ANEXO A

Quantificação das ações

a) Coeficientes de sobrepressão na descarga adotados por diversos autores

	PETROV (J)	SAFARIAN (J)	SAFARIAN (R)	RAVENET (J)	ACI 313-97
$K_{1/3}$ =	1,50	1,35	1,00	1,50	1,50
$K_{2/3}$ =	2,00	1,75	1,55	1,50	1,50

Quadro 4.3

	ACI 313-77	
	JANSSEN	REIMBERT
K_{H1} =	1,50	1,25
$K_{1/4}$ =	1,60	1,35
$K_{2/4}$ =	1,75	1,60
$K_{3/4}$ =	1,85	1,85
$K_{4/4}$ =	1,85	1,85

Quadro 4.5

b) Diferença de temperatura

As seguintes expressões propostas em *Ravenet* conduzem-nos ao valor de ΔT actuante ao longo de todas paredes do silo:

$T_1 = T_{int} - 26{,}67\ °C$ $\quad T_0 = 10°C \quad T_1 = 63{,}3°C$

$\Delta T = (T_1 - T_0).Kt$ $\quad \Delta T = (63{,}3°C - 10°C).0{,}235$

$Kt = 0{,}235$ $\quad \Delta T = 12{,}5°C$

T_{int} – temperatura do minério no interior do silo;

T_1 – temperatura na face interior da parede de betão;

T_0 – temperatura na face exterior da parede de betão;

K_t – relação da resistência térmica ao longo da parede, combinada com o ar exterior

c) Vento

h (m)	W_k^A (kN/m^2)
0	0.90
5	0.90
10	0.90
15	1.04
20	1.12
25	1.19
30	1.25
35	1.30
40	1.35
50	1.44
60	1.52
70	1.59
80	1.65
100	-
120	-

Quadro 4.6 – pressões dinâmicas

Ângulo	δi
0°	+1.00
10°	+0.90
20°	+0.70
30°	+0.35
40°	0.00
50°	-0.50
60°	-1.05
70°	-1.25
80°	-1.30
90°	-1.20
100°	-0.85
120°	-0.40
140°	-0.25
160°	-0.25
180°	-0.25

Quadro 4.7 – coeficientes de pressão

Donde resultam os valores de pressão para superfícies de revolução de que são caso os silos 1 e 2:

Ângulo (º)	0.00	11.25	22.50	33.75	45.00	56.25	67.50	78.75	90.00
δi	+1.00	+0.90	+0.70	+0.35	-0.25	-0.75	-1.25	-1.30	-1.20
h (m)									
0	1.17	1.05	0.82	0.41	-0.29	-0.88	-1.46	-1.52	-1.40
10	1.17	1.05	0.82	0.41	-0.29	-0.88	-1.46	-1.52	-1.40
20	1.43	1.29	1.00	0.50	-0.36	-1.07	-1.79	-1.86	-1.72
30	1.63	1.46	1.14	0.57	-0.41	-1.22	-2.03	-2.11	-1.95
40	1.76	1.58	1.23	0.61	-0.44	-1.32	-2.19	-2.28	-2.11
50	1.87	1.68	1.31	0.66	-0.47	-1.40	-2.34	-2.43	-2.25
60	1.98	1.78	1.38	0.69	-0.49	-1.48	-2.47	-2.57	-2.37
70	2.07	1.86	1.45	0.72	-0.52	-1.55	-2.58	-2.69	-2.48
80	2.15	1.93	1.50	0.75	-0.54	-1.61	-2.68	-2.79	-2.57

Quadro 4.8 – pressões dinâmicas em superfícies de revolução até 90º

Ângulo (º)	90.00	101.25	112.50	123.75	135.00	146.25	157.50	168.75	180.00
δi	-1.20	-0.85	-0.60	-0.40	-0.33	-0.25	-0.25	-0.25	-0.25
h (m)									
0	-1.40	-0.99	-0.70	-0.47	-0.39	-0.29	-0.29	-0.29	-0.29
10	-1.40	-0.99	-0.70	-0.47	-0.39	-0.29	-0.29	-0.29	-0.29
20	-1.72	-1.22	-0.86	-0.57	-0.47	-0.36	-0.36	-0.36	-0.36
30	-1.95	-1.38	-0.98	-0.65	-0.54	-0.41	-0.41	-0.41	-0.41
40	-2.11	-1.49	-1.05	-0.70	-0.58	-0.44	-0.44	-0.44	-0.44
50	-2.25	-1.59	-1.12	-0.75	-0.62	-0.47	-0.47	-0.47	-0.47
60	-2.37	-1.68	-1.19	-0.79	-0.65	-0.49	-0.49	-0.49	-0.49
70	-2.48	-1.76	-1.24	-0.83	-0.68	-0.52	-0.52	-0.52	-0.52
80	-2.57	-1.82	-1.29	-0.86	-0.71	-0.54	-0.54	-0.54	-0.54

Quadro 4.9 – pressões dinâmicas em superfícies de revolução de 90º até 180º

ANEXO B

Resultados

1. Calculo das Sobrepressões de descarga da farinha de cru

z (m)	g	f_i	f_w	tan $\phi_w = \mu'$	JANSSEN	REIMBERT	PETROV(J)	SAFARIAN(J)	SAFARIAN(R)	ACI 313-77(J)	ACI 313-77(R)	Ravenet	ACI 313-97
	kg/m³	°	°		Ph (kN/m²)	Ph (kN/m²)	Ph (kN/m²)	Ph (kN/m²)	Ph (kN/m²)	Ph (kN/m²)	Ph (kN/m²)	Ph (kN/m²)	Ph (kN/m²)
0	851.5	28.0	22.4	0.412	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	851.5	28.0	22.4	0.412	6.0	11.8	8.9	8.0	11.8	8.9	14.7	8.9	12.9
4	851.5	28.0	22.4	0.412	11.5	21.5	17.3	15.6	21.5	17.3	26.9	17.3	24.7
6	851.5	28.0	22.4	0.412	16.8	29.6	25.2	22.6	29.6	25.2	37.0	25.2	35.4
8	1097.8	28.0	22.4	0.412	28.0	47.0	41.9	37.7	47.0	41.9	58.8	41.9	58.2
10	1344.1	28.0	22.4	0.412	41.5	66.8	62.2	52.0	64.0	66.4	90.2	62.2	85.2
12	1345.5	28.1	22.5	0.414	48.2	74.5	72.3	66.3	80.9	77.1	100.6	72.3	98.1
14	1346.9	28.2	22.6	0.415	54.4	81.1	81.6	80.6	97.9	87.0	109.5	81.6	109.8
16	1348.3	28.3	22.6	0.417	60.2	86.8	90.3	94.9	114.8	96.3	117.1	90.3	120.4
18	1349.7	28.4	22.7	0.419	65.6	91.7	98.3	109.2	131.8	104.9	123.8	98.3	130.2
20	1351.1	28.5	22.8	0.420	70.6	96.0	141.1	123.5	148.8	112.9	129.6	105.9	139.1
22	1352.5	28.6	22.9	0.422	75.2	99.7	150.5	131.6	154.6	131.6	159.5	112.8	147.2
24	1354.0	28.7	23.0	0.423	79.6	103.0	159.1	139.2	159.6	139.2	164.8	119.3	154.6
26	1355.4	28.8	23.0	0.425	83.6	105.9	167.2	146.3	164.1	146.3	169.4	125.4	161.4
28	1356.8	28.9	23.1	0.427	87.3	108.4	174.6	152.8	168.1	152.8	173.5	131.0	167.6
30	1358.2	29.0	23.2	0.428	90.8	110.7	181.6	158.9	171.5	158.9	177.1	136.2	173.3
32	1359.6	29.1	23.3	0.430	94.0	112.7	188.0	164.5	174.6	164.5	180.3	141.0	178.4
34	1361.0	29.2	23.3	0.432	97.0	114.4	194.0	169.8	177.4	179.5	211.7	145.5	183.2
36	1362.4	29.3	23.4	0.433	99.8	116.0	199.5	174.6	179.8	184.6	214.6	149.7	187.5
38	1363.8	29.4	23.5	0.435	102.3	117.4	204.7	179.1	182.0	189.3	217.2	153.5	191.5
40	1365.2	29.5	23.6	0.437	104.7	118.7	209.4	183.2	183.9	193.7	219.5	157.1	195.1
42	1366.6	29.6	23.7	0.438	106.9	119.8	213.8	187.1	185.6	197.8	221.6	160.4	198.5
44	1368.0	29.7	23.7	0.440	108.9	120.7	217.9	190.7	187.2	201.5	223.4	163.4	201.5
46	1369.4	29.8	23.8	0.441	110.8	121.6	221.6	193.9	188.5	205.0	225.0	166.2	204.3
48	1370.8	29.9	23.9	0.443	112.6	122.4	225.1	197.0	189.7	208.2	226.5	168.8	206.9
50	1372.2	30.8	24.6	0.459	110.7	119.4	221.4	193.7	185.0	204.8	220.8	166.0	209.3
52	1373.7	31.8	25.4	0.475	108.6	116.2	217.1	190.0	180.1	200.8	214.9	162.8	211.4
54	1375.1	32.8	26.2	0.492	106.4	113.1	212.9	186.3	175.3	196.9	209.2	159.6	213.4
56	1376.5	35.0	28.0	0.532	100.0	105.5	200.0	175.0	163.6	185.0	195.2	150.0	215.3

quadro 3.1 – pressões horizontais sobre a parede do silo segundo as teorias mais relevantes

2. Análise estatística-recobrimento das armaduras

Rec. (mm)	Freq. Observada	Freq. Observada (%)	Freq. Acum. (%)
0 a 4	0	0,00	0,00
5 a 9	3	0,29	0,29
10 a 14	3	0,29	0,58
15 a 19	12	1,16	1,74
20 a 24	45	4,34	6,08
25 a 29	66	6,36	12,44
30 a 34	107	10,32	22,76
35 a 39	142	13,69	36,45
40 a 44	185	17,84	54,29
45 a 49	132	12,73	67,02
50 a 54	80	7,71	74,73
55 a 59	56	5,40	80,14
60 a 64	59	5,69	85,82
65 a 69	36	3,47	89,30
70 a 74	40	3,86	93,15
75 a 79	23	2,22	95,37
80 a 84	11	1,06	96,43
85 a 89	11	1,06	97,49
90 a 94	10	0,96	98,46
95 a 99	4	0,39	98,84
100 a 104	4	0,39	99,23
105 a 109	1	0,10	99,32
110 a 114	4	0,39	99,71
115 a 119	2	0,19	99,90
120 a 124	0	0,00	99,90
125 a 129	0	0,00	99,90
130 a 134	0	0,00	99,90
135 a 139	1	0,10	100,00
140 a 144	0	0,00	100,00
Total	1037		

quadro 4.6 – frequências

ANEXO C

VERIFICAÇÃO ESTRUTURAL

1. Esforços atuantes em serviço segundo diversos autores

z	PETROV (J)	SAFARIAN (J)	SAFARIAN (R)	ACI 313-77 (J)	ACI 313-77 (R)	RAVENET (J)	ACI 313-97 (J)
m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m	kN/m
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	83.7	74.4	108.9	82.6	136.1	82.6	121.2
14	162.3	144.1	198.8	160.1	248.5	160.1	231.5
16	235.9	209.5	273.9	232.7	342.4	232.7	331.9
18	393.1	349.1	434.9	387.9	543.7	387.9	545.6
20	583.5	481.3	591.8	614.1	834.0	575.8	799.1
22	677.4	613.5	748.6	712.9	930.2	668.4	919.3
24	764.8	745.7	905.5	804.9	1012.6	754.6	1029.0
26	846.2	877.9	1062.4	890.6	1083.6	834.9	1129.1
28	921.9	1010.1	1219.2	970.3	1145.0	909.6	1220.5
30	1323.2	1142.3	1376.1	1044.4	1198.5	979.1	1303.9
32	1410.5	1217.7	1429.7	1217.7	1475.8	1043.8	1380.1
34	1491.7	1287.8	1476.7	1287.8	1524.3	1103.9	1449.6
36	1567.2	1353.0	1518.1	1353.0	1567.0	1159.7	1513.2
38	1637.3	1413.5	1554.5	1413.5	1604.7	1211.6	1571.3
40	1702.3	1469.7	1586.8	1469.7	1638.0	1259.7	1624.3
42	1762.7	1521.8	1615.3	1521.8	1667.5	1304.4	1672.9
44	1818.8	1570.2	1640.7	1659.9	1958.3	1345.9	1717.3
46	1870.7	1615.0	1663.2	1707.3	1985.2	1384.3	1758.0
48	1918.8	1656.6	1683.3	1751.2	2009.1	1419.9	1795.2
50	1963.4	1695.0	1701.2	1791.9	2030.4	1452.9	1829.3
52	2004.6	1730.6	1717.1	1829.5	2049.4	1483.4	1860.5
54	2042.7	1763.5	1731.2	1864.3	2066.3	1511.6	1889.2
56	2077.9	1793.9	1743.9	1896.4	2081.4	1537.6	1915.5
58	2110.4	1822.0	1755.1	1926.1	2094.8	1561.7	1939.6
60	2075.2	1791.6	1711.4	1894.0	2042.7	1535.7	1961.8
62	2035.4	1757.2	1665.6	1857.6	1988.0	1506.2	1982.2
64	1995.6	1722.8	1621.3	1821.3	1935.1	1476.7	2001.0
66	1874.6	1618.4	1512.9	1710.9	1805.7	1387.2	2018.3

quadro 5.1 – esforços normais sobre a parede do silo, por metro, segundo as teorias mais relevantes

2. Propriedades da secção fendilhada

E_s	200 GPa
f_{syd}	348 MPa
E_c	22 GPa
f_{cd}	12 MPa
h	0.50 m
d	0.45 m
d`	0.05 m
b	1.00 m