5
Demais exemplos

Neste capítulo apresentam-se outros exemplos do uso do **Prestress**. Ao contrário do exemplo dado no Capítulo 4, cada exemplo apresentará apenas seu modelo, os dados de protensão, o arquivo de resultados e algumas observações.

5.1
Viaduto da Guarita - Pista Norte

Este projeto trata do reforço e alargamento de um viaduto existente. O viaduto apresenta três vãos e balanços nas extremidades. Após o alargamento a seção transversal apresenta quatro vigas moldadas *in loco*, sendo duas existentes e duas novas, e uma laje de 22cm. O Apêndice B.2 apresenta os dados relevantes do projeto; a Figura 5.1, o modelo; e a Tabela 5.1, os dados adotados no **Prestress**. A viga analisada aqui é a extrema, que apresenta as maiores solicitações.

Como as vigas neste projeto foram concretadas *in loco*, suas seções transversais consideram a laje colaborante e o modelo contém todas as transversinas. As vigas se apoiam em pilares por meio de articulações Freyssinet que permitem a rotação mas não o deslocamento. Os pilares são então modelados com rótulas (não vistas na figura). A fundação é locada em rocha sã, logo os apoios adotados são rígidos tanto à rotação quanto ao deslocamento. Desta forma, qualquer efeito destas condições de contorno será considerado pelo **Robot** e logo pelo **Prestress**.

Como consequência destas condições de contorno os resultados não são simétricos. Uma parcela significativa da protensão é absorvida pelos pilares. Um modelo bem mais simples, que desconsidera os pilares e considera todos os apoios como permitindo o deslocamento axial (resistindo apenas aos esforços verticais), apresenta esforços axiais até 40% maiores.

Observa-se que os resultados impressos consideram a descontinuidade que ocorre nas seções 13 e 27. São estas as seções onde os cabos C3 e C4 se ancoram. Tem-se então os resultados da seção antes e depois da influência destes cabos. Observa-se também que as faces onde estes cabos não atuam (13E e 27D) não satisfazem o ELS-D. Isto ocorre uma vez que estas sofrem dos mesmos esforços das faces vizinhas (13D e 27E), porém sem a compressão benéfica da protensão. Quando a carga acidental começa a atuar, o meio do vão também apresenta tração quase-permanente.

Estes resultados podem ser parcialmente explicados pelas simplificações do modelo, em especial o fato das lajes serem modeladas como "claddings", sem rigidez. Devido a isso, a colaboração das demais vigas devido à transmissão transversal de esforços não ocorre, com a vasta maioria da carga móvel sendo resistida apenas pela viga analisada. Se o mesmo modelo for adotado, porém com as lajes apresentando rigidez, o momento acidental máximo no meio do vão é de apenas 1873,52kNm, 11% menor que o esforço adotado no modelo.

Seção (m)	C1	C2	C3	C4
0,000	1,238	1,508	-	-
2,820	0,929	0,974	-	-
5,120	0,866	0,866	-	-
7,420	1,046	1,046	-	-
9,595	1,583	1,583	-	-
11,770	2,121	2,121	-	-
13,945	2,300	2,300	-	-
16,120	2,228	2,228	-	-
18,370	2,012	2,012	-	-
20,620	1,653	1,653	-	-
22,870	1,150	1,150	-	-
25,120	0,502	0,502	-	-
27,120	0,120	0,120	0,720	0,990
29,120	0,361	0,361	1,168	1,371
31,120	0,642	0,642	1,552	1,697
33,120	0,876	0,876	1,872	1,969
35,120	1,063	1,063	2,128	2,187
37,120	1,204	1,204	2,307	2,350
39,620	1,313	1,313	2,470	2,493
42,120	1,350	1,350	2,520	2,520

-Simetria-

(a) Traçado dos cabos

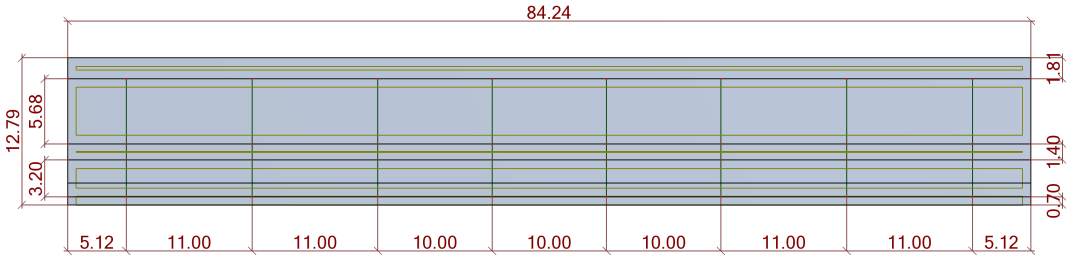
Propriedades	
do projeto	
ψ_F	0,5
ψ_D	0,3
das fases	
Umidade (%)	75
Temperatura (°C)	25
do concreto	
f_{ck} (MPa)	40
Slump (cm)	5-9
Tipo	CPV-ARI
da protensão	
E_p (MPa)	195000
f_{ptk} (MPa)	1900
A_p (cm^2)	11,84
σ_{p0} (MPa)	1406
μ (1/rad)	0,28
k (rad/m)	0,0028
δ (mm)	7
Relaxação	Baixa
Ancoragens ativas	Ambas

(b) Propriedades adotadas no cálculo

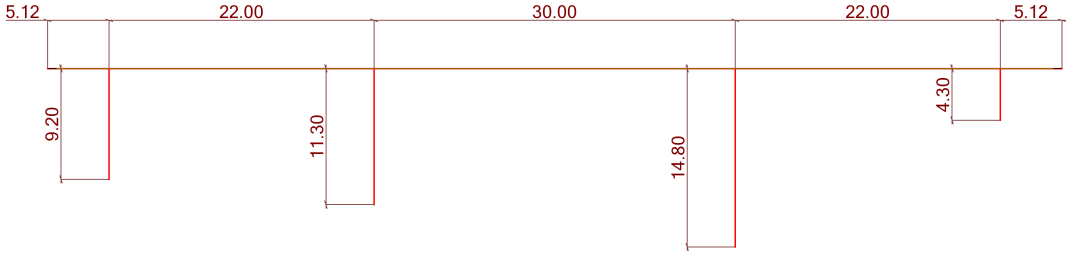
Fase	Data (dias)	Carga		Cabos protendidos
		Permanente	Acidental	
1	3	Peso-próprio da estrutura	-	C1 a C4
2	28	Pavimentação, recapeamento e guarda-rodas	TB-45	-
3	365	-	TB-45	-
4	18250	-	TB-45	-

(c) Propriedades das fases

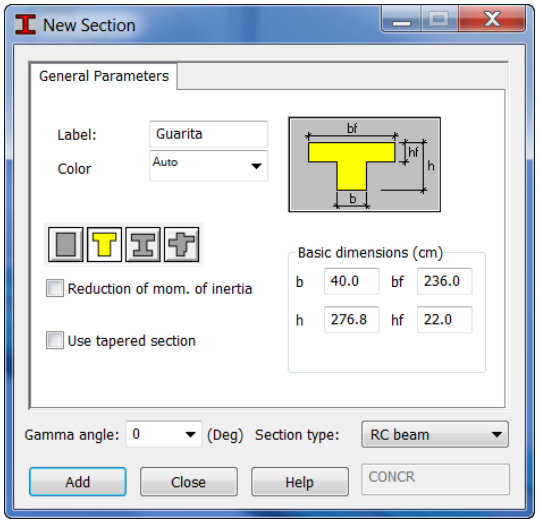
Tabela 5.1: Dados utilizados no **Prestress** para o Viaduto da Guarita - Pista Norte



(a) Vista em planta



(b) Vista em elevação



Propriedades	
Área (m^2)	1,5384
Perímetro (m)	6,340
I_y (m^4)	1,1858
y_i (m)	1,722
y_s (m)	1,046

(c) Seção transversal das vigas longarinas

Figura 5.1: Modelo do **Robot** do Viaduto da Guarita - Pista Norte

f_{ck} = 40 MPa
s = 0.2
ψ_F = 0.5
ψ_D = 0.3

Alongamentos (cm)
Cabo 1 45.6311
Cabo 2 44.3274
Cabo 3 19.9181
Cabo 4 20.0333

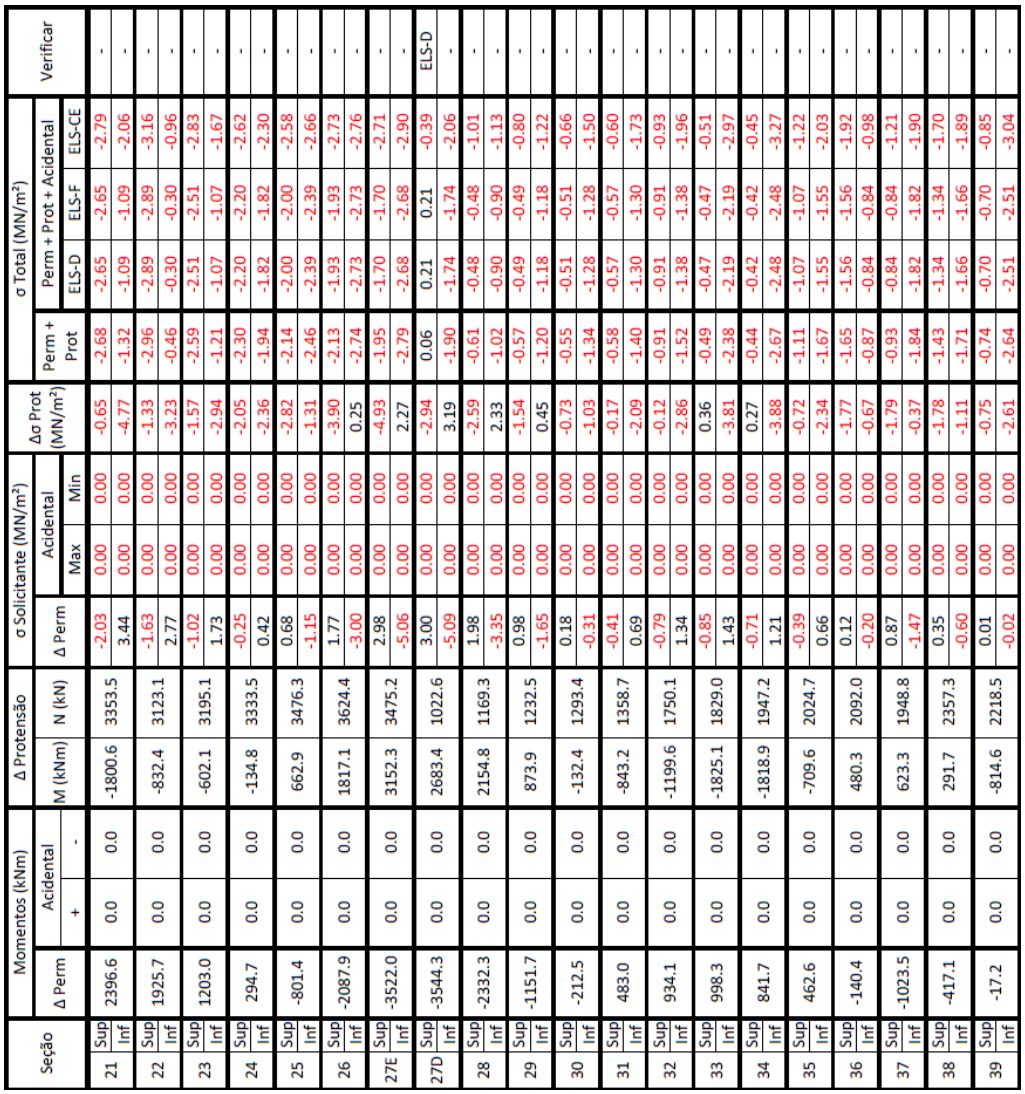
(a) Dados do projeto e alongamentos teóricos dos cabos

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte

Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)			Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental		
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE
1	Sup	-17.1	0.0	0.0	-817.0	0.01	0.00	0.00	-0.75	-0.73	-0.70	-0.70	-0.85
	Inf					-0.02	0.00	0.00	-2.61	-2.64	-2.51	-2.51	-3.04
2	Sup	-421.1	0.0	0.0	299.9	0.36	0.00	0.00	-1.78	-1.43	-1.34	-1.34	-1.70
	Inf					-0.60	0.00	0.00	-1.10	-1.70	-1.65	-1.65	-1.87
3	Sup	-1025.3	0.0	0.0	591.1	0.87	0.00	0.00	-2.11	-1.24	-1.13	-1.13	-1.56
	Inf					-1.47	0.00	0.00	-0.76	-2.23	-2.19	-2.19	-2.35
4	Sup	-154.0	0.0	0.0	495.1	0.13	0.00	0.00	-1.87	-1.74	-1.64	-1.64	-2.03
	Inf					-0.22	0.00	0.00	-0.74	-0.96	-0.92	-0.92	-1.07
5	Sup	449.8	0.0	0.0	-695.1	-0.38	0.00	0.00	-0.82	-1.20	-1.16	-1.16	-1.32
	Inf					0.65	0.00	0.00	-2.40	-1.76	-1.64	-1.64	-2.13
6	Sup	831.0	0.0	0.0	-1804.7	-0.70	0.00	0.00	0.17	-0.53	-0.52	-0.52	-0.54
	Inf					1.19	0.00	0.00	-3.95	-2.75	-2.56	-2.56	-3.36
7	Sup	988.1	0.0	0.0	-1811.6	-0.84	0.00	0.00	0.26	-0.58	-0.57	-0.57	-0.59
	Inf					1.42	0.00	0.00	-3.88	-2.46	-2.27	-2.27	-3.06
8	Sup	919.6	0.0	0.0	-1186.7	-0.78	0.00	0.00	-0.22	-1.00	-0.99	-0.99	-1.03
	Inf					1.32	0.00	0.00	-2.93	-1.61	-1.46	-1.46	-2.06
9	Sup	458.3	0.0	0.0	-826.3	-0.39	0.00	0.00	-0.26	-0.64	-0.63	-0.63	-0.68
	Inf					0.66	0.00	0.00	-2.14	-1.48	-1.38	-1.38	-1.82
10	Sup	-243.3	0.0	0.0	-112.9	0.21	0.00	0.00	-0.82	-0.61	-0.57	-0.57	-0.74
	Inf					-0.35	0.00	0.00	-1.08	-1.43	-1.37	-1.37	-1.59
11	Sup	-1188.4	0.0	0.0	896.0	1.01	0.00	0.00	-1.63	-0.63	-0.55	-0.55	-0.88
	Inf					-1.71	0.00	0.00	0.41	-1.29	-1.27	-1.27	-1.31
12	Sup	-2377.1	0.0	0.0	2179.4	2.01	0.00	0.00	-2.68	-0.67	-0.53	-0.53	-1.08
	Inf					-3.41	0.00	0.00	2.30	-1.12	-1.00	-1.00	-1.23
13E	Sup	-3620.2	0.0	0.0	2718.7	3.07	0.00	0.00	-3.04	0.03	0.18	0.18	-0.44
	Inf					-5.20	0.00	0.00	3.17	-2.03	-1.87	-1.87	-2.19
13D	Sup	-3602.0	0.0	0.0	3206.7	3.05	0.00	0.00	-5.00	-1.95	-1.70	-1.70	-2.73
	Inf					-5.17	0.00	0.00	2.32	-2.86	-2.74	-2.74	-2.97
14	Sup	-2140.8	0.0	0.0	1914.9	1.81	0.00	0.00	-3.86	-2.04	-1.85	-1.85	-2.64
	Inf					-3.07	0.00	0.00	0.52	-2.56	-2.53	-2.53	-2.58
15	Sup	-844.8	0.0	0.0	754.0	0.72	0.00	0.00	-2.88	-2.17	-2.02	-2.02	-2.61
	Inf					-1.21	0.00	0.00	-1.16	-2.37	-2.32	-2.32	-2.55
16	Sup	263.5	0.0	0.0	-162.0	-0.22	0.00	0.00	-2.12	-2.35	-2.24	-2.24	-2.67
	Inf					0.38	0.00	0.00	-2.49	-2.11	-1.99	-1.99	-2.50
17	Sup	1182.7	0.0	0.0	-833.0	-1.00	0.00	0.00	-1.57	-2.58	-2.50	-2.50	-2.82
	Inf					1.70	0.00	0.00	-3.48	-1.78	-1.60	-1.60	-2.32
18	Sup	1911.6	0.0	0.0	-1227.7	-1.62	0.00	0.00	-1.26	-2.88	-2.82	-2.82	-3.07
	Inf					2.75	0.00	0.00	-4.06	-1.32	-1.11	-1.11	-1.95
19	Sup	2388.7	0.0	0.0	-1925.6	-2.02	0.00	0.00	-0.63	-2.65	-2.62	-2.62	-2.75
	Inf					3.43	0.00	0.00	-5.03	-1.60	-1.35	-1.35	-2.38
20	Sup	2543.1	0.0	0.0	-2061.2	-2.15	0.00	0.00	-0.47	-2.62	-2.60	-2.60	-2.69
	Inf					3.65	0.00	0.00	-5.17	-1.52	-1.26	-1.26	-2.32

(b) Resultados da primeira fase - Folha 1/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)



Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)			Verificar
		Δ Perm	Acidental +	Acidental -	M (kNm)	N (kN)	Δ Perm	Acidental Max	Acidental Min		Perm + Prot	Perm + Prot + Acidental ELS-D	ELS-F	ELS-CE	
21	Sup	2396.6	0.0	0.0	-1800.6	3353.5	-2.03	0.00	0.00	-0.65	-2.68	-2.65	-2.65	-2.79	-
	Inf						3.44	0.00	0.00	-4.77	-1.32	-1.09	-1.09	-2.06	-
22	Sup	1925.7	0.0	0.0	-832.4	3123.1	-1.63	0.00	0.00	-1.33	-2.96	-2.89	-2.89	-3.16	-
	Inf						2.77	0.00	0.00	-3.23	-0.46	-0.30	-0.30	-0.96	-
23	Sup	1203.0	0.0	0.0	-602.1	3195.1	-1.02	0.00	0.00	-1.57	-2.59	-2.51	-2.51	-2.83	-
	Inf						1.73	0.00	0.00	-2.94	-1.21	-1.07	-1.07	-1.67	-
24	Sup	294.7	0.0	0.0	-134.8	3333.5	-0.25	0.00	0.00	-2.05	-2.30	-2.20	-2.20	-2.62	-
	Inf						0.42	0.00	0.00	-2.36	-1.94	-1.82	-1.82	-2.30	-
25	Sup	-801.4	0.0	0.0	662.9	3476.3	0.68	0.00	0.00	-2.82	-2.14	-2.00	-2.00	-2.58	-
	Inf						-1.15	0.00	0.00	-1.31	-2.46	-2.39	-2.39	-2.66	-
26	Sup	-2087.9	0.0	0.0	1817.1	3624.4	1.77	0.00	0.00	-3.90	-2.13	-1.93	-1.93	-2.73	-
	Inf						-3.00	0.00	0.00	0.25	-2.74	-2.73	-2.73	-2.76	-
27E	Sup	-3522.0	0.0	0.0	3152.3	3475.2	2.98	0.00	0.00	-4.93	-1.95	-1.70	-1.70	-2.71	-
	Inf						-5.06	0.00	0.00	2.27	-2.79	-2.68	-2.68	-2.90	-
27D	Sup	-3544.3	0.0	0.0	2683.4	1022.6	3.00	0.00	0.00	-2.94	0.06	0.21	0.21	-0.39	ELS-D
	Inf						-5.09	0.00	0.00	3.19	-1.90	-1.74	-1.74	-2.06	-
28	Sup	-2332.3	0.0	0.0	2154.8	1169.3	1.98	0.00	0.00	-2.59	-0.61	-0.48	-0.48	-1.01	-
	Inf						-3.35	0.00	0.00	2.33	-1.02	-0.90	-0.90	-1.13	-
29	Sup	-1151.7	0.0	0.0	873.9	1232.5	0.98	0.00	0.00	-1.54	-0.57	-0.49	-0.49	-0.80	-
	Inf						-1.65	0.00	0.00	0.45	-1.20	-1.18	-1.18	-1.22	-
30	Sup	-212.5	0.0	0.0	-132.4	1293.4	0.18	0.00	0.00	-0.73	-0.55	-0.51	-0.51	-0.66	-
	Inf						-0.31	0.00	0.00	-1.03	-1.34	-1.28	-1.28	-1.50	-
31	Sup	483.0	0.0	0.0	-843.2	1358.7	-0.41	0.00	0.00	-0.17	-0.58	-0.57	-0.57	-0.60	-
	Inf						0.69	0.00	0.00	-2.09	-1.40	-1.30	-1.30	-1.73	-
32	Sup	934.1	0.0	0.0	-1199.6	1750.1	-0.79	0.00	0.00	-0.12	-0.91	-0.91	-0.91	-0.93	-
	Inf						1.34	0.00	0.00	-2.86	-1.52	-1.38	-1.38	-1.96	-
33	Sup	998.3	0.0	0.0	-1825.1	1829.0	-0.85	0.00	0.00	0.36	-0.49	-0.47	-0.47	-0.51	-
	Inf						1.43	0.00	0.00	-3.81	-2.38	-2.19	-2.19	-2.97	-
34	Sup	841.7	0.0	0.0	-1818.9	1947.2	-0.71	0.00	0.00	0.27	-0.44	-0.42	-0.42	-0.45	-
	Inf						1.21	0.00	0.00	-3.88	-2.67	-2.48	-2.48	-3.27	-
35	Sup	462.6	0.0	0.0	-709.6	2024.7	-0.39	0.00	0.00	-0.72	-1.11	-1.07	-1.07	-1.22	-
	Inf						0.66	0.00	0.00	-2.34	-1.67	-1.55	-1.55	-2.03	-
36	Sup	-140.4	0.0	0.0	480.3	2092.0	0.12	0.00	0.00	-1.77	-1.65	-1.56	-1.56	-1.92	-
	Inf						-0.20	0.00	0.00	-0.67	-0.87	-0.84	-0.84	-0.98	-
37	Sup	-1023.5	0.0	0.0	623.3	1948.8	0.87	0.00	0.00	-1.79	-0.93	-0.84	-0.84	-1.21	-
	Inf						-1.47	0.00	0.00	-0.37	-1.84	-1.82	-1.82	-1.90	-
38	Sup	-417.1	0.0	0.0	291.7	2357.3	0.35	0.00	0.00	-1.78	-1.43	-1.34	-1.34	-1.70	-
	Inf						-0.60	0.00	0.00	-1.11	-1.71	-1.66	-1.66	-1.89	-
39	Sup	-17.2	0.0	0.0	-814.6	2218.5	0.01	0.00	0.00	-0.75	-0.74	-0.70	-0.70	-0.85	-
	Inf						-0.02	0.00	0.00	-2.61	-2.64	-2.51	-2.51	-3.04	-

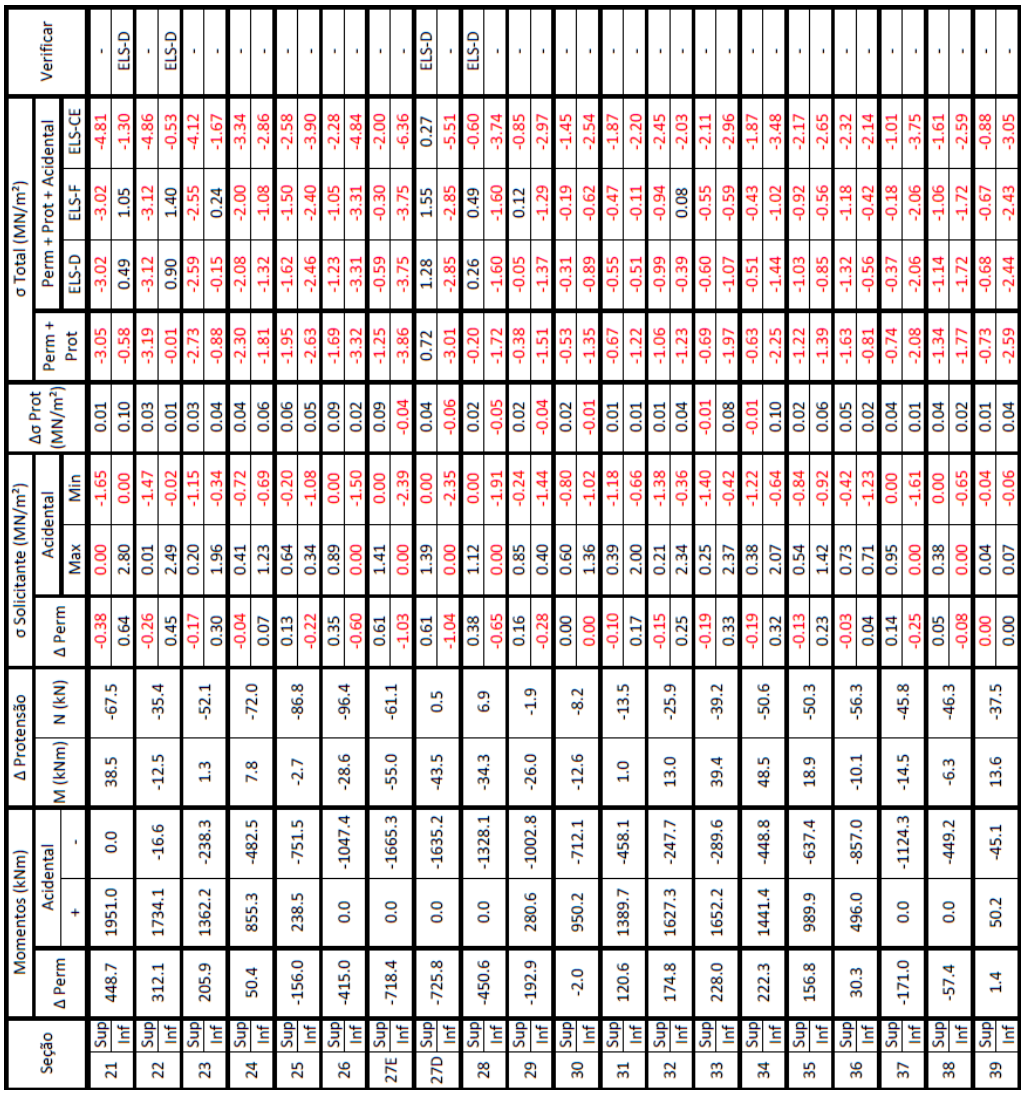
(c) Resultados da primeira fase - Folha 2/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)

Seção		Momentos (kNm)			Δ Protensão		σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)			Verificar
		Δ Perm	Acidental		M (kNm)	N (kN)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental		
			+	-				Max	Min			ELS-D	ELS-F	ELS-CE	
1	Sup	0.8	55.2	-44.4	13.7	-37.4	0.00	0.04	-0.05	0.01	-0.72	-0.67	-0.67	-0.88	-
	Inf						0.00	0.08	-0.06	0.04	-2.59	-2.44	-2.42	-3.05	-
2	Sup	-55.5	0.0	-520.6	-6.4	-46.1	0.05	0.44	0.00	0.04	-1.34	-1.13	-1.04	-1.62	-
	Inf						-0.08	0.00	-0.75	0.02	-1.76	-1.71	-1.71	-2.68	-
3	Sup	-169.9	0.0	-1254.2	-13.8	-55.8	0.14	1.06	0.00	0.05	-1.05	-0.62	-0.41	-1.36	-
	Inf						-0.24	0.00	-1.80	0.02	-2.46	-2.42	-2.42	-4.37	-
4	Sup	29.7	495.9	-930.5	-10.7	-59.7	-0.03	0.79	-0.42	0.05	-1.71	-1.39	-1.23	-2.42	-
	Inf						0.04	0.71	-1.34	0.02	-0.89	-0.64	-0.50	-2.34	-
5	Sup	156.9	987.8	-698.9	18.4	-53.7	-0.13	0.59	-0.84	0.02	-1.31	-1.09	-0.97	-2.27	-
	Inf						0.23	1.42	-1.00	0.06	-1.47	-0.93	-0.64	-2.84	-
6	Sup	224.3	1447.3	-496.9	48.0	-54.0	-0.19	0.42	-1.23	-0.01	-0.72	-0.59	-0.51	-1.96	-
	Inf						0.32	2.08	-0.71	0.10	-2.33	-1.51	-1.09	-3.64	-
7	Sup	230.8	1643.4	-325.8	38.6	-42.6	-0.20	0.28	-1.39	0.00	-0.78	-0.68	-0.63	-2.18	-
	Inf						0.33	2.36	-0.47	0.08	-2.05	-1.15	-0.68	-3.10	-
8	Sup	175.3	1632.9	-243.4	11.7	-29.4	-0.15	0.21	-1.38	0.01	-1.14	-1.07	-1.03	-2.55	-
	Inf						0.25	2.34	-0.35	0.04	-1.32	-0.47	0.00	-2.12	-
9	Sup	118.1	1402.5	-459.3	-0.8	-16.4	-0.10	0.39	-1.19	0.01	-0.73	-0.60	-0.53	-1.96	-
	Inf						0.17	2.01	-0.66	0.01	-1.31	-0.59	-0.19	-2.30	-
10	Sup	-5.3	942.3	-715.7	-15.0	-11.0	0.00	0.61	-0.80	0.02	-0.59	-0.37	-0.24	-1.51	-
	Inf						-0.01	1.35	-1.03	-0.01	-1.45	-0.99	-0.72	-2.64	-
11	Sup	-197.0	275.7	-1008.6	-29.1	-4.6	0.17	0.85	-0.23	0.03	-0.43	-0.10	0.08	-0.91	-
	Inf						-0.28	0.40	-1.45	-0.04	-1.62	-1.48	-1.40	-3.08	-
12	Sup	-457.0	0.0	-1338.2	-38.2	4.3	0.39	1.13	0.00	0.03	-0.25	0.22	0.45	-0.66	ELS-D
	Inf						-0.66	0.00	-1.92	-0.06	-1.83	-1.72	-1.72	-3.87	-
13E	Sup	-741.5	0.0	-1657.6	-47.4	-1.5	0.63	1.40	0.00	0.04	0.70	1.27	1.55	0.23	ELS-D
	Inf						-1.06	0.00	-2.38	-0.07	-3.16	-3.01	-3.01	-5.70	-
13D	Sup	-734.9	0.0	-1694.6	-59.8	-63.2	0.62	1.44	0.00	0.09	-1.24	-0.56	-0.28	-2.00	-
	Inf						-1.06	0.00	-2.43	-0.04	-3.96	-3.84	-3.84	-6.50	-
14	Sup	-427.0	0.0	-1070.2	-38.4	-74.8	0.36	0.91	0.00	0.08	-1.60	-1.14	-0.96	-2.19	-
	Inf						-0.61	0.00	-1.54	-0.01	-3.18	-3.15	-3.15	-4.74	-
15	Sup	-164.7	225.0	-768.5	-12.8	-82.5	0.14	0.65	-0.19	0.06	-1.96	-1.63	-1.50	-2.59	-
	Inf						-0.24	0.32	-1.10	0.04	-2.58	-2.42	-2.36	-3.85	-
16	Sup	46.7	853.1	-492.7	9.5	-85.8	-0.04	0.42	-0.72	0.05	-2.34	-2.11	-2.03	-3.38	-
	Inf						0.07	1.23	-0.71	0.07	-1.98	-1.49	-1.24	-3.06	-
17	Sup	206.3	1344.9	-242.7	25.1	-85.8	-0.17	0.21	-1.14	0.03	-2.72	-2.58	-2.54	-4.09	-
	Inf						0.30	1.93	-0.35	0.09	-1.39	-0.64	-0.25	-2.26	-
18	Sup	313.3	1726.3	-19.7	31.1	-82.6	-0.27	0.02	-1.46	0.03	-3.12	-3.05	-3.05	-4.77	-
	Inf						0.45	2.48	-0.03	0.10	-0.77	0.17	0.67	-1.41	ELS-D
19	Sup	448.7	1950.5	0.0	53.8	-83.8	-0.38	0.00	-1.65	0.01	-3.03	-2.99	-2.99	-4.77	-
	Inf						0.64	2.80	0.00	0.13	-0.82	0.26	0.82	-1.58	ELS-D
20	Sup	490.9	1873.3	0.0	51.1	-75.9	-0.42	0.00	-1.59	0.01	-3.03	-3.01	-3.01	-4.69	-
	Inf						0.70	2.69	0.00	0.12	-0.69	0.37	0.91	-1.47	ELS-D

(d) Resultados da segunda fase - Folha 1/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)



Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)				Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental			
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE	
21	Sup	448.7	1951.0	0.0	38.5	-0.38	0.00	-1.65	0.01	-3.05	-3.02	-3.02	-4.81	-
	Inf					0.64	2.80	0.00	0.10	-0.58	0.49	1.05	-1.30	ELS-D
22	Sup	312.1	1734.1	-16.6	-12.5	-0.26	0.01	-1.47	0.03	-3.19	-3.12	-3.12	-4.86	-
	Inf					0.45	2.49	-0.02	0.01	-0.01	0.90	1.40	-0.53	ELS-D
23	Sup	205.9	1362.2	-238.3	1.3	-0.17	0.20	-1.15	0.03	-2.73	-2.59	-2.55	-4.12	-
	Inf					0.30	1.96	-0.34	0.04	-0.88	-0.15	0.24	-1.67	-
24	Sup	50.4	855.3	-482.5	7.8	-0.04	0.41	-0.72	0.04	-2.30	-2.08	-2.00	-3.34	-
	Inf					0.07	1.23	-0.69	0.06	-1.81	-1.32	-1.08	-2.86	-
25	Sup	-156.0	238.5	-751.5	-2.7	0.13	0.64	-0.20	0.06	-1.95	-1.62	-1.50	-2.58	-
	Inf					-0.22	0.34	-1.08	0.05	-2.63	-2.46	-2.40	-3.90	-
26	Sup	-415.0	0.0	-1047.4	-28.6	0.35	0.89	0.00	0.09	-1.69	-1.23	-1.05	-2.28	-
	Inf					-0.60	0.00	-1.50	0.02	-3.32	-3.31	-3.31	-4.84	-
27E	Sup	-718.4	0.0	-1665.3	-55.0	0.61	1.41	0.00	0.09	-1.25	-0.59	-0.30	-2.00	-
	Inf					-1.03	0.00	-2.39	-0.04	-3.86	-3.75	-3.75	-6.36	-
27D	Sup	-725.8	0.0	-1635.2	-43.5	0.61	1.39	0.00	0.04	0.72	1.28	1.55	0.27	ELS-D
	Inf					-1.04	0.00	-2.35	-0.06	-3.01	-2.85	-2.85	-5.51	-
28	Sup	-450.6	0.0	-1328.1	-34.3	0.38	1.12	0.00	0.02	-0.20	0.26	0.49	-0.60	ELS-D
	Inf					-0.65	0.00	-1.91	-0.05	-1.72	-1.60	-1.60	-3.74	-
29	Sup	-192.9	280.6	-1002.8	-26.0	0.16	0.85	-0.24	0.02	-0.38	-0.05	0.12	-0.85	-
	Inf					-0.28	0.40	-1.44	-0.04	-1.51	-1.37	-1.29	-2.97	-
30	Sup	-2.0	950.2	-712.1	-12.6	0.00	0.60	-0.80	0.02	-0.53	-0.31	-0.19	-1.45	-
	Inf					0.00	1.36	-1.02	-0.01	-1.35	-0.89	-0.62	-2.54	-
31	Sup	120.6	1389.7	-458.1	1.0	-0.10	0.39	-1.18	0.01	-0.67	-0.55	-0.47	-1.87	-
	Inf					0.17	2.00	-0.66	0.01	-1.22	-0.51	-0.11	-2.20	-
32	Sup	174.8	1627.3	-247.7	13.0	-0.15	0.21	-1.38	0.01	-1.06	-0.99	-0.94	-2.45	-
	Inf					0.25	2.34	-0.36	0.04	-1.23	-0.39	0.08	-2.03	-
33	Sup	228.0	1652.2	-289.6	39.4	-0.19	0.25	-1.40	-0.01	-0.69	-0.60	-0.55	-2.11	-
	Inf					0.33	2.37	-0.42	0.08	-1.97	-1.07	-0.59	-2.96	-
34	Sup	222.3	1441.4	-448.8	48.5	-0.19	0.38	-1.22	-0.01	-0.63	-0.51	-0.43	-1.87	-
	Inf					0.32	2.07	-0.64	0.10	-2.25	-1.44	-1.02	-3.48	-
35	Sup	156.8	989.9	-637.4	18.9	-0.13	0.54	-0.84	0.02	-1.22	-1.03	-0.92	-2.17	-
	Inf					0.23	1.42	-0.92	0.06	-1.39	-0.85	-0.56	-2.65	-
36	Sup	30.3	496.0	-857.0	-10.1	-0.03	0.73	-0.42	0.05	-1.63	-1.32	-1.18	-2.32	-
	Inf					0.04	0.71	-1.23	0.02	-0.81	-0.56	-0.42	-2.14	-
37	Sup	-171.0	0.0	-1124.3	-14.5	0.14	0.95	0.00	0.04	-0.74	-0.37	-0.18	-1.01	-
	Inf					-0.25	0.00	-1.61	0.01	-2.08	-2.06	-2.06	-3.75	-
38	Sup	-57.4	0.0	-449.2	-6.3	0.05	0.38	0.00	0.04	-1.34	-1.14	-1.06	-1.61	-
	Inf					-0.08	0.00	-0.65	0.02	-1.77	-1.72	-1.72	-2.59	-
39	Sup	1.4	50.2	-45.1	13.6	0.00	0.04	-0.04	0.01	-0.73	-0.68	-0.67	-0.88	-
	Inf					0.00	0.07	-0.06	0.04	-2.59	-2.44	-2.43	-3.05	-

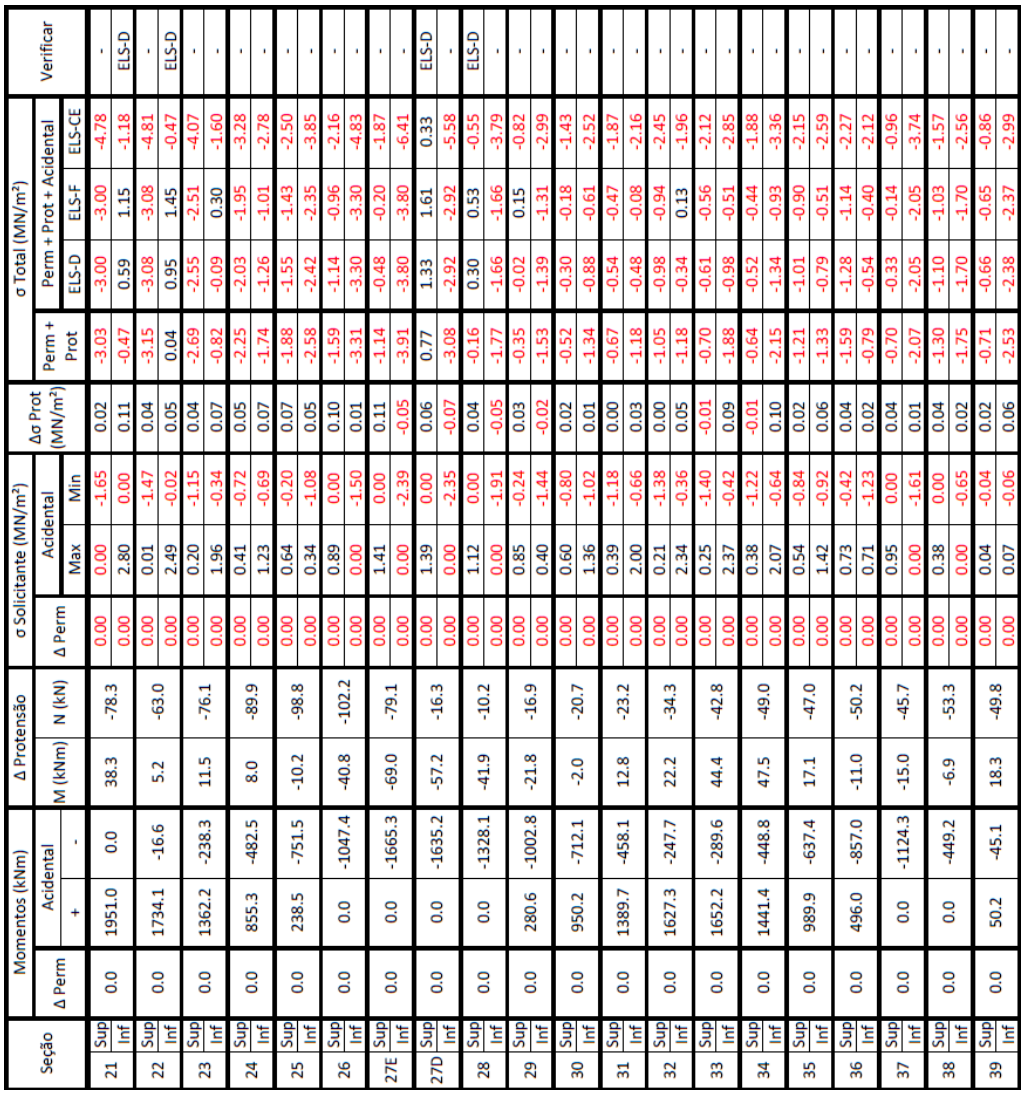
(e) Resultados da segunda fase - Folha 2/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)

Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)			Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental		
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE	
1	Sup	0.0	55.2	-44.4	18.4	0.00	0.04	-0.05	0.02	-0.70	-0.66	-0.65	-0.86	-
	Inf					0.00	0.08	-0.06	0.06	-2.53	-2.38	-2.37	-2.99	-
2	Sup	0.0	0.0	-520.6	-7.1	0.00	0.44	0.00	0.04	-1.30	-1.09	-1.00	-1.57	-
	Inf					0.00	0.00	-0.75	0.02	-1.74	-1.69	-1.69	-2.65	-
3	Sup	0.0	0.0	-1254.2	-14.2	0.00	1.06	0.00	0.05	-1.00	-0.58	-0.36	-1.31	-
	Inf					0.00	0.00	-1.80	0.02	-2.44	-2.40	-2.40	-4.35	-
4	Sup	0.0	495.9	-930.5	-11.6	0.00	0.79	-0.42	0.05	-1.67	-1.34	-1.19	-2.36	-
	Inf					0.00	0.71	-1.34	0.02	-0.87	-0.63	-0.48	-2.32	-
5	Sup	0.0	987.8	-698.9	16.7	0.00	0.59	-0.84	0.02	-1.29	-1.07	-0.96	-2.25	-
	Inf					0.00	1.42	-1.00	0.06	-1.41	-0.87	-0.59	-2.77	-
6	Sup	0.0	1447.3	-496.9	47.3	0.00	0.42	-1.23	-0.01	-0.73	-0.60	-0.51	-1.96	-
	Inf					0.00	2.08	-0.71	0.10	-2.22	-1.41	-1.00	-3.52	-
7	Sup	0.0	1643.4	-325.8	44.1	0.00	0.28	-1.39	-0.01	-0.79	-0.69	-0.64	-2.19	-
	Inf					0.00	2.36	-0.47	0.09	-1.95	-1.06	-0.59	-2.99	-
8	Sup	0.0	1632.9	-243.4	21.8	0.00	0.21	-1.38	0.01	-1.13	-1.06	-1.02	-2.55	-
	Inf					0.00	2.34	-0.35	0.06	-1.27	-0.42	0.05	-2.06	-
9	Sup	0.0	1402.5	-459.3	12.0	0.00	0.39	-1.19	0.01	-0.73	-0.60	-0.52	-1.95	-
	Inf					0.00	2.01	-0.66	0.03	-1.27	-0.56	-0.16	-2.26	-
10	Sup	0.0	942.3	-715.7	-3.3	0.00	0.61	-0.80	0.02	-0.57	-0.35	-0.23	-1.49	-
	Inf					0.00	1.35	-1.03	0.01	-1.44	-0.98	-0.71	-2.63	-
11	Sup	0.0	275.7	-1008.6	-23.5	0.00	0.85	-0.23	0.03	-0.40	-0.06	0.11	-0.88	-
	Inf					0.00	0.40	-1.45	-0.02	-1.64	-1.50	-1.42	-3.10	-
12	Sup	0.0	0.0	-1338.2	-44.2	0.00	1.13	0.00	0.05	-0.20	0.27	0.49	-0.61	ELS-D
	Inf					0.00	0.00	-1.92	-0.05	-1.89	-1.78	-1.78	-3.92	-
13E	Sup	0.0	0.0	-1657.6	-59.5	0.00	1.40	0.00	0.06	0.76	1.33	1.61	0.30	ELS-D
	Inf					0.00	0.00	-2.38	-0.07	-3.24	-3.09	-3.09	-5.77	-
13D	Sup	0.0	0.0	-1694.6	-71.9	0.00	1.44	0.00	0.11	-1.13	-0.45	-0.17	-1.87	-
	Inf					0.00	0.00	-2.43	-0.05	-4.01	-3.90	-3.90	-6.55	-
14	Sup	0.0	0.0	-1070.2	-45.7	0.00	0.91	0.00	0.10	-1.50	-1.05	-0.86	-2.07	-
	Inf					0.00	0.00	-1.54	-0.01	-3.18	-3.16	-3.16	-4.75	-
15	Sup	0.0	225.0	-768.5	-15.7	0.00	0.65	-0.19	0.08	-1.89	-1.55	-1.42	-2.50	-
	Inf					0.00	0.32	-1.10	0.04	-2.54	-2.38	-2.32	-3.81	-
16	Sup	0.0	853.1	-492.7	8.7	0.00	0.42	-0.72	0.06	-2.28	-2.06	-1.97	-3.32	-
	Inf					0.00	1.23	-0.71	0.08	-1.90	-1.42	-1.17	-2.97	-
17	Sup	0.0	1344.9	-242.7	24.2	0.00	0.21	-1.14	0.04	-2.68	-2.54	-2.50	-4.05	-
	Inf					0.00	1.93	-0.35	0.10	-1.29	-0.55	-0.16	-2.15	-
18	Sup	0.0	1726.3	-19.7	29.1	0.00	0.02	-1.46	0.03	-3.08	-3.02	-3.01	-4.73	-
	Inf					0.00	2.48	-0.03	0.10	-0.67	0.27	0.76	-1.30	ELS-D
19	Sup	0.0	1950.5	0.0	46.7	0.00	0.00	-1.65	0.02	-3.01	-2.98	-2.98	-4.75	-
	Inf					0.00	2.80	0.00	0.12	-0.70	0.38	0.94	-1.44	ELS-D
20	Sup	0.0	1873.3	0.0	46.7	0.00	0.00	-1.59	0.01	-3.02	-2.99	-2.99	-4.67	-
	Inf					0.00	2.69	0.00	0.12	-0.57	0.48	1.02	-1.33	ELS-D

(f) Resultados da terceira fase - Folha 1/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)



Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)				Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental			
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE	
21	Sup	0.0	1951.0	0.0	38.3	0.00	0.00	-1.65	0.02	-3.03	-3.00	-3.00	-4.78	-
	Inf					0.00	2.80	0.00	0.11	-0.47	0.59	1.15	-1.18	ELS-D
22	Sup	0.0	1734.1	-16.6	5.2	0.00	0.01	-1.47	0.04	-3.15	-3.08	-3.08	-4.81	-
	Inf					0.00	2.49	-0.02	0.05	0.04	0.95	1.45	-0.47	ELS-D
23	Sup	0.0	1362.2	-238.3	11.5	0.00	0.20	-1.15	0.04	-2.69	-2.55	-2.51	-4.07	-
	Inf					0.00	1.96	-0.34	0.07	-0.82	-0.09	0.30	-1.60	-
24	Sup	0.0	855.3	-482.5	8.0	0.00	0.41	-0.72	0.05	-2.25	-2.03	-1.95	-3.28	-
	Inf					0.00	1.23	-0.69	0.07	-1.74	-1.26	-1.01	-2.78	-
25	Sup	0.0	238.5	-751.5	-10.2	0.00	0.64	-0.20	0.07	-1.88	-1.55	-1.43	-2.50	-
	Inf					0.00	0.34	-1.08	0.05	-2.58	-2.42	-2.35	-3.85	-
26	Sup	0.0	0.0	-1047.4	-40.8	0.00	0.89	0.00	0.10	-1.59	-1.14	-0.96	-2.16	-
	Inf					0.00	0.00	-1.50	0.01	-3.31	-3.30	-3.30	-4.83	-
27E	Sup	0.0	0.0	-1665.3	-69.0	0.00	1.41	0.00	0.11	-1.14	-0.48	-0.20	-1.87	-
	Inf					0.00	0.00	-2.39	-0.05	-3.91	-3.80	-3.80	-6.41	-
27D	Sup	0.0	0.0	-1635.2	-57.2	0.00	1.39	0.00	0.06	0.77	1.33	1.61	0.33	ELS-D
	Inf					0.00	0.00	-2.35	-0.07	-3.08	-2.92	-2.92	-5.58	-
28	Sup	0.0	0.0	-1328.1	-41.9	0.00	1.12	0.00	0.04	-0.16	0.30	0.53	-0.55	ELS-D
	Inf					0.00	0.00	-1.91	-0.05	-1.77	-1.66	-1.66	-3.79	-
29	Sup	0.0	280.6	-1002.8	-21.8	0.00	0.85	-0.24	0.03	-0.35	-0.02	0.15	-0.82	-
	Inf					0.00	0.40	-1.44	-0.02	-1.53	-1.39	-1.31	-2.99	-
30	Sup	0.0	950.2	-712.1	-2.0	0.00	0.60	-0.80	0.02	-0.52	-0.30	-0.18	-1.43	-
	Inf					0.00	1.36	-1.02	0.01	-1.34	-0.88	-0.61	-2.52	-
31	Sup	0.0	1389.7	-458.1	12.8	0.00	0.39	-1.18	0.00	-0.67	-0.54	-0.47	-1.87	-
	Inf					0.00	2.00	-0.66	0.03	-1.18	-0.48	-0.08	-2.16	-
32	Sup	0.0	1627.3	-247.7	22.2	0.00	0.21	-1.38	0.00	-1.05	-0.98	-0.94	-2.45	-
	Inf					0.00	2.34	-0.36	0.05	-1.18	-0.34	0.13	-1.96	-
33	Sup	0.0	1652.2	-289.6	44.4	0.00	0.25	-1.40	-0.01	-0.70	-0.61	-0.56	-2.12	-
	Inf					0.00	2.37	-0.42	0.09	-1.88	-0.98	-0.51	-2.85	-
34	Sup	0.0	1441.4	-448.8	47.5	0.00	0.38	-1.22	-0.01	-0.64	-0.52	-0.44	-1.88	-
	Inf					0.00	2.07	-0.64	0.10	-2.15	-1.34	-0.93	-3.36	-
35	Sup	0.0	989.9	-637.4	17.1	0.00	0.54	-0.84	0.02	-1.21	-1.01	-0.90	-2.15	-
	Inf					0.00	1.42	-0.92	0.06	-1.33	-0.79	-0.51	-2.59	-
36	Sup	0.0	496.0	-857.0	-11.0	0.00	0.73	-0.42	0.04	-1.59	-1.28	-1.14	-2.27	-
	Inf					0.00	0.71	-1.23	0.02	-0.79	-0.54	-0.40	-2.12	-
37	Sup	0.0	0.0	-1124.3	-15.0	0.00	0.95	0.00	0.04	-0.70	-0.33	-0.14	-0.96	-
	Inf					0.00	0.00	-1.61	0.01	-2.07	-2.05	-2.05	-3.74	-
38	Sup	0.0	0.0	-449.2	-6.9	0.00	0.38	0.00	0.04	-1.30	-1.10	-1.03	-1.57	-
	Inf					0.00	0.00	-0.65	0.02	-1.75	-1.70	-1.70	-2.56	-
39	Sup	0.0	50.2	-45.1	18.3	0.00	0.04	-0.04	0.02	-0.71	-0.66	-0.65	-0.86	-
	Inf					0.00	0.07	-0.06	0.06	-2.53	-2.38	-2.37	-2.99	-

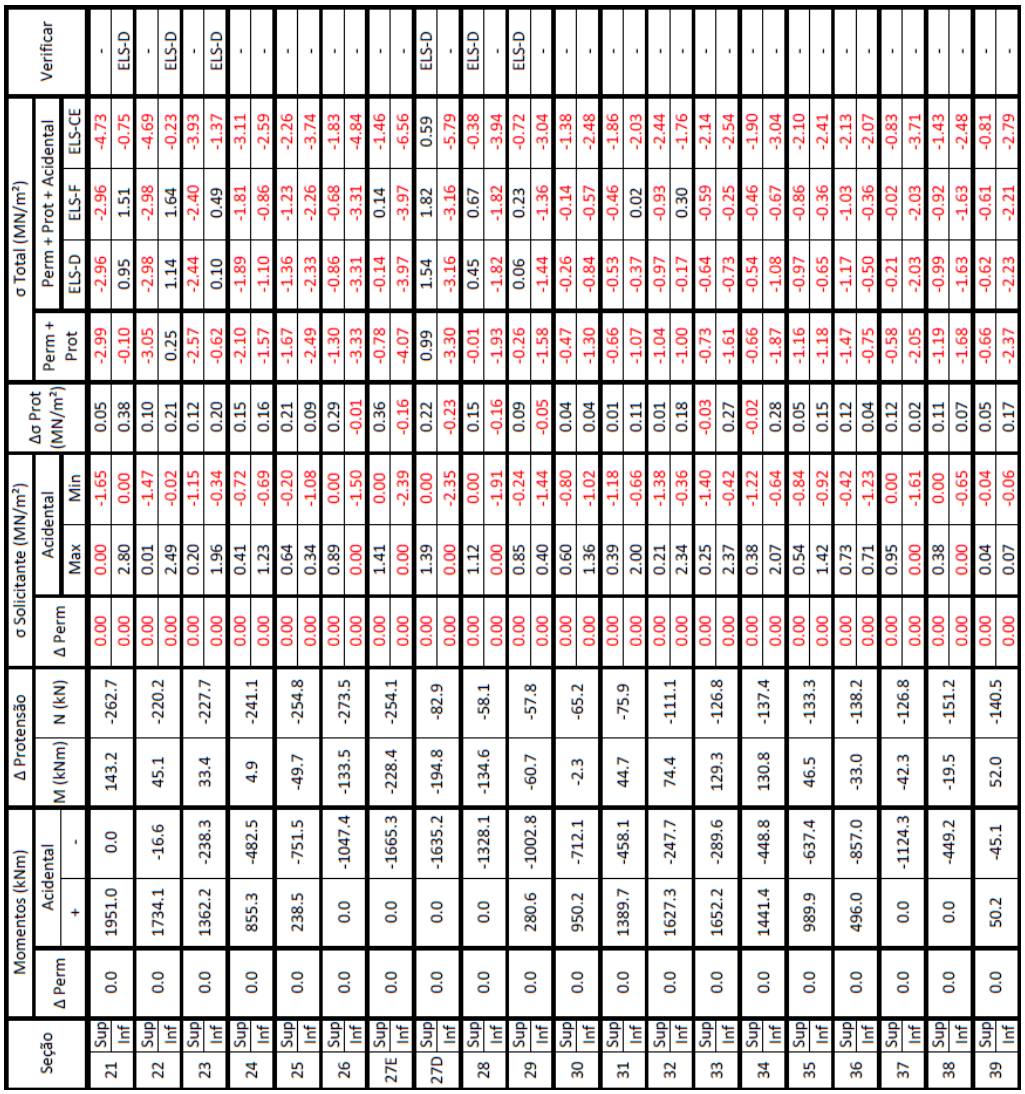
(g) Resultados da terceira fase - Folha 2/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)

Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)			Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental		
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE
1	Sup	0.0	55.2	-44.4	52.2	0.00	0.04	-0.05	0.05	-0.66	-0.61	-0.61	-0.81	-
	Inf					0.00	0.08	-0.06	0.17	-2.37	-2.23	-2.21	-2.80	-
2	Sup	0.0	0.0	-520.6	-20.0	0.00	0.44	0.00	0.12	-1.19	-0.98	-0.89	-1.44	-
	Inf					0.00	0.00	-0.75	0.07	-1.67	-1.62	-1.62	-2.57	-
3	Sup	0.0	0.0	-1254.2	-40.1	0.00	1.06	0.00	0.14	-0.86	-0.44	-0.23	-1.15	-
	Inf					0.00	0.00	-1.80	0.05	-2.39	-2.36	-2.36	-4.30	-
4	Sup	0.0	495.9	-930.5	-34.3	0.00	0.79	-0.42	0.13	-1.54	-1.22	-1.07	-2.22	-
	Inf					0.00	0.71	-1.34	0.05	-0.83	-0.58	-0.44	-2.26	-
5	Sup	0.0	987.8	-698.9	45.4	0.00	0.59	-0.84	0.05	-1.24	-1.02	-0.90	-2.18	-
	Inf					0.00	1.42	-1.00	0.16	-1.25	-0.72	-0.44	-2.59	-
6	Sup	0.0	1447.3	-496.9	130.0	0.00	0.42	-1.23	-0.01	-0.74	-0.61	-0.53	-1.98	-
	Inf					0.00	2.08	-0.71	0.28	-1.94	-1.14	-0.73	-3.19	-
7	Sup	0.0	1643.4	-325.8	128.4	0.00	0.28	-1.39	-0.02	-0.81	-0.71	-0.66	-2.21	-
	Inf					0.00	2.36	-0.47	0.27	-1.68	-0.80	-0.33	-2.68	-
8	Sup	0.0	1632.9	-243.4	73.1	0.00	0.21	-1.38	0.02	-1.12	-1.04	-1.00	-2.53	-
	Inf					0.00	2.34	-0.35	0.18	-1.08	-0.25	0.22	-1.84	-
9	Sup	0.0	1402.5	-459.3	42.7	0.00	0.39	-1.19	0.02	-0.71	-0.58	-0.50	-1.93	-
	Inf					0.00	2.01	-0.66	0.12	-1.15	-0.45	-0.05	-2.12	-
10	Sup	0.0	942.3	-715.7	-4.8	0.00	0.61	-0.80	0.05	-0.52	-0.30	-0.18	-1.43	-
	Inf					0.00	1.35	-1.03	0.04	-1.40	-0.94	-0.67	-2.58	-
11	Sup	0.0	275.7	-1008.6	-63.9	0.00	0.85	-0.23	0.10	-0.30	0.03	0.20	-0.76	ELS-D
	Inf					0.00	0.40	-1.45	-0.05	-1.69	-1.55	-1.47	-3.15	-
12	Sup	0.0	0.0	-1338.2	-138.7	0.00	1.13	0.00	0.16	-0.04	0.42	0.65	-0.42	ELS-D
	Inf					0.00	0.00	-1.92	-0.16	-2.04	-1.94	-1.94	-4.07	-
13E	Sup	0.0	0.0	-1657.6	-199.8	0.00	1.40	0.00	0.23	0.99	1.54	1.82	0.57	ELS-D
	Inf					0.00	0.00	-2.38	-0.23	-3.46	-3.32	-3.32	-5.98	-
13D	Sup	0.0	0.0	-1694.6	-234.7	0.00	1.44	0.00	0.37	-0.76	-0.11	0.18	-1.45	-
	Inf					0.00	0.00	-2.43	-0.17	-4.18	-4.07	-4.07	-6.71	-
14	Sup	0.0	0.0	-1070.2	-144.6	0.00	0.91	0.00	0.28	-1.22	-0.78	-0.59	-1.74	-
	Inf					0.00	0.00	-1.54	-0.05	-3.23	-3.21	-3.21	-4.79	-
15	Sup	0.0	225.0	-768.5	-61.0	0.00	0.65	-0.19	0.21	-1.67	-1.35	-1.22	-2.25	-
	Inf					0.00	0.32	-1.10	0.08	-2.46	-2.31	-2.25	-3.72	-
16	Sup	0.0	853.1	-492.7	7.1	0.00	0.42	-0.72	0.16	-2.12	-1.90	-1.82	-3.13	-
	Inf					0.00	1.23	-0.71	0.18	-1.72	-1.25	-1.00	-2.77	-
17	Sup	0.0	1344.9	-242.7	60.5	0.00	0.21	-1.14	0.12	-2.55	-2.42	-2.38	-3.91	-
	Inf					0.00	1.93	-0.35	0.26	-1.03	-0.30	0.08	-1.85	-
18	Sup	0.0	1726.3	-19.7	94.1	0.00	0.02	-1.46	0.10	-2.98	-2.92	-2.92	-4.62	-
	Inf					0.00	2.48	-0.03	0.31	-0.36	0.57	1.06	-0.93	ELS-D
19	Sup	0.0	1950.5	0.0	160.3	0.00	0.00	-1.65	0.05	-2.96	-2.93	-2.93	-4.70	-
	Inf					0.00	2.80	0.00	0.41	-0.28	0.77	1.33	-0.96	ELS-D
20	Sup	0.0	1873.3	0.0	171.3	0.00	0.00	-1.59	0.03	-2.98	-2.96	-2.96	-4.63	-
	Inf					0.00	2.69	0.00	0.43	-0.15	0.89	1.42	-0.84	ELS-D

(h) Resultados da quarta fase - Folha 1/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)



Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)			Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental		
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE	
21	Sup	0.0	1951.0	0.0	143.2	0.00	0.00	-1.65	0.05	-2.99	-2.96	-2.96	-4.73	-
	Inf				-262.7	0.00	2.80	0.00	0.38	-0.10	0.95	1.51	-0.75	ELS-D
22	Sup	0.0	1734.1	-16.6	45.1	0.00	0.01	-1.47	0.10	-3.05	-2.98	-2.98	-4.69	-
	Inf				-220.2	0.00	2.49	-0.02	0.21	0.25	1.14	1.64	-0.23	ELS-D
23	Sup	0.0	1362.2	-238.3	33.4	0.00	0.20	-1.15	0.12	-2.57	-2.44	-2.40	-3.93	-
	Inf				-227.7	0.00	1.96	-0.34	0.20	-0.62	0.10	0.49	-1.37	ELS-D
24	Sup	0.0	855.3	-482.5	4.9	0.00	0.41	-0.72	0.15	-2.10	-1.89	-1.81	-3.11	-
	Inf				-241.1	0.00	1.23	-0.69	0.16	-1.57	-1.10	-0.86	-2.59	-
25	Sup	0.0	238.5	-751.5	-49.7	0.00	0.64	-0.20	0.21	-1.67	-1.36	-1.23	-2.26	-
	Inf				-254.8	0.00	0.34	-1.08	0.09	-2.49	-2.33	-2.26	-3.74	-
26	Sup	0.0	0.0	-1047.4	-133.5	0.00	0.89	0.00	0.29	-1.30	-0.86	-0.68	-1.83	-
	Inf				-273.5	0.00	0.00	-1.50	-0.01	-3.33	-3.31	-3.31	-4.84	-
27E	Sup	0.0	0.0	-1665.3	-228.4	0.00	1.41	0.00	0.36	-0.78	-0.14	0.14	-1.46	-
	Inf				-254.1	0.00	0.00	-2.39	-0.16	-4.07	-3.97	-3.97	-6.56	-
27D	Sup	0.0	0.0	-1635.2	-194.8	0.00	1.39	0.00	0.22	0.99	1.54	1.82	0.59	ELS-D
	Inf				-82.9	0.00	0.00	-2.35	-0.23	-3.30	-3.16	-3.16	-5.79	-
28	Sup	0.0	0.0	-1328.1	-134.6	0.00	1.12	0.00	0.15	-0.01	0.45	0.67	-0.38	ELS-D
	Inf				-58.1	0.00	0.00	-1.91	-0.16	-1.93	-1.82	-1.82	-3.94	-
29	Sup	0.0	280.6	-1002.8	-60.7	0.00	0.85	-0.24	0.09	-0.26	0.06	0.23	-0.72	ELS-D
	Inf				-57.8	0.00	0.40	-1.44	-0.05	-1.58	-1.44	-1.36	-3.04	-
30	Sup	0.0	950.2	-712.1	-2.3	0.00	0.60	-0.80	0.04	-0.47	-0.26	-0.14	-1.38	-
	Inf				-65.2	0.00	1.36	-1.02	0.04	-1.30	-0.84	-0.57	-2.48	-
31	Sup	0.0	1389.7	-458.1	44.7	0.00	0.39	-1.18	0.01	-0.66	-0.53	-0.46	-1.86	-
	Inf				-75.9	0.00	2.00	-0.66	0.11	-1.07	-0.37	0.02	-2.03	-
32	Sup	0.0	1627.3	-247.7	74.4	0.00	0.21	-1.38	0.01	-1.04	-0.97	-0.93	-2.44	-
	Inf				-111.1	0.00	2.34	-0.36	0.18	-1.00	-0.17	0.30	-1.76	-
33	Sup	0.0	1652.2	-289.6	129.3	0.00	0.25	-1.40	-0.03	-0.73	-0.64	-0.59	-2.14	-
	Inf				-126.8	0.00	2.37	-0.42	0.27	-1.61	-0.73	-0.25	-2.54	-
34	Sup	0.0	1441.4	-448.8	130.8	0.00	0.38	-1.22	-0.02	-0.66	-0.54	-0.46	-1.90	-
	Inf				-137.4	0.00	2.07	-0.64	0.28	-1.87	-1.08	-0.67	-3.04	-
35	Sup	0.0	989.9	-637.4	46.5	0.00	0.54	-0.84	0.05	-1.16	-0.97	-0.86	-2.10	-
	Inf				-133.3	0.00	1.42	-0.92	0.15	-1.18	-0.65	-0.36	-2.41	-
36	Sup	0.0	496.0	-857.0	-33.0	0.00	0.73	-0.42	0.12	-1.47	-1.17	-1.03	-2.13	-
	Inf				-138.2	0.00	0.71	-1.23	0.04	-0.75	-0.50	-0.36	-2.07	-
37	Sup	0.0	0.0	-1124.3	-42.3	0.00	0.95	0.00	0.12	-0.58	-0.21	-0.02	-0.83	-
	Inf				-126.8	0.00	0.00	-1.61	0.02	-2.05	-2.03	-2.03	-3.71	-
38	Sup	0.0	0.0	-449.2	-19.5	0.00	0.38	0.00	0.11	-1.19	-0.99	-0.92	-1.43	-
	Inf				-151.2	0.00	0.00	-0.65	0.07	-1.68	-1.63	-1.63	-2.48	-
39	Sup	0.0	50.2	-45.1	52.0	0.00	0.04	-0.04	0.05	-0.66	-0.62	-0.61	-0.81	-
	Inf				-140.5	0.00	0.07	-0.06	0.17	-2.37	-2.23	-2.21	-2.79	-

(i) Resultados da quarta fase - Folha 2/2

Figura 5.2: Resultados do **Prestress** para o Viaduto da Guarita - Pista Norte (cont.)

5.2 Viaduto de Jacareí II

Trata-se de uma ponte de três vãos isostáticos. Adotou-se uma laje elástica que elimina a necessidade de juntas mas permite a rotação livre nos apoios. A seção transversal apresenta cinco vigas pré-moldadas e uma laje *in loco* de 20cm. O Apêndice B.3 apresenta os dados do projeto e as Figura 5.3 e Tabela 5.2 apresentam o modelo e os dados adotados no **Prestress**, respectivamente.

Como a estrutura se comporta como três vãos isostáticos, o modelo considera apenas o vão central da estrutura. Assim como o Viaduto de acesso a Santa Isabel, visto no Capítulo 4, o modelo aqui permite o deslocamento axial das vigas, uma vez que estas se assentam em aparelhos de apoio de neoprene fretado. A variação da seção das vigas que ocorre ao redor dos apoios é considerada pelo **Robot** e logo pelo **Prestress**.

Os resultados apresentam os pontos à esquerda e direita das seções 2 e 10, onde há uma descontinuidade de seção transversal. As seções 3 e 9 definem a interface entre a seção constante do vão e a variável, porém como as seções imediatamente a esquerda e a direita são iguais, o programa reconhece que não há necessidade de verificar as seções duas vezes. Nas fases em que a carga acidental atua, as seções 5 a 7, que representam o meio do vão, não satisfazem o ELS-D. Este resultado, no entanto, é negativamente afetado por duas limitações já discutidas do **Prestress**: o fato que este não permite o cálculo de estruturas com fases construtivas e a simplificação necessária do modelo.

Este viaduto apresenta vigas pré-moldadas com uma laje concretada *in loco*. A seção transversal adotada no modelo do **Robot** e logo pelo **Prestress** considera apenas a viga isolada, sem a laje colaborante. Porém, na realidade, a laje colabora para resistir aos esforços acidentais. O perfil real das tensões acidentais na viga (com laje colaborante) é então diferente e menor que o adotado pelo programa. Este erro é agravado pelo fato das lajes serem modeladas no **Robot** como "claddings" que distribuem esforços de forma simplificada sem adicionar à rigidez da estrutura. Sendo assim, a carga acidental é resistida em grande parte pela viga em estudo, sem que as demais vigas possam absorver parte da carga. Um modelo com as lajes apresentando rigidez leva a momentos acidentais 16% menores no meio do vão. O conjunto destes dois efeitos significa que a carga acidental não apenas gera tensões maiores que as reais para um esforço unitário, mas que os esforços em si são maiores que os reais, levando assim a um resultado pior que o real.

Seção (m)
0,000
1,100
2,600
7,117
11,633
16,150
20,667
25,183
29,700
31,200
32,300

(a) Seções de resultados

Seção (m)	C1	C2	C3-C4
0,000	0,160	0,430	1,150
3,230	0,535	0,754	1,222
6,460	0,837	1,018	1,279
9,690	1,050	1,202	1,318
12,920	1,174	1,310	1,341
16,150	1,220	1,350	1,350
19,380	1,174	1,310	1,341
22,610	1,050	1,202	1,318
25,840	0,837	1,018	1,279
29,070	0,535	0,754	1,222
32,300	0,160	0,430	1,150

(b) Traçado dos cabos

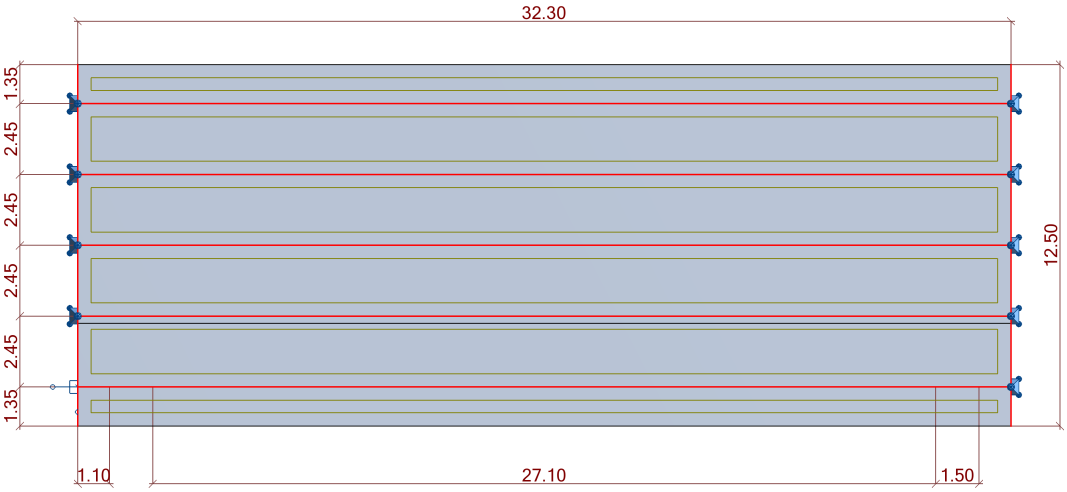
Propriedades	
do projeto	
ψ_F	0,5
ψ_D	0,3
das fases	
Umidade (%)	75
Temperatura (°C)	25
do concreto	
Slump (cm)	5-9
Tipo	CPV-ARI
da protensão	
E_p (MPa)	195000
A_p (cm^2)	11,84
σ_{p0} (MPa)	1406
μ (1/rad)	0,28
k (rad/m)	0,0028
δ (mm)	7
Relaxação	Baixa
Ancoragens ativas	Ambas

(c) Propriedades adotadas no cálculo do Viaduto de Jacareí II

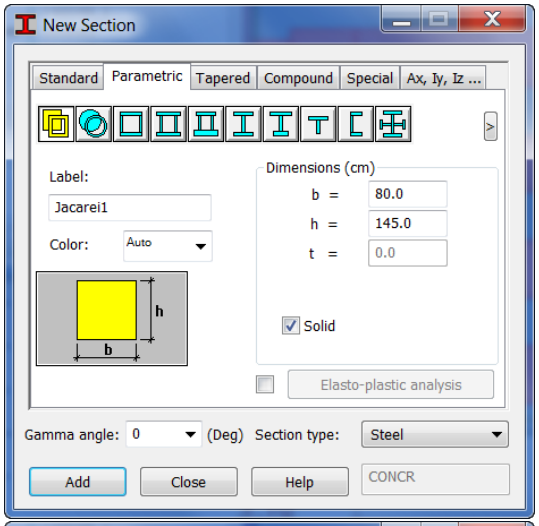
Fase	Data (dias)	Carga		Cabos protendidos
		Permanente	Acidental	
1	3	Peso-próprio da estrutura	-	C1 a C4
2	28	Pavimentação, recapeamento e guarda-rodas	✓	-
3	365	-	✓	-
4	18250	-	✓	-

(d) Propriedades das fases

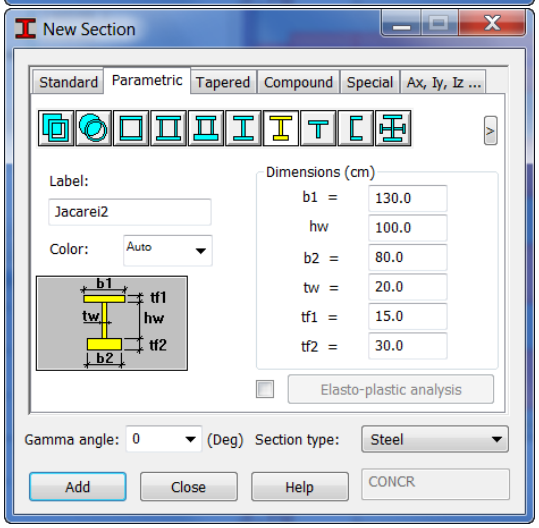
Tabela 5.2: Dados utilizados no **Prestress** para o Viaduto de Jacareí II



(a) Vista em planta



Propriedades (apoio)	
Área (m^2)	1,1600
Perímetro (m)	4,50
I_y (m^4)	0,2032
y_i (m)	0,725
y_s (m)	0,725



Propriedades (vão)	
Área (m^2)	0,6350
Perímetro (m)	6,700
I_y (m^4)	0,1817
y_i (m)	0,731
y_s (m)	0,719

(b) Seção transversal das vigas longarinas

Figura 5.3: Modelo do **Robot** do Viaduto de Jacareí II

f_{ck} = 40 MPa
s = 0.2
ψ_1 = 0.5
ψ_2 = 0.3

Alongamentos (cm)
Cabo 1 22.7166
Cabo 2 22.4957
Cabo 3 22.5323

(a) Dados do projeto e alongamentos teóricos dos cabos

Figura 5.4: Resultados do **Prestress** para o Viaduto de Jacareí II

Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)				Verificar
		Δ Perm	Acidental +	Acidental -	M (kNm)	N (kN)	Δ Perm	Acidental Max	Acidental Min		Perm + Prot	Perm + Prot + Acidental ELS-D	Perm + Prot + Acidental ELS-F	Perm + Prot + Acidental ELS-CE	
1	Sup	0.0	0.0	0.0	473.4	5830.6	0.00	0.00	0.00	-6.72	-6.72	-6.38	-6.38	-7.76	-
	Inf						0.00	0.00	0.00	-3.34	-3.34	-3.17	-3.17	-3.85	-
2E	Sup	276.2	0.0	0.0	16.8	5860.4	-0.99	0.00	0.00	-5.11	-6.10	-5.84	-5.84	-6.89	-
	Inf						0.99	0.00	0.00	-4.99	-4.01	-3.76	-3.76	-4.78	-
2D	Sup	276.7	0.0	0.0	15.9	5860.4	-0.81	0.00	0.00	-4.79	-5.61	-5.37	-5.37	-6.35	-
	Inf						0.91	0.00	0.00	-4.69	-3.79	-3.55	-3.55	-4.52	-
3	Sup	603.3	0.0	0.0	-606.9	5860.4	-2.39	0.00	0.00	-6.83	-9.21	-8.87	-8.87	-10.27	-
	Inf						2.43	0.00	0.00	-11.67	-9.24	-8.66	-8.66	-11.05	-
4	Sup	1367.9	0.0	0.0	-2128.1	6014.5	-5.41	0.00	0.00	-1.05	-6.46	-6.41	-6.41	-6.63	-
	Inf						5.50	0.00	0.00	-18.03	-12.53	-11.63	-11.63	-15.33	-
5	Sup	1826.5	0.0	0.0	-3081.0	6170.5	-7.23	0.00	0.00	2.48	-4.75	-4.63	-4.63	-4.88	-
	Inf						7.35	0.00	0.00	-22.11	-14.76	-13.66	-13.66	-18.19	-
6	Sup	1979.5	0.0	0.0	-3481.3	6250.0	-7.84	0.00	0.00	3.94	-3.90	-3.70	-3.70	-4.09	-
	Inf						7.96	0.00	0.00	-23.85	-15.88	-14.69	-14.69	-19.58	-
7	Sup	1826.5	0.0	0.0	-3081.0	6170.5	-7.23	0.00	0.00	2.48	-4.75	-4.63	-4.63	-4.88	-
	Inf						7.35	0.00	0.00	-22.11	-14.76	-13.66	-13.66	-18.19	-
8	Sup	1367.9	0.0	0.0	-2128.1	6014.5	-5.41	0.00	0.00	-1.05	-6.46	-6.41	-6.41	-6.63	-
	Inf						5.50	0.00	0.00	-18.03	-12.53	-11.63	-11.63	-15.33	-
9	Sup	603.8	0.0	0.0	-608.1	5860.5	-2.39	0.00	0.00	-6.82	-9.21	-8.87	-8.87	-10.27	-
	Inf						2.43	0.00	0.00	-11.68	-9.25	-8.66	-8.66	-11.06	-
10E	Sup	283.8	0.0	0.0	3.4	5860.4	-0.84	0.00	0.00	-4.80	-5.64	-5.40	-5.40	-6.39	-
	Inf						0.93	0.00	0.00	-4.78	-3.85	-3.61	-3.61	-4.59	-
10D	Sup	269.0	0.0	0.0	29.3	5859.6	-0.96	0.00	0.00	-5.16	-6.12	-5.86	-5.86	-6.91	-
	Inf						0.96	0.00	0.00	-4.95	-3.99	-3.74	-3.74	-4.75	-
11	Sup	0.0	0.0	0.0	473.4	5830.6	0.00	0.00	0.00	-6.72	-6.72	-6.38	-6.38	-7.76	-
	Inf						0.00	0.00	0.00	-3.34	-3.34	-3.17	-3.17	-3.85	-

(b) Resultados da primeira fase

Figura 5.4: Resultados do **Prestress** para o Viaduto de Jacareí II (cont.)

Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)				Verificar
		Δ Perm	Acidental		M (kNm)	N (kN)	Δ Perm	Acidental		Perm + Prot	Perm + Prot + Acidental			
			+	-				Max	Min		ELS-D	ELS-F	ELS-CE	
1	Sup	87.6	0.0	-198.6	-29.5	-192.7	-0.31	0.71	0.00	0.27	-6.76	-6.22	-6.08	-7.76	-
	Inf						0.31	0.00	-0.71	0.06	-2.96	-2.80	-2.80	-4.18	-
2E	Sup	446.8	221.8	0.0	-5.8	-238.3	-1.59	0.00	-0.79	0.23	-7.47	-7.22	-7.22	-9.01	-
	Inf						1.59	0.79	0.00	0.18	-2.23	-1.75	-1.59	-2.97	-
2D	Sup	447.5	222.6	0.0	-5.7	-238.3	-1.32	0.00	-0.65	0.21	-6.71	-6.48	-6.48	-8.08	-
	Inf						1.47	0.73	0.00	0.17	-2.15	-1.70	-1.55	-2.85	-
3	Sup	903.2	695.0	0.0	26.6	-238.3	-3.57	0.00	-2.75	0.27	-12.52	-12.19	-12.19	-16.29	-
	Inf						3.63	2.80	0.00	0.48	-5.13	-3.73	-3.17	-6.86	-
4	Sup	1987.8	1770.0	0.0	99.3	-234.7	-7.87	0.00	-7.01	-0.02	-14.35	-14.30	-14.30	-21.53	-
	Inf						8.00	7.12	0.00	0.77	-3.76	-0.76	0.66	-6.44	-
5	Sup	2638.5	2199.0	0.0	134.4	-214.7	-10.44	0.00	-8.70	-0.19	-15.39	-15.28	-15.28	-24.21	-
	Inf						10.62	8.85	0.00	0.88	-3.27	0.45	2.22	-6.56	ELS-D
6	Sup	2855.4	2148.8	0.0	148.9	-210.8	-11.30	0.00	-8.51	-0.26	-15.46	-15.27	-15.27	-24.15	-
	Inf						11.49	8.65	0.00	0.93	-3.47	0.27	2.00	-7.02	ELS-D
7	Sup	2638.5	2198.3	0.0	134.5	-214.7	-10.44	0.00	-8.70	-0.19	-15.39	-15.28	-15.28	-24.21	-
	Inf						10.62	8.84	0.00	0.88	-3.27	0.45	2.21	-6.56	ELS-D
8	Sup	1987.8	1772.0	0.0	99.4	-234.8	-7.87	0.00	-7.01	-0.02	-14.35	-14.30	-14.30	-21.53	-
	Inf						8.00	7.13	0.00	0.77	-3.76	-0.76	0.66	-6.44	-
9	Sup	904.0	697.1	0.0	26.7	-238.5	-3.58	0.00	-2.76	0.27	-12.52	-12.19	-12.19	-16.30	-
	Inf						3.64	2.80	0.00	0.48	-5.13	-3.73	-3.16	-6.86	-
10E	Sup	457.1	231.8	0.0	-5.1	-238.4	-1.35	0.00	-0.69	0.21	-6.78	-6.55	-6.55	-8.18	-
	Inf						1.50	0.76	0.00	0.18	-2.16	-1.71	-1.55	-2.88	-
10D	Sup	437.2	210.4	0.0	-6.4	-237.1	-1.56	0.00	-0.75	0.23	-7.45	-7.20	-7.20	-8.96	-
	Inf						1.56	0.75	0.00	0.18	-2.25	-1.78	-1.63	-2.98	-
11	Sup	87.6	0.0	-198.4	-29.5	-192.8	-0.31	0.71	0.00	0.27	-6.76	-6.22	-6.08	-7.76	-
	Inf						0.31	0.00	-0.71	0.06	-2.96	-2.80	-2.80	-4.18	-

(c) Resultados da segunda fase

Figura 5.4: Resultados do **Prestress** para o Viaduto de Jacareí II (cont.)

Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)				Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental			
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE	
1	Sup	0.0	0.0	-198.6	-28.9	0.00	0.71	0.00	0.26	-6.50	-5.97	-5.83	-7.45	-
	Inf					0.00	0.00	-0.71	0.05	-2.91	-2.75	-2.75	-4.12	-
2E	Sup	0.0	221.8	0.0	-5.4	0.00	0.00	-0.79	0.22	-7.24	-7.01	-7.01	-8.76	-
	Inf					0.00	0.79	0.00	0.18	-2.04	-1.58	-1.42	-2.76	-
2D	Sup	0.0	222.6	0.0	-5.3	0.00	0.00	-0.65	0.21	-6.51	-6.29	-6.29	-7.84	-
	Inf					0.00	0.73	0.00	0.17	-1.97	-1.54	-1.39	-2.65	-
3	Sup	0.0	695.0	0.0	26.7	0.00	0.00	-2.75	0.26	-12.25	-11.94	-11.94	-15.98	-
	Inf					0.00	2.80	0.00	0.48	-4.65	-3.28	-2.72	-6.31	-
4	Sup	0.0	1770.0	0.0	91.6	0.00	0.00	-7.01	-0.03	-14.39	-14.33	-14.33	-21.57	-
	Inf					0.00	7.12	0.00	0.70	-3.07	-0.10	1.32	-5.64	-
5	Sup	0.0	2199.0	0.0	110.2	0.00	0.00	-8.70	-0.19	-15.58	-15.47	-15.47	-24.38	-
	Inf					0.00	8.85	0.00	0.69	-2.58	1.10	2.87	-5.76	ELS-D
6	Sup	0.0	2148.8	0.0	114.4	0.00	0.00	-8.51	-0.23	-15.69	-15.52	-15.52	-24.37	-
	Inf					0.00	8.65	0.00	0.68	-2.78	0.92	2.65	-6.23	ELS-D
7	Sup	0.0	2198.3	0.0	110.2	0.00	0.00	-8.70	-0.19	-15.58	-15.47	-15.47	-24.38	-
	Inf					0.00	8.84	0.00	0.69	-2.58	1.10	2.87	-5.76	ELS-D
8	Sup	0.0	1772.0	0.0	91.6	0.00	0.00	-7.01	-0.03	-14.39	-14.33	-14.33	-21.57	-
	Inf					0.00	7.13	0.00	0.70	-3.07	-0.10	1.33	-5.63	-
9	Sup	0.0	697.1	0.0	26.8	0.00	0.00	-2.76	0.26	-12.26	-11.94	-11.94	-15.99	-
	Inf					0.00	2.80	0.00	0.48	-4.65	-3.27	-2.71	-6.31	-
10E	Sup	0.0	231.8	0.0	-4.7	0.00	0.00	-0.69	0.21	-6.58	-6.36	-6.36	-7.94	-
	Inf					0.00	0.76	0.00	0.18	-1.99	-1.54	-1.38	-2.67	-
10D	Sup	0.0	210.4	0.0	-6.0	0.00	0.00	-0.75	0.22	-7.22	-6.99	-6.99	-8.70	-
	Inf					0.00	0.75	0.00	0.18	-2.07	-1.61	-1.46	-2.78	-
11	Sup	0.0	0.0	-198.4	-28.9	0.00	0.71	0.00	0.26	-6.50	-5.97	-5.83	-7.45	-
	Inf					0.00	0.00	-0.71	0.05	-2.91	-2.75	-2.75	-4.12	-

(d) Resultados da terceira fase

Figura 5.4: Resultados do **Prestress** para o Viaduto de Jacareí II (cont.)

Seção		Momentos (kNm)			Δ Protensão	σ Solicitante (MN/m²)			Δσ Prot (MN/m²)	σ Total (MN/m²)				Verificar
		Δ Perm	Acidental		M (kNm)	Δ Perm	Acidental			Perm + Prot	Perm + Prot + Acidental			
			+	-			Max	Min			ELS-D	ELS-F	ELS-CE	
1	Sup	0.0	0.0	-198.6	-25.6	0.00	0.71	0.00	0.38	-6.11	-5.61	-5.47	-7.01	-
	Inf					0.00	0.00	-0.71	0.20	-2.71	-2.56	-2.56	-3.89	-
2E	Sup	0.0	221.8	0.0	-3.8	0.00	0.00	-0.79	0.29	-6.96	-6.74	-6.74	-8.43	-
	Inf					0.00	0.79	0.00	0.26	-1.79	-1.33	-1.17	-2.46	-
2D	Sup	0.0	222.6	0.0	-3.8	0.00	0.00	-0.65	0.27	-6.24	-6.04	-6.04	-7.53	-
	Inf					0.00	0.73	0.00	0.24	-1.73	-1.31	-1.16	-2.37	-
3	Sup	0.0	695.0	0.0	25.9	0.00	0.00	-2.75	0.39	-11.86	-11.57	-11.57	-15.53	-
	Inf					0.00	2.80	0.00	0.60	-4.05	-2.71	-2.15	-5.62	-
4	Sup	0.0	1770.0	0.0	96.5	0.00	0.00	-7.01	0.10	-14.29	-14.24	-14.24	-21.45	-
	Inf					0.00	7.12	0.00	0.87	-2.20	0.73	2.15	-4.63	ELS-D
5	Sup	0.0	2199.0	0.0	142.6	0.00	0.00	-8.70	-0.06	-15.64	-15.54	-15.54	-24.45	-
	Inf					0.00	8.85	0.00	1.07	-1.50	2.12	3.89	-4.52	ELS-D
6	Sup	0.0	2148.8	0.0	163.4	0.00	0.00	-8.51	-0.14	-15.82	-15.66	-15.66	-24.50	-
	Inf					0.00	8.65	0.00	1.17	-1.61	2.03	3.76	-4.88	ELS-D
7	Sup	0.0	2198.3	0.0	142.6	0.00	0.00	-8.70	-0.06	-15.64	-15.54	-15.54	-24.44	-
	Inf					0.00	8.84	0.00	1.07	-1.50	2.12	3.89	-4.52	ELS-D
8	Sup	0.0	1772.0	0.0	96.5	0.00	0.00	-7.01	0.10	-14.29	-14.24	-14.24	-21.46	-
	Inf					0.00	7.13	0.00	0.87	-2.19	0.73	2.15	-4.63	ELS-D
9	Sup	0.0	697.1	0.0	25.9	0.00	0.00	-2.76	0.39	-11.86	-11.57	-11.57	-15.54	-
	Inf					0.00	2.80	0.00	0.60	-4.05	-2.70	-2.14	-5.62	-
10E	Sup	0.0	231.8	0.0	-3.2	0.00	0.00	-0.69	0.27	-6.31	-6.10	-6.10	-7.63	-
	Inf					0.00	0.76	0.00	0.25	-1.74	-1.30	-1.15	-2.39	-
10D	Sup	0.0	210.4	0.0	-4.4	0.00	0.00	-0.75	0.29	-6.94	-6.72	-6.72	-8.37	-
	Inf					0.00	0.75	0.00	0.26	-1.81	-1.37	-1.22	-2.48	-
11	Sup	0.0	0.0	-198.4	-25.6	0.00	0.71	0.00	0.38	-6.11	-5.61	-5.47	-7.01	-
	Inf					0.00	0.00	-0.71	0.20	-2.71	-2.56	-2.56	-3.89	-

(e) Resultados da quarta fase

Figura 5.4: Resultados do **Prestress** para o Viaduto de Jacareí II (cont.)