	1'-0"13/16;1'-6"7/16
FL1	-0.43	0.88	1.41	-0.06	0.01	-0.02	Global	BP1	1'-0"13/16;1'-6"7/16
FL1	-0.09	0.88	1.61	0.04	0.01	0.00	Global	BP1	1'-0"13/16;1'-7"5/8
FL8	0.00	0.00	-103.31	0.00	0.00	0.00	Global	BP1	1'-10"1/2;1'-10"
FL8	0.00	0.00	-103.12	0.00	0.00	0.00	Global	BP1	4";1'-10"
FL8	0.00	0.00	-65.52	0.00	0.00	0.00	Global	BP1	1'-10"1/2;1'-4"
FL8	0.00	0.00	-58.60	0.00	0.00	0.00	Global	BP1	4";1'-4"
FL8	0.00	0.00	0.00	0.00	0.00	0.00	Global	BP1	1'-10"1/2;4"
FL8	0.00	0.00	0.00	0.00	0.00	0.00	Global	BP1	4";4"

Combination

Name	Type	Content	ξ [-]
1056: (2)	ULS	1056: (2)	-

Results

Summary

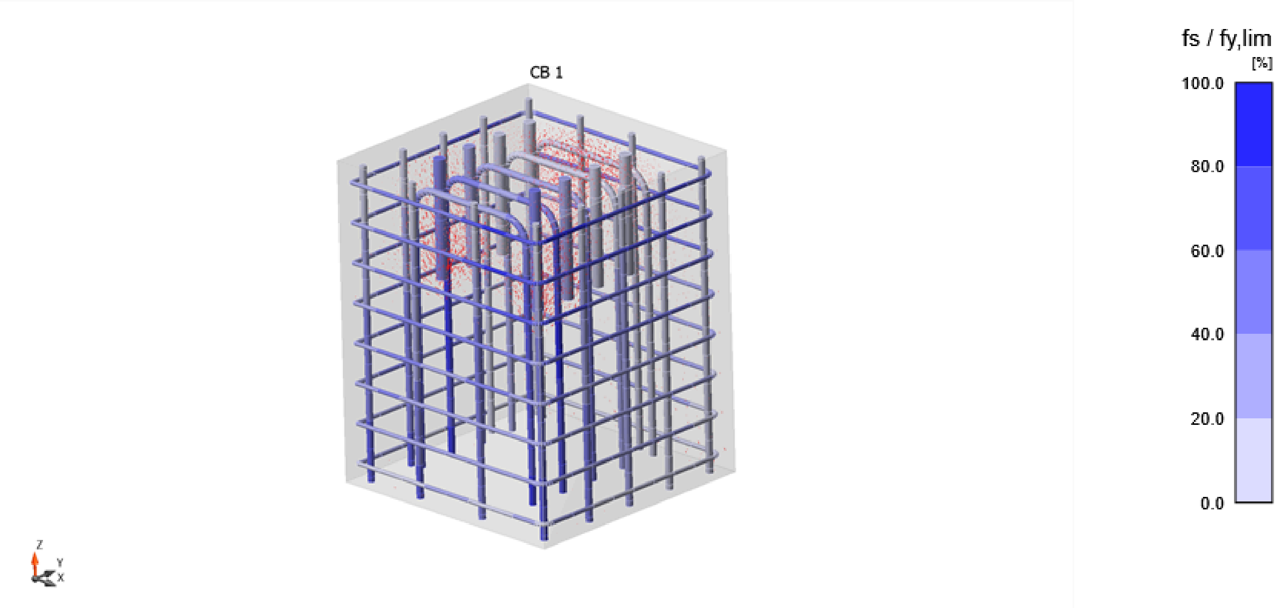
Overview table

Check item	Combination	Increment	Item	
Strength	1056: (2)	D100.0%	Strength of concrete	✓

Check item	Item	Utilization	
Strength of concrete	CB 1	fc/f'c,lim: 100.0%	✓
Strength of reinforcement		εs/εs,lim: 1.1%, fs/fy,lim: 92.1%	✓
Anchorage length		τb/fbu: 99.7%	✓

Strength - Summary

Stress flow



Above yield	Compression	Explanation
		Thickness proportional to force

Summary of reactions and applied loads: 1056: (2), Load increment: D100.0%

Type	F_x [kip]	F_y [kip]	F_z [kip]	M_x [kip.ft]	M_y [kip.ft]	M_z [kip.ft]
Summary of reactions	-1.55	-42.40	-27.13	288.77	-12.45	0.00
Summary of applied load	1.55	42.40	27.13	-289.21	12.45	0.12
Check of equilibrium	0.00	0.00	0.00	-0.45	0.00	0.12

Strength

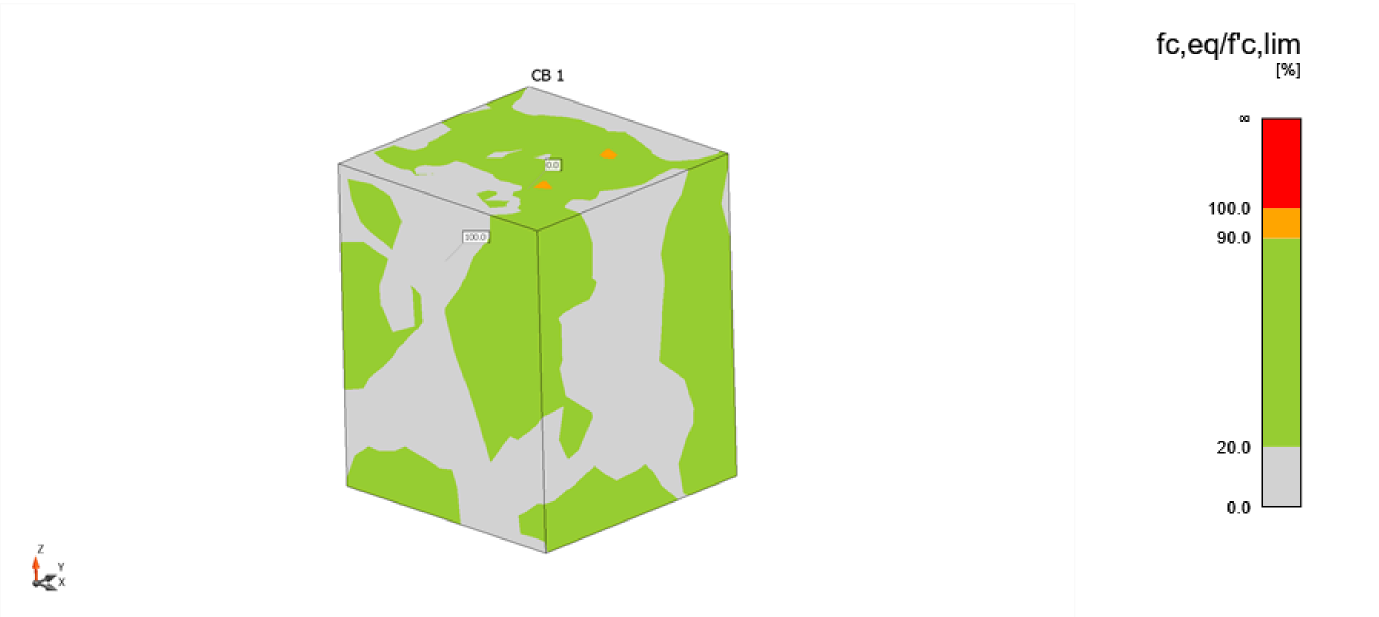
Detailed concrete strength results: 1056: (2), Load increment: D100.0%

Member	X [ft]	Y [ft]	Z [ft]	$f_{c,eq}$ [ksi]	$f_{c,3}/f'_{c,lim}$ [-]	ε_c [1e-4]	ε_{pl} [1e-4]	$f_{c,eq}/f'_{c,lim}$ [%]	
CB 1	-10"5/16	-7"9/16	-1'-5"3/16	-4.4	271.9	-514.2	-492.2	100.0	OK
CB 1	-9"	-8"11/16	-1'-6"1/4	-8.4	428.9	-511.4	-478.3	100.0	OK
CB 1	9"3/16	-9"9/16	-1'-9"1/8	-2.5	100.0	-41.8	-35.7	99.5	OK

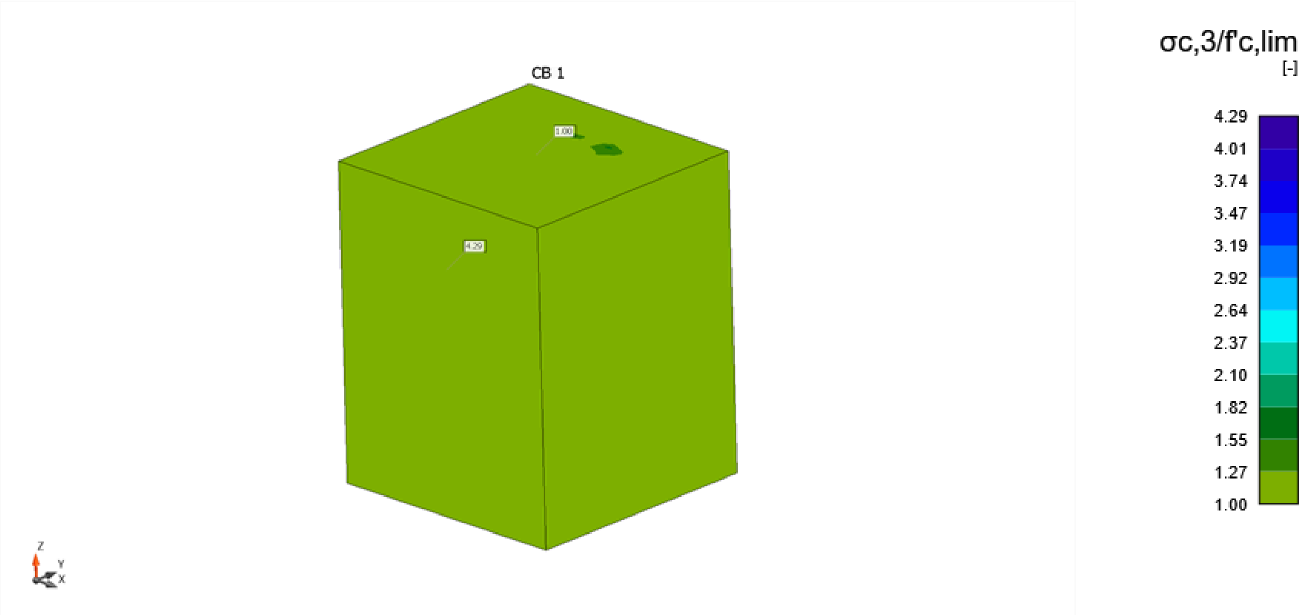
Detailed reinforcement strength results: 1056: (2), Load increment: D100.0%

Member	X [ft]	Y [ft]	Z [ft]	f_s [ksi]	ε_s [1e-4]	$f_s/f_{y,lim}$ [%]	$\varepsilon_s/\varepsilon_{s,lim}$ [%]	
Stirrups1	-10"3/4	-6"1/2	-1'-9"5/16	41.5	11.3	92.1	1.1	OK
Stirrups	1'-5"15/16	-1'-4"1/8	-4"13/16	39.6	11.0	87.9	1.1	OK
V4	-1'-4"3/4	-1'-4"1/2	-4'-1"1/2	32.4	9.2	72.0	0.9	OK
V1	1'-4"3/4	-1'-4"1/2	-4'-0"11/16	30.2	8.4	67.1	0.8	OK
V1	1'-4"3/4	-1'-4"1/2	-4'-1"1/2	29.5	8.6	65.4	0.9	OK
AN1	-9"1/4	-9"	-6"	44.7	11.7	56.7	1.2	OK
AN2	9"1/4	-9"	-6"	44.6	11.8	56.6	1.2	OK
V3	1'-4"3/4	-7"1/2	-4'-0"11/16	22.2	5.0	49.3	0.5	OK
AN3	-9"1/4	-3"	-6"	27.9	6.6	35.4	0.7	OK
AN4	9"1/4	-3"	-6"	24.8	5.6	31.5	0.6	OK
V2	-1'-4"3/4	1'-4"1/2	-4'-1"1/2	-10.3	-3.5	22.9	0.4	OK
V2	-1'-4"3/4	1'-4"1/2	-10"3/4	1.9	0.1	4.1	0.0	OK
AN6	9"1/4	9"	-10"1/2	-2.1	-0.7	2.7	0.1	OK
AN7	-9"1/4	3"	-1'-7"1/2	1.9	0.1	2.4	0.0	OK
AN5	-9"1/4	9"	-10"1/2	-1.2	-0.4	1.5	0.0	OK
AN8	9"1/4	3"	-1'-7"1/2	1.0	0.0	1.3	0.0	OK
AN6	9"1/4	9"	-1'-7"1/2	-0.8	-0.3	1.1	0.0	OK
AN5	-9"1/4	9"	-1'-7"1/2	-0.5	-0.2	0.6	0.0	OK

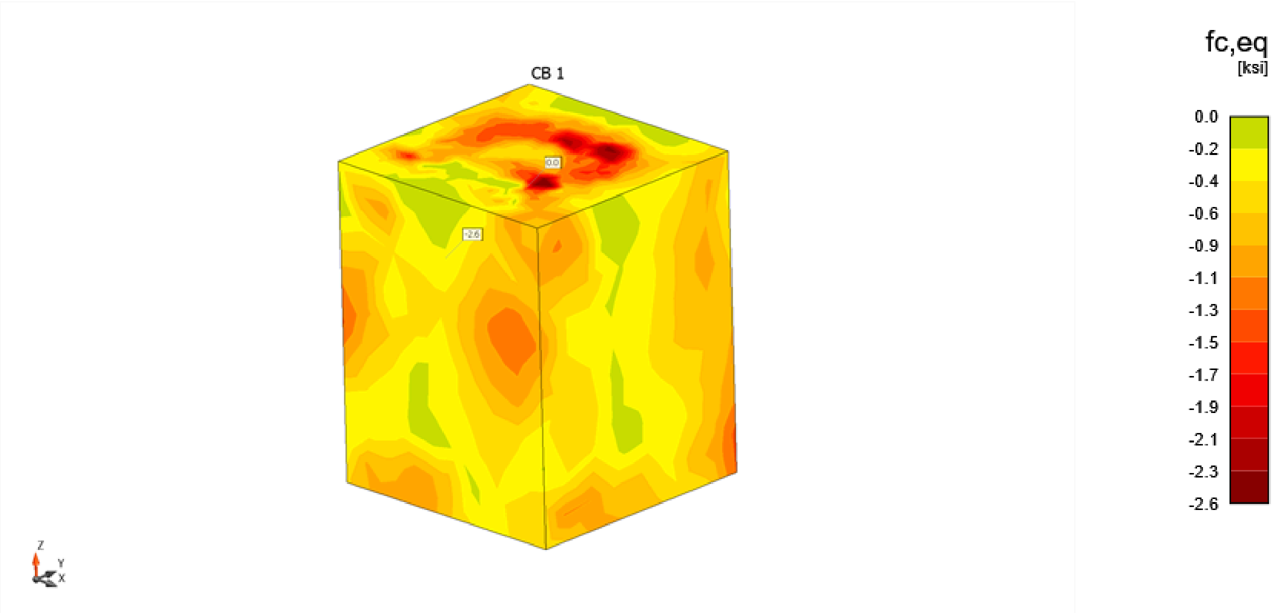
Concrete strain/limit strain ratio



Concrete principal stress $\sigma_{c3}/f'_{c,lim}$

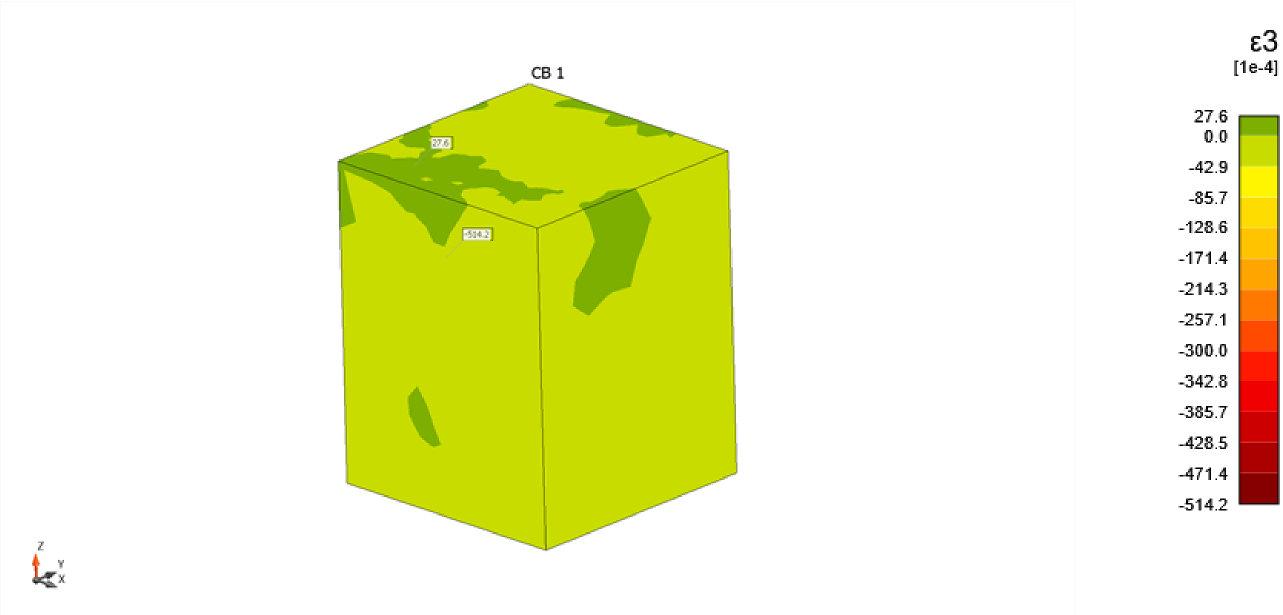


Concrete principal stress $f_{c,eq}$

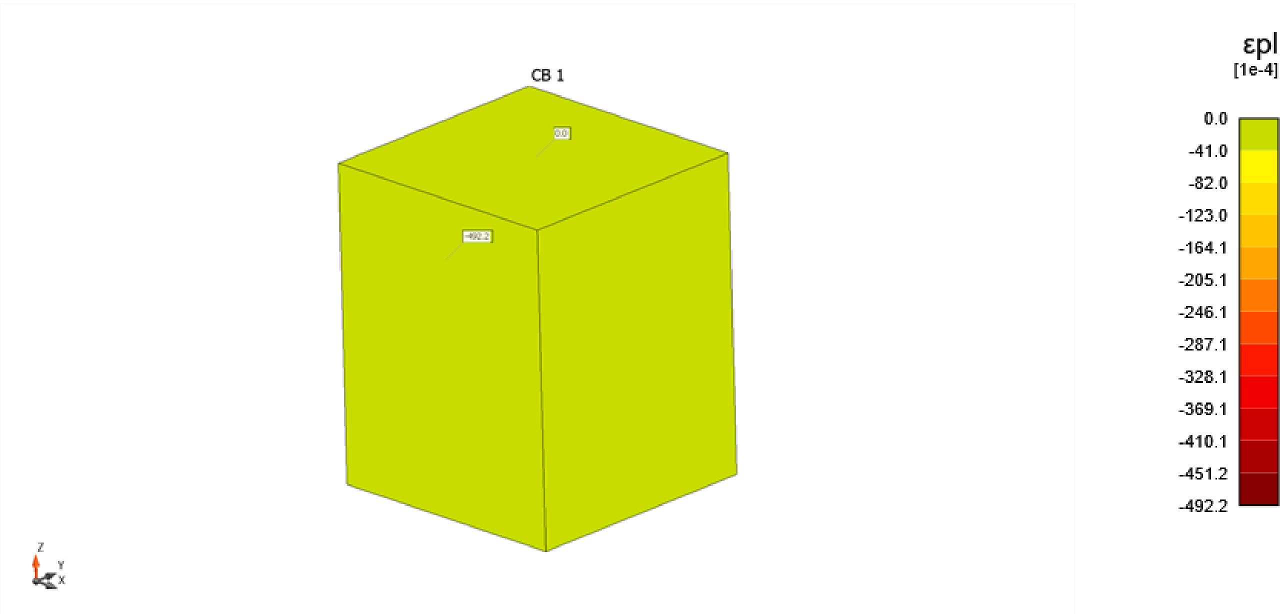


Project:
Project no:
Author:

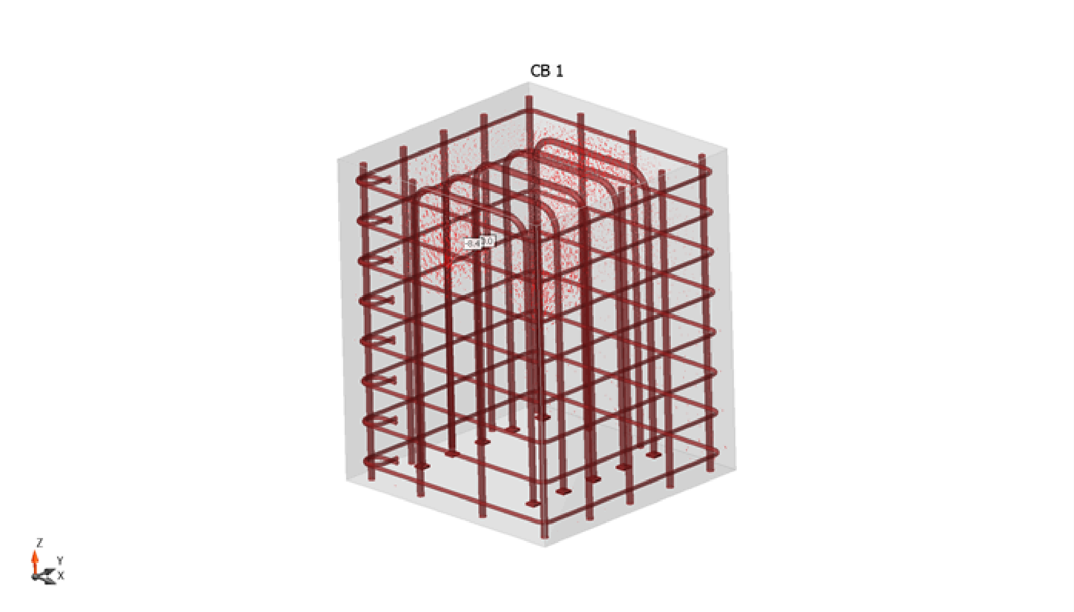
Concrete principal strain ε_c



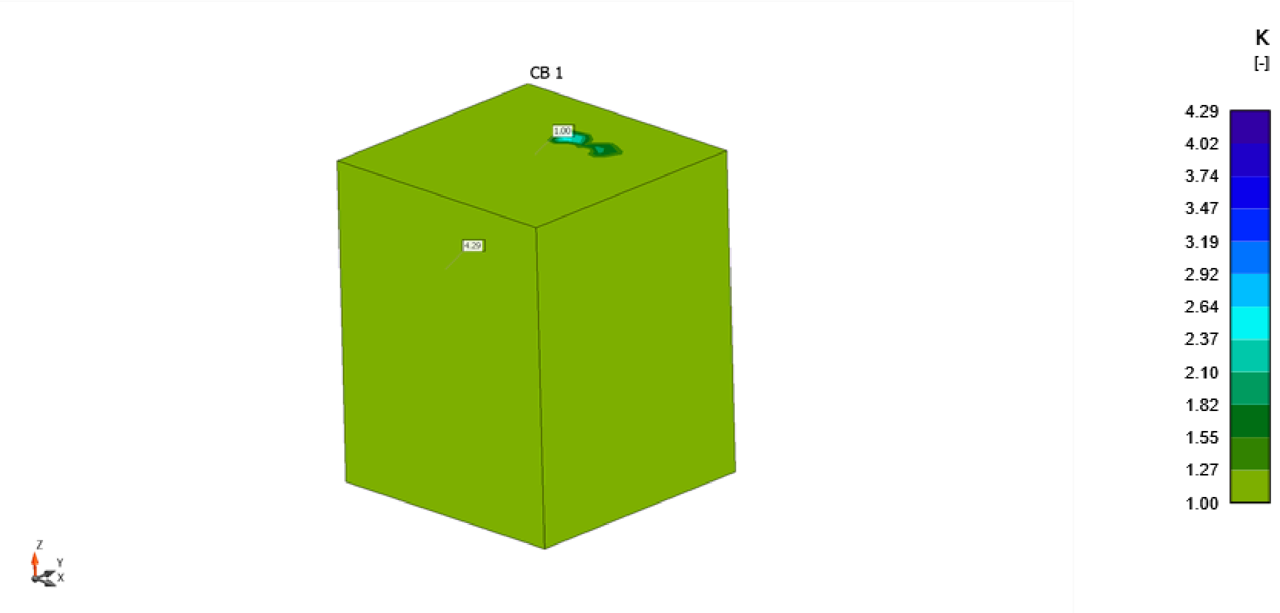
Concrete plastic strain ε_{pl}



Directions of principal stresses

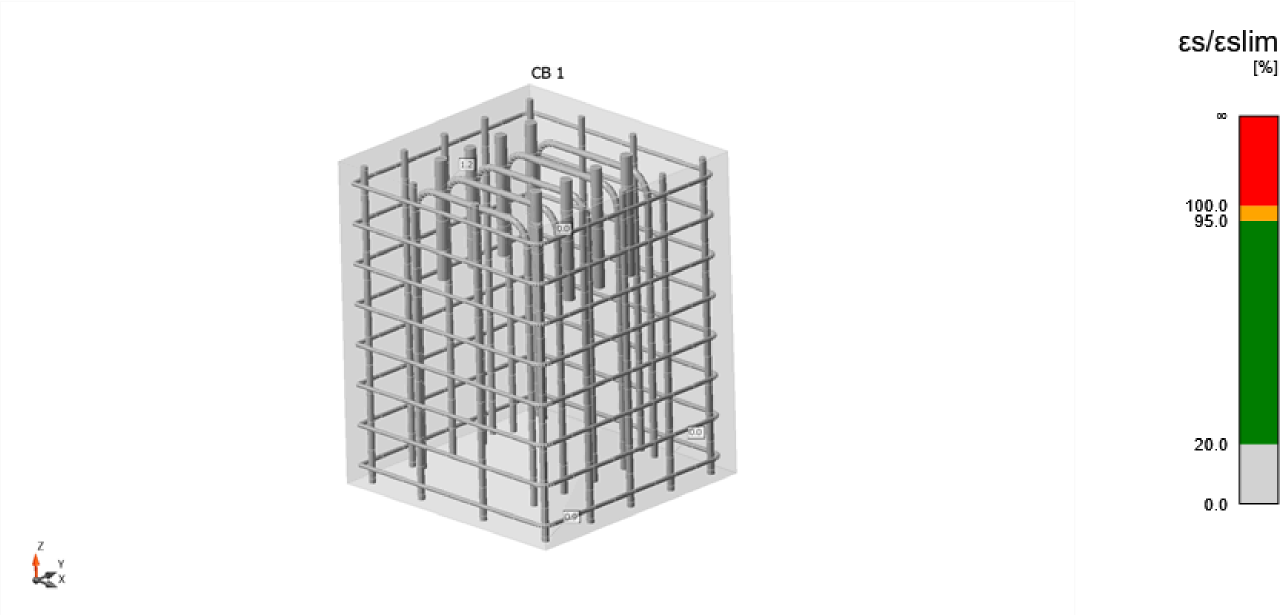


Compressive strength reduction factor κ

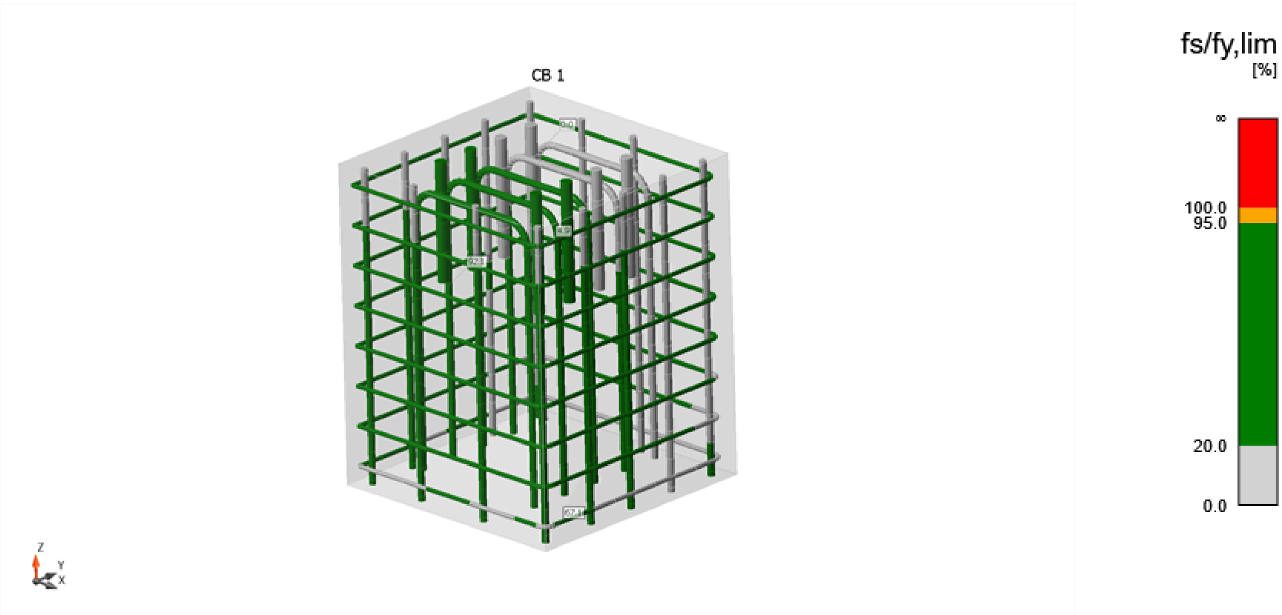


Project:
Project no:
Author:

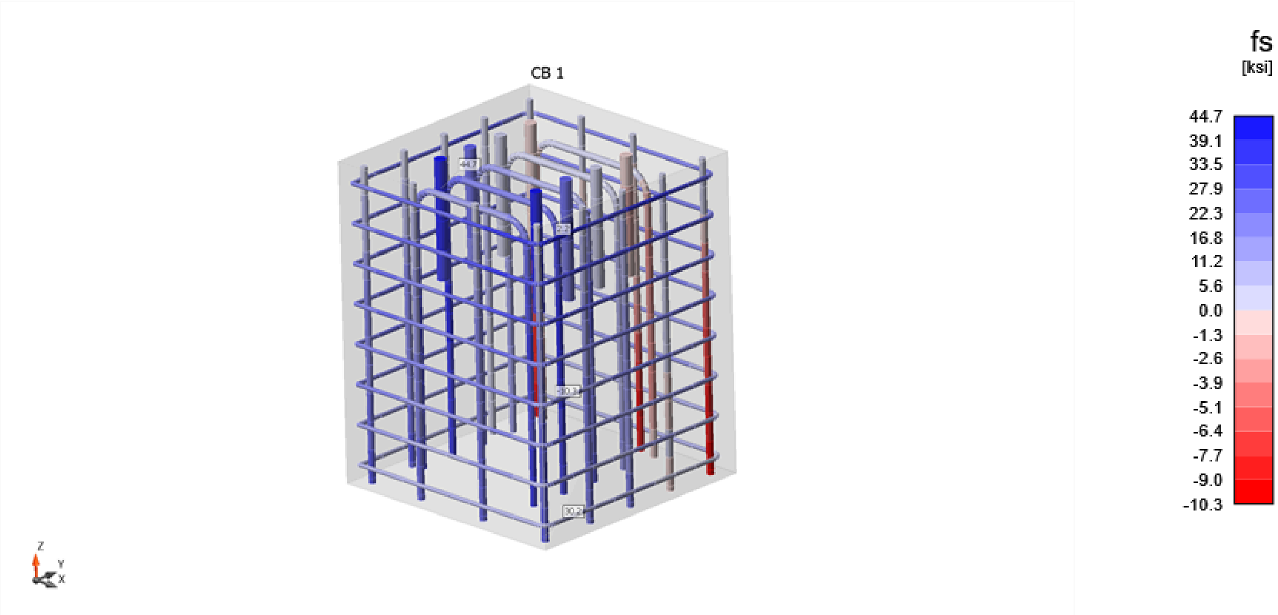
Reinforcement strain/limit strain ratio - $\varepsilon_s/\varepsilon_{s,lim}$ [%]



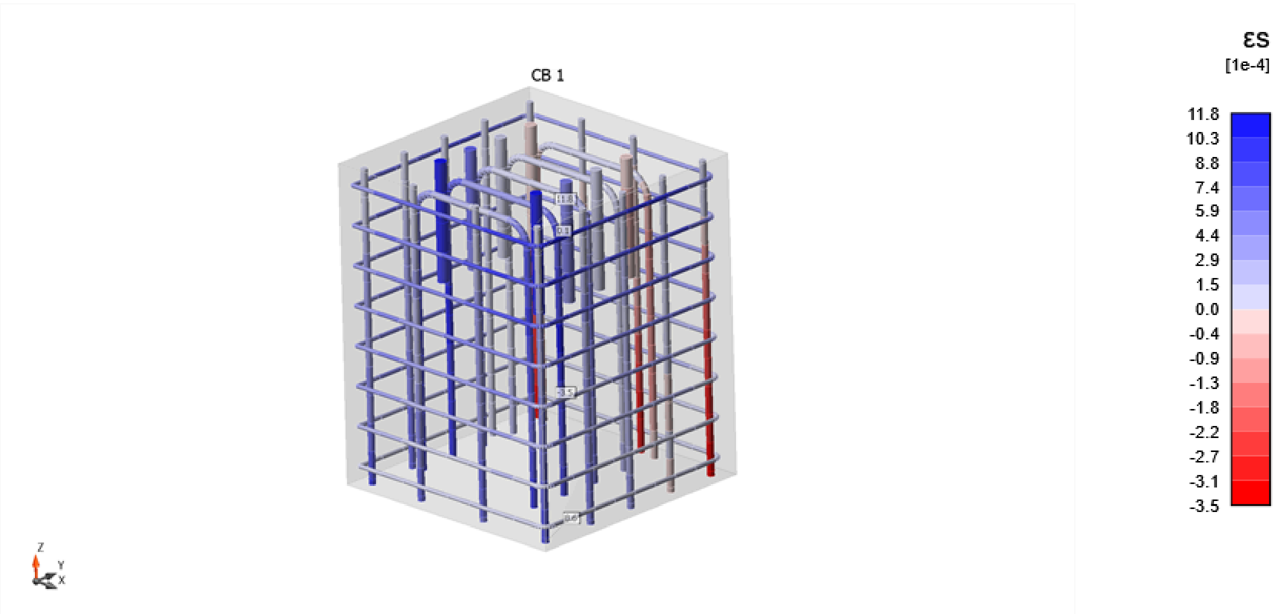
Reinforcement stress/strength ratio - $f_s/f_{y,lim}$ [%]



Reinforcement stress - f_s [ksi]



Reinforcement strain - ε_s [1e-4]



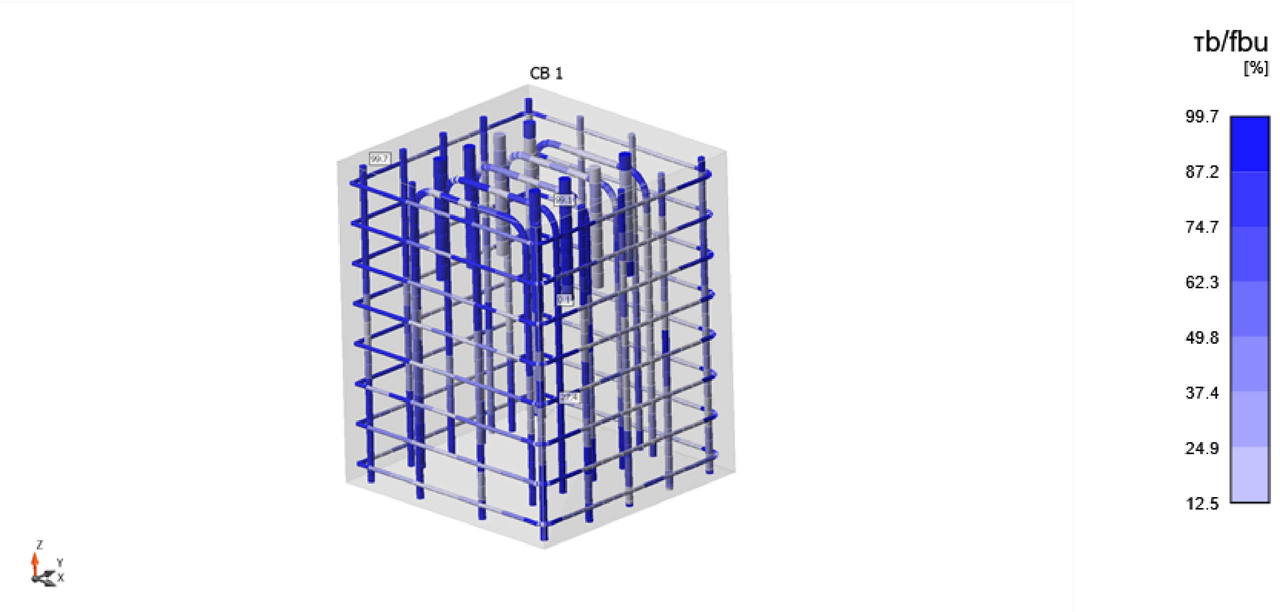
Strength - Anchorage

Detailed anchorage results - Reinforcement: 1056: (2), Load increment: D100.0%

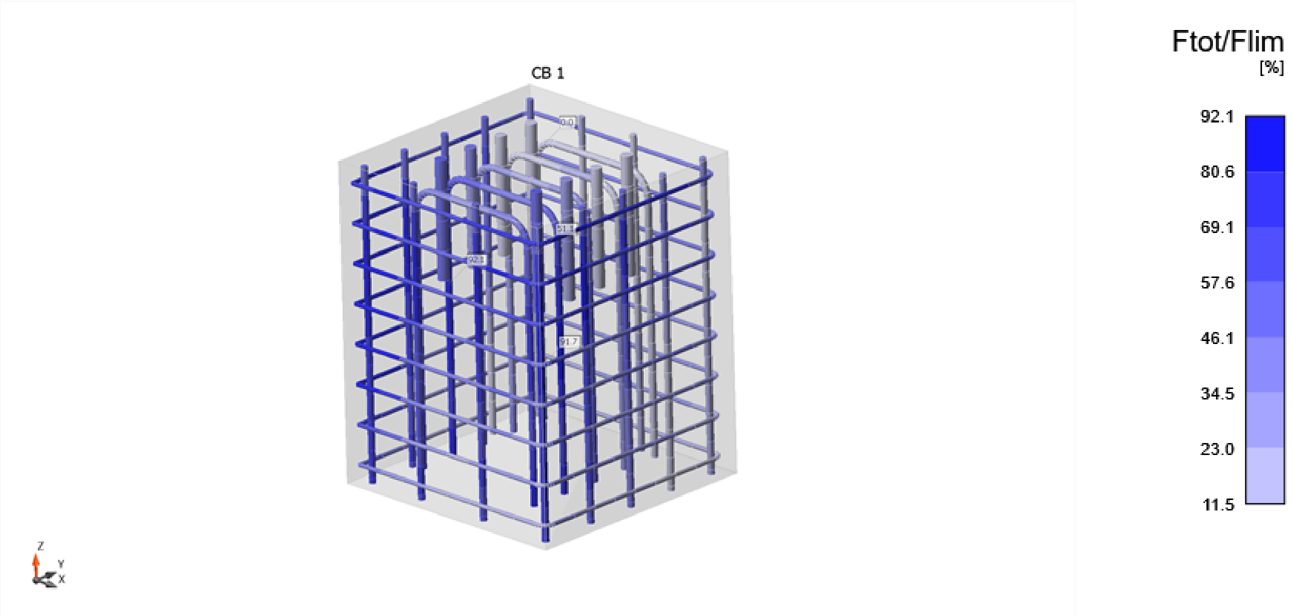
Member	X [ft]	Y [ft]	Z [ft]	τ_b [ksi]	F_a [kip]	F_{tot} [kip]	F_{tot}/F_{lim} [%]	F_{lim} [kip]	τ_b/f_{bu} [%]	
V1	1'-4"3/4	-1'-4"1/2	-2"5/16	0.3	22.89	1.75	51.1	3.42	99.1	OK
V1	1'-4"3/4	-1'-4"1/2	-4'-0"11/16	0.2	22.89	23.72	75.7	31.33	96.1	OK
V1	-7"1/4	-1'-4"1/2	-6"1/2	0.3	22.89	1.75	51.0	3.42	99.1	OK
V1	1'-4"3/4	-1'-4"1/2	-1'-11"3/8	0.1	22.89	14.25	91.7	15.54	43.7	OK
V1	1'-4"3/4	-1'-4"1/2	-4'-1"1/2	0.2	22.89	23.13	72.7	31.82	98.4	OK
V2	-1'-4"3/4	1'-4"1/2	-2"5/16	0.3	-7.95	1.26	36.9	3.42	99.1	OK
V2	-1'-4"3/4	1'-4"1/2	-10"3/4	0.1	-7.95	1.46	21.3	6.85	54.9	OK
V2	-1'-4"3/4	1'-4"1/2	-4'-1"1/2	0.2	-7.95	-8.08	22.9	-35.34	90.6	OK
V2	-1'-4"3/4	1'-4"1/2	-6"1/2	0.0	-7.95	1.26	36.9	3.42	9.7	OK
V3	1'-4"3/4	-7"1/2	-2"5/16	0.3	15.99	1.75	51.0	3.42	99.1	OK
V3	1'-4"3/4	-7"1/2	-4'-0"11/16	0.2	15.99	17.43	55.6	31.33	98.4	OK
V3	1'-4"3/4	1'-4"1/2	-4'-1"1/2	0.2	15.99	-7.68	21.7	-35.34	86.1	OK
V3	1'-4"3/4	-7"1/2	-1'-7"3/16	0.0	15.99	11.19	86.7	12.90	3.6	OK
V3	1'-4"3/4	1/2	-4'-1"1/2	0.2	15.99	13.31	41.8	31.82	98.4	OK
V4	-1'-4"3/4	-1'-4"1/2	-2"5/16	0.3	25.20	1.75	51.0	3.42	99.1	OK
V4	-1'-4"3/4	-1'-4"1/2	-4'-1"1/2	0.2	25.20	25.44	79.9	31.82	98.4	OK
V4	-1'-4"3/4	7"1/2	-4'-1"1/2	0.0	25.20	1.06	3.3	31.82	11.3	OK
V4	-1'-4"3/4	-1'-4"1/2	-1'-7"3/16	0.2	25.20	11.62	90.1	12.90	84.1	OK
Stirrups	-1'-5"15/16	-1'-5"11/16	-4"13/16	0.3	4.16	5.48	80.7	6.79	99.7	OK
Stirrups	1'-5"15/16	-1'-4"1/8	-4"13/16	0.3	4.16	12.14	87.9	13.81	99.4	OK
Stirrups	1'-5"7/8	1'-4"1/2	-3'-10"13/16	0.0	4.16	1.17	8.4	13.81	17.9	OK
Stirrups	1'-4"3/8	-1'-5"11/16	-4"13/16	0.1	4.16	9.66	70.0	13.81	36.4	OK
Stirrups1	10"3/4	-1'-0"1/2	-1'-0"3/4	0.3	30.18	20.24	57.3	35.34	99.1	OK
Stirrups1	10"3/4	-6"1/2	-1'-0"3/4	0.3	30.18	22.17	62.7	35.34	99.1	OK
Stirrups1	-10"3/4	-6"1/2	-1'-9"5/16	0.2	30.18	32.56	92.1	35.34	98.4	OK
Stirrups1	10"3/4	11"1/2	-1'-9"5/16	0.0	30.18	-2.47	7.0	-35.34	0.5	OK
Stirrups1	10"3/4	-1'-0"1/2	-2'-1"5/8	0.2	30.18	27.22	77.0	35.34	98.4	OK
AN1	-9"1/4	-9"	-1"1/2	0.2	82.93	100.60	56.7	177.28	96.6	OK
AN1	-9"1/4	-9"	-6"	0.2	82.93	100.60	56.7	177.28	96.6	OK
AN1	-9"1/4	-9"	-1'-7"1/2	0.2	82.93	85.00	47.9	177.28	94.3	OK
AN2	9"1/4	-9"	-1"1/2	0.2	82.74	100.41	56.6	177.28	96.6	OK
AN2	9"1/4	-9"	-6"	0.2	82.74	100.41	56.6	177.28	96.6	OK
AN2	9"1/4	-9"	-1'-7"1/2	0.2	82.74	84.81	47.8	177.28	94.3	OK
AN3	-9"1/4	-3"	-1"1/2	0.2	45.29	62.81	35.4	177.28	96.6	OK
AN3	-9"1/4	-3"	-6"	0.2	45.29	62.81	35.4	177.28	96.6	OK
AN3	-9"1/4	-3"	-1'-7"1/2	0.1	45.29	47.23	26.6	177.28	76.1	OK
AN4	9"1/4	-3"	-1"1/2	0.2	38.46	55.90	31.5	177.28	96.6	OK
AN4	9"1/4	-3"	-6"	0.2	38.46	55.90	31.5	177.28	96.6	OK
AN4	9"1/4	-3"	-1'-7"1/2	0.1	38.46	40.31	22.7	177.28	64.6	OK
AN5	-9"1/4	9"	-1"1/2	0.2	0.00	-1.69	1.0	-177.28	86.4	OK
AN5	-9"1/4	9"	-1'-7"1/2	0.1	0.00	-1.13	0.6	-177.28	70.6	OK

Member	X [ft]	Y [ft]	Z [ft]	τ_b [ksi]	F_a [kip]	F_{tot} [kip]	F_{tot}/F_{lim} [%]	F_{lim} [kip]	τ_b/f_{bu} [%]	
AN5	-9"1/4	9"	-10"1/2	0.0	0.00	-2.66	1.5	-177.28	13.2	OK
AN5	-9"1/4	9"	-6"	0.0	0.00	-1.69	1.0	-177.28	7.7	OK
AN6	9"1/4	9"	-1"1/2	0.2	0.00	-2.56	1.4	-177.28	96.5	OK
AN6	9"1/4	9"	-1'-7"1/2	0.2	0.00	-1.90	1.1	-177.28	94.3	OK
AN6	9"1/4	9"	-10"1/2	0.0	0.00	-4.76	2.7	-177.28	15.2	OK
AN6	9"1/4	9"	-6"	0.1	0.00	-2.56	1.4	-177.28	24.1	OK
AN7	-9"1/4	3"	-6"	0.1	4.43	2.25	1.3	177.28	34.3	OK
AN7	-9"1/4	3"	-1'-7"1/2	0.0	4.43	4.33	2.4	177.28	7.4	OK
AN7	-9"1/4	3"	-6"	0.1	4.43	0.65	0.4	177.28	34.3	OK
AN8	9"1/4	3"	-6"	0.1	2.31	1.55	0.9	177.28	25.6	OK
AN8	9"1/4	3"	-1'-7"1/2	0.0	2.31	2.35	1.3	177.28	3.9	OK
AN8	9"1/4	3"	-6"	0.1	2.31	0.40	0.2	177.28	25.6	OK

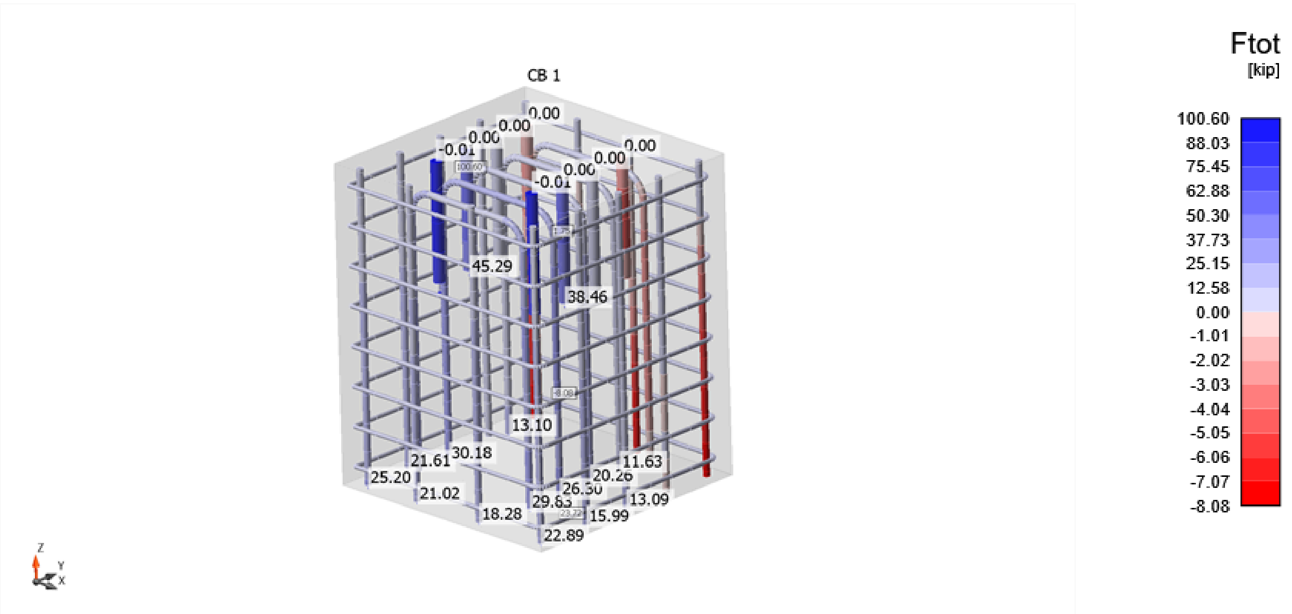
Bond stress check value - τ_b/f_{bu} [%]



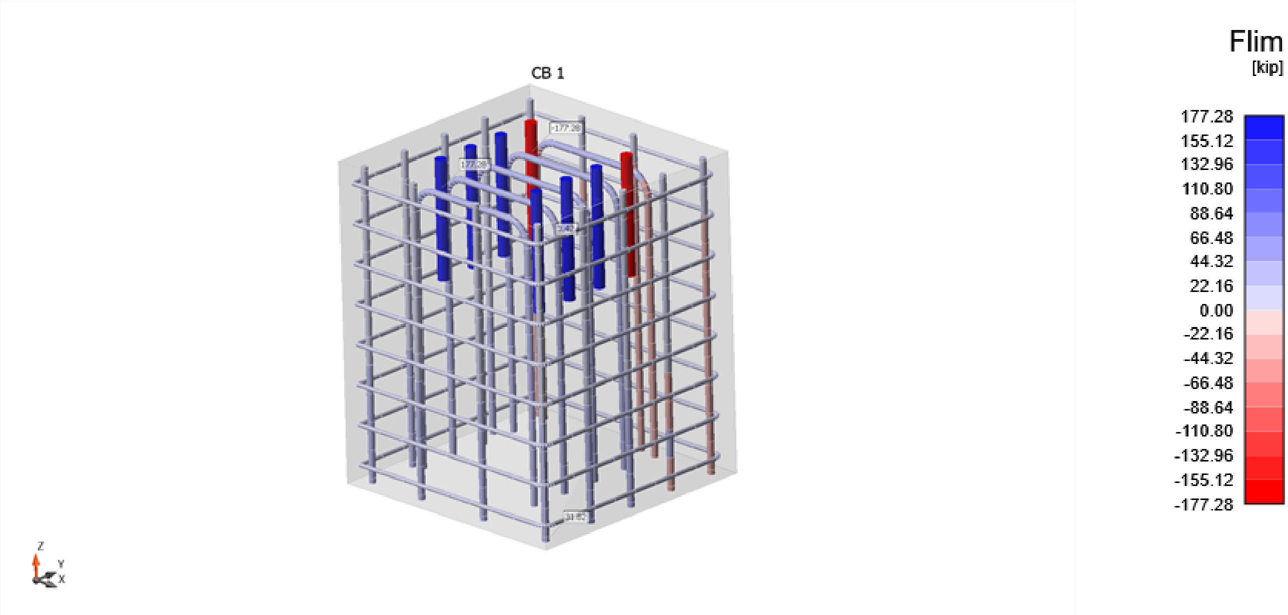
Force check value - F_{tot}/F_{lim} [%]



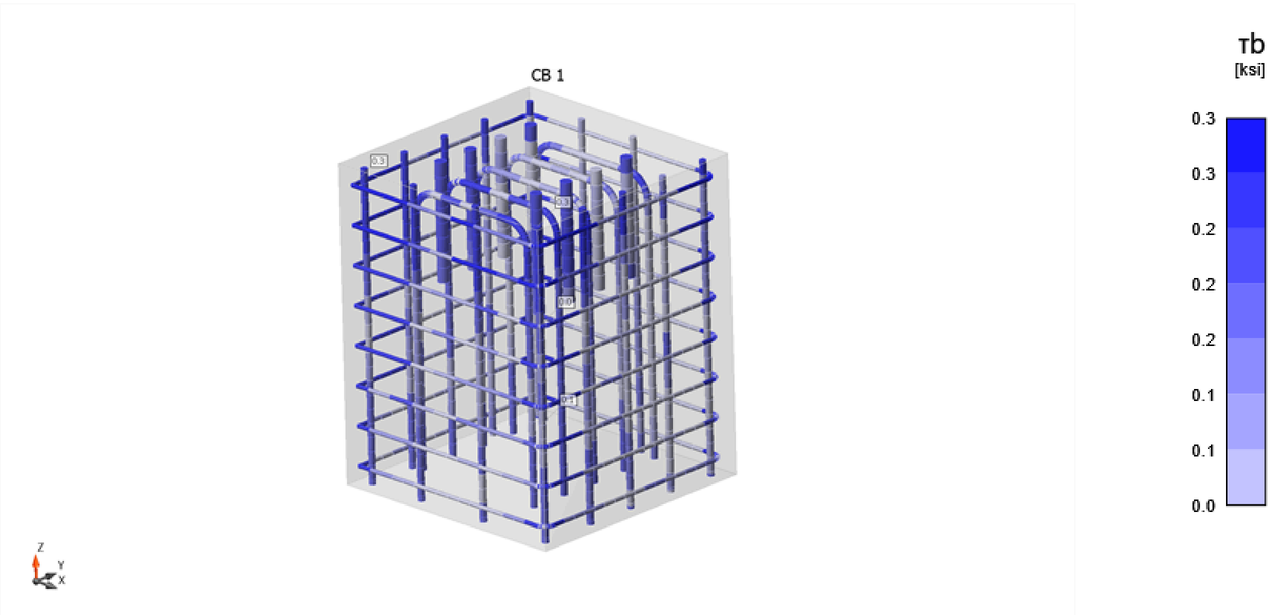
Total force in the bar - F_{tot} [kip]



Limit force in the bar - F_{lim} [kip]



Bond stress - τ_b [ksi]



Bill of material

Bill of material cannot be printed

Explanation

Symbol	Explanation
$f_{c'}$	Specified compressive strength of concrete.
E_c	Secant modulus of elasticity of concrete
ν	Poisson ratio
f_y	Specified yield strength of nonprestressed reinforcement.
E_s	Modulus of elasticity of reinforcement steel
Properties	W - Width; H - Height; T - Thickness; D - Depth; L - Length; r - Radius; α - Inclination

Symbol	Explanation
Position	M - Master; MP - Master point; IP - Insert point
ξ	Time-dependent factor for sustained loads
$f_{c,eq}$	Equivalent principal stress Sigma c,eq, which expresses the equivalent uni-axial stress for a general tri-axial stress state.
ε_c	Minimum compressive strain of concrete
ε_{pl}	Minimum compressive plastic strain of concrete
$f_{c,eq}/f'_{c,lim}$	The ratio of concrete stress and concrete strength. It presents the level of material utilization with respect to concrete strength.
f_s	Maximum stress along the length of reinforcement bar.
ε_s	Maximum strain along the length of reinforcement bar.
$f_s/f_{y,lim}$	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.
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.
F_{lim}	The limit value of the force. 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_{bu}	The ratio of bond stress and factored bond strength for selected (group of) bars and applied portion of the load. It shows the level of utilization with respect to factored bond strength between the rebar and adjacent concrete.

Code settings

Clause	Name	Value	Description
21.2.1	Φ_c	0.75	Strength reduction factor for concrete
21.2.1	Φ_s	0.75	Strength reduction factor for reinforcement
21.2.1	Φ_p	0.90	Strength reduction factor for prestress steel
22.2.2.4	α1	0.85	Reduction factor of concrete compressive strength
25.3.1	Φ m,min - Φs <= #8 (6.00 Φs)	6.00	Minimum mandrel diameter of longitudinal bars as multiple of bar diameter
25.3.1	Φ m,min - #9 <= Φs <= #11 (8.00 Φs)	8.00	Minimum mandrel diameter of longitudinal bars as multiple of bar diameter
25.3.1	Φ m,min - Φs >= #14 (10.00 Φs)	10.00	Minimum mandrel diameter of longitudinal bars as multiple of bar diameter
25.3.2	Φ m,min - Φs <= #5 (4.00 Φs)	4.00	Minimum mandrel diameter of stirrups as multiple of stirrups diameter.
25.3.2	Φ m,min - Φs >= #5 (6.00 Φs)	6.00	Minimum mandrel diameter of stirrups as multiple of stirrups diameter.

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.
- It is assumed that the user has included strength reduction factor (as its inverted value) into the load factors of all combinations

Theoretical Background

3D CSFM for anchoring and complex details

In practice, engineers may encounter problems that are not amenable to solutions using established analytical procedures, linear FEM calculations, or cannot be simplified to axial or planar behavior. These include complicated spatially stressed discontinuity regions (so-called D-regions) like cases of anchorage in concrete where the load capacity of plain or weakly reinforced concrete is insufficient.

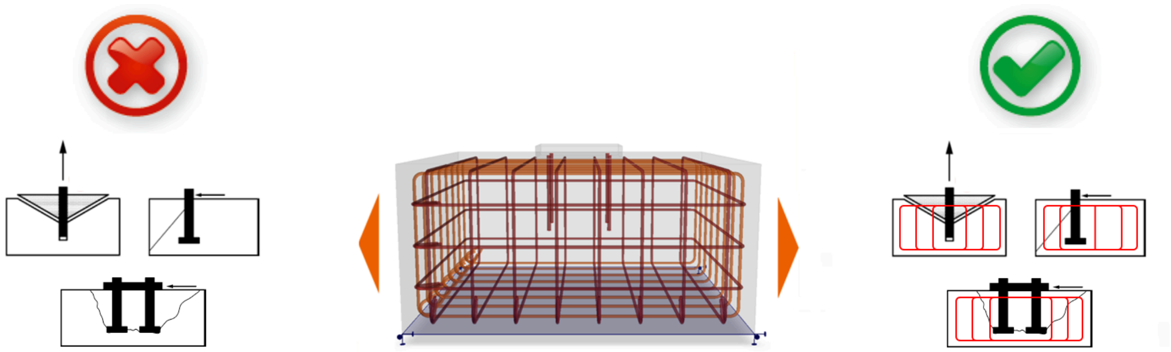


Fig. 1 3D CSFM for anchoring and complex details

The 3D Compatible Stress Field Method (3D CSFM) extends the established CSFM into a third dimension, offering a fast and code-compliant solution for the above-mentioned issues.

Main assumptions for 3D CSFM

3D CSFM defines the concrete behavior based on the **Modified Mohr-Coulomb** plasticity theory for monotonic loading. The method considers principal concrete stresses in compression and reinforcement stresses (σ_{sr}) at the cracks while **neglecting the concrete tensile strength** (tension cut-off), except for its stiffening effect on the reinforcement (Tension stiffening).

σ_{c1r}, σ_{c2r}, σ_{c2r} ≤ 0 MPa

Constraints of the Bond model allow slip between the concrete and reinforcement. 3D CSFM **is not suitable for simulating plain concrete** due to the absence of tension, which may result in misleading deformation and model divergence. **3D CSFM assumes a zero angle of internal friction**φ (Fig. 1e), leading to a safe design due to the plasticity surface resembling the Tresca model, which is independent of the first stress invariant.

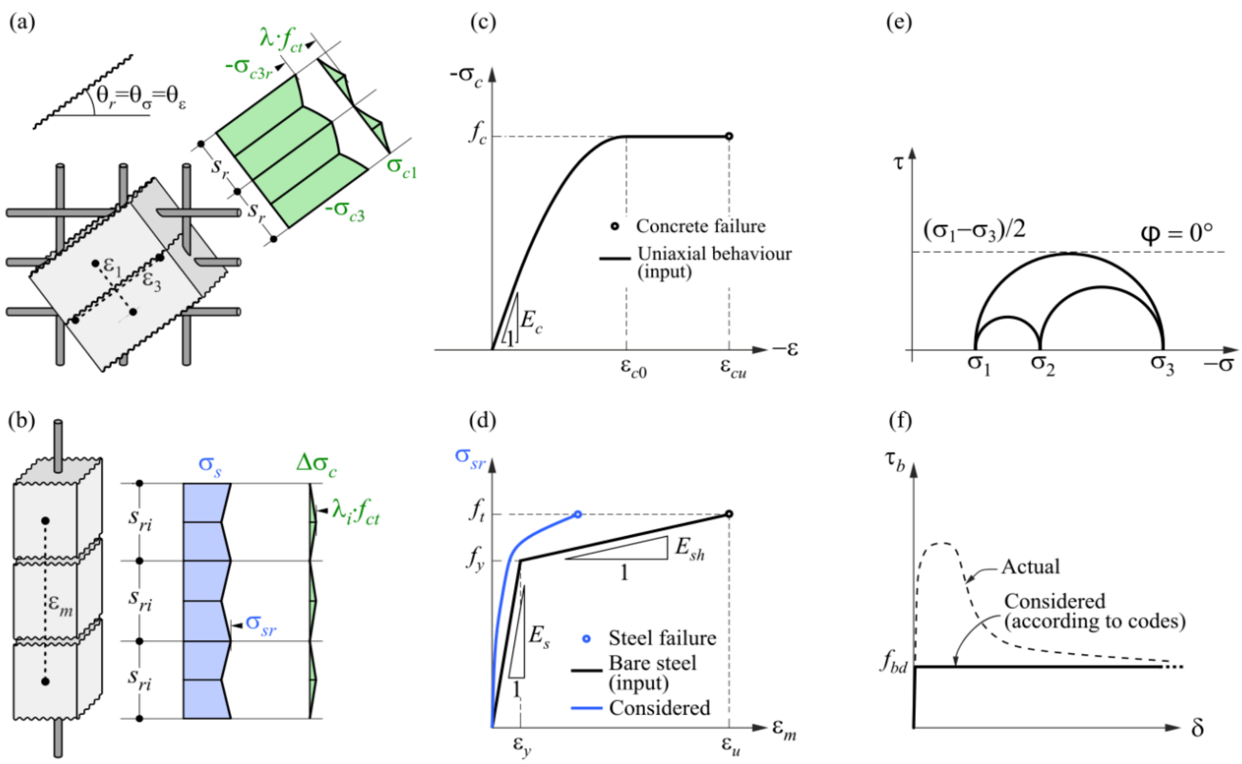


Fig. 2 Basic assumptions of the 3D CSFM: (a) principal stresses in concrete; (b) stresses in the reinforcement direction; (c) stress-strain diagram of concrete in terms of maximum axial stresses; (d) stress-strain diagram of reinforcement; (e) Mohr's circles for concrete model in 3D CSFM; (f) bond shear stress-slip in terms of stresses at cracks and average strains; (e) Mohr's circles for concrete model in 3D CSFM; (f) bond shear stress-slip relationship for anchorage length verifications

The concrete model is based on the uniaxial compression constitutive laws prescribed by design codes for the design of cross-sections, which only depends on compressive strength. The parabola-rectangle diagram is used by default (see Fig. 2c), or a simplified elastic ideal plastic relationship can be chosen.

$$f_{c,red} = \eta_{fc} \cdot f_c$$

$$\eta_{fc} = \left(\frac{30}{f_c}\right)^{\frac{1}{3}} \leq 1.0$$

Where f_c is the concrete cylinder characteristic strength (in MPa for the definition of η_{fc}); η_{fc} represents the increase in the brittleness of concrete as its strength rises – defined in *fib* Model Code 2010.

The $f_{c,red}$ is then compared with the Equivalent Principal Stress $\sigma_{c,eq}$ (defined further).

The idealized bilinear stress-strain diagram for reinforcement (Fig. 2d) is considered. A user-defined stress-strain relationship can also be defined. Tension stiffening is automatically considered for each reinforcement element by modifying the input stress-strain relationship.

Bond-slip between the reinforcement and concrete is introduced in the finite element (FE) model by the relationship presented in Fig. 2f, with f_{bd}being the design value (factored value) of the ultimate bond stress specified by the design code for the specific bond conditions.

Anchors are defined as 1D elements being able to transfer normal forces as well as shear forces also considering the bending stiffness. However, only normal stress in the anchors is evaluated. The Cast-in-place reinforcement anchor behavior is the same as ribbed reinforcement (Anchorage type, bond, etc.) For Adhesive anchors, the user must define the design (factored) value of Bond strength based on the properties of assumed mortar.

Mohr-Coulomb plasticity theory implementation in 3D CSFM

In 3D CSFM implemented in IDEA StatiCa Detail, the angle of internal friction is considered as $\varphi = 0°$, as shown in Fig. 3

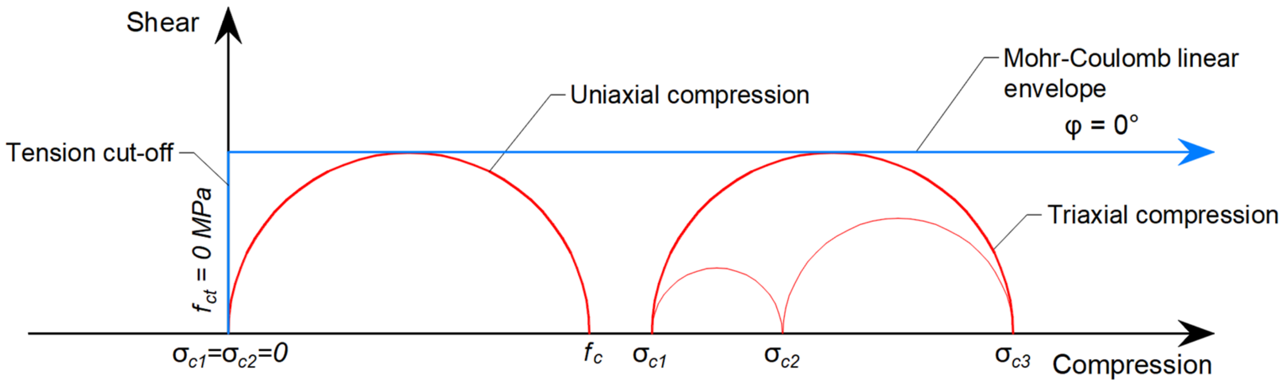


Fig. 3 Mohr's circles for concrete implemented in IDEA StatiCa Detail

Where f_c is concrete strength in compression, f_{ct} is concrete strength in tension, φ is the angle of internal friction, and σ_{c1}, σ_{c2}, σ_{c3} are the principal stresses of concrete under triaxial compression.

Equivalent Principal Stress expresses the equivalent uni-axial stress for a general tri-axial stress state.

$$\sigma_{c,eq} = \sigma_{c3} - \sigma_{c1}$$

The $\sigma_{c,eq}$ value is directly compared with uniaxial strength limits according to codes.

For a better understanding of the areas affected by tri-axial compression stress, the expression of the increase of the effective material strength due to tri-axial compression has been added to the IDEA StatiCa Detail application as a ratio $\sigma_{c3}/\sigma_{c,lim}$.

Finite element types for a 3D solution

Concrete and reinforcement elements are meshed independently and connected using multi-point constraints (MPC). Bond and anchorage end spring elements are inserted between the reinforcement and the MPC elements.

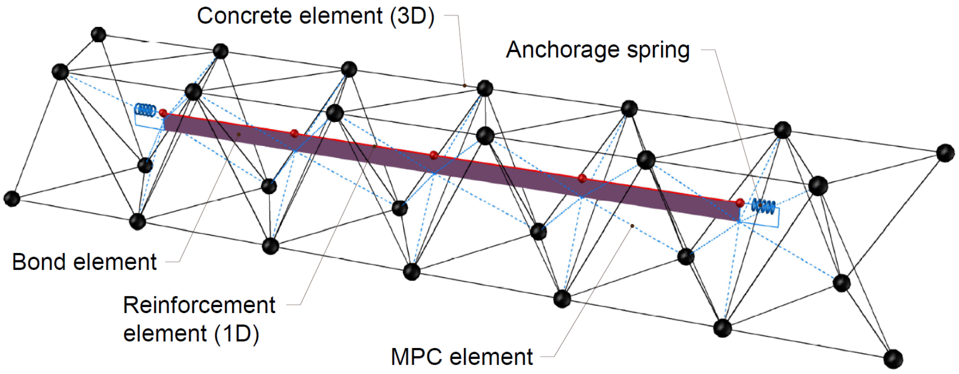


Fig. 4 Finite element model: reinforcement elements mapped to concrete mesh using MPC elements and bond elements.

$$G_b = k_g \cdot E_c / \emptyset$$

Concrete is modeled using mixed tetrahedral elements with nodal rotations. Implemented formulation guarantees accurate deformation results without spurious shear stress known as the shear lock effect even for the coarse mesh which would not be suitable for linear tetrahedral elements formulation. Elements are equipped with four integration points situated within the volume.

Reinforcement bars are modeled by 1D elements (only axial stiffness) which are connected to the bond elements modeling the slip behavior between rebars and concrete.

The bond element is a shell element with only a non-zero stiffness in shear between the two layers of nodes. The first layer (upper) nodes are connected to the reinforcement elements and the second layer (lower) nodes to the concrete mesh via MPC. The behavior of this element is described by the bond stress τ_b as a bilinear function of the slip between the upper and lower nodes, δ_u (see Fig. 5).

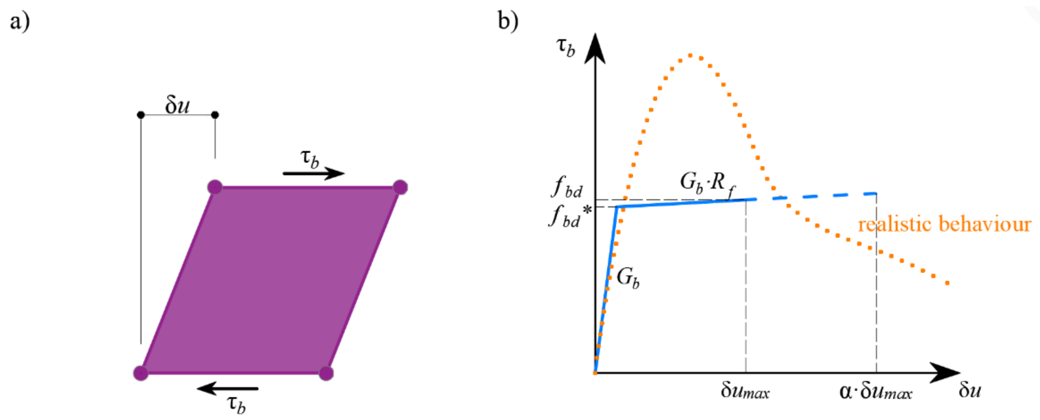


Fig. 5 (a) a conceptual illustration of the deformation of a bond element; (b) a stress-deformation function.

Where k_g is the coefficient depending on the reinforcing bar surface, E_c is the secant modulus of elasticity of concrete, Φ is the diameter of the rebar, and f_{bd} is the ultimate bond stress defined in the specified design code. The hardening of the plastic branch is calculated as $G_b/10^5$.

Anchorage spring behavior is determined from prescriptions of design codes, allowing the reduction of the basic anchorage length of the bars ($l_{b,net}$) due to bends, hooks, loop, etc., by a certain factor β. The intended reduction in $l_{b,net}$ is equivalent to the activation of the reinforcing bar at its end at a percentage of its maximum capacity given by the anchorage reduction coefficient β, as shown in Fig. 6a.

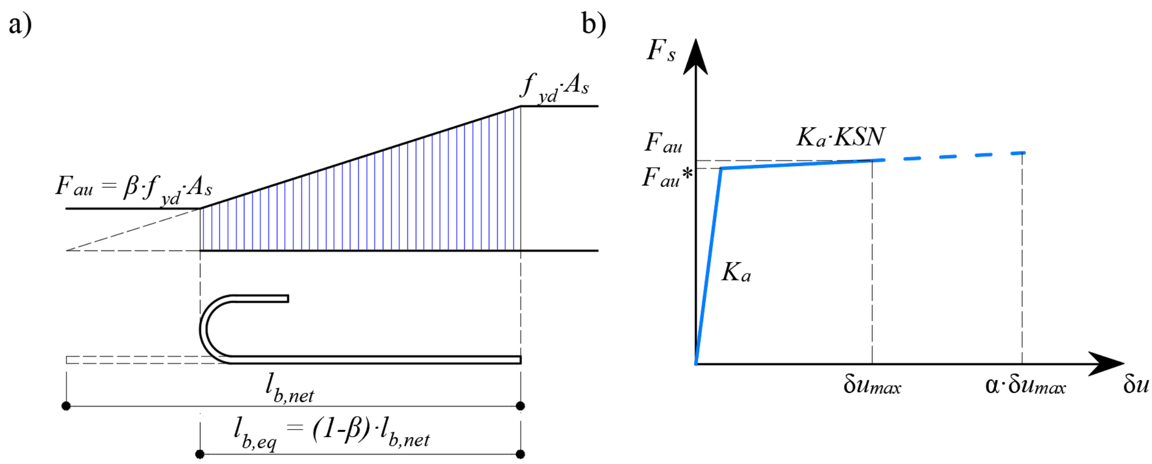


Fig. 6 A model for the reduction of the anchorage length: (a) anchorage force along the anchorage length of the reinforcing bar; (b) the slip-anchorage force constitutive relationship.

Where $l_{b,eq}$ is the design value (factored value) of the anchorage length, f_{yd} is the design value (factored value) of the yield strength of the reinforcement, A_s is the area of the cross-section of the reinforcing bar.

Load transfer devices

The base plate is modeled as a linear shell element defined by the modulus of elasticity *E*. The base plate can be loaded by the point load (Fx, Fy, Fz, Mx, My, Mz) and group of forces (Fx, Fy, Fz). Point loads and point moments directly load the corresponding node of the base plate. It means that there is no redistribution, only by the stiffness of the base plate.

Frictional compression-only contact is defined between the base plate and concrete, for the **shear transfer**, the user can choose from three options: **by anchors, by friction** (the design value of friction coefficient is to be input by the user), and **by shear lug**. The software does not allow the combination of these shear transfer mechanisms.

The shear lug is connected with the concrete mesh by constraints allowing only compression normal stress transfer.

Import from IDEA StatiCa Connection

The load is imported as a group of forces with values determined from the general stress state of the weld finite elements connecting the base plate and the adjacent element. To ensure identical forces in the anchors in both models, the anchors are disconnected in terms of axial forces after import. The anchors are then directly loaded with the force read from Connection and the plate is loaded in the same location with a directionally opposite force of the same value.

The solution method and load-control algorithm

A standard full Newton-Raphson (NR) algorithm is used. The load is applied sequentially in multiple increments. Results from the previous load increment are used to start the Newton solution of a subsequent one. If the NR iterations do not converge, the current load increment is reduced to half its value, and the NR iterations are retried. This load-control algorithm is also used to find the critical load, which corresponds to certain “stop criteria”.

·maximum strain in concrete 5% strain in compression (7% in tension)

·maximum strain in reinforcing bars – 5% strain in compression and tension by default

·maximum slip in bond elements – α·δ_{umax} (see Fig. 5)

·maximum displacement in anchorage elements – α·δ_{umax} (see Fig. 6)

·maximum shear deformation u_{xy} in frictional contact of a base plate and concrete

Where δ_{umax} is the maximal slip used in code checks and α = 10.

Structural element checks according to ACI 318-19

The nonlinear solution of the 3D CSFM is in accordance with ACI 318-19, chapter 6.8.1.1. Verifications and validations are available on ideastatica.com to ensure that the 3D CSFM meets the requirements of ACI 318-19, Section 6.8.1.

Material models:

The considered concrete model for Strength is based on the Portland Cement Association’s parabolic stress-strain curve described in PCA’s Notes on ACI 318-99 Building Code Requirements for Structural Concrete, Figure 6-8. The tensile strength is neglected, as it is in classic reinforced concrete design.

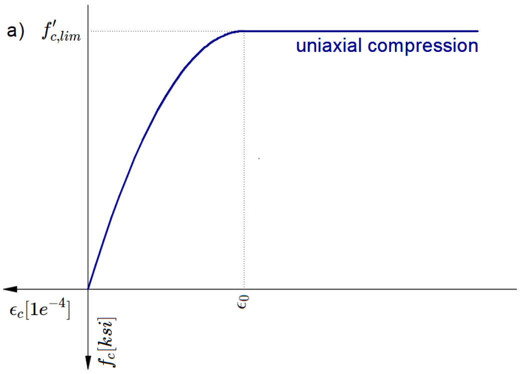


Fig. 7 The stress-strain diagram of concrete for Strength analysis

Explicit failure criterion in terms of strains for concrete in compression is not considered. (i.e., after the peak stress is reached, it considers a plastic branch with ε_{c0} in “stop criteria” of 5% by default while ACI 318-19 Art. 22.2.2.1 assumes ultimate strain less than 0.3%). This simplification does not allow the deformation capacity of structures failing in compression to be verified.

Concrete compressive strength is assumed as follows:

$$f'_{c,lim} = \alpha_1 \cdot \emptyset_c \cdot \eta_{fc} \cdot f'_c \qquad \left(\eta_{fc} = \left(\frac{30}{f'c}\right)^{\frac{1}{3}} \leq 1\right)$$

A perfectly elasto-plastic stress-strain diagram with a defined yield point for the non-prestresses reinforcement is considered, see ACI 319-19 CL. 20.2.1.

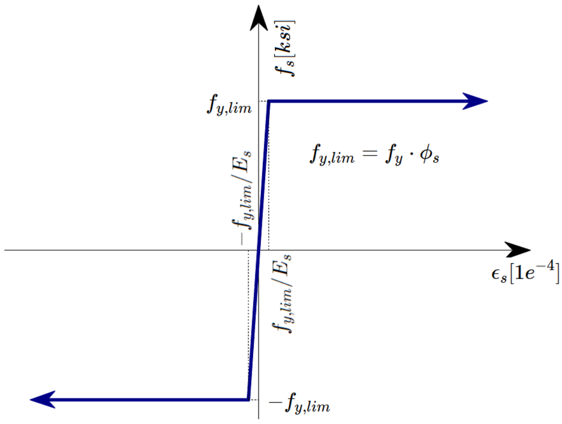


Fig. 8 Stress-strain diagram of reinforcement

Tension stiffening is accounted for by modifying the stress-strain relationship of the bare reinforcing bar to capture the average stiffness of the bars embedded in the concrete (ε_i) (see Fig. 2d).

Strength verifications:

The concrete strength in compression is evaluated as the ratio between the Equivalent principal stress fc,eq obtained from FE analysis and the limit value $f'_{c,lim}$.

The strength of the reinforcement is evaluated in both tension and compression as the ratio between the stress in the reinforcement at the cracks f_s and the specified limit value $f_{y,lim}$.

The bond shear stress is evaluated independently as the ratio between the bond stress τ_b calculated by FE analysis and the bond strength f_{bu} derived from the rules for determining development length in Section 25.4.2.

The anchorage reduction coefficients β (see Fig. 9a) are derived from the comparison of the equation from section ACI 318-19 25.4.3.1 and equations taken from section ACI 318-19 25.4.2.3 as follows.

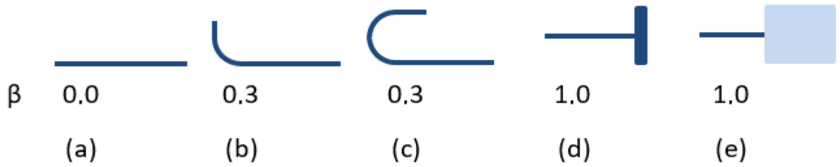


Fig. Available anchorage types and respective anchorage coefficients for longitudinal reinforcing bars in CSFM: (a) straight bar; (b) 90-degree hook; (c) 180-degree hook; (d) perfect bond; (e) continuous bar

For stirrups $\beta = 1.0$ for all anchorage types.

In order to comply with ACI, the anchorage spring should be used in the calculation, the anchorage spring is modified by the B coefficient so the user must use one of the available anchorage types when defining the reinforcement start and end conditions.