

Idejno rešenje dispozicije baterije ćelija silosa:

kapacitet 9000 t žita

oblik ćelija kvadratni

temeljenje na šipovima „Franki“ Ø520, nosivosti 1100 kN

Predpostavljena sopstvena težina ćelija silosa, prema težini skladištenja materijala u odnosu 45% konstrukcija 55% skladišteni materijal.

$$9000 : g = 55 : 45$$

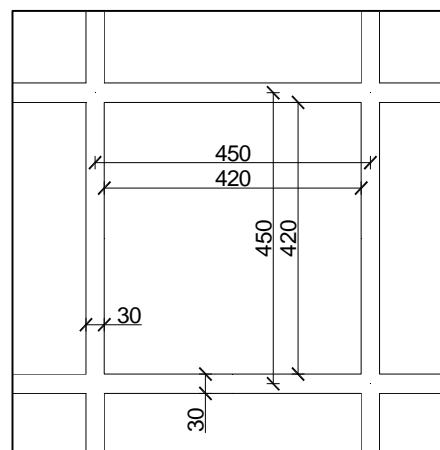
$$g \approx \frac{45 \cdot 9000}{55} = 7363 \quad \text{usvojeno : } g = 7500t$$

Iz usvojenog oblika ćelije Slika 1 imamo:

$$V' = 4.2^2 = 17.64 m^3 / m$$

$$V_{pot} = \frac{90000}{7.5} = 12000 m^3 \quad (\text{težina žita } 7.5 \text{ kN/m}^3; 1t = 10kN)$$

$$pretp : n = 24 \rightarrow h_{pot} = \frac{12000}{24 \cdot 17.64} = 28.35m$$



Slika 1

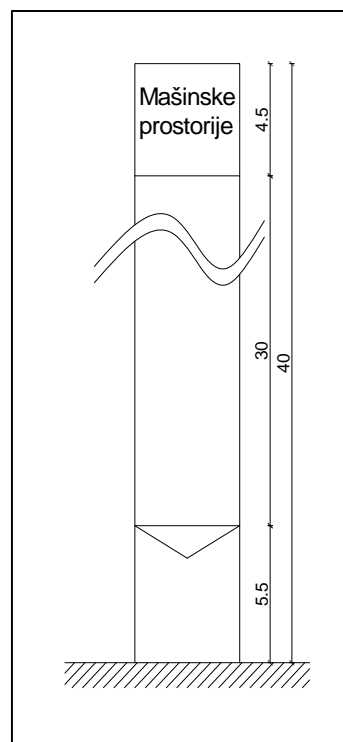
Potreban broj šipova:

$$S_{dop} = 1100 kN$$

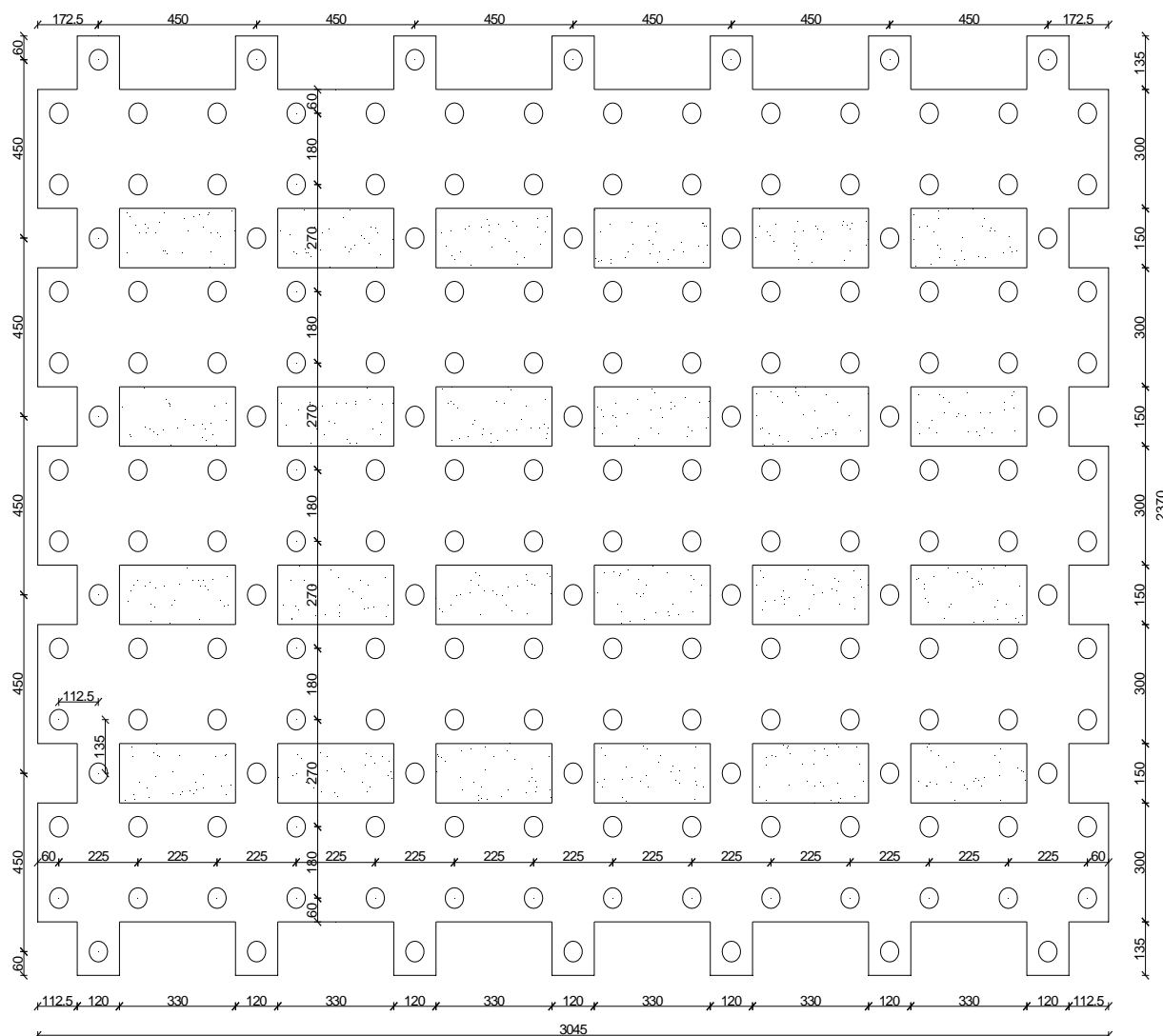
$$G + P = 75000 + 90000 = 165000 kN$$

$$n = \frac{165000}{1100} = 150 kom$$

raspored šipova i širine naglavnih greda date su na Slika 5, pa je prema tome usvojeni broj „Franki“ Ø520 šipova 182 komada.



Slika 2



Slika 3

Otporni moment grupa šipova, Slika 4:

$$x_1 = 14.62m \quad (n = 20)$$

$$x_2 = 12.38m$$

$$x_3 = 10.12m$$

$$x_4 = 7.88m$$

$$x_5 = 5.62m$$

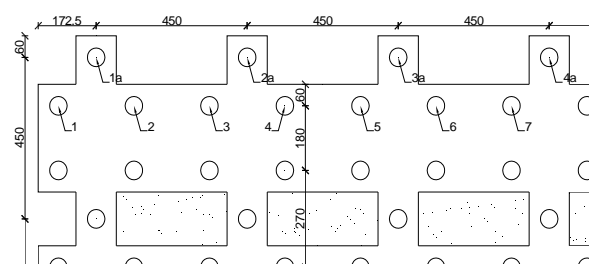
$$x_6 = 3.38m$$

$$x_7 = 1.12m$$

$$x_{1a} = 13.5m \quad (n = 12)$$

$$x_{2a} = 9.0m$$

$$x_{3a} = 4.5m$$



Slika 4

$$W = 20 \cdot (14.62^2 + 12.38^2 + 10.12^2 + 7.88^2 + 5.62^2 + 3.38^2 + 1.12^2) = 11515.62 m^2$$

$$W_a = 12 \cdot (13.5^2 + 9^2 + 4.5^2) = 3402 m^2$$

$$W = 11515.62 + 3402 = 14917.62 m^2$$

Proračun naprezanja šipova

Pun silos

$$V = 90000 + 75000 = 165000 kN$$

$$S = \frac{165000}{182} = 906.59 kN < S_{dop} = 1100 kN$$

Za najnepovoljniji način punjenja, Slika 6

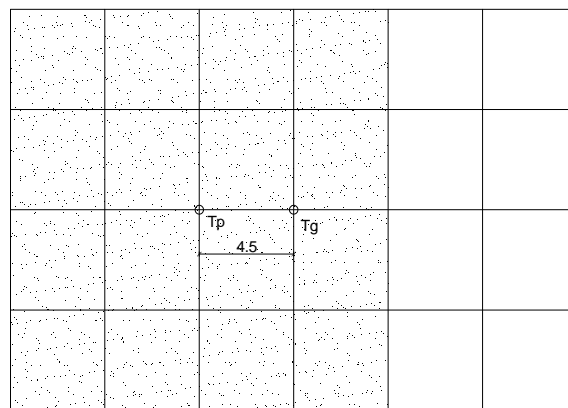
$$P = \frac{2}{3} \cdot 90000 = 60000 kN$$

$$V = 75000 + 60000 = 135000 kN$$

$$M = 60000 \cdot 4.5 = 270000 kNm$$

$$S_{max} = \frac{135000}{182} + \frac{270000}{14917.62} \cdot 14.62 = 1006.3 kN < S_{dop} = 1100 kN$$

$$S_{min} = \frac{135000}{182} - \frac{270000}{14917.62} \cdot 14.62 = 472.22 kN > 0 \text{ (nema zatezanja u šipu)}$$



Slika 6

Pri zemljotresu, seizmička zona $a=0.11g$

seizmička sila deluje na polovini visine silosa, Slika 7

$$G = 75000 kN$$

$$P = 90000 kN \text{ (pun silos)}$$

$$S_{dop,se} = \frac{2 \cdot 1100}{1.5} = 1450 kN$$

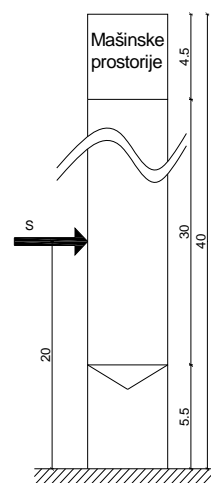
$$S = \frac{0.11g}{g} (75000 + 90000) = 18150 kN$$

$$M = 18150 \cdot 20 = 363000 kNm$$

sile u najopterećenijim šipovima

$$S_{max} = \frac{165000}{182} + \frac{363000}{14917.62} \cdot 14.62 = 1262.25 kN < S_{dop,se} = 1450 kN$$

$$S_{min} = \frac{165000}{182} - \frac{363000}{14917.62} \cdot 14.62 = 550.8 kN > 0$$



Slika 7

Proračun opterećenja za zid silosa (sa korakom od 1.0 m)

karakteristike materijala za proračun sila

$$\gamma = 8.5 \text{ kN} / \text{m}^3$$

$$\mu = 0.3$$

$$\lambda = 0.6$$

Za izračunavanje maksimalnih projektnih opterećenja, uzimaju se sledeće kombinacije za μ i λ .

$$p_h : 1.15\lambda \quad 0.9\mu$$

$$p_v : 0.9\lambda \quad 0.9\mu$$

$$p_w : 1.15\lambda \quad 1.15\mu$$

za kvadratni silos

$$R = a / 2 = 4.2 / 2 = 2.1 \text{ m}$$

$$z_0 = \frac{R}{\lambda' \cdot \mu'}$$

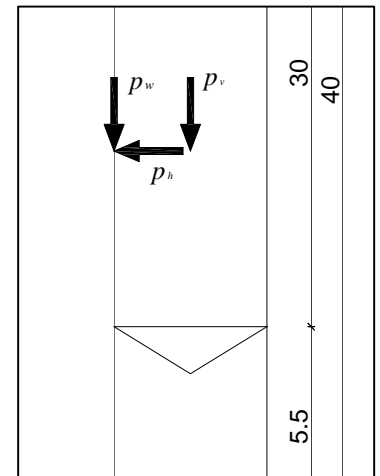
$$C_z = 1 - e^{\left(-\frac{z}{z_0}\right)}$$

$$p_{he}(z) = \frac{\gamma \cdot R}{\mu'} \cdot C_z(z) \cdot C$$

$$p_{ve}(z) = \frac{\gamma \cdot R}{\lambda' \cdot \mu'} \cdot C_z(z) \cdot C$$

$$p_{we}(z) = \gamma \cdot R \cdot C_z(z) \cdot C$$

koeficijent nadpritiska C, uvećava opterećenje pri pražnjenju i iznosi 1.35 za ovaj silos ($h/d > 1.5$)



Slika 8

Tabelarni prikaz opterećenja sa korakom od 1m.

$\lambda =$	0.6	$\lambda' =$	0.69	$\lambda =$	0.6	$\lambda' =$	0.54	$\lambda =$	0.6	$\lambda' =$	0.69
$\mu =$	0.3	$\mu' =$	0.27	$\mu =$	0.3	$\mu' =$	0.27	$\mu =$	0.3	$\mu' =$	0.345
$\gamma =$	8.5 kN/m ³			$\gamma =$	8.5 kN/m ³			$\gamma =$	8.5 kN/m ³		
$C =$	1.35			$C =$	1.35			$C =$	1.35		
$z_0 =$	11.272			$z_0 =$	14.403			$z_0 =$	8.821		

z	C_z	p_{hf}	p_{he}
0	0.000	0.00	0.00
1	0.085	5.61	7.58
2	0.163	10.75	14.51
3	0.234	15.45	20.86
4	0.299	19.75	26.66
5	0.358	23.68	31.97
6	0.413	27.29	36.84
7	0.463	30.58	41.29
8	0.508	33.60	45.36
9	0.550	36.36	49.08
10	0.588	38.88	52.49
11	0.623	41.20	55.61
12	0.655	43.31	58.47
13	0.684	45.25	61.08
14	0.711	47.02	63.47
15	0.736	48.64	65.66
16	0.758	50.12	67.66
17	0.779	51.48	69.50
18	0.797	52.72	71.17
19	0.815	53.86	72.71
20	0.830	54.90	74.11
21	0.845	55.85	75.40
22	0.858	56.72	76.57
23	0.870	57.52	77.65
24	0.881	58.25	78.63
25	0.891	58.92	79.54
26	0.900	59.53	80.36
27	0.909	60.09	81.12
28	0.917	60.60	81.81
29	0.924	61.06	82.44
30	0.930	61.49	83.02

$p_{h0} = 61.49 \text{ kN/m}^2$

z	C_z	p_{vf}	p_{ve}
0	0.000	0.00	0.00
1	0.067	8.21	11.09
2	0.130	15.87	21.43
3	0.188	23.02	31.08
4	0.242	29.69	40.08
5	0.293	35.91	48.48
6	0.341	41.71	56.31
7	0.385	47.12	63.62
8	0.426	52.18	70.44
9	0.465	56.89	76.80
10	0.501	61.28	82.73
11	0.534	65.38	88.27
12	0.565	69.21	93.43
13	0.594	72.78	98.25
14	0.622	76.11	102.75
15	0.647	79.22	106.94
16	0.671	82.12	110.86
17	0.693	84.82	114.51
18	0.713	87.34	117.91
19	0.733	89.70	121.09
20	0.751	91.89	124.05
21	0.767	93.94	126.82
22	0.783	95.85	129.40
23	0.797	97.63	131.80
24	0.811	99.30	134.05
25	0.824	100.85	136.14
26	0.836	102.29	138.10
27	0.847	103.64	139.92
28	0.857	104.90	141.62
29	0.866	106.08	143.21
30	0.875	107.18	144.69

z	C_z	p_{wf}	p_{we}
0	0.000	0.00	0.00
1	0.107	1.91	2.58
2	0.203	3.62	4.89
3	0.288	5.15	6.95
4	0.365	6.51	8.78
5	0.433	7.72	10.43
6	0.493	8.81	11.89
7	0.548	9.78	13.20
8	0.596	10.64	14.37
9	0.639	11.41	15.41
10	0.678	12.10	16.34
11	0.713	12.72	17.17
12	0.743	13.27	17.91
13	0.771	13.76	18.58
14	0.795	14.20	19.17
15	0.817	14.59	19.70
16	0.837	14.94	20.17
17	0.854	15.25	20.59
18	0.870	15.53	20.97
19	0.884	15.78	21.30
20	0.896	16.00	21.60
21	0.907	16.20	21.87
22	0.917	16.38	22.11
23	0.926	16.53	22.32
24	0.934	16.67	22.51
25	0.941	16.80	22.68
26	0.948	16.91	22.83
27	0.953	17.01	22.97
28	0.958	17.10	23.09
29	0.963	17.18	23.20
30	0.967	17.25	23.29

Raspodela horizontalnog opterećenja po zidu silosa prikazana na Sliku 9, nsjoptrećeniji presek je najniža tačka silosa, kod spoja ćelije sa levkom.

Računski potrebna armatura u najopterećenijem preseku $h=0\text{m}$ (sa grafika 30m)

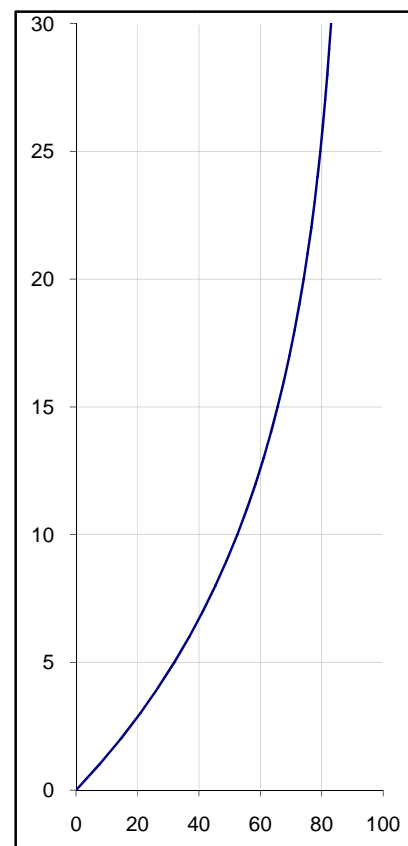
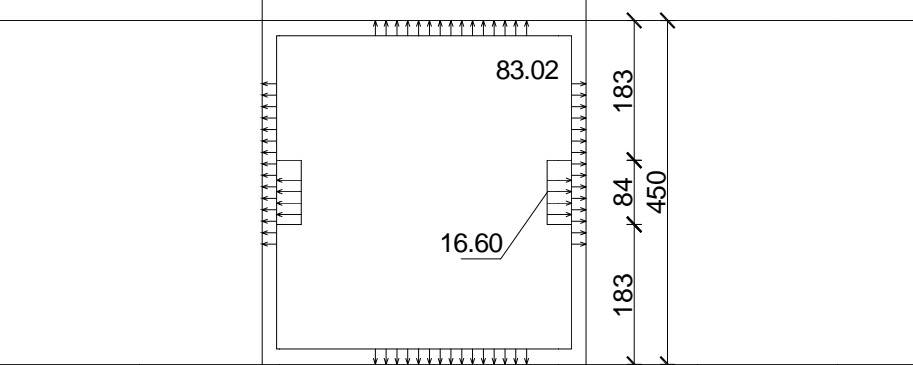
Shema opterećenja, zajedno sa dodatnim opterećenjem

$$p = 83.02 \text{ kN} / \text{m}^2$$

$$p_{dod} = 0.2 \cdot 83.02 = 16.60 \text{ kN} / \text{m}^2$$

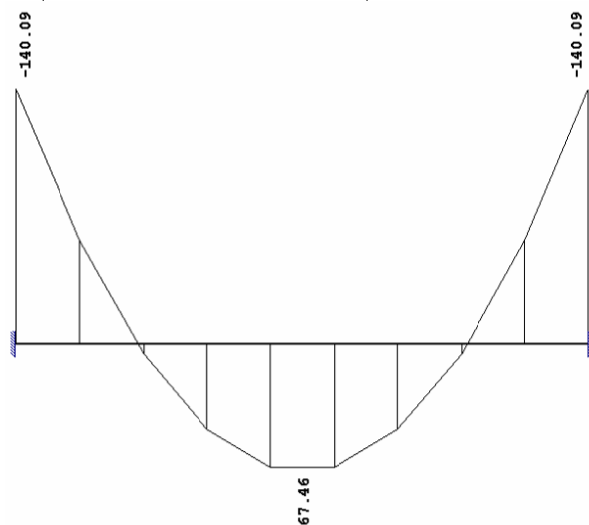
deo na koji deluje dodatno opterećenje je

$$0.8 \cdot \frac{A}{u} = 0.8 \cdot \frac{17.64}{16.8} = 0.84 \text{ m}$$

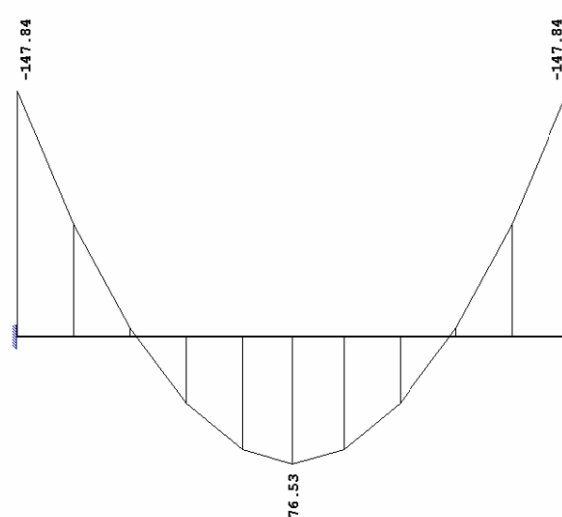


Slika 9

Uticaji:
samo od p_h



$p_h + \text{dopunsko}$



Proračun potrebne armature za preseke u uglovima

$$Z = \frac{83.02 \cdot 4.5}{2} = 186.79 \text{ kN}$$

$$M_{\max} = 147.84 \text{ kNm}$$

$$Z_u = 1.8 \cdot 186.79 = 336.22 \text{ kN}$$

$$M_u = 1.8 \cdot 140.10 = 252.18 \text{ kNm}$$

$$M_{au} = 252.18 - 336.22 \cdot \left(\frac{0.30}{2} - 0.045 \right) = 216.88 \text{ kNm}$$

RA400/500 MB40

$$k = \frac{25.5}{\sqrt{\frac{216.88}{2.55}}} = 2.765 \quad \rightarrow \bar{\mu} = 14.152\%$$

$$A_a = 14.152 \cdot \frac{100 \cdot 25.5}{100} \cdot \frac{2.55}{40} + \frac{336.22}{40} = 26.90 \text{ cm}^2$$

usvojeno : RØ22/20 + RØ16/20

$$A_{a,sv} = \frac{381}{20} + \frac{201}{20} = 19.05 + 10.05 = 29.10 \text{ cm}^2$$

Proračun potrebne armature za sredine zidova čelija

$$Z = \frac{83.02 \cdot 4.5}{2} = 186.79 \text{ kN}$$

$$M_{\max} = 76.53 \text{ kNm}$$

$$Z_u = 1.8 \cdot 186.79 = 336.22 \text{ kN}$$

$$M_u = 1.8 \cdot 76.53 = 137.54 \text{ kNm}$$

$$M_{au} = 137.54 - 336.22 \cdot \left(\frac{0.30}{2} - 0.045 \right) = 102.45 \text{ kNm}$$

RA400/500 MB40

$$k = \frac{25.5}{\sqrt{\frac{102.45}{2.55}}} = 4.023 \quad \rightarrow \bar{\mu} = 6.591\%$$

$$A_a = 6.591 \cdot \frac{100 \cdot 25.5}{100} \cdot \frac{2.55}{40} + \frac{336.22}{40} = 18.89 \text{ cm}^2$$

$$e_a(RØ22) = \frac{3.80 \cdot 100}{18.89} = 20.11 \text{ cm} \rightarrow \text{usvojeno : RØ22/20}$$

Proračun opterećenja za levak prema JUS.ISO.11697

$$p_{h0} = 61.49 \text{ kN} / \text{m}^2$$

$$\alpha = 30^\circ \quad \cos \alpha = 0.866 \quad \sin \alpha = 0.5$$

$$\lambda = 0.9 \cdot 0.6 = 0.54 \quad \mu = 0.9 \cdot 0.3 = 0.27$$

$$p_{n1} = 1.5 \cdot p_{h0} \cdot \left(\frac{1}{\lambda} \cdot \cos^2 \alpha + \sin^2 \alpha \right) = 1.5 \cdot 61.49 \cdot \left(\frac{1}{0.54} \cdot 0.866^2 + 0.5^2 \right) = 151.163 \text{ kN} / \text{m}^2$$

$$p_{n2} = \frac{1.5}{\lambda} \cdot p_{h0} \cdot \cos^2 \alpha = \frac{1.5}{0.54} \cdot 61.49 \cdot 0.866^2 = 128.1 \text{ kN} / \text{m}^2$$

$$p_{n3} = \frac{3 \cdot A}{u} \cdot \frac{\gamma \cdot \lambda}{\sqrt{\mu}} \cdot \sin^2 \alpha = \frac{3 \cdot 17.64}{16.8} \cdot \frac{8.5 \cdot 0.54}{\sqrt{0.27}} \cdot 0.5^2 = 7.33 \text{ kN} / \text{m}^2$$

$$p_t = \mu \cdot (p_{n1} + p_{n2} + p_{n3}) = 0.27 \cdot (151.16 + 128.1 + 7.33) = 85.98 \text{ kN} / \text{m}^2$$

$$p_s = 2 \cdot p_{h0} = 2 \cdot 61.49 = 122.98 \text{ kN} / \text{m}^2$$