IV35 – CAVALCAFERROVIA CASCINA PERGOLA VECCHIA - PK 125+738,979
ALLEGATO A

1. TRAVE PRINCIPALE

	Concio 1	Concio 2	Concio 3	Concio 1a
Altezza sezione H	2400-3400	3400-4000	4000	3400-2400
Piattabanda superiore	950x37	950x47	950x50	950x37
Anima	18	16	15	18
Piattabanda inferiore	950x37	950x50	950x55	950x37
stiffener verticale	300x15 + 300x25	300x15 + 450x25	300x15 + 450x25	300x15 + 300x25
stiffener longitudinale	200x20 390x20	200x20 200x20 240x20	200x20 200x20 240x20	200x20 390x20

1.1 Sez 1 - x = 0.00 m (sezione di spalla A)

IV35
Verifiche Tensioni SLU Sezione X=0.00

Sezioni e loro proprietà.

Be�m	x[m]	Sezione	A[m2]	yc[m]	zc[m]	Iyz[m4]	Iy[m4]	Iz[m4]	ycr[m]	zcr[m]
10115	0.000	lorda	1.196E-01	0.031	-1.156	0.00E+00	1.219E-01	4.574E-03	0.031	-1.156
		Inclinazioni	(dZ/dx /	dY/dx)		0.083	0.000			

A[m2] area della sezione — Iyz[m4],Iy[m4],Iz[m4] momento d'inerzia flessionale
yc[m],zc[m] coordinate del baricentro — ycr[m],zcr[m] punto di riferimento per forze e momenti

Tensioni non line�ri.
Tensioni non line�ri.

Be�m	x[m]	Sez.	C�so	Ni [kN]	Myi [kNm]	Mzi [kNm]	xc [m]	ε [o/oo]	σ-c [MP�]	σ-s [MP�]	σ-t [MP�]	Ey-eff [MP�]
10115	0.000	130	9340	778.8	236.04	0.00	0.000	0.044	8.71			200000
					Vz-i	2898.80	fac	1.00			G-eff	76924
					Mt-i	58.37	fac	1.00			G-eff	78524
			9341	-541.9	-326.11	0.00	2.442	-0.036	-7.21			210000
					Mt-i	56.83	fac	1.00			G-eff	78531
			9342	77.8	24.63	0.00	0.000	0.004	0.88			200000
					Mt-i	83.61	fac	1.00			G-eff	79285
			9343	-417.3	-8.25	0.00	2.442	-0.017	-3.40			200000
					Vz-i	2091.54	fac	1.00			G-eff	76932
					Mt-i	67.01	fac	1.00			G-eff	78485

Ni,Myi,Mzi forze interne (integrale delle tensioni non lineari) — σ-s tensione nell'armatura
xc altezza della zona compressa — σ-t tensione nei cavi
ε factor on shear strain or stresses — Ey-eff modulo elastico effettivo riferito alla lsezione lorda
σ-c tensione nella sezione

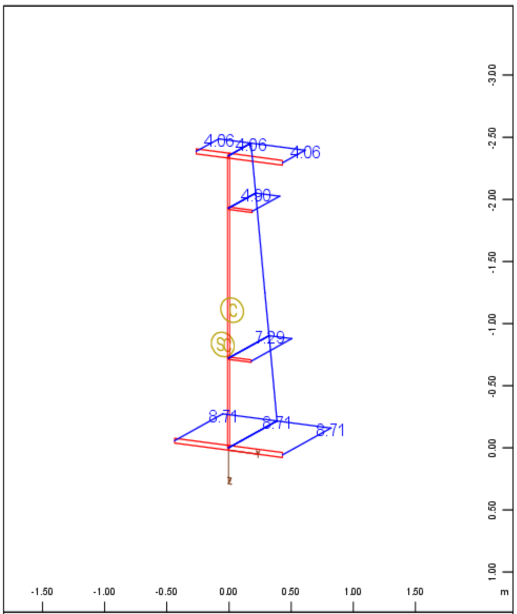
Snellezz� c/t.

Be�m	x[m]	Sez.	C�so	Pi�st	σ-�	σ-e	ψ	k-σ	c[m]	t[m]	c/t	c/t-lim
10115	0.000	130	max	3.10[1]	c/t-lim(1:4)	=	27.24	31.36	34.93	346.0	67.39(3)[2]	346.015(4)
			9343	FLS1	-1.09	-1.09	1.00	0.44	0.465	0.040	11.66(3)[2]	< 14.0× 14.3(4)
				FLS2	-1.09	-1.09	1.00	0.44	0.273	0.040	6.85(1)	< 14.0× 14.3(4)
				WEB1	-2.16	-1.09	0.50	5.28	0.422	0.018	23.43(1)	< 50.2× 10.2(4)
				WEB2	-5.31	-2.22	0.42	5.59	1.213	0.018	67.39(3)[2]	< 52.0× 6.49(4)
				FLI1	-7.21	-7.21	1.00	0.44	0.465	0.040	11.66(3)[2]	< 14.0× 5.57(4)
				FLI2	-7.21	-7.21	1.00	0.44	0.465	0.040	11.66(3)[2]	< 14.0× 5.57(4)
				RIB1	-2.19	-2.19	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 10.1(4)
				RIB3	-5.33	-5.33	1.00	0.44	0.191	0.020	9.55(3)	< 14.0× 6.48(4)
				WEB3	-7.16	-5.36	0.75	4.56	0.707	0.018	39.28(3)[2]	< 45.8× 5.59(4)
			9343	FLS1	-3.24	-3.24	1.00	0.44	0.465	0.040	11.66(3)[2]	< 14.0× 8.31(4)
				FLS2	-3.24	-3.24	1.00	0.44	0.273	0.040	6.85(1)	< 14.0× 8.31(4)
				WEB1	-3.27	-3.24	0.99	4.02	0.422	0.018	23.43(1)	< 42.1× 8.27(4)
				WEB2	-3.35	-3.27	0.98	4.05	1.213	0.018	67.39(3)[2]	< 42.3× 8.17(4)
				FLI1	-3.40	-3.40	1.00	0.44	0.465	0.040	11.66(3)[2]	< 14.0× 8.12(4)
				FLI2	-3.40	-3.40	1.00	0.44	0.465	0.040	11.66(3)[2]	< 14.0× 8.12(4)
				RIB1	-3.27	-3.27	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 8.27(4)
				RIB3	-3.35	-3.35	1.00	0.44	0.191	0.020	9.55(3)	< 14.0× 8.17(4)
				WEB3	-3.40	-3.35	0.99	4.03	0.707	0.018	39.28(3)[2]	< 42.2× 8.12(4)

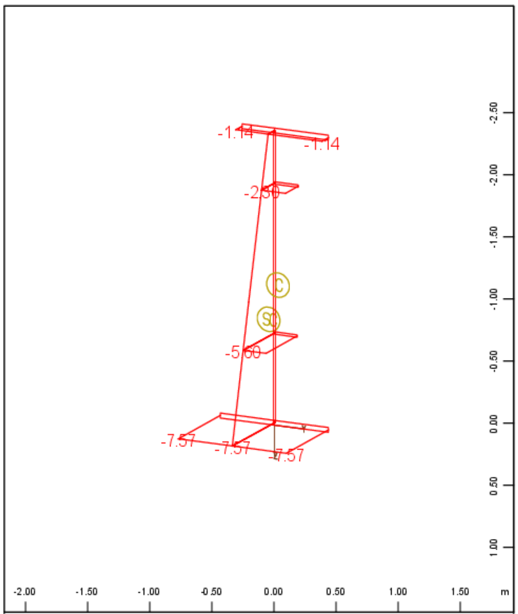
[1] indice di calssificazione (es. 1,5 = classe della sezione SCl tra 1 e 2)
[2] I bassi valori di tensione consentono di trattare la sezione in classe 4 come in classe 3 (EN 1993-1-1 5.5.2 (9))

σ-a,σ-e tensione nel punto finale — t[m] spessore del pannello
ψ distribuzione della tensione — c/t rapporto c/T o D/t esistente (classe della sezione)
k-σ fattore d'instabilità — c/t-lim limite del rapporto c/t (valore base * fattore tendione)
c[m] lunghezza o diametro del tubo

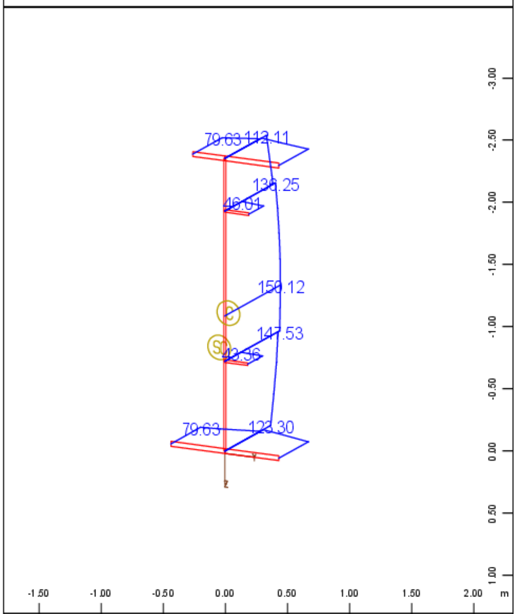
Rigidezza non salvata nel database



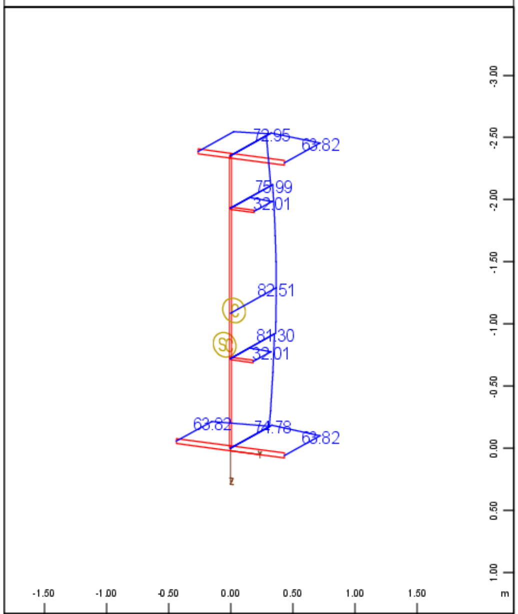
Axial stress in cross section from stresses of beams (AQB) [MPa] M 1 : 50
LC: 9340 BEAM: 10115 X: 0 Sezione numero 130



Axial stress in cross section from stresses of beams (AQB) [MPa] M 1 : 50
LC: 9341 BEAM: 10115 X: 0 Sezione numero 130



Shear stress in cross section from stresses of beams (AQB) [MPa] M 1 : 50
LC: 9342 BEAM: 10115 X: 0 Sezione numero 130



Shear stress in cross section from stresses of beams (AQB) [MPa] M 1 : 50
LC: 9343 BEAM: 10115 X: 0 Sezione numero 130

1.2 Sez 2a-2b - x = 11.50 m (sezione di fine concio 1-inizio concio 2)

IV35
Verifiche Tensioni SLU Sezione X=11.5

Sezioni e loro proprietà.

Be⊠m	x[m]	Sezione	A[m2]	yc[m]	zc[m]	Iyz[m4]	Iy[m4]	Iz[m4]	ycr[m]	zcr[m]
10057	0.000	lorda	1.610E-01	0.008	-1.718	0.00E+00	3.275E-01	7.311E-03	0.008	-1.718
		Inclinazioni	(dZ/dx / dY/dx)			0.050	0.000			
10128	0.350	lorda	1.390E-01	0.006	-1.682	0.00E+00	2.597E-01	5.397E-03	0.006	-1.682
		Inclinazioni	(dZ/dx / dY/dx)			0.083	0.000			

A[m2] area della sezione; Iyz[m4],Iy[m4],Iz[m4] momento d'inerzia flessionale
yc[m],zc[m] coordinate del baricentro; ycr[m],zcr[m] punto di riferimento per forze e momenti

Tensioni non line⊠ri.
Tensioni non line⊠ri.

Be⊠m	x[m]	Sez.	C⊠so	Ni	Myi	Mzi	xc	ε	σ-c	σ-s	σ-t	Ey-eff
				[kN]	[kNm]	[kNm]	[m]	[o/oo]	[MP⊠]	[MP⊠]	[MP⊠]	[MP⊠]
10057	0.000	3	9340	3216.6	45165.68	0.00	1.529	1.267	253.40			200884
					Vz-i	1869.10	fac	1.00			G-eff	76924
					Mt-i	8.18	fac	1.04			G-eff	77351
			9341	-1575.3	19254.00	0.00	1.840	-0.530	-106.1			201124
					Vz-i	969.35	fac	1.00			G-eff	76924
					Mt-i	4.00	fac	1.04			G-eff	77402
			9342	1029.8	43263.76	0.00	1.623	1.149	229.89			201401
					Vz-i	2215.98	fac	1.00			G-eff	76924
					Mt-i	15.71	fac	1.04			G-eff	77738
			9343	901.1	26763.76	0.00	1.607	0.720	143.95			200733
					Vz-i	773.36	fac	1.00			G-eff	80770
					Mt-i	0.30	fac	1.05			G-eff	77166
10128	0.350	2	9340	3016.4	44938.81	0.00	1.642	1.548	309.54			194464
					Vz-i	1492.74	fac	1.12			G-eff	71925
					Mt-i	6.42	fac	1.06			G-eff	76159
			9341	-1560.2	19344.73	0.00	1.874	-0.693	-138.7			199339
					Vz-i	743.10	fac	1.03			G-eff	76923
					Mt-i	5.06	fac	1.04			G-eff	76923
			9342	939.3	43207.01	0.00	1.733	-1.476	-295.1			193350
					Vz-i	1814.65	fac	1.13			G-eff	71330
					Mt-i	14.33	fac	1.06			G-eff	76081
			9343	795.7	26669.16	0.00	1.680	0.883	176.57			197936
					Vz-i	524.04	fac	1.06			G-eff	76533
					Mt-i	0.19	fac	1.05			G-eff	76835

Ni,Myi,Mzi forze interne (integrale delle tensioni non lineari); σ-s tensione nell'armatura
xc altezza della zona compressa; σ-t tensione nei cavi
ε factor on shear strain or stresses; Ey-eff modulo elastico effettivo riferito alla lsezione lorda
σ-c tensione nella sezione

Snellezz⊠ c/t.

Be⊠m	x[m]	Sez.	C⊠so	Pi⊠st	σ-⊠	σ-e	ψ	k-σ	c[m]	t[m]	c/t	c/t-lim
10057	0.000	3	max	3.66[1]	c/t-lim(1:4) =		27.24	31.36	47.45	68.47	61.25(3)[2]	68.475(4)
			9343	FLS1	-206.6	-206.6	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.04(4)
				FLS2	-206.6	-206.6	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.04(4)
				WEB1	-206.6	-155.1	0.75	4.55	0.375	0.016	23.44(1)	< 45.8× 1.04(4)
				WEB2	-152.3	-17.77	0.12	7.03	0.980	0.016	61.25(3)[2]	< 59.3× 1.21(4)
				RIB1	-153.7	-153.7	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.21(4)
				WEB3	-15.02	151.52	-10.1	734.8	1.213	0.016	75.81(1)	<2182.× 3.86(4)
				RIB2	-16.40	-16.40	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 3.69(4)
			9343	FLS1	-106.1	-106.1	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.45(4)
				FLS2	-106.1	-106.1	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.45(4)
				WEB1	-106.1	-84.16	0.79	4.45	0.375	0.016	23.44(1)	< 45.1× 1.45(4)
				WEB2	-82.99	-25.70	0.31	6.03	0.980	0.016	61.25(3)[2]	< 54.4× 1.64(4)
				RIB1	-83.58	-83.58	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.64(4)
				WEB3	-24.53	46.38	-1.89	49.97	1.213	0.016	75.81(1)	< 246.× 3.02(4)
				RIB2	-25.12	-25.12	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 2.99(4)
			9343	FLS1	-209.6	-209.6	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.03(4)
				FLS2	-209.6	-209.6	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.03(4)
				WEB1	-209.6	-160.4	0.77	4.52	0.375	0.016	23.44(1)	< 45.5× 1.03(4)

IV35
Verifiche Tensioni SLU Sezione X=11.5

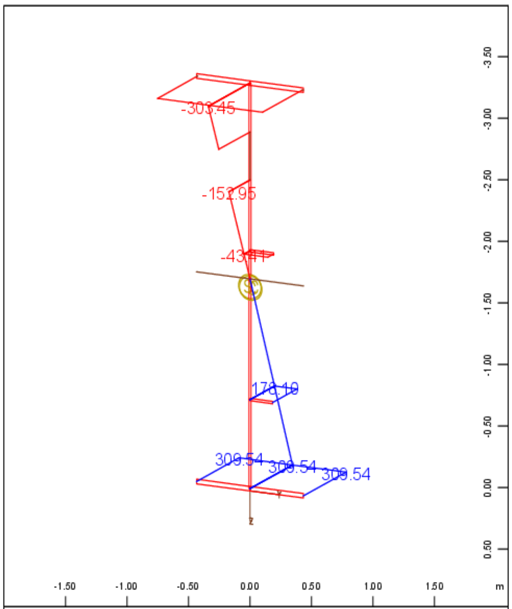
Snellezz� c/t.

Be�m	x[m]	Sez.C	�so	Pi�st	σ-�	σ-e	ψ	k-σ	c[m]	t[m]	c/t	c/t-lim
10057	0.000	3	9343	WEB2	-157.8	-29.20	0.19	6.64	0.980	0.016	61.25(3)[2]	< 57.5× 1.19(4)
				RIB1	-159.1	-159.1	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.19(4)
				WEB3	-26.57	132.55	-4.99	214.5	1.213	0.016	75.81(1)	< 829.× 2.90(4)
				RIB2	-27.88	-27.88	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 2.83(4)
			9343	FLS1	-128.8	-128.8	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.32(4)
				FLS2	-128.8	-128.8	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.32(4)
				WEB1	-128.8	-98.27	0.76	4.52	0.375	0.016	23.44(1)	< 45.6× 1.32(4)
				WEB2	-96.65	-16.85	0.17	6.70	0.980	0.016	61.25(3)[2]	< 57.8× 1.52(4)
				RIB1	-97.46	-97.46	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.52(4)
				WEB3	-15.22	83.54	-5.49	251.6	1.213	0.016	75.81(1)	< 942.× 3.83(4)
				RIB2	-16.04	-16.04	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 3.74(4)
10128	0.350	2	max	4.54[1]	c/t-lim(1:4) =		27.24	31.36	47.25	49.85	**76.75(4)**	49.850(4)
			9343	FLS1	-289.0	-289.0	1.00	0.44	0.465	0.037	12.57(4)	beff= 0.463(4)
				FLS2	-289.0	-289.0	1.00	0.44	0.465	0.037	12.57(4)	beff= 0.463(4)
				WEB1	-289.0	-43.12	0.15	6.84	1.381	0.018	76.75(4)	beff= 1.003(4)
				WEB2	-39.56	176.32	-4.46	178.1	1.213	0.018	67.39(1)	< 714.× 2.38(4)
				RIB1	-41.34	-41.34	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 2.33(4)
			9343	FLS1	-138.7	-138.7	1.00	0.44	0.465	0.037	12.57(3)[2]	< 14.0× 1.27(4)
				FLS2	-138.7	-138.7	1.00	0.44	0.465	0.037	12.57(3)[2]	< 14.0× 1.27(4)
				WEB1	-138.7	-35.40	0.26	6.28	1.381	0.018	76.75(4)	beff= 1.284(4)
				WEB2	-33.91	56.75	-1.67	42.75	1.213	0.018	67.39(1)	< 214.× 2.57(4)
				RIB1	-34.66	-34.66	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 2.54(4)
			9343	FLS1	-295.1	-295.1	1.00	0.44	0.465	0.037	12.57(4)	beff= 0.460(4)
				FLS2	-295.1	-295.1	1.00	0.44	0.465	0.037	12.57(4)	beff= 0.460(4)
				WEB1	-295.1	-57.38	0.19	6.59	1.381	0.018	76.75(4)	beff= 0.977(4)
				WEB2	-53.94	154.82	-2.87	89.58	1.213	0.018	67.39(1)	< 407.× 2.04(4)
				RIB1	-55.66	-55.66	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 2.01(4)
			9343	FLS1	-172.4	-172.4	1.00	0.44	0.465	0.037	12.57(3)[2]	< 14.0× 1.14(4)
				FLS2	-172.4	-172.4	1.00	0.44	0.465	0.037	12.57(3)[2]	< 14.0× 1.14(4)
				WEB1	-172.4	-29.05	0.17	6.73	1.381	0.018	76.75(4)	beff= 1.223(4)
				WEB2	-26.97	98.90	-3.67	130.3	1.213	0.018	67.39(1)	< 554.× 2.88(4)
				RIB1	-28.01	-28.01	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 2.83(4)

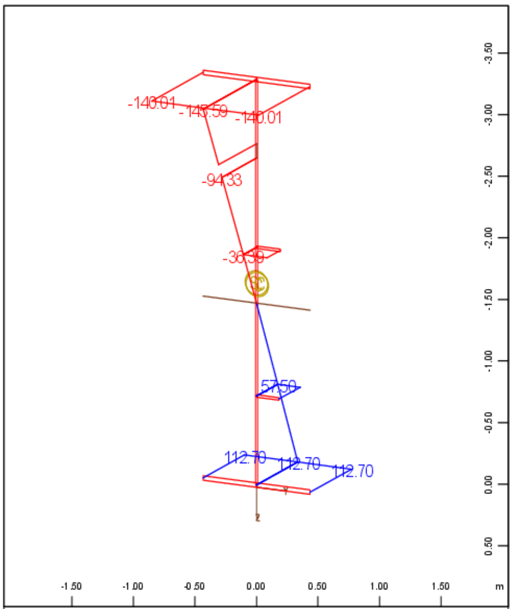
[1] indice di calssificazione (es. 1,5 = classe della sezione SCl tra 1 e 2)
[2] I bassi valori di tensione consentono di trattare la sezione in classe 4 come in classe 3 (EN 1993-1-1 5.5.2 (9))

σ-a,σ-e	tensione nel punto finale	t[m]	spessore del pannello
ψ	distribuzione della tensione	c/t	rapporto c/T o D/t esistente (classe della sezione)
k-σ	fattore d'instabilità	c/t-lim	limite del rapporto c/t (valore base * fattore tendione)
c[m]	lunghezza o diametro del tubo		

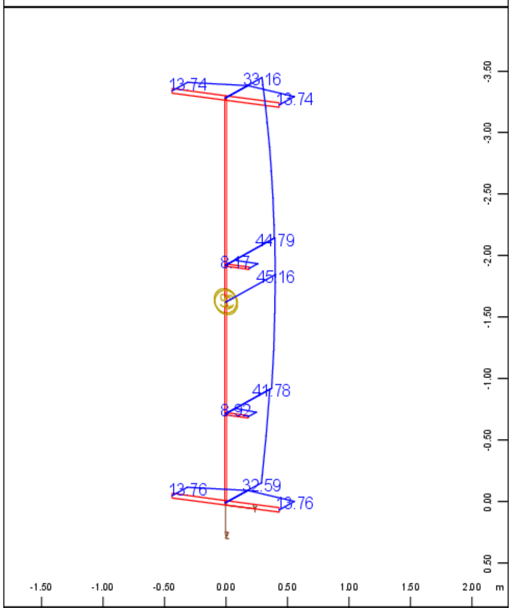
Rigidezza non salvata nel database



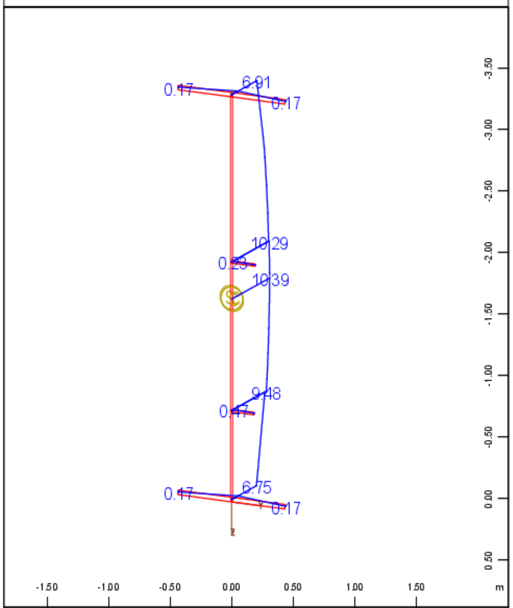
Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9340 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50



Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9341 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50

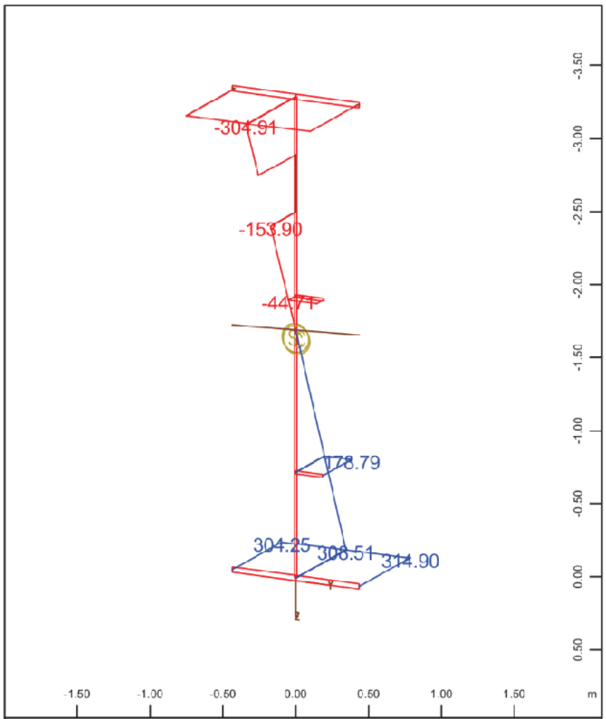


Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9342 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50

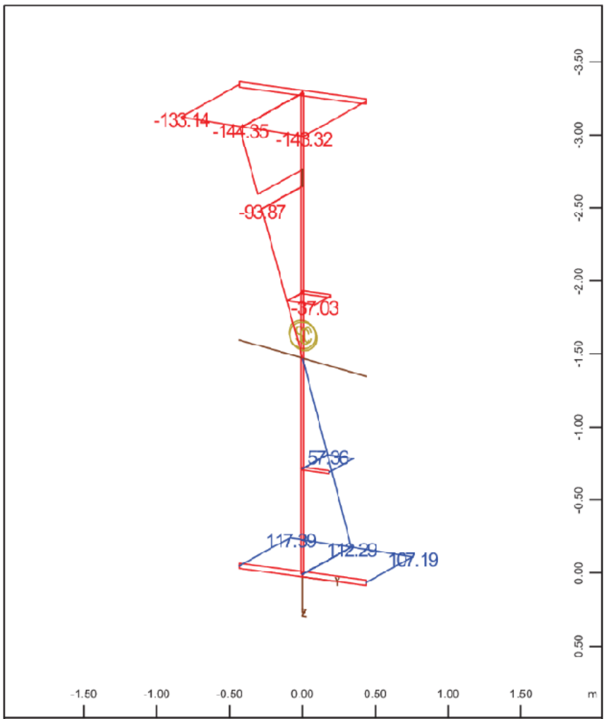


Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9343 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50

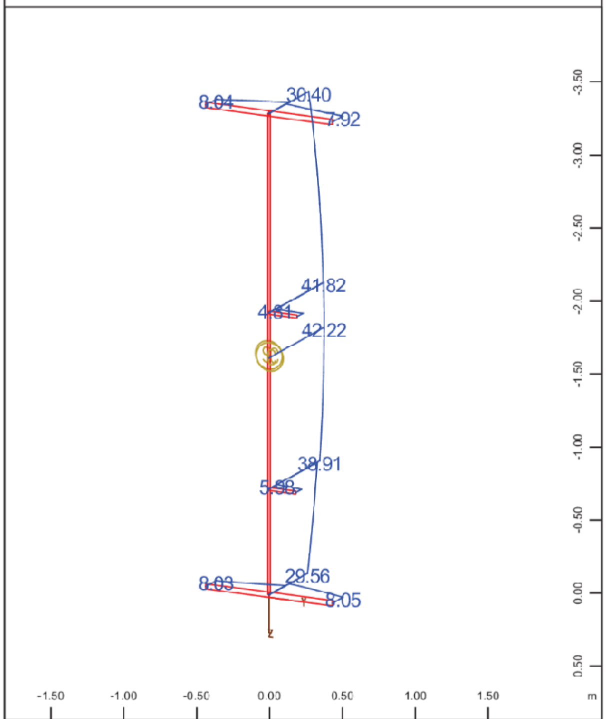
IV35



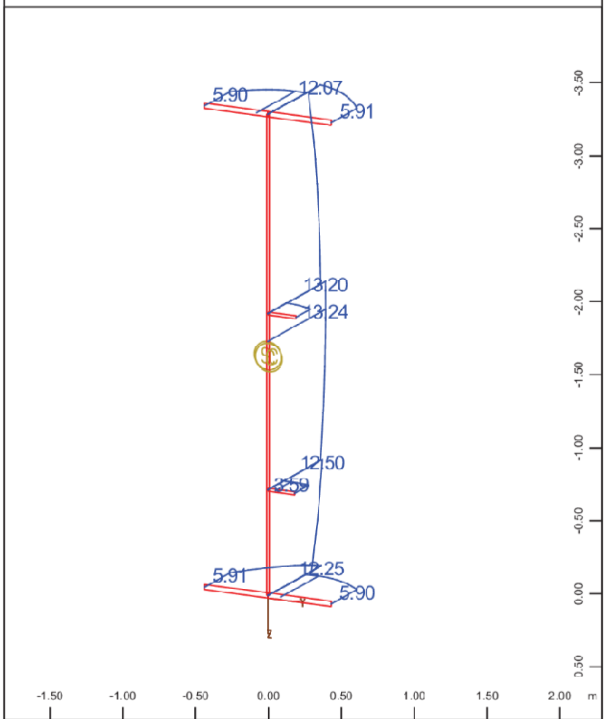
Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9340 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50



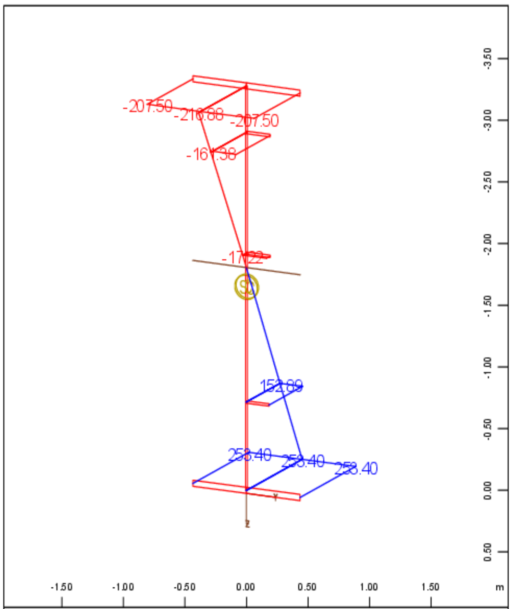
Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9341 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50



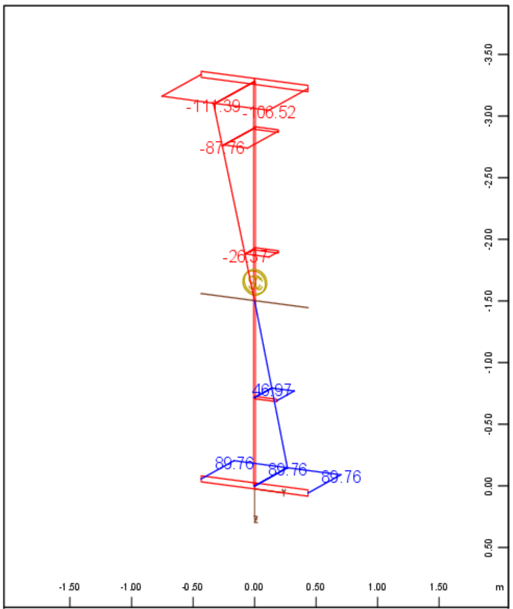
Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9342 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50



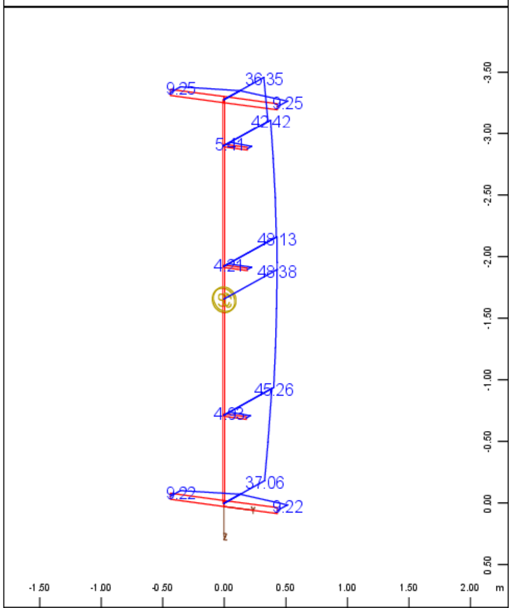
Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9343 BEAM: 10128 X: 0.35 Sezione numero 2
M 1 : 50



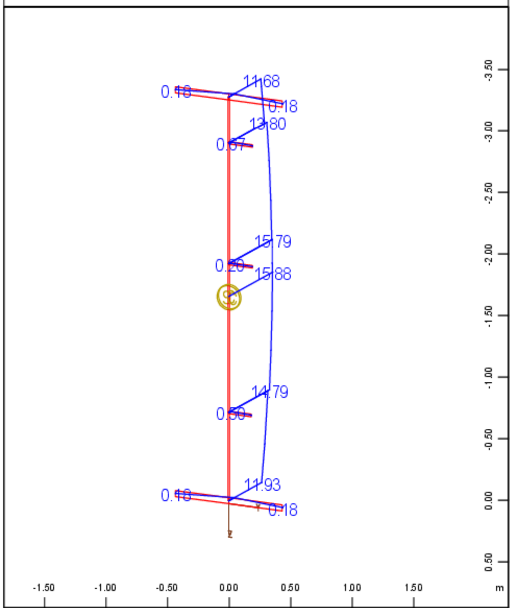
Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9340 BEAM: 10057 X: 0 Sezione numero 3
M 1 : 50



Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9341 BEAM: 10057 X: 0 Sezione numero 3
M 1 : 50



Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9342 BEAM: 10057 X: 0 Sezione numero 3
M 1 : 50



Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9343 BEAM: 10057 X: 0 Sezione numero 3
M 1 : 50

1.3 Sez 3a-3b - x = 23.50 m (sezione di fine concio 2-inizio concio 3)

IV35
Verifiche Tensioni SLU Sezione X=23.50

Sezioni e loro proprietà.

Be⍰m	x[m]	Sezione	A[m2]	yc[m]	zc[m]	Iyz[m4]	Iy[m4]	Iz[m4]	ycr[m]	zcr[m]
10070	0.950	lorda	1.706E-01	0.008	-1.995	0.00E+00	4.630E-01	7.312E-03	0.008	-1.995
		Inclinazioni	(dZ/dx / dY/dx)			0.050	0.000			
10071	0.000	lorda	1.761E-01	0.007	-1.995	0.00E+00	4.936E-01	8.027E-03	0.007	-1.995

A[m2] area della sezione; Iyz[m4],Iy[m4],Iz[m4] momento d'inerzia flessionale
yc[m],zc[m] coordinate del baricentro; ycr[m],zcr[m] punto di riferimento per forze e momenti

Tensioni non line⍰ri.
Tensioni non line⍰ri.

Be⍰m	x[m]	Sez.C⍰so		Ni [kN]	Myi [kNm]	Mzi [kNm]	xc [m]	ε [o/oo]	σ-c [MP⍰]	σ-s [MP⍰]	σ-t [MP⍰]	Ey-eff [MP⍰]
10070	0.950	4	9340	3539.5	68367.45	0.00	1.894	1.561	312.15			196911
					Vz-i	210.70	fac	1.09			G-eff	74394
					Mt-i	-1.86	fac	1.07			G-eff	75547
			9341	-1743.4	29247.18	0.00	2.167	-0.676	-135.3			200003
					Vz-i	20.48	fac	1.05			G-eff	77265
					Mt-i	0.18	fac	1.05			G-eff	76944
			9342	519.3	64674.50	0.00	2.013	-1.412	-282.5			196573
					Vz-i	364.55	fac	1.08			G-eff	75022
					Mt-i	-0.85	fac	1.05			G-eff	76801
			9343	1263.1	41602.25	0.00	1.927	0.923	184.58			199346
					Vz-i	-345.70	fac	1.03			G-eff	76917
					Mt-i	-0.27	fac	1.05			G-eff	76923
10071	0.000	5	9340	3578.5	68385.92	0.00	1.881	1.467	293.30			197559
					Vz-i	993.03	fac	1.06			G-eff	76340
					Mt-i	-2.27	fac	1.05			G-eff	76905
			9341	-1747.5	29230.35	0.00	2.165	-0.631	-126.2			200617
					Vz-i	425.91	fac	1.00			G-eff	76923
			9342	3306.1	67508.29	0.00	1.890	1.441	288.23			197640
					Vz-i	1165.36	fac	1.06			G-eff	76537
					Mt-i	-1.20	fac	1.05			G-eff	76912
			9343	-734.8	39666.05	0.00	2.068	-0.825	-165.1			198657
					Vz-i	149.22	fac	1.05			G-eff	76756
					Mt-i	-1.33	fac	1.05			G-eff	76918

Ni,Myi,Mzi forze interne (integrale delle tensioni non lineari); σ-s tensione nell'armatura
xc altezza della zona compressa; σ-t tensione nei cavi
ε factor on shear strain or stresses; Ey-eff modulo elastico effettivo riferito alla lsezione lorda
σ-c tensione nella sezione

Snellezz⍰ c/t.

Be⍰m	x[m]	Sez.C⍰so		Pi⍰st	σ-⍰	σ-e	ψ	k-σ	c[m]	t[m]	c/t	c/t-lim
10070	0.950	4	max	4.37^{1}	c/t-lim(1:4) =		27.24	31.36	41.37	44.62	**60.94(4)**	44.619(4)
			9343	FLS1	-280.2	-280.2	1.00	0.44	0.465	0.050	9.30(3)	< 14.0×0.894(4)
				FLS2	-280.2	-280.2	1.00	0.44	0.465	0.050	9.30(3)	< 14.0×0.894(4)
				WEB1	-280.2	-134.0	0.48	5.37	0.975	0.016	60.94(4)	beff= 0.767(4)
				WEB2	-131.0	15.96	-0.12	8.72	0.980	0.016	61.25(3)^{2}	< 66.8× 1.31(4)
				RIB1	-132.5	-132.5	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.30(4)
			9343	FLS1	-135.3	-135.3	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.29(4)
				FLS2	-135.3	-135.3	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.29(4)
				WEB1	-135.3	-73.69	0.54	5.14	0.975	0.016	60.94(3)^{2}	< 49.4× 1.29(4)
				WEB2	-72.43	-10.53	0.15	6.86	0.980	0.016	61.25(3)^{2}	< 58.5× 1.76(4)
				RIB1	-73.06	-73.06	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.75(4)
				WEB3	-9.27	67.35	-7.27	408.9	1.213	0.016	75.81(1)	<1382.× 4.91(4)
				RIB2	-9.90	-9.90	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 4.76(4)
			9343	FLS1	-282.5	-282.5	1.00	0.44	0.465	0.050	9.30(3)	< 14.0×0.890(4)
				FLS2	-282.5	-282.5	1.00	0.44	0.465	0.050	9.30(3)	< 14.0×0.890(4)
				WEB1	-282.5	-143.9	0.51	5.26	0.975	0.016	60.94(4)	beff= 0.757(4)
				WEB2	-141.1	-1.82	0.01	7.71	0.980	0.016	61.25(3)^{2}	< 62.3× 1.26(4)
				RIB1	-142.5	-142.5	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.25(4)
				RIB2	-0.40	-0.40	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 23.8(4)
			9343	FLS1	-171.5	-171.5	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.14(4)

IV35
Verifiche Tensioni SLU Sezione X=23.50

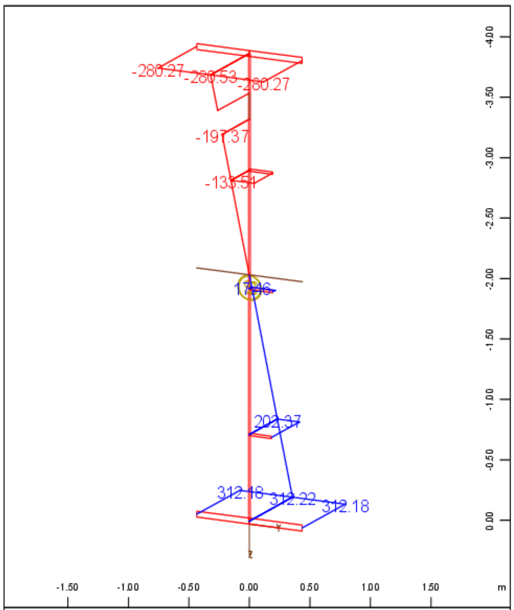
Snellezz⍰ c/t.

Be⍰m	x[m]	Sez.	C⍰so	Pi⍰st	σ-⍰	σ-e	ψ	k-σ	c[m]	t[m]	c/t	c/t-lim
10070	0.950	4	9343	FLS2	-171.5	-171.5	1.00	0.44	0.465	0.050	9.30(3)	< 14.0× 1.14(4)
				WEB1	-171.5	-83.60	0.49	5.33	0.975	0.016	60.94(4)	beff= 0.916(4)
				WEB2	-81.80	6.54	-0.08	8.38	0.980	0.016	61.25(3)[2]	< 65.3× 1.65(4)
				RIB1	-82.70	-82.70	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.65(4)
10071	0.000	5	max	4.38[1]	c/t-lim(1:4) =		27.24	31.36	41.94	47.15	**64.83(4)**	47.145(4)
			9343	FLS1	-260.0	-260.0	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.928(4)
				FLS2	-260.0	-260.0	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.928(4)
				WEB1	-260.0	-123.6	0.48	5.38	0.973	0.015	64.83(4)	beff= 0.751(4)
				WEB2	-120.8	16.66	-0.14	8.86	0.980	0.015	65.33(3)[2]	< 67.3× 1.36(4)
				RIB1	-122.2	-122.2	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.35(4)
			9343	FLS1	-126.2	-126.2	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.33(4)
				FLS2	-126.2	-126.2	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.33(4)
				WEB1	-126.2	-68.80	0.55	5.14	0.973	0.015	64.83(3)[2]	< 49.4× 1.33(4)
				WEB2	-67.62	-9.76	0.14	6.87	0.980	0.015	65.33(3)[2]	< 58.6× 1.82(4)
				RIB1	-68.21	-68.21	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.81(4)
				WEB3	-8.58	63.03	-7.34	416.4	1.213	0.015	80.87(1)	<1402.× 5.11(4)
				RIB2	-9.17	-9.17	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 4.94(4)
			9343	FLS1	-257.7	-257.7	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.932(4)
				FLS2	-257.7	-257.7	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.932(4)
				WEB1	-257.7	-123.1	0.48	5.37	0.973	0.015	64.83(4)	beff= 0.753(4)
				WEB2	-120.4	15.25	-0.13	8.76	0.980	0.015	65.33(3)[2]	< 66.9× 1.36(4)
				RIB1	-121.8	-121.8	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.36(4)
			9343	FLS1	-165.1	-165.1	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.16(4)
				FLS2	-165.1	-165.1	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.16(4)
				WEB1	-165.1	-86.39	0.52	5.21	0.973	0.015	64.83(4)	beff= 0.877(4)
				WEB2	-84.77	-5.49	0.06	7.36	0.980	0.015	65.33(3)[2]	< 60.8× 1.62(4)
				RIB1	-85.58	-85.58	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.62(4)
				WEB3	-3.87	94.26	-24.3	3842.	1.213	0.015	80.87(1)	<7754.× 7.60(4)
				RIB2	-4.68	-4.68	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 6.91(4)

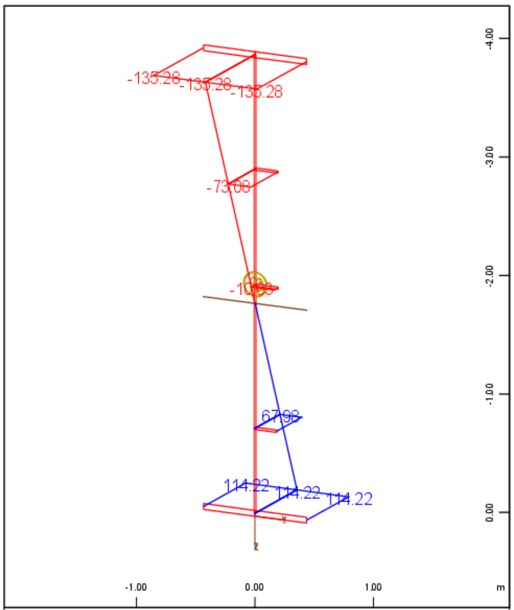
[1] indice di calssificazione (es. 1,5 = classe della sezione SCl tra 1 e 2)
[2] I bassi valori di tensione consentono di trattare la sezione in classe 4 come in classe 3 (EN 1993-1-1 5.5.2 (9))

σ-a,σ-e	tensione nel punto finale	t[m]	spessore del pannello
ψ	distribuzione della tensione	c/t	rapporto c/T o D/t esistente (classe della sezione)
k-σ	fattore d'instabilità	c/t-lim	limite del rapporto c/t (valore base * fattore tendione)
c[m]	lunghezza o diametro del tubo		

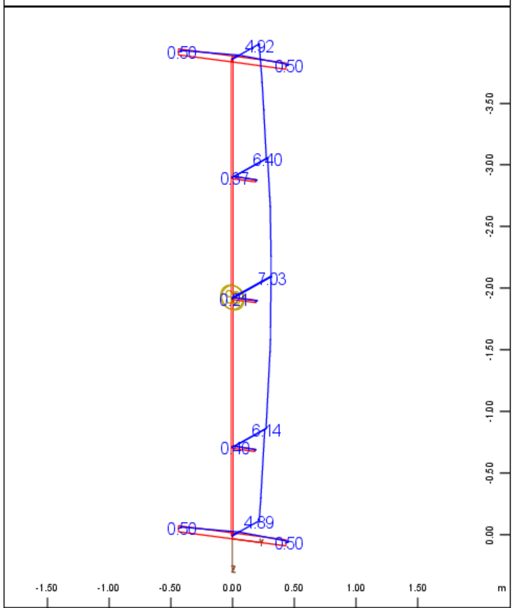
Rigidezza non salvata nel database



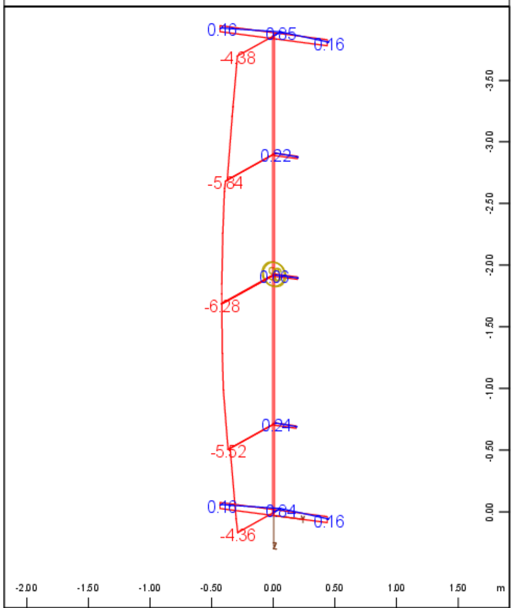
Axial stress in cross section from stresses of beams (AQB) [MPa] M 1 : 51
LC: 9340 BEAM: 10070 X: 0.950001 Sezione numero 4



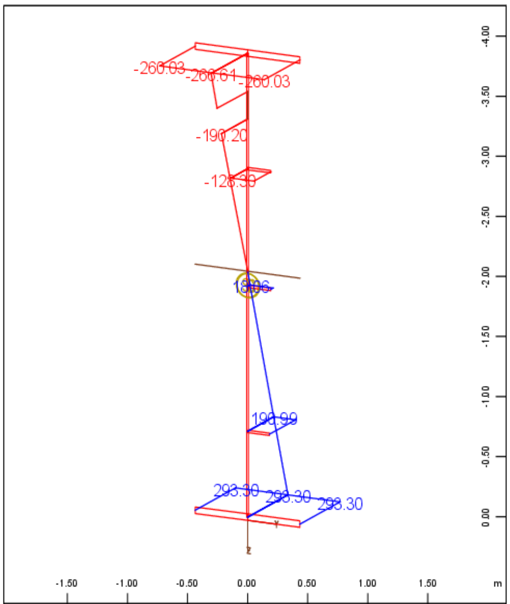
Axial stress in cross section from stresses of beams (AQB) [MPa] M 1 : 52
LC: 9341 BEAM: 10070 X: 0.950001 Sezione numero 4



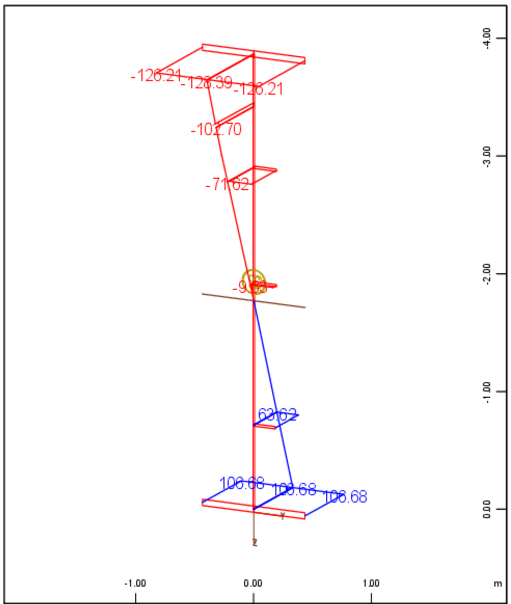
Shear stress in cross section from stresses of beams (AQB) [MPa] M 1 : 50
LC: 9342 BEAM: 10070 X: 0.950001 Sezione numero 4



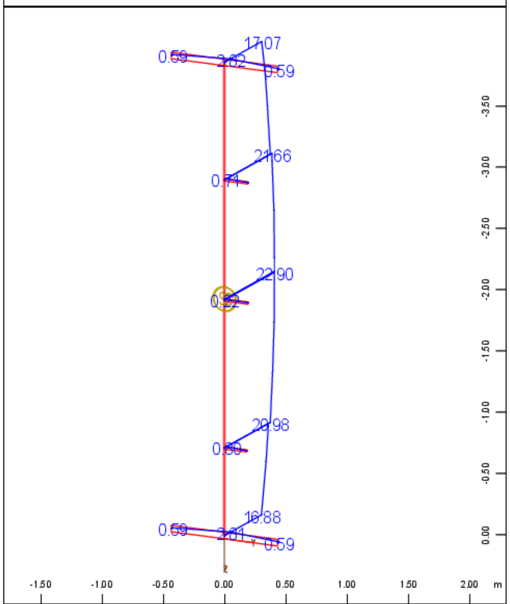
Shear stress in cross section from stresses of beams (AQB) [MPa] M 1 : 50
LC: 9343 BEAM: 10070 X: 0.950001 Sezione numero 4



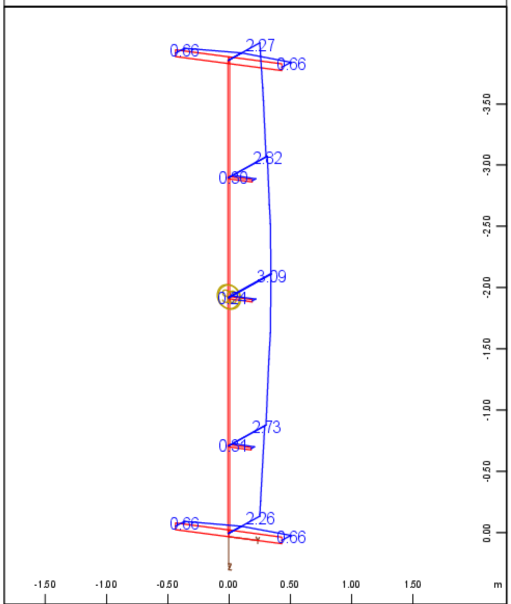
Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9340 BEAM: 10071 X: 0 Sezione numero 5
M 1 : 51



Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9341 BEAM: 10071 X: 0 Sezione numero 5
M 1 : 52



Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9342 BEAM: 10071 X: 0 Sezione numero 5
M 1 : 50



Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9343 BEAM: 10071 X: 0 Sezione numero 5
M 1 : 50

1.5 Sez 4 - x = 28.80 m (sezione di mezzeria)

IV35
Verifiche Tensioni SLU Sezione X=28.8

Sezioni e loro proprietà.

Be�m	x[m]	Sezione	A[m2]	yc[m]	zc[m]	Iyz[m4]	Iy[m4]	Iz[m4]	ycr[m]	zcr[m]
10077	0.000	lorda	1.761E-01	0.007	-1.995	0.00E+00	4.936E-01	8.027E-03	0.007	-1.995

A[m2] area della sezione — Iyz[m4],Iy[m4],Iz[m4] momento d'inerzia flessionale
yc[m],zc[m] coordinate del baricentro — ycr[m],zcr[m] punto di riferimento per forze e momenti

Tensioni non line�ri.
Tensioni non line�ri.

Be�m	x[m]	Sez.C�so		Ni [kN]	Myi [kNm]	Mzi [kNm]	xc [m]	ε [o/oo]	σ-c [MP�]	σ-s [MP�]	σ-t [MP�]	Ey-eff [MP�]
10077	0.000	5	9340	3443.8	71037.52	0.00	1.894	1.516	303.11			197323
					Vz-i	-509.35	fac	1.07			G-eff	75234
					Mt-i	14.01	fac	1.05			G-eff	77022
			9341	-1757.5	30428.16	0.00	2.170	-0.662	-132.4			199545
					Vz-i	-112.50	fac	1.04			G-eff	76922
					Mt-i	0.23	fac	1.05			G-eff	76924
			9342	-711.5	40886.15	0.00	2.054	-0.838	-167.6			200317
					Vz-i	211.94	fac	1.05			G-eff	76844
					Mt-i	25.62	fac	1.03			G-eff	76890
			9343	3162.7	70243.74	0.00	1.906	1.492	298.42			197119
					Vz-i	-592.37	fac	1.07			G-eff	75416

Ni,Myi,Mzi forze interne (integrale delle tensioni non lineari) — σ-s tensione nell'armatura
xc altezza della zona compressa — σ-t tensione nei cavi
ε factor on shear strain or stresses — Ey-eff modulo elastico effettivo riferito alla lsezione lorda
σ-c tensione nella sezione

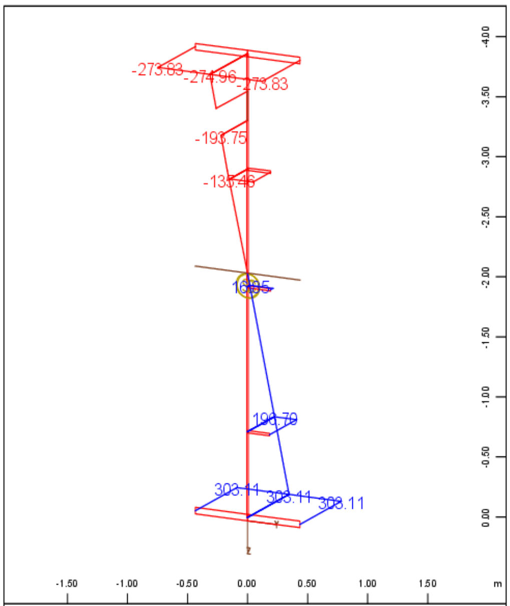
Snellezz� c/t.

Be�m	x[m]	Sez.C�so		Pi�st	σ-�	σ-e	ψ	k-σ	c[m]	t[m]	c/t	c/t-lim
10077	0.000	5	max	4.41[1]	c/t-lim(1:4) = 27.24			31.36	41.87	46.00	**64.83(4)**	45.997(4)
			9343	FLS1	-272.3	-272.3	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.907(4)
				FLS2	-272.3	-272.3	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.907(4)
				WEB1	-272.3	-130.5	0.48	5.36	0.973	0.015	64.83(4)	beff= 0.737(4)
				WEB2	-127.6	15.39	-0.12	8.71	0.980	0.015	65.33(3)[2]	< 66.7× 1.32(4)
				RIB1	-129.0	-129.0	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.32(4)
			9343	FLS1	-132.4	-132.4	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.30(4)
				FLS2	-132.4	-132.4	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.30(4)
				WEB1	-132.4	-72.27	0.55	5.14	0.973	0.015	64.83(4)	beff= 0.939(4)
				WEB2	-71.03	-10.48	0.15	6.85	0.980	0.015	65.33(3)[2]	< 58.5× 1.78(4)
				RIB1	-71.65	-71.65	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.77(4)
				WEB3	-9.25	65.70	-7.10	392.8	1.213	0.015	80.87(1)	<1339.× 4.92(4)
				RIB2	-9.86	-9.86	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 4.76(4)
			9343	FLS1	-167.6	-167.6	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.16(4)
				FLS2	-167.6	-167.6	1.00	0.44	0.465	0.055	8.45(3)	< 14.0× 1.16(4)
				WEB1	-167.6	-87.15	0.52	5.22	0.973	0.015	64.83(4)	beff= 0.873(4)
				WEB2	-85.49	-4.45	0.05	7.44	0.980	0.015	65.33(3)[2]	< 61.2× 1.62(4)
				RIB1	-86.32	-86.32	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.61(4)
				WEB3	-2.80	97.52	-34.9	7695.	1.213	0.015	80.87(1)	<*****× 8.95(4)
				RIB2	-3.62	-3.62	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 7.86(4)
			9343	FLS1	-271.2	-271.2	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.908(4)
				FLS2	-271.2	-271.2	1.00	0.44	0.465	0.055	8.45(3)	< 14.0×0.908(4)
				WEB1	-271.2	-130.8	0.48	5.35	0.973	0.015	64.83(4)	beff= 0.737(4)
				WEB2	-127.9	13.63	-0.11	8.59	0.980	0.015	65.33(3)[2]	< 66.2× 1.32(4)
				RIB1	-129.3	-129.3	1.00	0.44	0.200	0.020	10.00(3)	< 14.0× 1.32(4)

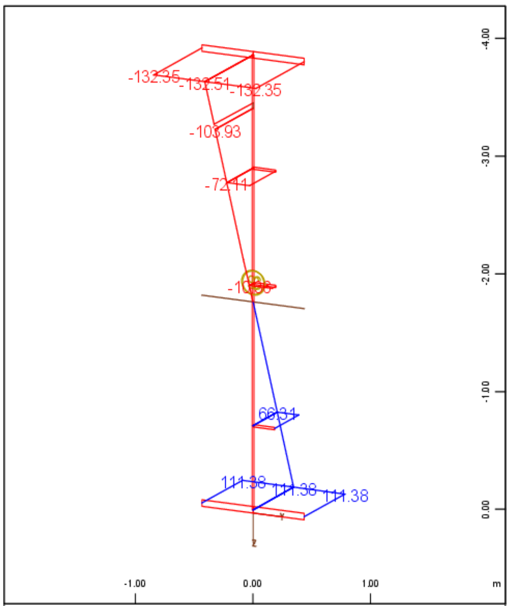
[1] indice di calssificazione (es. 1,5 = classe della sezione SCl tra 1 e 2)
[2] I bassi valori di tensione consentono di trattare la sezione in classe 4 come in classe 3 (EN 1993-1-1 5.5.2 (9))

σ-a,σ-e tensione nel punto finale — t[m] spessore del pannello
ψ distribuzione della tensione — c/t rapporto c/T o D/t esistente (classe della sezione)
k-σ fattore d'instabilità — c/t-lim limite del rapporto c/t (valore base * fattore tendione)
c[m] lunghezza o diametro del tubo

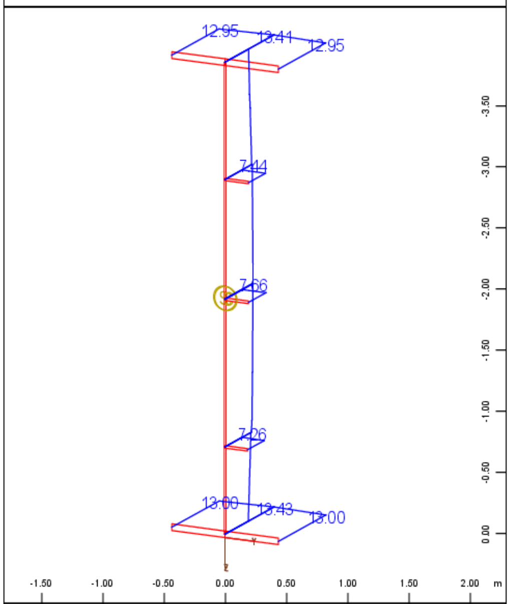
Rigidezza non salvata nel database



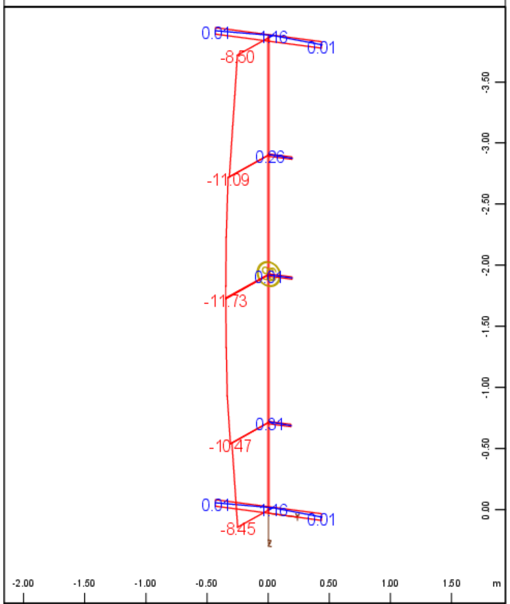
Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9340 BEAM: 10077 X: 0 Sezione numero 5 M 1 : 51



Axial stress in cross section from stresses of beams (AQB) [MPa]
LC: 9341 BEAM: 10077 X: 0 Sezione numero 5 M 1 : 52



Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9342 BEAM: 10077 X: 0 Sezione numero 5 M 1 : 50



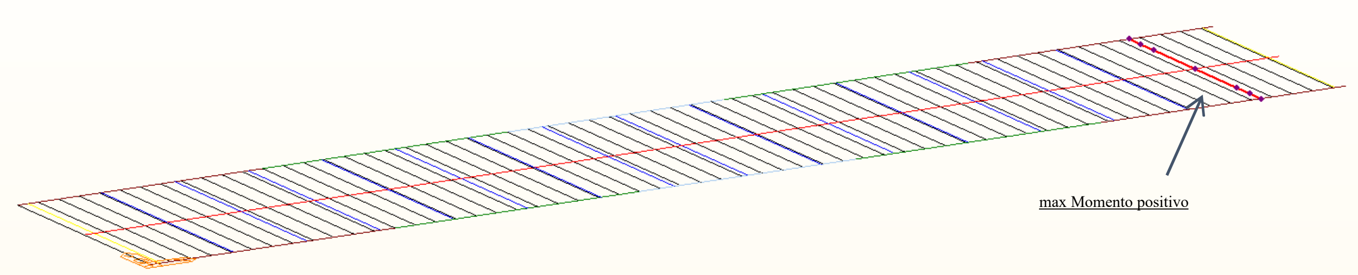
Shear stress in cross section from stresses of beams (AQB) [MPa]
LC: 9343 BEAM: 10077 X: 0 Sezione numero 5 M 1 : 50

2. TRAVERSI SEZIONE COMPOSTA

Il fascicolo delle verifiche riporta appunto le verifiche, e le loro procedure, eseguite automaticamente dal software *Midas Civil* in accordo con la normativa vigente.
Per una lettura più agevole si riporta il sommario delle verifiche effettuate per ciascuna sezione che va a comporre l'intero traverso (in numero 4 come riportato all'interno della figura nel paragrafo precedente "Caratteristiche geometrico-inerziali e classificazione delle sezioni"; la numerazione della sezione risulta essere in accordo con quanto scritto all'inizio del capitolo):

1. Condizioni di progetto;
2. Verifica di resistenza a momento;
3. Verifica di resistenza a taglio;
4. Verifica a buckling;
5. Verifica delle piolature allo SLU;
6. Verifica allo SLE per quanto concerne la limitazione delle tensioni:
   a. della sezione in acciaio;
   b. della soletta in calcestruzzo;
   c. dell'armatura all'interno della soletta.
7. Verifica delle piolature allo SLE.

Per quanto concerne il traverso tipico in campata, si identificano le sezioni più sollecitate (la cui numerazione risulta essere: 133, 209, 281, 450, 471, 547).



Si riportano le schede di verifica:

Element Number	133
Position Information	I

1 **Design Condition**

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

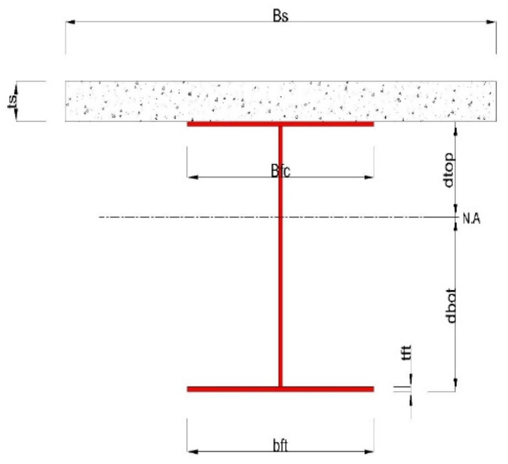
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	1990.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	735.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	26775.000	mm^2
$I_{y,a}$	2700507545.956	mm^4

After

$A_{,c}$	101046.633	mm^2
$I_{y,c}$	8553036434.007	mm^4

$I_{z,a}$	265987968.750	mm^4	$I_{z,c}$	24776245741.881	mm^4
$C_{y,a}$	225.000	mm	$C_{y,c}$	225.000	mm
$C_{z,a}$	355.147	mm	$C_{z,c}$	744.601	mm

Crack

$A_{,c}$	30795.000	mm^2
$I_{y,c}$	3698825679.912	mm^4
$I_{z,c}$	1599730142.226	mm^4
$C_{y,c}$	219.126	mm
$C_{z,c}$	424.315	mm

2 **Bending Resistance**

2.1 Negative Moment

■ Design load

Load combination name : SLU_2

$N_{a,Ed}$	119.782	kN
$N_{c,Ed}$	1364.873	kN
$M_{a,Ed}$	-103.405	kN・m
$M_{c,Ed}$	-836.950	kN・m

- Stress

Top Flange

Left	y_1	-219.126	mm	z_1	345.685	mm	σ_1	158.800	MPa
	y_2	-1.626	mm	z_2	345.685	mm	σ_2	143.281	MPa
Right	y_1	230.874	mm	z_1	345.685	mm	σ_1	126.691	MPa
	y_2	13.374	mm	z_2	345.685	mm	σ_2	142.211	MPa

Bottom Flange

Left	y_1	-219.126	mm	z_1	-424.315	mm	σ_1	-44.915	MPa
	y_2	-1.626	mm	z_2	-424.315	mm	σ_2	-60.435	MPa
Right	y_1	230.874	mm	z_1	-424.315	mm	σ_1	-77.024	MPa
	y_2	13.374	mm	z_2	-424.315	mm	σ_2	-61.505	MPa

Web

Right	y_1	5.874	mm	z_1	330.685	mm	σ_1	138.777	MPa
	y_2	5.874	mm	z_2	-404.315	mm	σ_2	-55.678	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	2
Bottom flange	3
Section	3

- Elastic resistance moment, $M_{el,Rd}$

k = 3.290 : the lowest factor such that a stress limit is reached.

(Calculate minimum value between Steel Girder and Slab Reinforcement.)

$M_{el,Rd}$ = $M_{a,Ed} + k \cdot M_{c,Ed}$ = 2753.287 kN・m

M_{Rd} = $M_{el,Rd}$ = 2753.287 kN・m

M_{Rd} = 2753.287 kN・m > M_{Ed} = -836.950 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_2

N_{Ed} = 927.542 kN

$M_{a,Ed}$ = -103.405 kN・m

$M_{c,Ed}$ = -529.697 kN・m

$V_{Ed,a}$ = -126.958 kN

$V_{Ed,c}$ = -603.717 kN

V_{Ed} = -730.675 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 699.667 kN・m

$M_{Ed,t}$ = 699.667 kN・m

$M_{Ed,b}$ = 648.241 kN・m

- Stress

Top Flange

Left	y_1	-219.126	mm	z_1	345.685	mm	σ_1	96.218	MPa
	y_2	-1.626	mm	z_2	345.685	mm	σ_2	100.218	MPa
Right	y_1	230.874	mm	z_1	345.685	mm	σ_1	104.494	MPa
	y_2	13.374	mm	z_2	345.685	mm	σ_2	100.494	MPa

Bottom Flange

Left	y_1	-219.126	mm	z_1	-424.315	mm	σ_1	-43.535	MPa
	y_2	-1.626	mm	z_2	-424.315	mm	σ_2	-39.535	MPa
Right	y_1	230.874	mm	z_1	-424.315	mm	σ_1	-35.259	MPa
	y_2	13.374	mm	z_2	-424.315	mm	σ_2	-39.259	MPa

Web

Right	y_1	5.874	mm	z_1	330.685	mm	σ_1	97.634	MPa
	y_2	5.874	mm	z_2	-404.315	mm	σ_2	-35.767	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	2
Bottom flange	3
Section	3

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 467.589 mm

N_{slab} = 0.000 kN

$N_{rebar,t}$ = 1573.043 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 3739.728 kN (Upper side of PNA)

$N_{g,bot}$ = 5312.772 kN (Lower side of PNA)

$M_{pl,Rd}$ = 3439.472 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

λ_w = h_w / (86.4・t・ε) = 0.697

X_w = 0.83 / λ_w = 1.191 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2446.072 \text{ kN}$$

V_{Rd} = 2446.072 kN

V_{Edi} = V_{Ed} / Num. of Web = -730.675 kN

η'_3 = V_{Edi} / $V_{bw,Rd}$ = 0.299 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 2487.458 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 2487.458 kN・m

M_{Ed} = 699.667 kN・m (Taken as the greatest value of ($\sum\sigma_i$)W)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

V_{Edi} / ($V_{bw,Rd}$+$V_{bf,Rd}$) = 0.299 < 1.0 … OK

■ Interaction M-V

η'_3 = 0.299 < 0.5

There is no need to verify the interaction criterion

4 Resistance to Lateral Torsional Buckling

- Design load

Load combination name : SLU_2

N_{Ed} = 1496.878 kN

M_{Ed} = -937.624 kN・m

V_1 = -287.114 kN

V_2 = -281.120 kN

M_1 = -937.624 kN・m

M_2 = -653.477 kN・m

$M_{pl,Rd}$ = 3439.472 kN・m

$M_{el,Rd}$ = 2753.287 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 1.000 m

c = C_d / l = 0.000 kN/m^2

γ = c・L^4 / (E・I) = 0.000

μ = V_2 / V_1 = 0.979

Φ = 2・(1-M_2/M_1) / (1+μ) = 0.306

m_1 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu)$ = 1.148

m_2 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5}$ = 1.148

m = $\mathrm{Min}(m_1, m_2)$ = 1.148

α_{LT} = 0.490

λ_{LT} = $1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.104

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.482

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 1$$

M_{Rd} = 2753.287 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 2753.287 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd}$ = $X_{LT} \cdot \mathrm{Area} \cdot f_{yd}$ = 10411.643 kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.484316617$$

5 **Resistance to Longitudinal Shear**

- Design load

Load combination name : SLU_2

$N_{c,el}$ = 0.000 kN

$N_{c,f}$ = 0.000 kN

M_{Ed} = -633.102 kN・m

V_{Ed} = -603.717 kN

$M_{pl,Rd}$ = 3439.472 kN・m

$M_{el,Rd}$ = 2753.287 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $\mathrm{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 734.373 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot \mathrm{Num./Space}$ = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 **Stress Limitation**

- In the structural steel

Characteristic load combination name : CAR_3

$\sigma_{Ed,ser}$ = 62.658 MPa (Bottom-right fiber in the flange)

$\tau_{Ed,ser}$ = 50.087 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

62.658 MPa < 338.095 MPa ... OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

50.087 MPa < 195.199 MPa ... OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

107.015 MPa < 338.095 MPa ... OK

- In the concrete of the slab

Characteristic load combination name : CAR_1

$\sigma_c \leq k_1 f_{ck}$

4.853 MPa < 21.000 MPa ... OK

- In the reinforcement

Load combination name : CAR_1

$\sigma_s \leq k_3 f_{yk}$

110.513 MPa < 202.500 MPa ... OK

7 **Longitudinal Shear for SLS(Serviceability limit state)**

- Shear resistance of a single connector

Load combination name : CAR_2

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 557.320 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot Num./Space$ = 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ ... OK

Element Number	133
Position Information	J

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

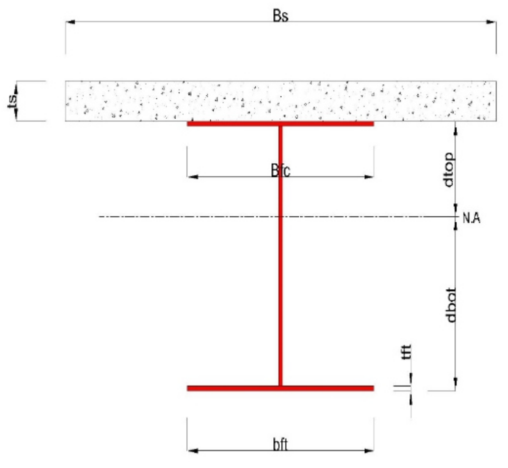
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	1990.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	755.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27075.000	mm^2
$I_{y,a}$	2861139006.666	mm^4

After

$A_{,c}$	101346.633	mm^2
$I_{y,c}$	8981412905.522	mm^4

$I_{z,a}$	265993593.750	mm^4		$I_{z,c}$	24776251366.881	mm^4
$C_{y,a}$	225.000	mm		$C_{y,c}$	225.000	mm
$C_{z,a}$	364.675	mm		$C_{z,c}$	760.651	mm

Crack

$A_{,c}$	31095.000	mm^2
$I_{y,c}$	3885219169.007	mm^4
$I_{z,c}$	1599746019.675	mm^4
$C_{y,c}$	219.182	mm
$C_{z,c}$	434.018	mm

2 **Bending Resistance**

2.1 Positive Moment

■ Design load

Load combination name : SLU_1

$N_{a,Ed}$	119.858	kN
$N_{c,Ed}$	423.451	kN
$M_{a,Ed}$	20.564	kN・m
$M_{c,Ed}$	284.972	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	29.349	mm	σ_1	8.462	MPa
	y_2	-7.500	mm	z_2	29.349	mm	σ_2	4.745	MPa
Right	y_1	225.000	mm	z_1	29.349	mm	σ_1	0.772	MPa
	y_2	7.500	mm	z_2	29.349	mm	σ_2	4.489	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-760.651	mm	σ_1	39.206	MPa
	y_2	-7.500	mm	z_2	-760.651	mm	σ_2	35.489	MPa
Right	y_1	225.000	mm	z_1	-760.651	mm	σ_1	31.516	MPa
	y_2	7.500	mm	z_2	-760.651	mm	σ_2	35.233	MPa

Web

Right	y_1	0.000	mm	z_1	14.349	mm	σ_1	5.201	MPa
	y_2	0.000	mm	z_2	-740.651	mm	σ_2	34.583	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 789.750 mm

N_{slab} = 9077.717 kN

$N_{g,top}$ = 38.106 kN (Upper side of PNA)

$N_{g,bot}$ = 9115.823 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4937.327 kN・m
x_{pl} = 230.250 mm
M_{Rd} = $\beta M_{pl,Rd}$ = 4937.327 kN・m
here, β = 1.000

M_{Rd} = 4937.327 kN・m > M_{Ed} = 305.536 kN・m …OK

2 **Bending Resistance**

2.2 Negative Moment

■ Design load

Load combination name : SLU_2

$N_{a,Ed}$	119.858	kN
$N_{c,Ed}$	1376.479	kN
$M_{a,Ed}$	20.564	kN・m
$M_{c,Ed}$	-675.181	kN・m

- Stress

Top Flange

Left	y_1	-219.182	mm	z_1	355.982	mm	σ_1	108.780	MPa
	y_2	-1.682	mm	z_2	355.982	mm	σ_2	107.687	MPa
Right	y_1	230.818	mm	z_1	355.982	mm	σ_1	106.518	MPa
	y_2	13.318	mm	z_2	355.982	mm	σ_2	107.612	MPa

Bottom Flange

Left	y_1	-219.182	mm	z_1	-434.018	mm	σ_1	-22.830	MPa
	y_2	-1.682	mm	z_2	-434.018	mm	σ_2	-23.923	MPa
Right	y_1	230.818	mm	z_1	-434.018	mm	σ_1	-25.091	MPa
	y_2	13.318	mm	z_2	-434.018	mm	σ_2	-23.998	MPa

Web

Right	y_1	5.818	mm	z_1	340.982	mm	σ_1	105.150	MPa
	y_2	5.818	mm	z_2	-414.018	mm	σ_2	-20.629	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	2
Bottom flange	3
Section	3

- Elastic resistance moment, $M_{el,Rd}$

k = 4.232 : the lowest factor such that a stress limit is reached.
(Calculate minimum value between Steel Girder and Slab Reinforcement.)

$M_{el,Rd}$ = $M_{a,Ed} + k \cdot M_{c,Ed}$ = 2857.536 kN・m

M_{Rd} = $M_{el,Rd}$ = 2857.536 kN・m

M_{Rd} = 2857.536 kN・m > M_{Ed} = -675.181 kN・m …OK

3 **Resistance to Vertical Shear**

■ Design load

Load combination name : SLU_2

N_{Ed} = 927.542 kN

$M_{a,Ed}$ = 20.564 kN・m

$M_{c,Ed}$ = 74.099 kN・m

$V_{Ed,a}$ = -120.964 kN

$V_{Ed,c}$ = -603.717 kN

V_{Ed} = -724.681 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 1009.589 kN・m

$M_{Ed,t}$ = 1009.589 kN・m

$M_{Ed,b}$ = 105.047 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	29.349	mm	σ_1	15.990	MPa
	y_2	-7.500	mm	z_2	29.349	mm	σ_2	10.470	MPa
Right	y_1	225.000	mm	z_1	29.349	mm	σ_1	4.570	MPa
	y_2	7.500	mm	z_2	29.349	mm	σ_2	10.090	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-760.651	mm	σ_1	28.185	MPa
	y_2	-7.500	mm	z_2	-760.651	mm	σ_2	22.666	MPa
Right	y_1	225.000	mm	z_1	-760.651	mm	σ_1	16.766	MPa
	y_2	7.500	mm	z_2	-760.651	mm	σ_2	22.285	MPa

Web

Right	y_1	0.000	mm	z_1	14.349	mm	σ_1	10.512	MPa
	y_2	0.000	mm	z_2	-740.651	mm	σ_2	22.167	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 789.750 mm

N_{slab} = 9077.717 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 38.106 kN (Upper side of PNA)

$N_{g,bot}$ = 9115.823 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4937.327 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

λ_w = h_w / (86.4 · t · ε) = 0.697

X_w = 0.83 / λ_w = 1.191 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2512.631 \text{ kN}$$

V_{Rd} = 2512.631 kN

V_{Edi} = V_{Ed} / Num. of Web = -724.681 kN

η'_3 = V_{Edi} / $V_{bw,Rd}$ = 0.288 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3256.075 kN · m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3256.075 kN · m

M_{Ed} = 1009.589 kN · m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

V_{Edi} / ($V_{bw,Rd}$+$V_{bf,Rd}$) = 0.288 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_2

N_{Ed} = 1496.336 kN

M_{Ed} = -654.617 kN · m

V_1 = -432.254 kN

V_2 = -281.253 kN

M_1 = -940.355 kN · m

M_2 = -654.617 kN · m

$M_{pl,Rd}$ = 3540.020 kN · m

$M_{el,Rd}$ = 2857.536 kN · m

- $M_{b,Rd}$ Buckling resistance moment

L = 1.000 m

c = C_d / l = 0.000 kN/m^2

γ = c · L^4 / (E · I) = 0.000

μ = V_2 / V_1 = 0.651

Φ = 2 · (1-M_2/M_1) / (1+μ) = 0.368

m_1 = 1+0.44 · (1+μ) · $\Phi^{1.5}$+(3+2 · Φ) · γ/(350-50 · μ) = 1.162

m_2 = 1+0.44 · (1+μ) · $\Phi^{1.5}$+(0.195+(0.05+μ/100) · Φ) · $\gamma^{0.5}$ = 1.162

m = Min(m_1, m_2) = 1.162

α_{LT} = 0.490

λ_{LT} = 1.103 · L/b · $\sqrt{(f_y/Em)}$ · $\sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.104

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.482

$X_{LT} = \dfrac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}}$ = 1

M_{Rd} = 2857.536 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 2857.536 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd}$ = $X_{LT} \cdot Area \cdot f_{yd}$ = 10513.071 kN

Combined Ratio $= \dfrac{N_{Ed}}{N_{b,Rd}} + \dfrac{M_{Ed}}{M_{b,Rd}}$ = 0.371415426

5 **Resistance to Longitudinal Shear**

- Design load

Load combination name : SLU_2

$N_{c,el}$ = 4717.685 kN

$N_{c,f}$ = 9077.717 kN

M_{Ed} = 94.663 kN・m

V_{Ed} = -603.717 kN

$M_{pl,Rd}$ = 4937.327 kN・m

$M_{el,Rd}$ = 3981.688 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 719.025 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot$ Num./Space = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 **Stress Limitation**

- In the structural steel

Characteristic load combination name : CAR_1

$\sigma_{Ed,ser}$ = 34.957 MPa (Top-right fiber in the flange)

$\tau_{Ed,ser}$ = 48.368 MPa (Neutral axis in the web)

$\sigma_{Ed,ser} < f_y / \gamma_{M,ser}$

34.957 MPa < 338.095 MPa … OK

$\tau_{Ed,ser} < f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

48.368 MPa < 195.199 MPa ... OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

90.777 MPa < 338.095 MPa ... OK

- In the concrete of the slab

Characteristic load combination name : CAR_1

$\sigma_c \leq k_1 f_{ck}$

5.350 MPa < 21.000 MPa ... OK

- In the reinforcement

Load combination name : CAR_2

$\sigma_s \leq k_3 f_{yk}$

-49.345 MPa

Rebar is under compression. No need to check.

7 **Longitudinal Shear for SLS(Serviceability limit state)**

- Shear resistance of a single connector

Load combination name : CAR_2

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 545.673 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot Num./Space$ = 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ ... OK

Element Number	209
Position Information	I

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

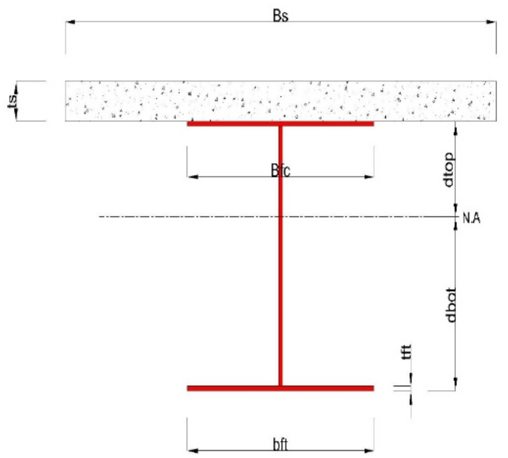
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	755.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27075.000	mm^2
$I_{y,a}$	2861139006.666	mm^4

After

$A_{,c}$	161435.743	mm^2
$I_{y,c}$	10032327520.874	mm^4

$I_{z,a}$	265993593.750	mm^4
$C_{y,a}$	225.000	mm
$C_{z,a}$	364.675	mm

$I_{z,c}$	145375595879.464	mm^4
$C_{y,c}$	225.000	mm
$C_{z,c}$	814.380	mm

Crack

$A_{,c}$	34311.000	mm^2
$I_{y,c}$	4558861068.187	mm^4
$I_{z,c}$	8071144324.544	mm^4
$C_{y,c}$	214.455	mm
$C_{z,c}$	478.626	mm

2 Bending Resistance

2.1 Positive Moment

■ Design load

Load combination name : SLU_1

$N_{a,Ed}$	119.466	kN
$N_{c,Ed}$	540.207	kN
$M_{a,Ed}$	20.714	kN・m
$M_{c,Ed}$	310.710	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-24.380	mm	σ_1	12.420	MPa
	y_2	-7.500	mm	z_2	-24.380	mm	σ_2	5.667	MPa
Right	y_1	225.000	mm	z_1	-24.380	mm	σ_1	-1.551	MPa
	y_2	7.500	mm	z_2	-24.380	mm	σ_2	5.202	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-814.380	mm	σ_1	42.606	MPa
	y_2	-7.500	mm	z_2	-814.380	mm	σ_2	35.854	MPa
Right	y_1	225.000	mm	z_1	-814.380	mm	σ_1	28.635	MPa
	y_2	7.500	mm	z_2	-814.380	mm	σ_2	35.388	MPa

Web

Right	y_1	0.000	mm	z_1	-39.380	mm	σ_1	6.008	MPa
	y_2	0.000	mm	z_2	-794.380	mm	σ_2	34.857	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 891.794 mm

N_{slab} = 9153.929 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9153.929 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5412.007 kN・m
x_{pl} = 128.206 mm
M_{Rd} = $\beta M_{pl,Rd}$ = 5412.007 kN・m
here, β = 1.000

M_{Rd} = 5412.007 kN・m > M_{Ed} = 331.424 kN・m …OK

2 Bending Resistance

2.2 Negative Moment

■ Design load

Load combination name : SLU_2

$N_{a,Ed}$	119.466	kN
$N_{c,Ed}$	1375.405	kN
$M_{a,Ed}$	20.714	kN・m
$M_{c,Ed}$	-601.690	kN・m

- Stress

Top Flange

Left	y_1	-214.455	mm	z_1	311.374	mm	σ_1	88.369	MPa
	y_2	3.045	mm	z_2	311.374	mm	σ_2	82.762	MPa
Right	y_1	235.545	mm	z_1	311.374	mm	σ_1	76.769	MPa
	y_2	18.045	mm	z_2	311.374	mm	σ_2	82.375	MPa

Bottom Flange

Left	y_1	-214.455	mm	z_1	-478.626	mm	σ_1	-10.178	MPa
	y_2	3.045	mm	z_2	-478.626	mm	σ_2	-15.785	MPa
Right	y_1	235.545	mm	z_1	-478.626	mm	σ_1	-21.778	MPa
	y_2	18.045	mm	z_2	-478.626	mm	σ_2	-16.171	MPa

Web

Right	y_1	10.545	mm	z_1	296.374	mm	σ_1	80.698	MPa
	y_2	10.545	mm	z_2	-458.626	mm	σ_2	-13.483	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	3
Bottom flange	3
Section	3

- Elastic resistance moment, $M_{el,Rd}$

k = 5.394 : the lowest factor such that a stress limit is reached.
(Calculate minimum value between Steel Girder and Slab Reinforcement.)

$M_{el,Rd}$ = $M_{a,Ed} + k \cdot M_{c,Ed}$ = 3224.753 kN・m

M_{Rd} = $M_{el,Rd}$ = 3224.753 kN・m

M_{Rd} = 3224.753 kN・m > M_{Ed} = -580.977 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_2

N_{Ed} = 923.590 kN

$M_{a,Ed}$ = 20.714 kN・m

$M_{c,Ed}$ = 123.842 kN・m

$V_{Ed,a}$ = -121.351 kN

$V_{Ed,c}$ = -609.746 kN

V_{Ed} = -731.097 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 1143.247 kN・m

$M_{Ed,t}$ = 1143.247 kN・m

$M_{Ed,b}$ = 156.365 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-24.380	mm	σ_1	14.090	MPa
	y_2	-7.500	mm	z_2	-24.380	mm	σ_2	7.580	MPa
Right	y_1	225.000	mm	z_1	-24.380	mm	σ_1	0.620	MPa
	y_2	7.500	mm	z_2	-24.380	mm	σ_2	7.131	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-814.380	mm	σ_1	29.561	MPa
	y_2	-7.500	mm	z_2	-814.380	mm	σ_2	23.051	MPa
Right	y_1	225.000	mm	z_1	-814.380	mm	σ_1	16.092	MPa
	y_2	7.500	mm	z_2	-814.380	mm	σ_2	22.602	MPa

Web

Right	y_1	0.000	mm	z_1	-39.380	mm	σ_1	7.649	MPa
	y_2	0.000	mm	z_2	-794.380	mm	σ_2	22.435	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 891.794 mm

N_{slab} = 9153.929 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9153.929 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5412.007 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

$\lambda_w = h_w / (86.4 \cdot t \cdot \varepsilon) = 0.716$

$X_w = 0.83 / \lambda_w = 1.159$ $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2446.072 \text{ kN}$$

$V_{Rd} = 2446.072$ kN

$V_{Edi} = V_{Ed}$ / Num. of Web $= -731.097$ kN

$\eta'_3 = V_{Edi} / V_{bw,Rd} = 0.299 \leq 1.0$

■ Contribution from the flange

$M_{f,Rd} = 3416.726$ kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd} = 3416.726$ kN・m

$M_{Ed} = 1143.247$ kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

$V_{Edi} / (V_{bw,Rd} + V_{bf,Rd}) = 0.299 < 1.0$ … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_2

$N_{Ed} = 1494.871$ kN

$M_{Ed} = -580.977$ kN・m

$V_1 = -290.602$ kN

$V_2 = -281.783$ kN

$M_1 = -580.977$ kN・m

$M_2 = -258.773$ kN・m

$M_{pl,Rd} = 4006.034$ kN・m

$M_{el,Rd} = 3224.753$ kN・m

- $M_{b,Rd}$ Buckling resistance moment

$L = 1.125$ m

$c = C_d / l = 0.000$ kN/m^2

$\gamma = c \cdot L^4 / (E \cdot I) = 0.000$

$\mu = V_2 / V_1 = 0.970$

$\Phi = 2 \cdot (1 - M_2/M_1) / (1+\mu) = 0.563$

$m_1 = 1 + 0.44 \cdot (1+\mu) \cdot \Phi^{1.5} + (3 + 2 \cdot \Phi) \cdot \gamma / (350 - 50 \cdot \mu) = 1.366$

$m_2 = 1 + 0.44 \cdot (1+\mu) \cdot \Phi^{1.5} + (0.195 + (0.05 + \mu/100) \cdot \Phi) \cdot \gamma^{0.5} = 1.366$

$m = \mathrm{Min}(m_1, m_2) = 1.366$

$\alpha_{LT} = 0.490$

$\lambda_{LT} = 1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1 + A_{wc}/(3 \cdot A_f))} = 0.109$

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.484

$X_{LT} = \dfrac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}}$ = 1

M_{Rd} = 3224.753 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 3224.753 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd}$ = $X_{LT} \cdot Area \cdot f_{yd}$ = 11600.386 kN

Combined Ratio $= \dfrac{N_{Ed}}{N_{b,Rd}} + \dfrac{M_{Ed}}{M_{b,Rd}}$ = 0.309025498

5 **Resistance to Longitudinal Shear**

- Design load

Load combination name : SLU_2

$N_{c,el}$ = 5004.049 kN

$N_{c,f}$ = 9153.929 kN

M_{Ed} = 144.555 kN・m

V_{Ed} = -609.746 kN

$M_{pl,Rd}$ = 5412.007 kN・m

$M_{el,Rd}$ = 4153.177 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 740.020 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot$ Num./Space = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 **Stress Limitation**

- In the structural steel

Characteristic load combination name : CAR_1

$\sigma_{Ed,ser}$ = 38.652 MPa (Top-right fiber in the flange)

$\tau_{Ed,ser}$ = 48.867 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

38.652 MPa < 338.095 MPa … OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

48.867 MPa < 195.199 MPa … OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

93.047 MPa < 338.095 MPa … OK

- In the concrete of the slab

Characteristic load combination name : CAR_1

$\sigma_c \leq k_1 f_{ck}$

1.960 MPa < 21.000 MPa … OK

- In the reinforcement

Load combination name : CAR_2

$\sigma_s \leq k_3 f_{yk}$

-21.108 MPa

Rebar is under compression. No need to check.

7 **Longitudinal Shear for SLS(Serviceability limit state)**

- Shear resistance of a single connector

Load combination name : CAR_2

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = \mathrm{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 562.559 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot$ Num./Space = 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

Element Number	209
Position Information	J

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

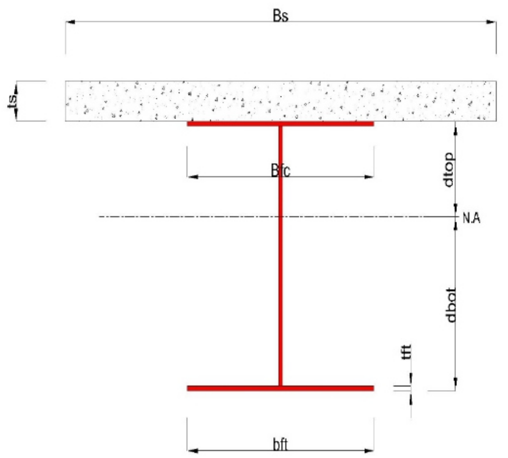
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	784.189	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27512.838	mm^2
$I_{y,a}$	3105288005.288	mm^4

After

$A_{,c}$	161873.581	mm^2
$I_{y,c}$	10746839769.980	mm^4

$I_{z,a}$	266001803.209	mm^4
$C_{y,a}$	225.000	mm
$C_{z,a}$	378.598	mm

$I_{z,c}$	145375604088.924	mm^4
$C_{y,c}$	225.000	mm
$C_{z,c}$	839.758	mm

Crack

$A_{,c}$	34748.838	mm^2
$I_{y,c}$	4803849451.675	mm^4
$I_{z,c}$	8071200604.295	mm^4
$C_{y,c}$	214.588	mm
$C_{z,c}$	490.953	mm

2 Bending Resistance

2.1 Positive Moment

■ Design load

Load combination name : SLU_1

$N_{a,Ed}$	119.585	kN
$N_{c,Ed}$	680.951	kN
$M_{a,Ed}$	153.430	kN・m
$M_{c,Ed}$	898.782	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-8.011	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-11.380	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-14.981	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-11.612	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	100.975	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	97.606	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	94.005	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	97.374	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-9.500	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	94.829	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m
x_{pl} = 130.280 mm
M_{Rd} = $\beta M_{pl,Rd}$ = 5631.885 kN・m
here, β = 1.000

M_{Rd} = 5631.885 kN・m > M_{Ed} = 1052.212 kN・m …OK

2 **Bending Resistance**

2.2 Negative Moment

■ Design load

Load combination name : SLU_2

$N_{a,Ed}$	119.585	kN
$N_{c,Ed}$	1375.447	kN
$M_{a,Ed}$	153.430	kN・m
$M_{c,Ed}$	-412.203	kN・m

- Stress

Top Flange

Left	y_1	-214.588	mm	z_1	328.236	mm	σ_1	52.403	MPa
	y_2	2.912	mm	z_2	328.236	mm	σ_2	50.450	MPa
Right	y_1	235.412	mm	z_1	328.236	mm	σ_1	48.363	MPa
	y_2	17.912	mm	z_2	328.236	mm	σ_2	50.315	MPa

Bottom Flange

Left	y_1	-214.588	mm	z_1	-490.953	mm	σ_1	22.587	MPa
	y_2	2.912	mm	z_2	-490.953	mm	σ_2	20.634	MPa
Right	y_1	235.412	mm	z_1	-490.953	mm	σ_1	18.546	MPa
	y_2	17.912	mm	z_2	-490.953	mm	σ_2	20.499	MPa

Web

Right	y_1	10.412	mm	z_1	313.236	mm	σ_1	49.837	MPa
	y_2	10.412	mm	z_2	-470.953	mm	σ_2	21.294	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 616.254 mm

N_{slab} = 0.000 kN
$N_{rebar,t}$ = 2831.478 kN (Upper side of PNA)
$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)
$N_{g,top}$ = 3235.241 kN (Upper side of PNA)
$N_{g,bot}$ = 6066.719 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4136.627 kN・m

M_{Rd} = $M_{pl,Rd}$ = 4136.627 kN・m

M_{Rd} = 4136.627 kN・m > M_{Ed} = -258.773 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_2

N_{Ed} = 923.636 kN

$M_{a,Ed}$ = 153.430 kN・m

$M_{c,Ed}$ = 809.013 kN・m

$V_{Ed,a}$ = -114.561 kN

$V_{Ed,c}$ = -607.721 kN

V_{Ed} = -722.282 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 10564.984 kN・m

$M_{Ed,t}$ = 10564.984 kN・m

$M_{Ed,b}$ = 1048.407 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-7.145	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-10.068	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-13.192	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-10.269	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	94.998	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	92.076	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	88.952	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	91.874	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-8.298	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	89.481	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

$\lambda_w = h_w / (86.4 \cdot t \cdot \varepsilon)$ = 0.716

$X_w = 0.83 / \lambda_w$ = 1.159 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2540.640 \text{ kN}$$

V_{Rd} = 2540.640 kN

$V_{Edi} = V_{Ed}$ / Num. of Web = -722.282 kN

$\eta'_3 = V_{Edi} / V_{bw,Rd}$ = 0.284 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3505.544 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3505.544 kN・m

M_{Ed} = 10564.984 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

$V_{Edi} / (V_{bw,Rd} + V_{bf,Rd})$ = 0.284 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_1

N_{Ed} = 800.536 kN

M_{Ed} = 1052.212 kN・m

V_1 = -642.541 kN

V_2 = -673.104 kN

M_1 = 1052.212 kN・m

M_2 = 331.424 kN・m

$M_{pl,Rd}$ = 5631.885 kN・m

$M_{el,Rd}$ = 4240.824 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 1.125 m

c = C_d / l = 0.000 kN/m^2

$\gamma = c \cdot L^4 / (E \cdot I)$ = 0.000

$\mu = V_2 / V_1$ = 0.955

$\Phi = 2 \cdot (1 - M_2/M_1) / (1+\mu)$ = 0.701

m_1 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu)$ = 1.505

m_2 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5}$ = 1.505

m = Min(m_1, m_2) = 1.505

α_{LT} = 0.490

λ_{LT} = $1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.092

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.478

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 1$$

M_{Rd} = 5631.885 kN · m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 5631.885 kN · m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd}$ = $X_{LT} \cdot$ Area $\cdot f_{yd}$ = 54728.687 kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.201458555$$

5 Resistance to Longitudinal Shear

- Design load

Load combination name : SLU_2

$N_{c,el}$ = 4814.714 kN

$N_{c,f}$ = 9301.959 kN

M_{Ed} = 962.443 kN · m

V_{Ed} = -607.721 kN

$M_{pl,Rd}$ = 5631.885 kN · m

$M_{el,Rd}$ = 4240.824 kN · m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = Min($P_{Rd,1}$, $P_{Rd,2}$) = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 717.482 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot$ Num./Space = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 Stress Limitation

- In the structural steel

Characteristic load combination name : CAR_1

$\sigma_{Ed,ser}$ = -80.617 MPa (Bottom-left fiber in the flange)

$\tau_{Ed,ser}$ = 46.493 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

-80.617 MPa < 338.095 MPa … OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

46.493 MPa < 195.199 MPa … OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

113.946 MPa < 338.095 MPa … OK

- In the concrete of the slab

Characteristic load combination name : CAR_4

$\sigma_c \leq k_1 f_{ck}$

2.838 MPa < 21.000 MPa … OK

- In the reinforcement

Load combination name : CAR_2

$\sigma_s \leq k_3 f_{yk}$

-23.319 MPa

Rebar is under compression. No need to check.

7 Longitudinal Shear for SLS(Serviceability limit state)

- Shear resistance of a single connector

Load combination name : CAR_2

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 545.471 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot Num./Space$ = 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

Element Number	281
Position Information	I

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

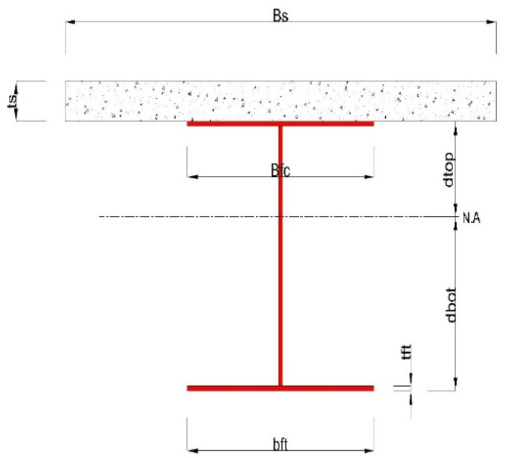
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	784.189	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27512.838	mm^2
$I_{y,a}$	3105288005.288	mm^4

After

$A_{,c}$	161873.581	mm^2
$I_{y,c}$	10746839769.980	mm^4

$I_{z,a}$	266001803.209	mm^4	$I_{z,c}$	145375604088.924	mm^4
$C_{y,a}$	225.000	mm	$C_{y,c}$	225.000	mm
$C_{z,a}$	378.598	mm	$C_{z,c}$	839.758	mm

Crack

$A_{,c}$	34748.838	mm^2
$I_{y,c}$	4904473180.082	mm^4
$I_{z,c}$	8071200604.295	mm^4
$C_{y,c}$	214.588	mm
$C_{z,c}$	494.293	mm

2 **Bending Resistance**

2.1 Positive Moment

■ Design load

Load combination name : SLU_1

$N_{a,Ed}$	119.621	kN
$N_{c,Ed}$	681.014	kN
$M_{a,Ed}$	153.360	kN・m
$M_{c,Ed}$	898.775	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-7.999	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-11.368	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-14.969	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-11.600	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	100.968	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	97.599	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	93.998	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	97.367	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-9.489	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	94.823	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m

x_{pl} = 130.280 mm

M_{Rd} = $\beta M_{pl,Rd}$ = 5631.885 kN・m

here, β = 1.000

M_{Rd} = 5631.885 kN・m > M_{Ed} = 1052.135 kN・m …OK

2 Bending Resistance

2.2 Negative Moment

■ Design load

Load combination name : SLU_2

$N_{a,Ed}$	119.621	kN
$N_{c,Ed}$	1375.466	kN
$M_{a,Ed}$	153.360	kN・m
$M_{c,Ed}$	-412.219	kN・m

- Stress

Top Flange

Left	y_1	-214.588	mm	z_1	324.896	mm	σ_1	51.558	MPa
	y_2	2.912	mm	z_2	324.896	mm	σ_2	49.604	MPa
Right	y_1	235.412	mm	z_1	324.896	mm	σ_1	47.517	MPa
	y_2	17.912	mm	z_2	324.896	mm	σ_2	49.470	MPa

Bottom Flange

Left	y_1	-214.588	mm	z_1	-494.293	mm	σ_1	23.162	MPa
	y_2	2.912	mm	z_2	-494.293	mm	σ_2	21.209	MPa
Right	y_1	235.412	mm	z_1	-494.293	mm	σ_1	19.121	MPa
	y_2	17.912	mm	z_2	-494.293	mm	σ_2	21.074	MPa

Web

Right	y_1	10.412	mm	z_1	309.896	mm	σ_1	49.017	MPa
	y_2	10.412	mm	z_2	-474.293	mm	σ_2	21.835	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 616.254 mm

N_{slab} = 0.000 kN

$N_{rebar,t}$ = 2831.478 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 3235.241 kN (Upper side of PNA)

$N_{g,bot}$ = 6066.719 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4182.037 kN・m

M_{Rd} = $M_{pl,Rd}$ = 4182.037 kN・m

M_{Rd} = 4182.037 kN・m > M_{Ed} = -258.859 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_2

N_{Ed} = 923.704 kN

$M_{a,Ed}$ = 153.360 kN・m

$M_{c,Ed}$ = 809.003 kN・m

$V_{Ed,a}$ = -114.523 kN

$V_{Ed,c}$ = -607.619 kN

V_{Ed} = -722.142 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 10559.800 kN・m

$M_{Ed,t}$ = 10559.800 kN・m

$M_{Ed,b}$ = 1048.288 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-7.133	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-10.056	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-13.180	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-10.258	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	94.991	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	92.068	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	88.944	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	91.867	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-8.287	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	89.474	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

$\lambda_w = h_w / (86.4 \cdot t \cdot \varepsilon)$ = 0.744

$X_w = 0.83 / \lambda_w$ = 1.116 $0.83/\eta \le \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2446.072 \text{ kN}$$

V_{Rd} = 2446.072 kN

V_{Edi} = V_{Ed} / Num. of Web = -722.142 kN

$\eta'_3 = V_{Edi} / V_{bw,Rd}$ = 0.295 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3505.544 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3505.544 kN・m

M_{Ed} = 10559.800 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

$V_{Edi} / (V_{bw,Rd}+V_{bf,Rd})$ = 0.295 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 Resistance to Lateral Torsional Buckling

- Design load

Load combination name : SLU_1

N_{Ed} = 800.635 kN

M_{Ed} = 1052.135 kN・m

V_1 = -672.991 kN

V_2 = -638.738 kN

M_1 = 3394.058 kN・m

M_2 = 1052.135 kN・m

$M_{pl,Rd}$ = 5631.885 kN・m

$M_{el,Rd}$ = 4240.863 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 3.500 m

$c = C_d / l$ = 0.000 kN/m^2

$\gamma = c \cdot L^4 / (E \cdot I)$ = 0.000

$\mu = V_2 / V_1$ = 0.949

$\Phi = 2 \cdot (1-M_2/M_1) / (1+\mu)$ = 0.708

m_1 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu)$ = 1.511

m_2 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5}$ = 1.511

m = $Min(m_1, m_2)$ = 1.511

α_{LT} = 0.490

λ_{LT} = $1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.287

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.562

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 0.955796579$$

M_{Rd} = 5631.885 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 5382.936 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 0.922

$N_{b,Rd}$ = $X_{LT} \cdot Area \cdot f_{yd}$ = 50462.939 kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.211323248$$

5 **Resistance to Longitudinal Shear**

- Design load

Load combination name : SLU_2

$N_{c,el}$ = 4814.843 kN

$N_{c,f}$ = 9301.959 kN

M_{Ed} = 962.363 kN・m

V_{Ed} = -607.619 kN

$M_{pl,Rd}$ = 5631.885 kN・m

$M_{el,Rd}$ = 4240.863 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $Min(P_{Rd,1} , P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 2

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 717.361 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot Num./Space$ = 1094.782 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 **Stress Limitation**

- In the structural steel

Characteristic load combination name : CAR_1

$\sigma_{Ed,ser}$ = -80.590 MPa (Bottom-left fiber in the flange)

$\tau_{Ed,ser}$ = 46.482 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

-80.590 MPa < 338.095 MPa … OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

46.482 MPa < 195.199 MPa … OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

113.915 MPa < 338.095 MPa … OK

- In the concrete of the slab

Characteristic load combination name : CAR_4

$\sigma_c \leq k_1 f_{ck}$

2.841 MPa < 21.000 MPa … OK

- In the reinforcement

Load combination name : CAR_2

$\sigma_s \leq k_3 f_{yk}$

-24.628 MPa

Rebar is under compression. No need to check.

7 Longitudinal Shear for SLS(Serviceability limit state)

- Shear resistance of a single connector

Load combination name : CAR_2

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = \mathrm{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 2

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 545.364 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot$ Num./Space = 821.087 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

Element Number	281
Position Information	J

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

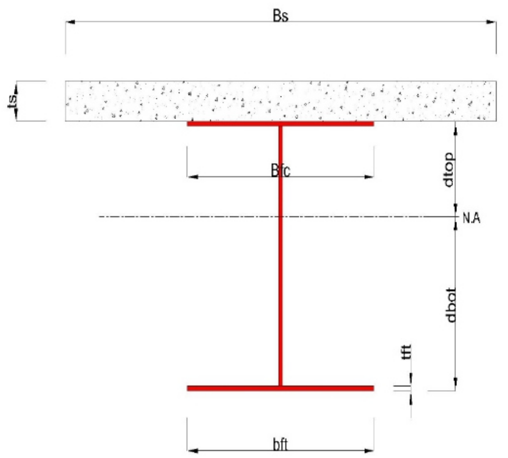
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	875.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	28875.000	mm^2
$I_{y,a}$	3940507315.341	mm^4

After

$A_{,c}$	163235.743	mm^2
$I_{y,c}$	13173501310.263	mm^4

$I_{z,a}$	266027343.750	mm^4
$C_{y,a}$	225.000	mm
$C_{z,a}$	422.045	mm

$I_{z,c}$	145375629629.464	mm^4
$C_{y,c}$	225.000	mm
$C_{z,c}$	918.343	mm

Crack

$A_{,c}$	36111.000	mm^2
$I_{y,c}$	5964320128.160	mm^4
$I_{z,c}$	8071368242.237	mm^4
$C_{y,c}$	214.981	mm
$C_{z,c}$	539.653	mm

2 **Bending Resistance**

2.1 Positive Moment

■ Design load

Load combination name : SLU_4

$N_{a,Ed}$	119.991	kN
$N_{c,Ed}$	758.165	kN
$M_{a,Ed}$	516.781	kN・m
$M_{c,Ed}$	2877.290	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-8.343	mm	σ_1	-61.889	MPa
	y_2	-7.500	mm	z_2	-8.343	mm	σ_2	-53.655	MPa
Right	y_1	225.000	mm	z_1	-8.343	mm	σ_1	-44.853	MPa
	y_2	7.500	mm	z_2	-8.343	mm	σ_2	-53.087	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-918.343	mm	σ_1	256.212	MPa
	y_2	-7.500	mm	z_2	-918.343	mm	σ_2	264.445	MPa
Right	y_1	225.000	mm	z_1	-918.343	mm	σ_1	273.247	MPa
	y_2	7.500	mm	z_2	-918.343	mm	σ_2	265.013	MPa

Web

Right	y_1	0.000	mm	z_1	-23.343	mm	σ_1	-48.128	MPa
	y_2	0.000	mm	z_2	-898.343	mm	σ_2	257.738	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 1003.270 mm

N_{slab} = 9762.500 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9762.500 kN (Lower side of PNA)

$M_{pl,Rd}$ = 6341.619 kN・m
x_{pl} = 136.730 mm
M_{Rd} = $\beta M_{pl,Rd}$ = 6341.619 kN・m
here, β = 1.000

M_{Rd} = 6341.619 kN・m > M_{Ed} = 3394.071 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_2

N_{Ed} = 924.735 kN
$M_{a,Ed}$ = 516.781 kN・m
$M_{c,Ed}$ = 2855.833 kN・m
$V_{Ed,a}$ = -93.039 kN
$V_{Ed,c}$ = -561.703 kN
V_{Ed} = -654.742 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 98194.461 kN・m
$M_{Ed,t}$ = 98194.461 kN・m
$M_{Ed,b}$ = 3649.814 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-8.343	mm	σ_1	-60.886	MPa
	y_2	-7.500	mm	z_2	-8.343	mm	σ_2	-52.648	MPa
Right	y_1	225.000	mm	z_1	-8.343	mm	σ_1	-43.842	MPa
	y_2	7.500	mm	z_2	-8.343	mm	σ_2	-52.080	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-918.343	mm	σ_1	255.732	MPa
	y_2	-7.500	mm	z_2	-918.343	mm	σ_2	263.970	MPa
Right	y_1	225.000	mm	z_1	-918.343	mm	σ_1	272.776	MPa
	y_2	7.500	mm	z_2	-918.343	mm	σ_2	264.538	MPa

Web

Right	y_1	0.000	mm	z_1	-23.343	mm	σ_1	-47.145	MPa
	y_2	0.000	mm	z_2	-898.343	mm	σ_2	257.295	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 1003.270 mm

N_{slab} = 9762.500 kN
$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)
$N_{g,top}$ = 0.000 kN (Upper side of PNA)
$N_{g,bot}$ = 9762.500 kN (Lower side of PNA)

$M_{pl,Rd}$ = 6341.619 kN・m

■ Calculation. $V_{bw,Rd}$
Web
■ Contribution from the web
$\lambda_w = h_w / (86.4 \cdot t \cdot \varepsilon)$ = 0.744

$X_w = 0.83 / \lambda_w$ = 1.116 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2729.332 \text{ kN}$$

V_{Rd} = 2729.332 kN
$V_{Edi} = V_{Ed}$ / Num. of Web = -654.742 kN

$\eta'_3 = V_{Edi} / V_{bw,Rd}$ = 0.240 ≤ 1.0

■ Contribution from the flange
$M_{f,Rd}$ = 3781.869 kN・m
$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}} \right)^2 \right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3781.869 kN・m
M_{Ed} = 98194.461 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance
$V_{Edi} / (V_{bw,Rd} + V_{bf,Rd})$ = 0.240 < 1.0 … OK

■ Interaction M-V
For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**
- Design load
Load combination name : SLU_1
N_{Ed} = 877.788 kN
M_{Ed} = 3394.058 kN・m
V_1 = -672.991 kN
V_2 = -638.738 kN
M_1 = 3394.058 kN・m
M_2 = 1052.135 kN・m
$M_{pl,Rd}$ = 6341.619 kN・m
$M_{el,Rd}$ = 4572.731 kN・m

- $M_{b,Rd}$ Buckling resistance moment
L = 3.500 m

c = C_d / l = 0.000 kN/m^2

γ = $c \cdot L^4 / (E \cdot I)$ = 0.000

μ = V_2 / V_1 = 0.949

Φ = $2 \cdot (1-M_2/M_1) / (1+\mu)$ = 0.708

m_1 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu)$ = 1.511

m_2 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5}$ = 1.511

m = $Min(m_1, m_2)$ = 1.511

α_{LT} = 0.760

λ_{LT} = $1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.287

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.574

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 0.933195722$$

M_{Rd} = 6341.619 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 5917.972 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 0.885

$N_{b,Rd}$ = $X_{LT} \cdot Area \cdot f_{yd}$ = 48821.655 kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.591496462$$

5 Resistance to Longitudinal Shear

- Design load

Load combination name : SLU_2

$N_{c,el}$ = 4402.229 kN

$N_{c,f}$ = 9762.500 kN

M_{Ed} = 3372.614 kN・m

V_{Ed} = -561.703 kN

$M_{pl,Rd}$ = 6341.619 kN・m

$M_{el,Rd}$ = 4572.731 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $Min(P_{Rd,1} , P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 2

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 611.040 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot$ Num./Space = 1094.782 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 Stress Limitation

- In the structural steel

Characteristic load combination name : CAR_4

$\sigma_{Ed,ser}$ = -212.576 MPa (Bottom-right fiber in the flange)

$\tau_{Ed,ser}$ = 37.854 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

-212.576 MPa < 338.095 MPa … OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

37.854 MPa < 195.199 MPa … OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

222.458 MPa < 338.095 MPa … OK

- In the concrete of the slab

Characteristic load combination name : CAR_1

$\sigma_c \leq k_1 f_{ck}$

5.922 MPa < 21.000 MPa … OK

- In the reinforcement

Load combination name : CAR_1

$\sigma_s \leq k_3 f_{yk}$

-34.678 MPa

Rebar is under compression. No need to check.

7 Longitudinal Shear for SLS(Serviceability limit state)

- Shear resistance of a single connector

Load combination name : CAR_2

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 2

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 465.508 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot Num./Space$ = 821.087 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

Element Number	450
Position Information	I

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

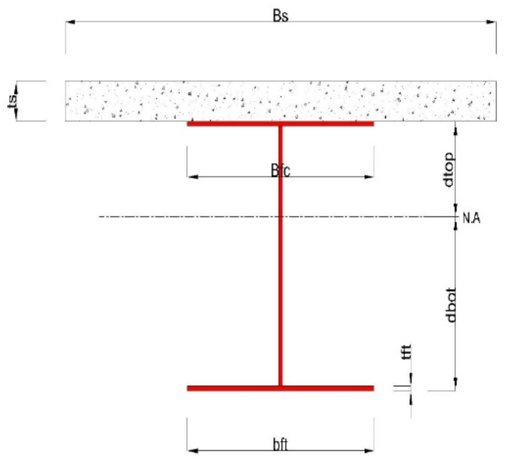
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	784.189	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27512.838	mm^2
$I_{y,a}$	3105288005.288	mm^4

After

$A_{,c}$	161873.581	mm^2
$I_{y,c}$	10746839769.980	mm^4

$I_{z,a}$	266001803.209	mm^4
$C_{y,a}$	225.000	mm
$C_{z,a}$	378.598	mm

$I_{z,c}$	145375604088.924	mm^4
$C_{y,c}$	225.000	mm
$C_{z,c}$	839.758	mm

Crack

$A_{,c}$	34748.838	mm^2
$I_{y,c}$	4904473180.082	mm^4
$I_{z,c}$	8071200604.295	mm^4
$C_{y,c}$	214.588	mm
$C_{z,c}$	494.293	mm

2 **Bending Resistance**

2.1 Positive Moment

■ Design load

Load combination name : SLU_4

$N_{a,Ed}$	119.635	kN
$N_{c,Ed}$	761.114	kN
$M_{a,Ed}$	153.365	kN・m
$M_{c,Ed}$	883.273	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-14.385	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-11.131	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-7.653	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-10.907	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	93.401	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	96.655	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	100.134	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	96.880	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-9.046	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	94.136	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m
x_{pl} = 130.280 mm
M_{Rd} = $\beta M_{pl,Rd}$ = 5631.885 kN・m
here, β = 1.000

M_{Rd} = 5631.885 kN・m > M_{Ed} = 1036.638 kN・m …OK

2 **Bending Resistance**

2.2 Negative Moment

■ Design load

Load combination name : SLU_3

$N_{a,Ed}$	119.635	kN
$N_{c,Ed}$	1375.655	kN
$M_{a,Ed}$	153.365	kN・m
$M_{c,Ed}$	-412.363	kN・m

- Stress

Top Flange

Left	y_1	-214.588	mm	z_1	324.896	mm	σ_1	47.755	MPa
	y_2	2.912	mm	z_2	324.896	mm	σ_2	49.365	MPa
Right	y_1	235.412	mm	z_1	324.896	mm	σ_1	51.087	MPa
	y_2	17.912	mm	z_2	324.896	mm	σ_2	49.476	MPa

Bottom Flange

Left	y_1	-214.588	mm	z_1	-494.293	mm	σ_1	19.337	MPa
	y_2	2.912	mm	z_2	-494.293	mm	σ_2	20.947	MPa
Right	y_1	235.412	mm	z_1	-494.293	mm	σ_1	22.669	MPa
	y_2	17.912	mm	z_2	-494.293	mm	σ_2	21.058	MPa

Web

Right	y_1	10.412	mm	z_1	309.896	mm	σ_1	48.901	MPa
	y_2	10.412	mm	z_2	-474.293	mm	σ_2	21.696	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 616.254 mm

N_{slab} = 0.000 kN
$N_{rebar,t}$ = 2831.478 kN (Upper side of PNA)
$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)
$N_{g,top}$ = 3235.241 kN (Upper side of PNA)
$N_{g,bot}$ = 6066.719 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4182.037 kN・m

M_{Rd} = $M_{pl,Rd}$ = 4182.037 kN・m

M_{Rd} = 4182.037 kN・m > M_{Ed} = -258.998 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_3

N_{Ed} = 927.889 kN

$M_{a,Ed}$ = 153.365 kN・m

$M_{c,Ed}$ = 805.525 kN・m

$V_{Ed,a}$ = -114.520 kN

$V_{Ed,c}$ = -608.618 kN

V_{Ed} = -723.138 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 10563.633 kN・m

$M_{Ed,t}$ = 10563.633 kN・m

$M_{Ed,b}$ = 1044.817 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-13.133	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-10.238	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-7.142	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-10.038	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	88.727	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	91.623	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	94.718	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	91.822	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-8.273	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	89.236	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

$\lambda_w = h_w / (86.4 \cdot t \cdot \varepsilon)$ = 0.744

$X_w = 0.83 / \lambda_w$ = 1.116 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2446.072 \text{ kN}$$

V_{Rd} = 2446.072 kN

V_{Edi} = V_{Ed} / Num. of Web = -723.138 kN

$\eta'_3 = V_{Edi} / V_{bw,Rd}$ = 0.296 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3505.544 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3505.544 kN・m

M_{Ed} = 10563.633 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

$V_{Edi} / (V_{bw,Rd}+V_{bf,Rd})$ = 0.296 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_4

N_{Ed} = 880.748 kN

M_{Ed} = 1036.638 kN・m

V_1 = -707.054 kN

V_2 = -639.727 kN

M_1 = 3394.204 kN・m

M_2 = 1036.638 kN・m

$M_{pl,Rd}$ = 5631.885 kN・m

$M_{el,Rd}$ = 4240.860 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 3.500 m

c = C_d / l = 0.000 kN/m^2

$\gamma = c \cdot L^4 / (E \cdot I)$ = 0.000

$\mu = V_2 / V_1$ = 0.905

$\Phi = 2 \cdot (1-M_2/M_1) / (1+\mu)$ = 0.729

m_1 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu)$ = 1.522

m_2 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5}$ = 1.522

m = $\mathrm{Min}(m_1, m_2)$ = 1.522

α_{LT} = 0.490

λ_{LT} = $1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.286

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.562

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 0.956328504$$

M_{Rd} = 5631.885 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 5385.932 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 0.922

$N_{b,Rd}$ = $X_{LT} \cdot Area \cdot f_{yd}$ = 50462.939 kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.209924792$$

5 Resistance to Longitudinal Shear

- Design load

Load combination name : SLU_3

$N_{c,el}$ = 4814.834 kN

$N_{c,f}$ = 9301.959 kN

M_{Ed} = 958.890 kN・m

V_{Ed} = -608.618 kN

$M_{pl,Rd}$ = 5631.885 kN・m

$M_{el,Rd}$ = 4240.860 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $\mathrm{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 2

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 718.540 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot$ Num./Space = 1094.782 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 Stress Limitation

- In the structural steel

Characteristic load combination name : CAR_4

$\sigma_{Ed,ser}$ = -79.981 MPa (Bottom-right fiber in the flange)

$\tau_{Ed,ser}$ = 46.545 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

-79.981 MPa < 338.095 MPa … OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

46.545 MPa < 195.199 MPa … OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

113.562 MPa < 338.095 MPa … OK

- In the concrete of the slab

Characteristic load combination name : CAR_1

$\sigma_c \leq k_1 f_{ck}$

2.711 MPa < 21.000 MPa … OK

- In the reinforcement

Load combination name : CAR_1

$\sigma_s \leq k_3 f_{yk}$

-23.571 MPa

Rebar is under compression. No need to check.

7 Longitudinal Shear for SLS(Serviceability limit state)

- Shear resistance of a single connector

Load combination name : CAR_3

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = Min(P_{Rd,1} , P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 2

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 546.238 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot Num./Space$ = 821.087 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

Element Number	450
Position Information	J

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

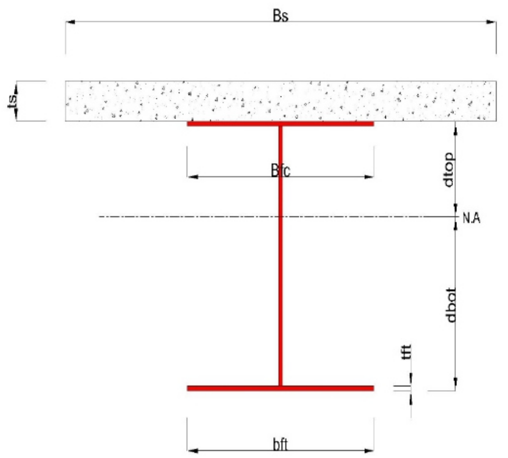
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	875.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	28875.000	mm^2
$I_{y,a}$	3940507315.341	mm^4

After

$A_{,c}$	163235.743	mm^2
$I_{y,c}$	13173501310.263	mm^4

$I_{z,a}$	266027343.750	mm^4
$C_{y,a}$	225.000	mm
$C_{z,a}$	422.045	mm

$I_{z,c}$	145375629629.464	mm^4
$C_{y,c}$	225.000	mm
$C_{z,c}$	918.343	mm

Crack

$A_{,c}$	36111.000	mm^2
$I_{y,c}$	5964320128.160	mm^4
$I_{z,c}$	8071368242.237	mm^4
$C_{y,c}$	214.981	mm
$C_{z,c}$	539.653	mm

2 **Bending Resistance**

2.1 Positive Moment

■ Design load

Load combination name : SLU_1

$N_{a,Ed}$	120.004	kN
$N_{c,Ed}$	762.412	kN
$M_{a,Ed}$	516.775	kN・m
$M_{c,Ed}$	2877.443	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-8.343	mm	σ_1	-44.524	MPa
	y_2	-7.500	mm	z_2	-8.343	mm	σ_2	-53.050	MPa
Right	y_1	225.000	mm	z_1	-8.343	mm	σ_1	-62.163	MPa
	y_2	7.500	mm	z_2	-8.343	mm	σ_2	-53.638	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-918.343	mm	σ_1	273.585	MPa
	y_2	-7.500	mm	z_2	-918.343	mm	σ_2	265.060	MPa
Right	y_1	225.000	mm	z_1	-918.343	mm	σ_1	255.947	MPa
	y_2	7.500	mm	z_2	-918.343	mm	σ_2	264.472	MPa

Web

Right	y_1	0.000	mm	z_1	-23.343	mm	σ_1	-48.100	MPa
	y_2	0.000	mm	z_2	-898.343	mm	σ_2	257.774	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 1003.270 mm

N_{slab} = 9762.500 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9762.500 kN (Lower side of PNA)

$M_{pl,Rd}$ = 6341.619 kN・m
x_{pl} = 136.730 mm
M_{Rd} = $\beta M_{pl,Rd}$ = 6341.619 kN・m
here, β = 1.000

M_{Rd} = 6341.619 kN・m > M_{Ed} = 3394.218 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_3
N_{Ed} = 928.920 kN
$M_{a,Ed}$ = 516.775 kN・m
$M_{c,Ed}$ = 2855.852 kN・m
$V_{Ed,a}$ = -93.036 kN
$V_{Ed,c}$ = -562.702 kN
V_{Ed} = -655.738 kN

M_{Ed} = $\max(M_{Ed,t}, M_{Ed,b})$ = 98193.206 kN・m
$M_{Ed,t}$ = 98193.206 kN・m
$M_{Ed,b}$ = 3649.824 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-8.343	mm	σ_1	-43.535 MPa
	y_2	-7.500	mm	z_2	-8.343	mm	σ_2	-52.044 MPa
Right	y_1	225.000	mm	z_1	-8.343	mm	σ_1	-61.139 MPa
	y_2	7.500	mm	z_2	-8.343	mm	σ_2	-52.631 MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-918.343	mm	σ_1	273.083 MPa
	y_2	-7.500	mm	z_2	-918.343	mm	σ_2	264.574 MPa
Right	y_1	225.000	mm	z_1	-918.343	mm	σ_1	255.479 MPa
	y_2	7.500	mm	z_2	-918.343	mm	σ_2	263.987 MPa

Web

Right	y_1	0.000	mm	z_1	-23.343	mm	σ_1	-47.118 MPa
	y_2	0.000	mm	z_2	-898.343	mm	σ_2	257.322 MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 1003.270 mm

N_{slab} = 9762.500 kN
$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)
$N_{g,top}$ = 0.000 kN (Upper side of PNA)
$N_{g,bot}$ = 9762.500 kN (Lower side of PNA)

$M_{pl,Rd}$ = 6341.619 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

$\lambda_w = h_w / (86.4 \cdot t \cdot \varepsilon)$ = 0.744

$X_w = 0.83 / \lambda_w$ = 1.116 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2729.332 \text{ kN}$$

V_{Rd} = 2729.332 kN

$V_{Edi} = V_{Ed}$ / Num. of Web = -655.738 kN

$\eta'_3 = V_{Edi} / V_{bw,Rd}$ = 0.240 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3781.869 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3781.869 kN・m

M_{Ed} = 98193.206 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

$V_{Edi} / (V_{bw,Rd} + V_{bf,Rd})$ = 0.240 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_4

N_{Ed} = 882.048 kN
M_{Ed} = 3394.204 kN・m
V_1 = -707.054 kN
V_2 = -639.727 kN
M_1 = 3394.204 kN・m
M_2 = 1036.638 kN・m
$M_{pl,Rd}$ = 6341.619 kN・m
$M_{el,Rd}$ = 4572.735 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 3.500 m

$c = C_d / l = 0.000$ kN/m^2

$\gamma = c \cdot L^4 / (E \cdot I) = 0.000$

$\mu = V_2 / V_1 = 0.905$

$\Phi = 2 \cdot (1-M_2/M_1) / (1+\mu) = 0.729$

$m_1 = 1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu) = 1.522$

$m_2 = 1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5} = 1.522$

$m = \mathrm{Min}(m_1, m_2) = 1.522$

$\alpha_{LT} = 0.760$

$\lambda_{LT} = 1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))} = 0.286$

$\Phi_{LT} = 0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2) = 0.574$

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 0.933978489$$

$M_{Rd} = 6341.619$ kN・m

$M_{b,Rd} = X_{LT} \cdot M_{Rd} = 5922.936$ kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N} = 0.885$

$N_{b,Rd} = X_{LT} \cdot Area \cdot f_{yd} = 48821.655$ kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.591127798$$

5 Resistance to Longitudinal Shear

- Design load

Load combination name : SLU_3

$N_{c,el} = 4402.240$ kN

$N_{c,f} = 9762.500$ kN

$M_{Ed} = 3372.627$ kN・m

$V_{Ed} = -562.702$ kN

$M_{pl,Rd} = 6341.619$ kN・m

$M_{el,Rd} = 4572.735$ kN・m

- Shear resistance of a single connector

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V = 109.478$ kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V = 122.492$ kN

$P_{Rd} = \mathrm{Min}(P_{Rd,1}, P_{Rd,2}) = 109.478$ kN

where, $f_u = 450.000$ MPa

$\alpha = 1$ for $h_{sc}/d > 4$

Num. = 2

$d = 22.000$ mm

$h_{sc} = 175.000$ mm

Space = 200.000 mm

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I) = 612.127$ kN/m

$v_{L,Rd} = P_{Rd} \cdot Num./Space = 1094.782$ kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 Stress Limitation

- In the structural steel

Characteristic load combination name : CAR_1

$\sigma_{Ed,ser}$ = -212.805 MPa (Bottom-left fiber in the flange)

$\tau_{Ed,ser}$ = 37.911 MPa (Neutral axis in the web)

$\sigma_{Ed,ser} < f_y / \gamma_{M,ser}$

-212.805 MPa < 338.095 MPa … OK

$\tau_{Ed,ser} < f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

37.911 MPa < 195.199 MPa … OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)} < f_y / \gamma_{M,ser}$

222.705 MPa < 338.095 MPa … OK

- In the concrete of the slab

Characteristic load combination name : CAR_4

$\sigma_c \leq k_1 f_{ck}$

5.796 MPa < 21.000 MPa … OK

- In the reinforcement

Load combination name : CAR_2

$\sigma_s \leq k_3 f_{yk}$

-33.458 MPa

Rebar is under compression. No need to check.

7 **Longitudinal Shear for SLS(Serviceability limit state)**

- Shear resistance of a single connector

Load combination name : CAR_3

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = \mathrm{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 2

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 466.314 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot$ Num./Space = 821.087 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

Element Number	471
Position Information	I

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

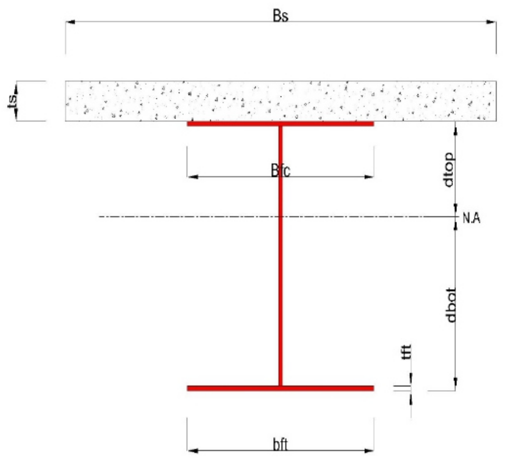
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	755.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27075.000	mm^2
$I_{y,a}$	2861139006.666	mm^4

After

$A_{,c}$	161435.743	mm^2
$I_{y,c}$	10032327520.874	mm^4

$I_{z,a}$	265993593.750	mm^4
$C_{y,a}$	225.000	mm
$C_{z,a}$	364.675	mm

$I_{z,c}$	145375595879.464	mm^4
$C_{y,c}$	225.000	mm
$C_{z,c}$	814.380	mm

Crack

$A_{,c}$	34311.000	mm^2
$I_{y,c}$	4558861068.187	mm^4
$I_{z,c}$	8071144324.544	mm^4
$C_{y,c}$	214.455	mm
$C_{z,c}$	478.626	mm

2 **Bending Resistance**

2.1 Positive Moment

■ Design load

Load combination name : SLU_4

$N_{a,Ed}$	119.480	kN
$N_{c,Ed}$	466.607	kN
$M_{a,Ed}$	20.722	kN・m
$M_{c,Ed}$	280.027	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-24.380	mm	σ_1	-1.467	MPa
	y_2	-7.500	mm	z_2	-24.380	mm	σ_2	4.691	MPa
Right	y_1	225.000	mm	z_1	-24.380	mm	σ_1	11.274	MPa
	y_2	7.500	mm	z_2	-24.380	mm	σ_2	5.116	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-814.380	mm	σ_1	26.306	MPa
	y_2	-7.500	mm	z_2	-814.380	mm	σ_2	32.463	MPa
Right	y_1	225.000	mm	z_1	-814.380	mm	σ_1	39.046	MPa
	y_2	7.500	mm	z_2	-814.380	mm	σ_2	32.888	MPa

Web

Right	y_1	0.000	mm	z_1	-39.380	mm	σ_1	5.431	MPa
	y_2	0.000	mm	z_2	-794.380	mm	σ_2	31.973	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 891.794 mm

N_{slab} = 9153.929 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9153.929 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5412.007 kN・m

x_{pl} = 128.206 mm

M_{Rd} = $\beta M_{pl,Rd}$ = 5412.007 kN・m

here, β = 1.000

M_{Rd} = 5412.007 kN・m > M_{Ed} = 300.749 kN・m …OK

2 **Bending Resistance**

2.2 Negative Moment

■ Design load

Load combination name : SLU_3

$N_{a,Ed}$	119.480	kN
$N_{c,Ed}$	1375.447	kN
$M_{a,Ed}$	20.722	kN・m
$M_{c,Ed}$	-601.927	kN・m

- Stress

Top Flange

Left	y_1	-214.455	mm	z_1	311.374	mm	σ_1	76.884	MPa
	y_2	3.045	mm	z_2	311.374	mm	σ_2	82.280	MPa
Right	y_1	235.545	mm	z_1	311.374	mm	σ_1	88.049	MPa
	y_2	18.045	mm	z_2	311.374	mm	σ_2	82.653	MPa

Bottom Flange

Left	y_1	-214.455	mm	z_1	-478.626	mm	σ_1	-21.702	MPa
	y_2	3.045	mm	z_2	-478.626	mm	σ_2	-16.305	MPa
Right	y_1	235.545	mm	z_1	-478.626	mm	σ_1	-10.537	MPa
	y_2	18.045	mm	z_2	-478.626	mm	σ_2	-15.933	MPa

Web

Right	y_1	10.545	mm	z_1	296.374	mm	σ_1	80.595	MPa
	y_2	10.545	mm	z_2	-458.626	mm	σ_2	-13.623	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	3
Bottom flange	3
Section	3

- Elastic resistance moment, $M_{el,Rd}$

k = 5.392 : the lowest factor such that a stress limit is reached.

(Calculate minimum value between Steel Girder and Slab Reinforcement.)

$M_{el,Rd}$ = $M_{a,Ed} + k \cdot M_{c,Ed}$ = 3224.755 kN・m

M_{Rd} = $M_{el,Rd}$ = 3224.755 kN・m

M_{Rd} = 3224.755 kN・m > M_{Ed} = -581.205 kN・m …OK

3 **Resistance to Vertical Shear**

■ Design load

Load combination name : SLU_3

N_{Ed} = 927.775 kN

$M_{a,Ed}$ = 20.722 kN・m

$M_{c,Ed}$ = 119.238 kN・m

$V_{Ed,a}$ = -121.348 kN

$V_{Ed,c}$ = -610.745 kN

V_{Ed} = -732.093 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 1148.362 kN・m

$M_{Ed,t}$ = 1148.362 kN・m

$M_{Ed,b}$ = 151.775 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-24.380	mm	σ_1	0.581	MPa
	y_2	-7.500	mm	z_2	-24.380	mm	σ_2	7.143	MPa
Right	y_1	225.000	mm	z_1	-24.380	mm	σ_1	14.157	MPa
	y_2	7.500	mm	z_2	-24.380	mm	σ_2	7.596	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-814.380	mm	σ_1	15.692	MPa
	y_2	-7.500	mm	z_2	-814.380	mm	σ_2	22.254	MPa
Right	y_1	225.000	mm	z_1	-814.380	mm	σ_1	29.268	MPa
	y_2	7.500	mm	z_2	-814.380	mm	σ_2	22.707	MPa

Web

Right	y_1	0.000	mm	z_1	-39.380	mm	σ_1	7.656	MPa
	y_2	0.000	mm	z_2	-794.380	mm	σ_2	22.098	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 891.794 mm

N_{slab} = 9153.929 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9153.929 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5412.007 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

λ_w = h_w / (86.4 · t · ε) = 0.716

X_w = 0.83 / λ_w = 1.159 0.83/η≤λ_w<1.08

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2446.072 \text{ kN}$$

V_{Rd} = 2446.072 kN

V_{Edi} = V_{Ed} / Num. of Web = -732.093 kN

η'_3 = V_{Edi} / $V_{bw,Rd}$ = 0.299 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3416.726 kN · m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3416.726 kN · m

M_{Ed} = 1148.362 kN · m (Taken as the greatest value of (∑σ_i)W)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

V_{Edi} / ($V_{bw,Rd}$+$V_{bf,Rd}$) = 0.299 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 Resistance to Lateral Torsional Buckling

- Design load

Load combination name : SLU_3

N_{Ed} = 1494.927 kN

M_{Ed} = -581.205 kN · m

V_1 = -290.685 kN

V_2 = -281.860 kN

M_1 = -581.205 kN · m

M_2 = -258.912 kN · m

$M_{pl,Rd}$ = 4006.034 kN · m

$M_{el,Rd}$ = 3224.755 kN · m

- $M_{b,Rd}$ Buckling resistance moment

L = 1.125 m

c = C_d / l = 0.000 kN/m^2

γ = c · L^4 / (E · I) = 0.000

μ = V_2 / V_1 = 0.970

Φ = 2 · (1-M_2/M_1) / (1+μ) = 0.563

m_1 = 1+0.44 · (1+μ) · $\Phi^{1.5}$+(3+2 · Φ) · γ/(350-50 · μ) = 1.366

m_2 = 1+0.44 · (1+μ) · $\Phi^{1.5}$+(0.195+(0.05+μ/100) · Φ) · $\gamma^{0.5}$ = 1.366

m = Min(m_1, m_2) = 1.366

α_{LT} = 0.490

λ_{LT} = 1.103 · L/b · √(f_y/Em) · √(1+A_{wc}/(3 · A_f)) = 0.109

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.484

$X_{LT} = \dfrac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} =$ 1

M_{Rd} = 3224.755 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 3224.755 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd}$ = $X_{LT} \cdot$ Area $\cdot f_{yd}$ = 11600.386 kN

Combined Ratio $= \dfrac{N_{Ed}}{N_{b,Rd}} + \dfrac{M_{Ed}}{M_{b,Rd}} =$ 0.309101035

5 Resistance to Longitudinal Shear

- Design load

Load combination name : SLU_3

$N_{c,el}$ = 5004.033 kN

$N_{c,f}$ = 9153.929 kN

M_{Ed} = 139.960 kN・m

V_{Ed} = -610.745 kN

$M_{pl,Rd}$ = 5412.007 kN・m

$M_{el,Rd}$ = 4153.173 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $\text{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 741.233 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot$ Num./Space = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 Stress Limitation

- In the structural steel

Characteristic load combination name : CAR_4

$\sigma_{Ed,ser}$ = 38.577 MPa (Top-left fiber in the flange)

$\tau_{Ed,ser}$ = 48.932 MPa (Neutral axis in the web)

$\sigma_{Ed,ser} < f_y / \gamma_{M,ser}$

38.577 MPa < 338.095 MPa … OK

$\tau_{Ed,ser} < f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

48.932 MPa < 195.199 MPa ... OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

93.119 MPa < 338.095 MPa ... OK

- In the concrete of the slab

Characteristic load combination name : CAR_4

$\sigma_c \le k_1 f_{ck}$

1.910 MPa < 21.000 MPa ... OK

- In the reinforcement

Load combination name : CAR_1

$\sigma_s \le k_3 f_{yk}$

-20.541 MPa

Rebar is under compression. No need to check.

7 **Longitudinal Shear for SLS(Serviceability limit state)**

- Shear resistance of a single connector

Load combination name : CAR_3

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 563.458 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot Num./Space$ = 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ ... OK

Element Number	471
Position Information	J

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

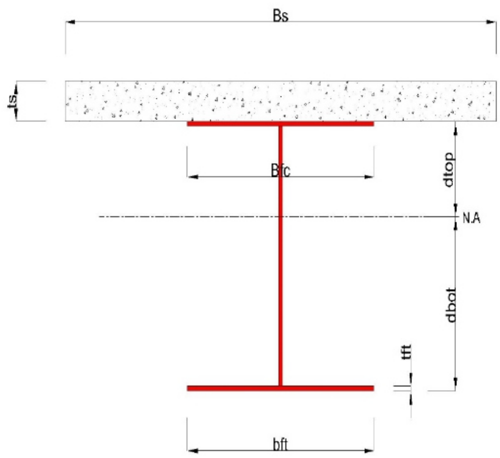
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	3600.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	784.189	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27512.838	mm^2
$I_{y,a}$	3105288005.288	mm^4

After

$A_{,c}$	161873.581	mm^2
$I_{y,c}$	10746839769.980	mm^4

$I_{z,a}$	266001803.209	mm^4
$C_{y,a}$	225.000	mm
$C_{z,a}$	378.598	mm

$I_{z,c}$	145375604088.924	mm^4
$C_{y,c}$	225.000	mm
$C_{z,c}$	839.758	mm

Crack

$A_{,c}$	34748.838	mm^2
$I_{y,c}$	4803849451.675	mm^4
$I_{z,c}$	8071200604.295	mm^4
$C_{y,c}$	214.588	mm
$C_{z,c}$	490.953	mm

2 Bending Resistance

2.1 Positive Moment

■ Design load

Load combination name : SLU_4

$N_{a,Ed}$	119.598	kN
$N_{c,Ed}$	761.047	kN
$M_{a,Ed}$	153.435	kN・m
$M_{c,Ed}$	883.281	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-14.397	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-11.143	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-7.665	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-10.919	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	93.409	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	96.663	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	100.141	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	96.887	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-9.057	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	94.143	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m
x_{pl} = 130.280 mm
M_{Rd} = $\beta M_{pl,Rd}$ = 5631.885 kN・m
here, β = 1.000

M_{Rd} = 5631.885 kN・m > M_{Ed} = 1036.716 kN・m …OK

2 **Bending Resistance**

2.2 Negative Moment

■ Design load

Load combination name : SLU_3

$N_{a,Ed}$	119.598	kN
$N_{c,Ed}$	1375.636	kN
$M_{a,Ed}$	153.435	kN・m
$M_{c,Ed}$	-412.347	kN・m

- Stress

Top Flange

Left	y_1	-214.588	mm	z_1	328.236	mm	σ_1	48.601	MPa
	y_2	2.912	mm	z_2	328.236	mm	σ_2	50.211	MPa
Right	y_1	235.412	mm	z_1	328.236	mm	σ_1	51.933	MPa
	y_2	17.912	mm	z_2	328.236	mm	σ_2	50.322	MPa

Bottom Flange

Left	y_1	-214.588	mm	z_1	-490.953	mm	σ_1	18.761	MPa
	y_2	2.912	mm	z_2	-490.953	mm	σ_2	20.372	MPa
Right	y_1	235.412	mm	z_1	-490.953	mm	σ_1	22.093	MPa
	y_2	17.912	mm	z_2	-490.953	mm	σ_2	20.483	MPa

Web

Right	y_1	10.412	mm	z_1	313.236	mm	σ_1	49.720	MPa
	y_2	10.412	mm	z_2	-470.953	mm	σ_2	21.156	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 616.254 mm

N_{slab} = 0.000 kN
$N_{rebar,t}$ = 2831.478 kN (Upper side of PNA)
$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)
$N_{g,top}$ = 3235.241 kN (Upper side of PNA)
$N_{g,bot}$ = 6066.719 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4136.627 kN・m

M_{Rd} = $M_{pl,Rd}$ = 4136.627 kN・m

M_{Rd} = 4136.627 kN・m > M_{Ed} = -258.912 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_3

N_{Ed} = 927.821 kN

$M_{a,Ed}$ = 153.435 kN・m

$M_{c,Ed}$ = 805.535 kN・m

$V_{Ed,a}$ = -114.558 kN

$V_{Ed,c}$ = -608.721 kN

V_{Ed} = -723.279 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 10568.818 kN・m

$M_{Ed,t}$ = 10568.818 kN・m

$M_{Ed,b}$ = 1044.936 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	-20.569	mm	σ_1	-13.145	MPa
	y_2	-7.500	mm	z_2	-20.569	mm	σ_2	-10.249	MPa
Right	y_1	225.000	mm	z_1	-20.569	mm	σ_1	-7.154	MPa
	y_2	7.500	mm	z_2	-20.569	mm	σ_2	-10.050	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-839.758	mm	σ_1	88.735	MPa
	y_2	-7.500	mm	z_2	-839.758	mm	σ_2	91.630	MPa
Right	y_1	225.000	mm	z_1	-839.758	mm	σ_1	94.726	MPa
	y_2	7.500	mm	z_2	-839.758	mm	σ_2	91.830	MPa

Web

Right	y_1	0.000	mm	z_1	-35.569	mm	σ_1	-8.284	MPa
	y_2	0.000	mm	z_2	-819.758	mm	σ_2	89.243	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 918.910 mm

N_{slab} = 9301.959 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 0.000 kN (Upper side of PNA)

$N_{g,bot}$ = 9301.959 kN (Lower side of PNA)

$M_{pl,Rd}$ = 5631.885 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

λ_w = h_w / (86.4・t・ε) = 0.716

X_w = 0.83 / λ_w = 1.159 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2540.640 \text{ kN}$$

V_{Rd} = 2540.640 kN

V_{Edi} = V_{Ed} / Num. of Web = -723.279 kN

η'_3 = V_{Edi} / $V_{bw,Rd}$ = 0.285 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3505.544 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}} \right)^2 \right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3505.544 kN・m

M_{Ed} = 10568.818 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

V_{Edi} / ($V_{bw,Rd}$+$V_{bf,Rd}$) = 0.285 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_4

N_{Ed} = 880.645 kN

M_{Ed} = 1036.716 kN・m

V_1 = -632.468 kN

V_2 = -707.176 kN

M_1 = 1036.716 kN・m

M_2 = 300.749 kN・m

$M_{pl,Rd}$ = 5631.885 kN・m

$M_{el,Rd}$ = 4240.821 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 1.125 m

c = C_d / l = 0.000 kN/m²

γ = c・L^4 / (E・I) = 0.000

μ = V_2 / V_1 = 0.894

Φ = 2・(1-M_2/M_1) / (1+μ) = 0.749

m_1 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu)$ = 1.541

m_2 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5}$ = 1.541

m = $Min(m_1, m_2)$ = 1.541

α_{LT} = 0.490

λ_{LT} = $1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.091

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.478

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 1$$

M_{Rd} = 5631.885 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 5631.885 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd}$ = $X_{LT} \cdot Area \cdot f_{yd}$ = 54728.687 kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.200170871$$

5 **Resistance to Longitudinal Shear**

- Design load

Load combination name : SLU_3

$N_{c,el}$ = 4814.705 kN

$N_{c,f}$ = 9301.959 kN

M_{Ed} = 958.970 kN・m

V_{Ed} = -608.721 kN

$M_{pl,Rd}$ = 5631.885 kN・m

$M_{el,Rd}$ = 4240.821 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $Min(P_{Rd,1} , P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 718.662 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot$ Num./Space = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 **Stress Limitation**

- In the structural steel

Characteristic load combination name : CAR_4

$\sigma_{Ed,ser}$ = -80.007 MPa (Bottom-right fiber in the flange)

$\tau_{Ed,ser}$ = 46.555 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

-80.007 MPa < 338.095 MPa … OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

46.555 MPa < 195.199 MPa … OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

113.593 MPa < 338.095 MPa … OK

- In the concrete of the slab

Characteristic load combination name : CAR_1

$\sigma_c \leq k_1 f_{ck}$

2.708 MPa < 21.000 MPa … OK

- In the reinforcement

Load combination name : CAR_1

$\sigma_s \leq k_3 f_{yk}$

-22.521 MPa

Rebar is under compression. No need to check.

7 Longitudinal Shear for SLS(Serviceability limit state)

- Shear resistance of a single connector

Load combination name : CAR_3

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = \text{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 546.346 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot \text{Num./Space}$ = 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

Element Number	547
Position Information	I

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

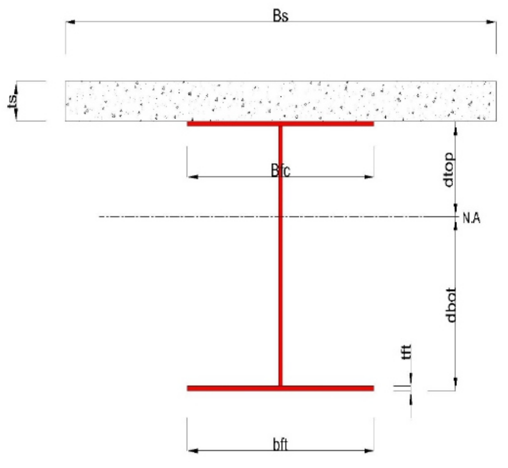
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	1990.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	735.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	26775.000	mm^2
$I_{y,a}$	2700507545.956	mm^4

After

$A_{,c}$	101046.633	mm^2
$I_{y,c}$	8553036434.007	mm^4

$I_{z,a}$	265987968.750	mm^4	$I_{z,c}$	24776245741.881	mm^4
$C_{y,a}$	225.000	mm	$C_{y,c}$	225.000	mm
$C_{z,a}$	355.147	mm	$C_{z,c}$	744.601	mm

Crack

$A_{,c}$	30795.000	mm^2
$I_{y,c}$	3698825679.912	mm^4
$I_{z,c}$	1599730142.226	mm^4
$C_{y,c}$	219.126	mm
$C_{z,c}$	424.315	mm

2 **Bending Resistance**

2.1 Negative Moment

■ Design load

Load combination name : SLU_3

$N_{a,Ed}$	119.795	kN
$N_{c,Ed}$	1376.519	kN
$M_{a,Ed}$	-103.393	kN・m
$M_{c,Ed}$	-835.818	kN・m

- Stress

Top Flange

Left	y_1	-219.126	mm	z_1	345.685	mm	σ_1	139.014	MPa
	y_2	-1.626	mm	z_2	345.685	mm	σ_2	142.872	MPa
Right	y_1	230.874	mm	z_1	345.685	mm	σ_1	146.996	MPa
	y_2	13.374	mm	z_2	345.685	mm	σ_2	143.138	MPa

Bottom Flange

Left	y_1	-219.126	mm	z_1	-424.315	mm	σ_1	-64.463	MPa
	y_2	-1.626	mm	z_2	-424.315	mm	σ_2	-60.605	MPa
Right	y_1	230.874	mm	z_1	-424.315	mm	σ_1	-56.481	MPa
	y_2	13.374	mm	z_2	-424.315	mm	σ_2	-60.339	MPa

Web

Right	y_1	5.874	mm	z_1	330.685	mm	σ_1	139.041	MPa
	y_2	5.874	mm	z_2	-404.315	mm	σ_2	-55.187	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	2
Bottom flange	3
Section	3

- Elastic resistance moment, $M_{el,Rd}$

k = 3.294 : the lowest factor such that a stress limit is reached.

(Calculate minimum value between Steel Girder and Slab Reinforcement.)

$M_{el,Rd} = M_{a,Ed} + k \cdot M_{c,Ed}$ = 2753.287 kN・m

$M_{Rd} = M_{el,Rd}$ = 2753.287 kN・m

M_{Rd} = 2753.287 kN・m > M_{Ed} = -835.818 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_3

N_{Ed} = 931.730 kN

$M_{a,Ed}$ = -103.393 kN・m

$M_{c,Ed}$ = -535.498 kN・m

$V_{Ed,a}$ = -126.954 kN

$V_{Ed,c}$ = -604.690 kN

V_{Ed} = -731.644 kN

M_{Ed} = $\max(M_{Ed,t}, M_{Ed,b})$ = 705.449 kN・m

$M_{Ed,t}$ = 705.449 kN・m

$M_{Ed,b}$ = 654.029 kN・m

- Stress

Top Flange

Left	y_1	-219.126	mm	z_1	345.685	mm	σ_1	103.969	MPa
	y_2	-1.626	mm	z_2	345.685	mm	σ_2	100.416	MPa
Right	y_1	230.874	mm	z_1	345.685	mm	σ_1	96.619	MPa
	y_2	13.374	mm	z_2	345.685	mm	σ_2	100.171	MPa

Bottom Flange

Left	y_1	-219.126	mm	z_1	-424.315	mm	σ_1	-36.989	MPa
	y_2	-1.626	mm	z_2	-424.315	mm	σ_2	-40.541	MPa
Right	y_1	230.874	mm	z_1	-424.315	mm	σ_1	-44.338	MPa
	y_2	13.374	mm	z_2	-424.315	mm	σ_2	-40.786	MPa

Web

Right	y_1	5.874	mm	z_1	330.685	mm	σ_1	97.548	MPa
	y_2	5.874	mm	z_2	-404.315	mm	σ_2	-37.002	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	2
Bottom flange	3
Section	3

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 467.589 mm

N_{slab} = 0.000 kN

$N_{rebar,t}$ = 1573.043 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 3739.728 kN (Upper side of PNA)

$N_{g,bot}$ = 5312.772 kN (Lower side of PNA)

$M_{pl,Rd}$ = 3439.472 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

$\lambda_w = h_w / (86.4 \cdot t \cdot \varepsilon)$ = 0.697

$X_w = 0.83 / \lambda_w$ = 1.191 $0.83/\eta \leq \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2446.072 \text{ kN}$$

V_{Rd} = 2446.072 kN

$V_{Edi} = V_{Ed}$ / Num. of Web = -731.644 kN

$\eta'_3 = V_{Edi} / V_{bw,Rd}$ = 0.299 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 2487.458 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 2487.458 kN・m

M_{Ed} = 705.449 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

$V_{Edi} / (V_{bw,Rd}+V_{bf,Rd})$ = 0.299 < 1.0 … OK

■ Interaction M-V

η'_3 = 0.299 < 0.5

There is no need to verify the interaction criterion

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_3

N_{Ed} = 1496.314 kN

M_{Ed} = -939.212 kN・m

V_1 = -287.338 kN

V_2 = -281.329 kN

M_1 = -939.212 kN・m

M_2 = -654.853 kN・m

$M_{pl,Rd}$ = 3439.472 kN・m

$M_{el,Rd}$ = 2753.287 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 1.000 m

$c = C_d / l$ = 0.000 kN/m^2

$\gamma = c \cdot L^4 / (E \cdot I)$ = 0.000

$\mu = V_2 / V_1$ = 0.979

$\Phi = 2 \cdot (1-M_2/M_1) / (1+\mu)$ = 0.306

m_1 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(3+2 \cdot \Phi) \cdot \gamma/(350-50 \cdot \mu)$ = 1.147

m_2 = $1+0.44 \cdot (1+\mu) \cdot \Phi^{1.5}+(0.195+(0.05+\mu/100) \cdot \Phi) \cdot \gamma^{0.5}$ = 1.147

m = $\mathrm{Min}(m_1, m_2)$ = 1.147

α_{LT} = 0.490

λ_{LT} = $1.103 \cdot L/b \cdot \sqrt{(f_y/Em)} \cdot \sqrt{(1+A_{wc}/(3 \cdot A_f))}$ = 0.104

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.482

$$X_{LT} = \frac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}} = 1$$

M_{Rd} = 2753.287 kN・m

$M_{b,Rd}$ = $X_{LT} \cdot M_{Rd}$ = 2753.287 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd}$ = $X_{LT} \cdot \mathrm{Area} \cdot f_{yd}$ = 10411.643 kN

$$\text{Combined Ratio} = \frac{N_{Ed}}{N_{b,Rd}} + \frac{M_{Ed}}{M_{b,Rd}} = 0.484839282$$

5 Resistance to Longitudinal Shear

- Design load

Load combination name : SLU_3

$N_{c,el}$ = 0.000 kN

$N_{c,f}$ = 0.000 kN

M_{Ed} = -638.891 kN・m

V_{Ed} = -604.690 kN

$M_{pl,Rd}$ = 3439.472 kN・m

$M_{el,Rd}$ = 2753.287 kN・m

- Shear resistance of a single connector

$P_{Rd,1}$ = $0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2}$ = $0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

P_{Rd} = $\mathrm{Min}(P_{Rd,1} , P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed}$ = $V_{Ed} \cdot (A \cdot z / I)$ = 735.556 kN/m

$v_{L,Rd}$ = $P_{Rd} \cdot \mathrm{Num./Space}$ = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 Stress Limitation

- In the structural steel

Characteristic load combination name : CAR_2

$\sigma_{Ed,ser}$ = 62.237 MPa (Bottom-left fiber in the flange)

$\tau_{Ed,ser}$ = 50.152 MPa (Neutral axis in the web)

$\sigma_{Ed,ser}$ < $f_y / \gamma_{M,ser}$

62.237 MPa < 338.095 MPa ... OK

$\tau_{Ed,ser}$ < $f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

50.152 MPa < 195.199 MPa ... OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

106.860 MPa < 338.095 MPa ... OK

- In the concrete of the slab

Characteristic load combination name : CAR_4

$\sigma_c \leq k_1 f_{ck}$

4.647 MPa < 21.000 MPa ... OK

- In the reinforcement

Load combination name : CAR_4

$\sigma_s \leq k_3 f_{yk}$

-85.964 MPa

Rebar is under compression. No need to check.

7 **Longitudinal Shear for SLS(Serviceability limit state)**

- Shear resistance of a single connector

Load combination name : CAR_3

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = \mathrm{Min}(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd}$ = 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 558.197 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot \mathrm{Num./Space}$ = 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ ... OK

Element Number	547
Position Information	J

1 Design Condition

1.1 Design Parameters

■ Partial factors

γ_C for concrete	1.50	γ_V for headed sutd	1.25
γ_S for reinforcing steel	1.15	γ_{Ff} for equivalent constant Amplitude stress range	1.00
γ_{M0} for structural steel	1.05	γ_{Mf} for fatigue strength	1.35
γ_{M1} for structural steel	1.10	$\gamma_{Mf,s}$ for fatigue strength of studs in shear	1.00

1.2 Material Information

■ Structural steel

f_{sk} = 355.000 MPa E_s = 210000.000 MPa

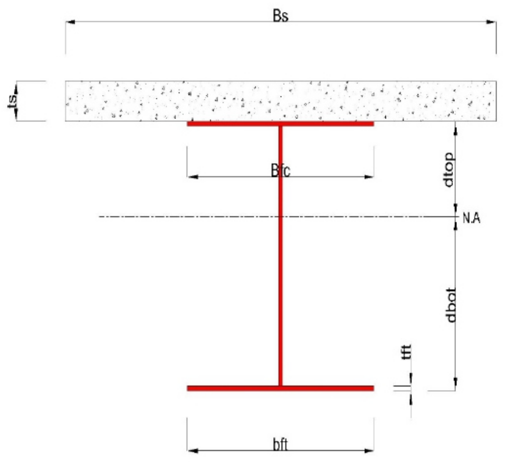
■ Concrete

f_{ck} = 35.000 MPa E_{cm} = 34000.000 MPa

■ Reinforcement

f_{yk} = 450.000 MPa E_r = 210000.000 MPa

1.3 Sectional Information



■ Section Dimensions

Slab

B_c	1990.000	mm	t_c	230.000	mm	H_h	0.000	mm

Girder

H_w	755.000	mm	B_1	450.000	mm	B_2	450.000	mm
t_w	15.000	mm	t_{f1}	15.000	mm	t_{f2}	20.000	mm

■ Section Stiffness

Before

$A_{,a}$	27075.000	mm^2
$I_{y,a}$	2861139006.666	mm^4

After

$A_{,c}$	101346.633	mm^2
$I_{y,c}$	8981412905.522	mm^4

$I_{z,a}$	265993593.750	mm^4		$I_{z,c}$	24776251366.881	mm^4
$C_{y,a}$	225.000	mm		$C_{y,c}$	225.000	mm
$C_{z,a}$	364.675	mm		$C_{z,c}$	760.651	mm

Crack

$A_{,c}$	31095.000	mm^2
$I_{y,c}$	3885219169.007	mm^4
$I_{z,c}$	1599746019.675	mm^4
$C_{y,c}$	219.182	mm
$C_{z,c}$	434.018	mm

2 **Bending Resistance**

2.1 Positive Moment

■ Design load

Load combination name : SLU_4

$N_{a,Ed}$	119.872	kN
$N_{c,Ed}$	469.908	kN
$M_{a,Ed}$	20.572	kN・m
$M_{c,Ed}$	254.963	kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	29.349	mm	σ_1	1.755	MPa
	y_2	-7.500	mm	z_2	29.349	mm	σ_2	5.059	MPa
Right	y_1	225.000	mm	z_1	29.349	mm	σ_1	8.590	MPa
	y_2	7.500	mm	z_2	29.349	mm	σ_2	5.287	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-760.651	mm	σ_1	29.862	MPa
	y_2	-7.500	mm	z_2	-760.651	mm	σ_2	33.165	MPa
Right	y_1	225.000	mm	z_1	-760.651	mm	σ_1	36.697	MPa
	y_2	7.500	mm	z_2	-760.651	mm	σ_2	33.393	MPa

Web

Right	y_1	0.000	mm	z_1	14.349	mm	σ_1	5.706	MPa
	y_2	0.000	mm	z_2	-740.651	mm	σ_2	32.568	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

- Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 789.750 mm

N_{slab} = 9077.717 kN

$N_{g,top}$ = 38.106 kN (Upper side of PNA)

$N_{g,bot}$ = 9115.823 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4937.327 kN・m

x_{pl} = 230.250 mm

M_{Rd} = $\beta M_{pl,Rd}$ = 4937.327 kN・m

here, β = 1.000

M_{Rd} = 4937.327 kN・m > M_{Ed} = 275.536 kN・m …OK

2 Bending Resistance

2.2 Negative Moment

■ Design load

Load combination name : SLU_3

$N_{a,Ed}$	119.872	kN
$N_{c,Ed}$	1376.668	kN
$M_{a,Ed}$	20.572	kN・m
$M_{c,Ed}$	-675.425	kN・m

- Stress

Top Flange

Left	y_1	-219.182	mm	z_1	355.982	mm	σ_1	107.255	MPa
	y_2	-1.682	mm	z_2	355.982	mm	σ_2	107.346	MPa
Right	y_1	230.818	mm	z_1	355.982	mm	σ_1	107.442	MPa
	y_2	13.318	mm	z_2	355.982	mm	σ_2	107.352	MPa

Bottom Flange

Left	y_1	-219.182	mm	z_1	-434.018	mm	σ_1	-24.402	MPa
	y_2	-1.682	mm	z_2	-434.018	mm	σ_2	-24.312	MPa
Right	y_1	230.818	mm	z_1	-434.018	mm	σ_1	-24.215	MPa
	y_2	13.318	mm	z_2	-434.018	mm	σ_2	-24.305	MPa

Web

Right	y_1	5.818	mm	z_1	340.982	mm	σ_1	104.849	MPa
	y_2	5.818	mm	z_2	-414.018	mm	σ_2	-20.975	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	2
Bottom flange	3
Section	3

- Elastic resistance moment, $M_{el,Rd}$

k = 4.231 : the lowest factor such that a stress limit is reached.

(Calculate minimum value between Steel Girder and Slab Reinforcement.)

$M_{el,Rd}$ = $M_{a,Ed} + k \cdot M_{c,Ed}$ = 2857.536 kN・m

M_{Rd} = $M_{el,Rd}$ = 2857.536 kN・m

M_{Rd} = 2857.536 kN・m > M_{Ed} = -675.425 kN・m …OK

3 Resistance to Vertical Shear

■ Design load

Load combination name : SLU_3

N_{Ed} = 931.730 kN

$M_{a,Ed}$ = 20.572 kN・m

$M_{c,Ed}$ = 69.270 kN・m

$V_{Ed,a}$ = -120.960 kN

$V_{Ed,c}$ = -604.690 kN

V_{Ed} = -725.650 kN

M_{Ed} = max($M_{Ed,t}$, $M_{Ed,b}$) = 1005.139 kN・m

$M_{Ed,t}$ = 1005.139 kN・m

$M_{Ed,b}$ = 100.230 kN・m

- Stress

Top Flange

Left	y_1	-225.000	mm	z_1	29.349	mm	σ_1	4.470	MPa
	y_2	-7.500	mm	z_2	29.349	mm	σ_2	10.141	MPa
Right	y_1	225.000	mm	z_1	29.349	mm	σ_1	16.202	MPa
	y_2	7.500	mm	z_2	29.349	mm	σ_2	10.532	MPa

Bottom Flange

Left	y_1	-225.000	mm	z_1	-760.651	mm	σ_1	16.243	MPa
	y_2	-7.500	mm	z_2	-760.651	mm	σ_2	21.914	MPa
Right	y_1	225.000	mm	z_1	-760.651	mm	σ_1	27.976	MPa
	y_2	7.500	mm	z_2	-760.651	mm	σ_2	22.305	MPa

Web

Right	y_1	0.000	mm	z_1	14.349	mm	σ_1	10.560	MPa
	y_2	0.000	mm	z_2	-740.651	mm	σ_2	21.812	MPa

■ Classification of sections

Part	Class
Top flange	1
Web	1
Bottom flange	1
Section	1

■ Plastic resistance moment, $M_{pl,Rd}$

Plastic NA = 789.750 mm

N_{slab} = 9077.717 kN

$N_{rebar,t}$ = 0.000 kN (Upper side of PNA)

$N_{rebar,b}$ = 0.000 kN (Lower side of PNA)

$N_{g,top}$ = 38.106 kN (Upper side of PNA)

$N_{g,bot}$ = 9115.823 kN (Lower side of PNA)

$M_{pl,Rd}$ = 4937.327 kN・m

■ Calculation. $V_{bw,Rd}$

Web

■ Contribution from the web

λ_w = h_w / (86.4 ・ t ・ ε) = 0.697

X_w = 0.83 / λ_w = 1.191 $0.83/\eta \le \lambda_w < 1.08$

$$V_{bw,Rd} = \frac{X_w \cdot f_{yw} \cdot h_w \cdot t}{\sqrt{3} \cdot \gamma_{M1}} = 2512.631 \text{ kN}$$

V_{Rd} = 2512.631 kN

V_{Edi} = V_{Ed} / Num. of Web = -725.650 kN

η'_3 = V_{Edi} / $V_{bw,Rd}$ = 0.289 ≤ 1.0

■ Contribution from the flange

$M_{f,Rd}$ = 3256.075 kN・m

$M_{f,Rd}$ is calculated as $M_{pl,Rd}$ but neglecting the web contribution.

$$V_{bf,Rd} = \frac{b_f \cdot t_f^2 \cdot f_{yf}}{c \cdot \gamma_{M1}} \left(1 - \left(\frac{M_{Ed}}{M_{f,Rd}}\right)^2\right) = 0.000 \text{ kN}$$

where, $M_{f,Rd}$ = 3256.075 kN・m

M_{Ed} = 1005.139 kN・m (Taken as the greatest value of $(\sum\sigma_i)W$)

$$c = a \cdot \left(0.25 + \frac{1.6 \cdot b_f \cdot t_f^2 \cdot f_{yf}}{t \cdot h_w^2 \cdot f_{yw}}\right) = 0.000$$

■ Check Shear Resistance

V_{Edi} / ($V_{bw,Rd}$+$V_{bf,Rd}$) = 0.289 < 1.0 … OK

■ Interaction M-V

For the section class 1 or 2, M-V interaction should be checked separately by the user.

4 **Resistance to Lateral Torsional Buckling**

- Design load

Load combination name : SLU_3

N_{Ed} = 1496.540 kN

M_{Ed} = -654.853 kN・m

V_1 = -287.338 kN

V_2 = -281.329 kN

M_1 = -939.212 kN・m

M_2 = -654.853 kN・m

$M_{pl,Rd}$ = 3540.020 kN・m

$M_{el,Rd}$ = 2857.536 kN・m

- $M_{b,Rd}$ Buckling resistance moment

L = 1.000 m

c = C_d / l = 0.000 kN/m^2

γ = c・L^4 / (E・I) = 0.000

μ = V_2 / V_1 = 0.979

Φ = 2・(1-M_2/M_1) / (1+μ) = 0.306

m_1 = 1+0.44・(1+μ)・$\Phi^{1.5}$+(3+2・Φ)・γ/(350-50・μ) = 1.147

m_2 = 1+0.44・(1+μ)・$\Phi^{1.5}$+(0.195+(0.05+μ/100)・Φ)・$\gamma^{0.5}$ = 1.147

m = Min(m_1, m_2) = 1.147

α_{LT} = 0.490

λ_{LT} = 1.103・L/b・√(f_y/Em)・√(1+A_{wc}/(3・A_f)) = 0.104

Φ_{LT} = $0.5 \cdot (1+\alpha_{LT} \cdot (\lambda_{LT} - 0.2)+\lambda_{LT}^2)$ = 0.482

$X_{LT} = \dfrac{1}{\Phi_{LT} + \sqrt{(\Phi_{LT}^2 - \lambda_{LT}^2)}}$ = 1

M_{Rd} = 2857.536 kN・m

$M_{b,Rd} = X_{LT} \cdot M_{Rd}$ = 2857.536 kN・m

- $N_{b,Rd}$ Axial buckling resistance

$X_{LT,N}$ = 1.000

$N_{b,Rd} = X_{LT} \cdot Area \cdot f_{yd}$ = 10513.071 kN

Combined Ratio $= \dfrac{N_{Ed}}{N_{b,Rd}} + \dfrac{M_{Ed}}{M_{b,Rd}}$ = 0.371517323

5 **Resistance to Longitudinal Shear**

- Design load

Load combination name : SLU_3

$N_{c,el}$ = 4717.670 kN

$N_{c,f}$ = 9077.717 kN

M_{Ed} = 89.842 kN・m

V_{Ed} = -604.690 kN

$M_{pl,Rd}$ = 4937.327 kN・m

$M_{el,Rd}$ = 3981.684 kN・m

- Shear resistance of a single connector

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V$ = 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V$ = 122.492 kN

$P_{Rd} = Min(P_{Rd,1}, P_{Rd,2})$ = 109.478 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I)$ = 720.183 kN/m

$v_{L,Rd} = P_{Rd} \cdot Num./Space$ = 1642.173 kN/m

$v_{L,Ed} < v_{L,Rd}$ … OK

6 **Stress Limitation**

- In the structural steel

Characteristic load combination name : CAR_4

$\sigma_{Ed,ser}$ = 34.676 MPa (Top-left fiber in the flange)

$\tau_{Ed,ser}$ = 48.431 MPa (Neutral axis in the web)

$\sigma_{Ed,ser} < f_y / \gamma_{M,ser}$

34.676 MPa < 338.095 MPa … OK

$\tau_{Ed,ser} < f_y / (\sqrt{3} \cdot \gamma_{M,ser})$

48.431 MPa < 195.199 MPa ... OK

$\sqrt{(\sigma_{Ed,ser}^2 + 3\tau_{Ed,ser}^2)}$ < $f_y / \gamma_{M,ser}$

90.770 MPa < 338.095 MPa ... OK

- In the concrete of the slab

Characteristic load combination name : CAR_4

$\sigma_c \leq k_1 f_{ck}$

5.211 MPa < 21.000 MPa ... OK

- In the reinforcement

Load combination name : CAR_1

$\sigma_s \leq k_3 f_{yk}$

-46.571 MPa

Rebar is under compression. No need to check.

7 **Longitudinal Shear for SLS(Serviceability limit state)**

- Shear resistance of a single connector

Load combination name : CAR_3

$P_{Rd,1} = 0.8 \cdot f_u \cdot \pi \cdot d^2 / 4 / \gamma_V =$ 109.478 kN

$P_{Rd,2} = 0.29 \cdot \alpha \cdot d^2 \cdot \sqrt{(f_{ck} \cdot E_{cm})} / \gamma_V =$ 122.492 kN

$P_{Rd} = \mathrm{Min}(P_{Rd,1}, P_{Rd,2}) =$ 109.478 kN

$P_{Rd,ser} = k_s \cdot P_{Rd} =$ 82.109 kN

where, f_u = 450.000 MPa

α = 1 for $h_{sc}/d > 4$

Num. = 3

d = 22.000 mm

h_{sc} = 175.000 mm

Space = 200.000 mm

k_s = 0.750

- Verification

$v_{L,Ed} = V_{Ed} \cdot (A \cdot z / I) =$ 546.531 kN/m

$v_{L,Rd} = P_{Rd,ser} \cdot \mathrm{Num./Space} =$ 1231.630 kN/m

$v_{L,Ed} < v_{L,Rd}$ ... OK