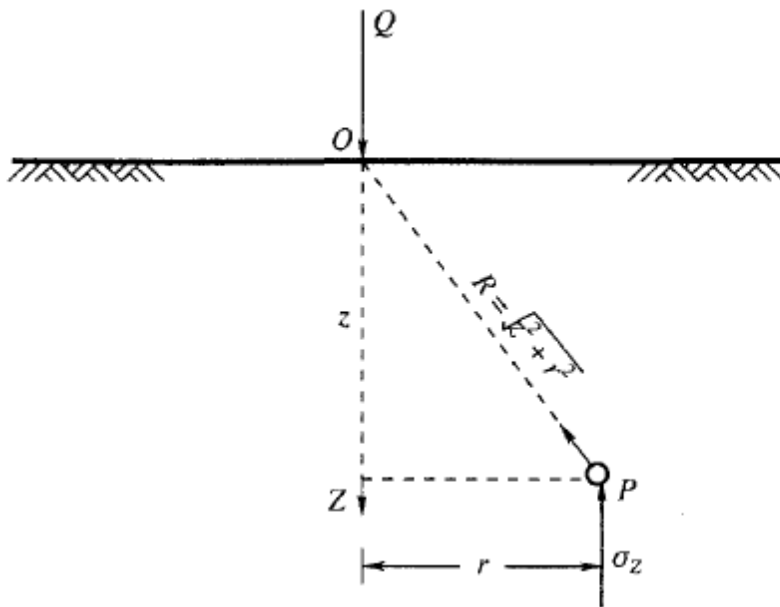


5.1 BOUSSINESQUE-ova FORMULA ZA KONCENTRISANO OPTEREĆENJE

$$\sigma_z = \frac{3Q}{2\pi z^2} \frac{1}{[1+(r/z)^2]^{5/2}} = \frac{Q}{z^2} I_B \quad 5.1$$

$$I_B = \frac{3}{2\pi} \frac{1}{[1+(r/z)^2]^{5/2}} \quad 5.2$$



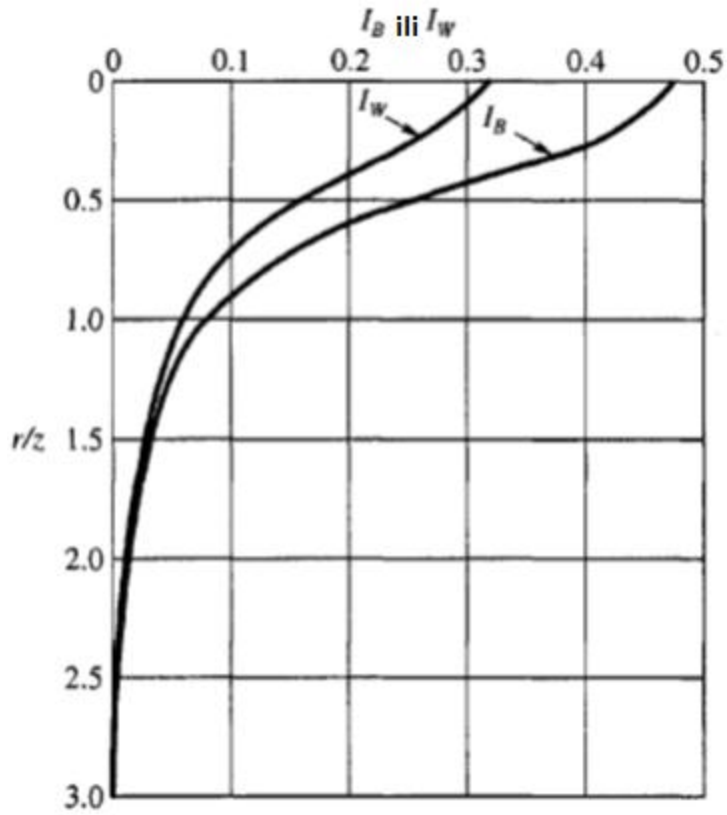
Slika: 5.1 Vertikalni pritisak unutar mase tla

5.2 WESTERGAARDE-ova FORMULA ZA KONCENTRISANO OPTEREĆENJE

$$\sigma_z = \frac{Q}{2\pi z^2} \frac{\sqrt{(1-2\mu)/(2-2\mu)}}{[(1-2\mu)/(2-\mu) + (r/z)^2]^{3/2}} = \frac{Q}{z^2} I_w \quad 5.3$$

$$\sigma_z = \frac{Q}{\pi z^2} \frac{1}{[1+2(r/z)^2]^{3/2}} = \frac{Q}{z^2} I_w \quad 5.4$$

$$I_w = \frac{(1/\pi)}{[1+2(r/z)^2]^{3/2}} \quad 5.5$$

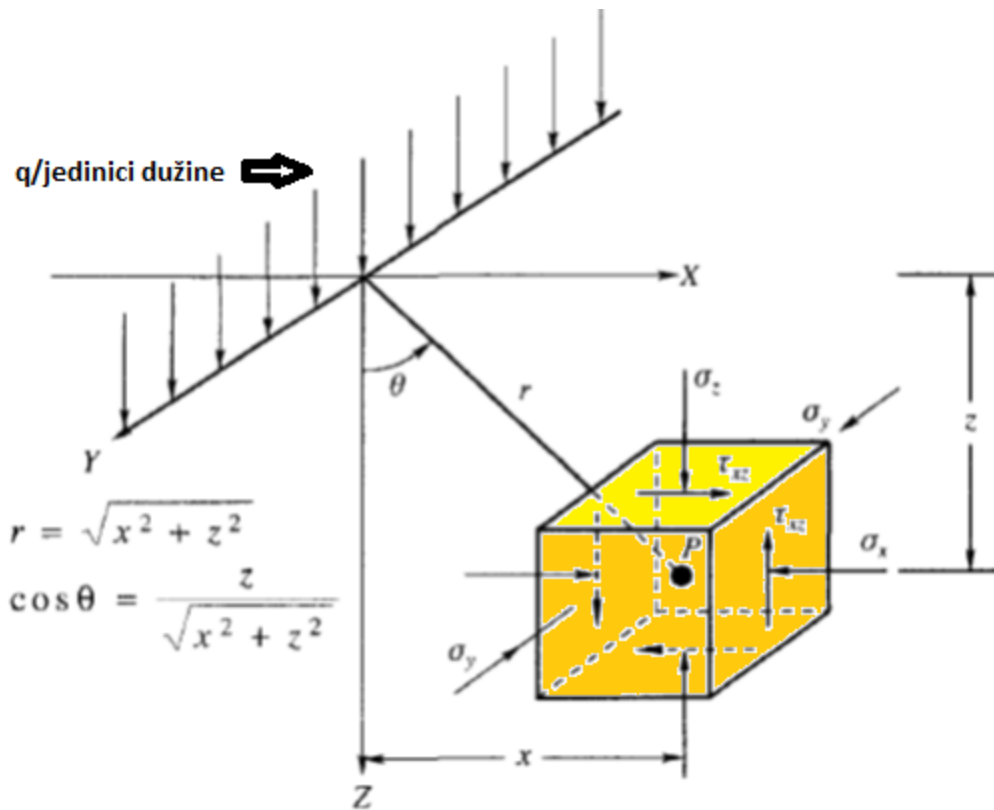


Slika: 5.2 Veličine I_B ili I_W za upotrebu u Boussinesque-ovim ili Westergaarde-ovim formulama

5.3 LINIJSKO OPTEREĆENJE

$$\sigma_z = \frac{q}{z} \frac{2/\pi}{[1+(x/z)^2]^2} = \frac{q}{z} I_z$$

5.6



Slika: 5.3 Naponi od vertikalnog linijskog opterećenja u pravouglim koordinatama

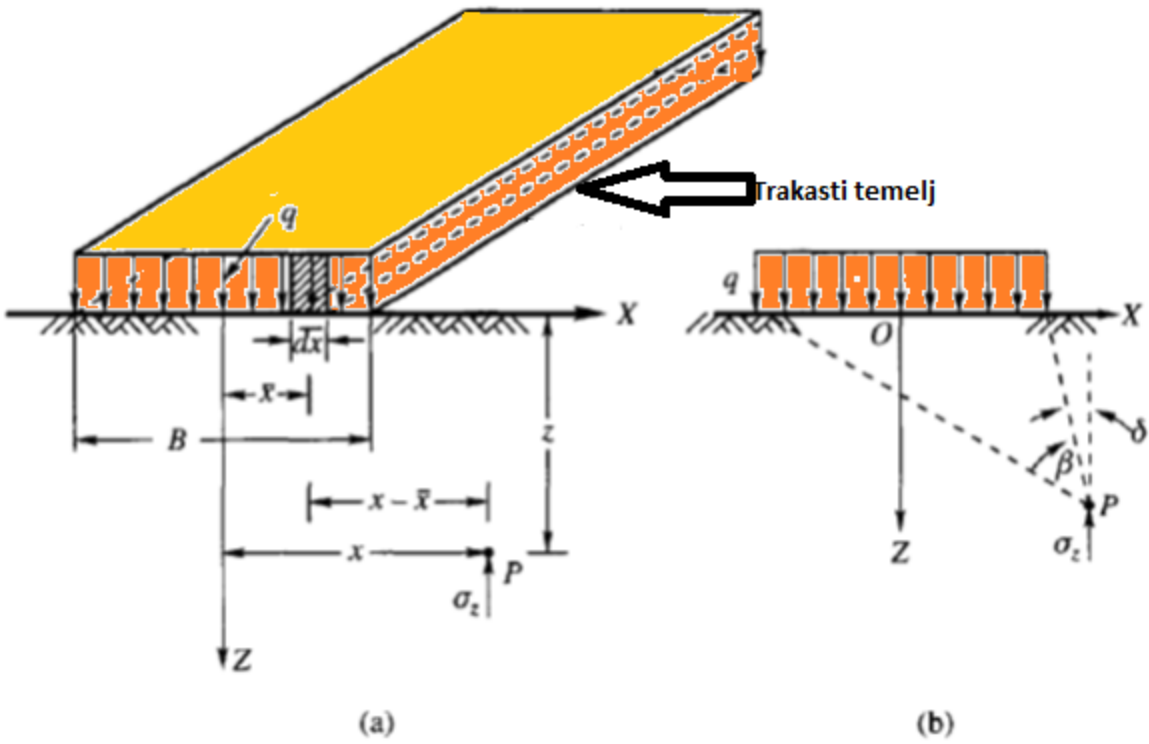
5.5 TRAKASTO OPTEREĆENJE

$$d\sigma_z = \frac{2q}{\pi} \frac{z^3}{[(x - \bar{x})^2 + z^2]^2} \quad 5.7$$

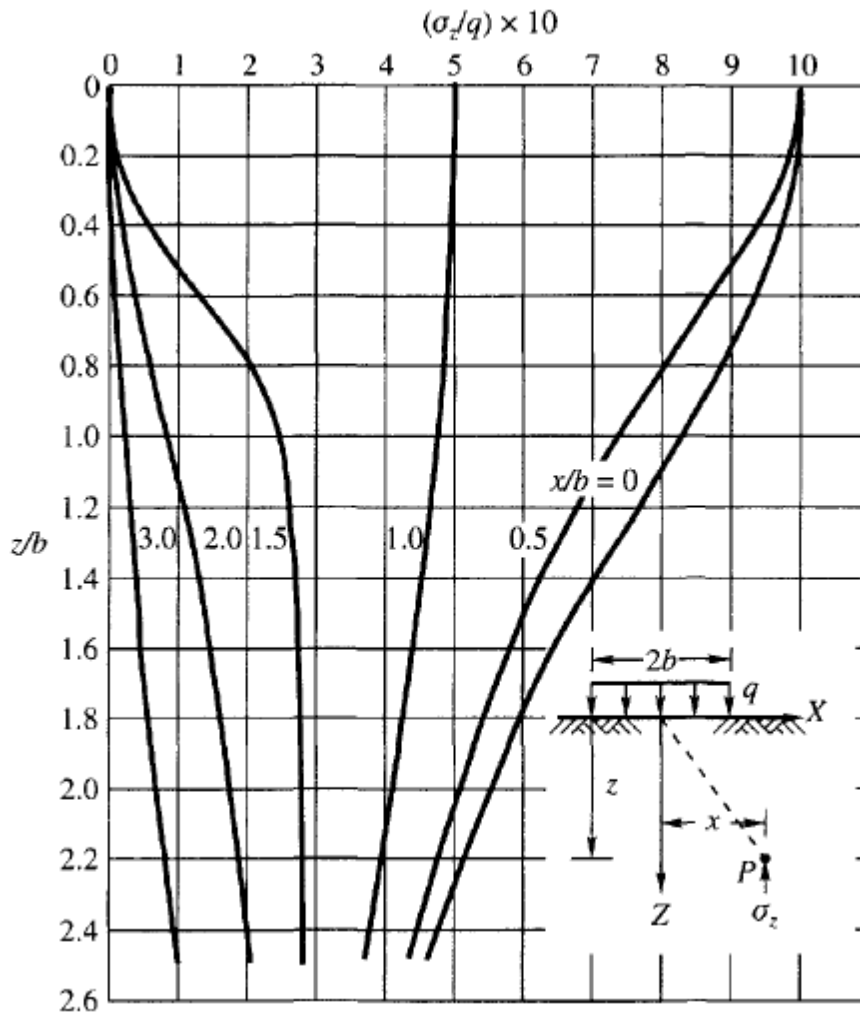
$$\sigma_z = \frac{2q}{\pi} \int_{-b}^{+b} \frac{z^3}{[(x - \bar{x})^2 + z^2]^2} dx \quad 5.8$$

$$\sigma_z = \frac{q}{\pi} \tan^{-1} \frac{z}{x-b} - \tan^{-1} \frac{z}{x+b} - \frac{2bz(x^2 - b^2 - z^2)}{(x^2 - b^2 + z^2)^2 + 4b^2z^2} \quad 5.9$$

$$\sigma_z = \frac{q}{\pi} [\beta + \sin \beta \cos(\beta + 2\delta)] \quad 5.10$$



Slika: 5.4 Trakasto opterećenje



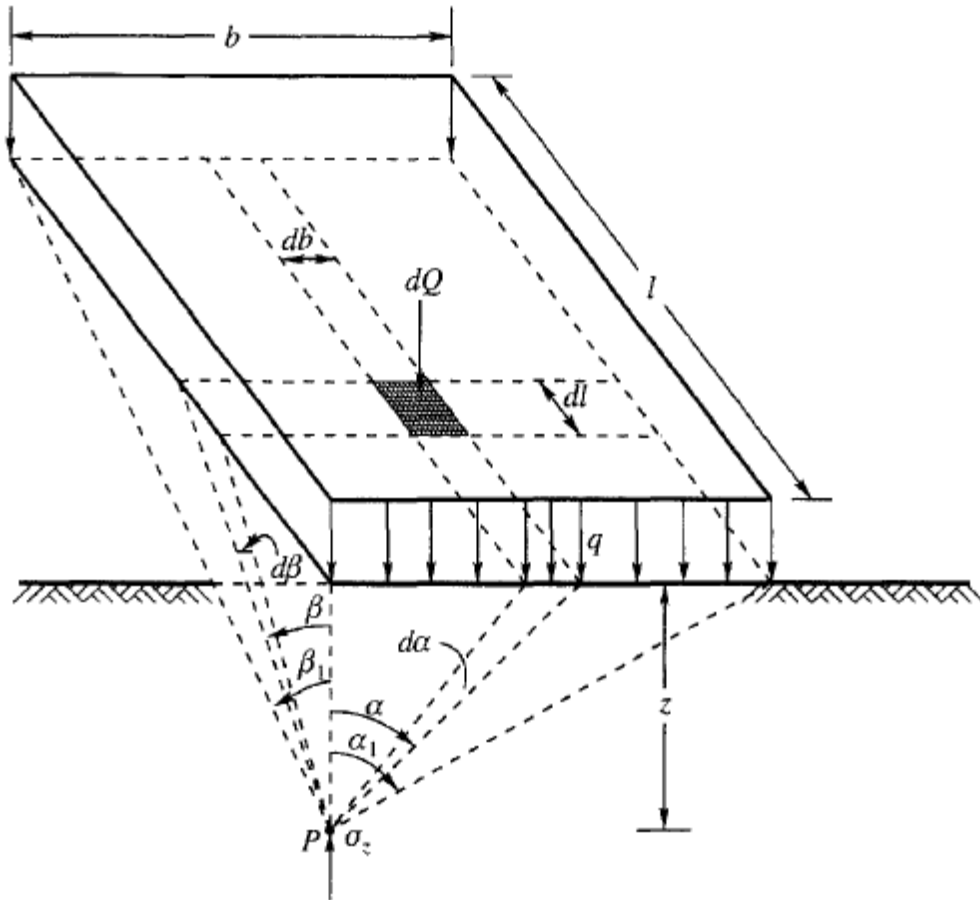
Slika: 5.5 Bez-dimenzionalna veličina σ_z/q za trakasto opterećenje

$$\sigma_1 = \frac{q}{\pi}(\beta + \sin \beta) \quad 5.11$$

$$\sigma_3 = \frac{q}{\pi}(\beta - \sin \beta) \quad 5.12$$

5.6 NAPON ISPOD UGLA PRAVOUGAONOG TEMELJA

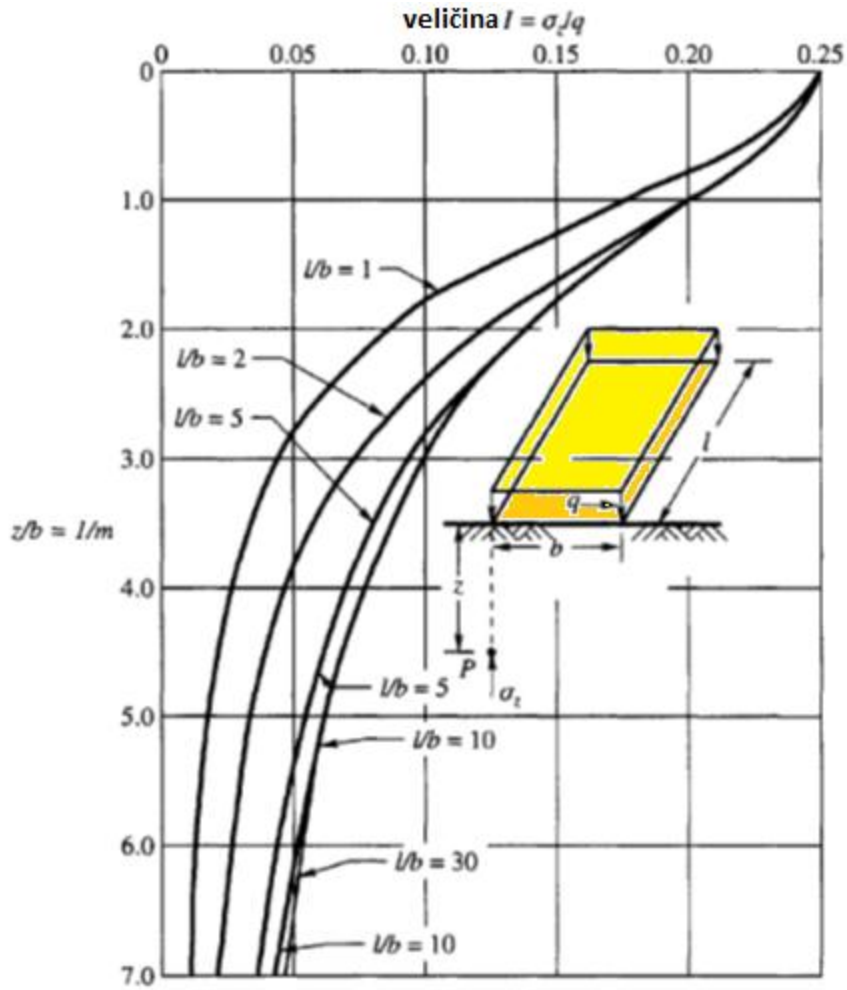
$$dQ = q \, db \cdot dl \quad 5.13$$



Slika: 5.6 Vertikalni naprezanje ispod ugla pravougaonog temelja

$$d\sigma_z = \frac{dQ}{2\pi} \frac{3z^3}{(z^2 + r^2)^{5/2}}$$

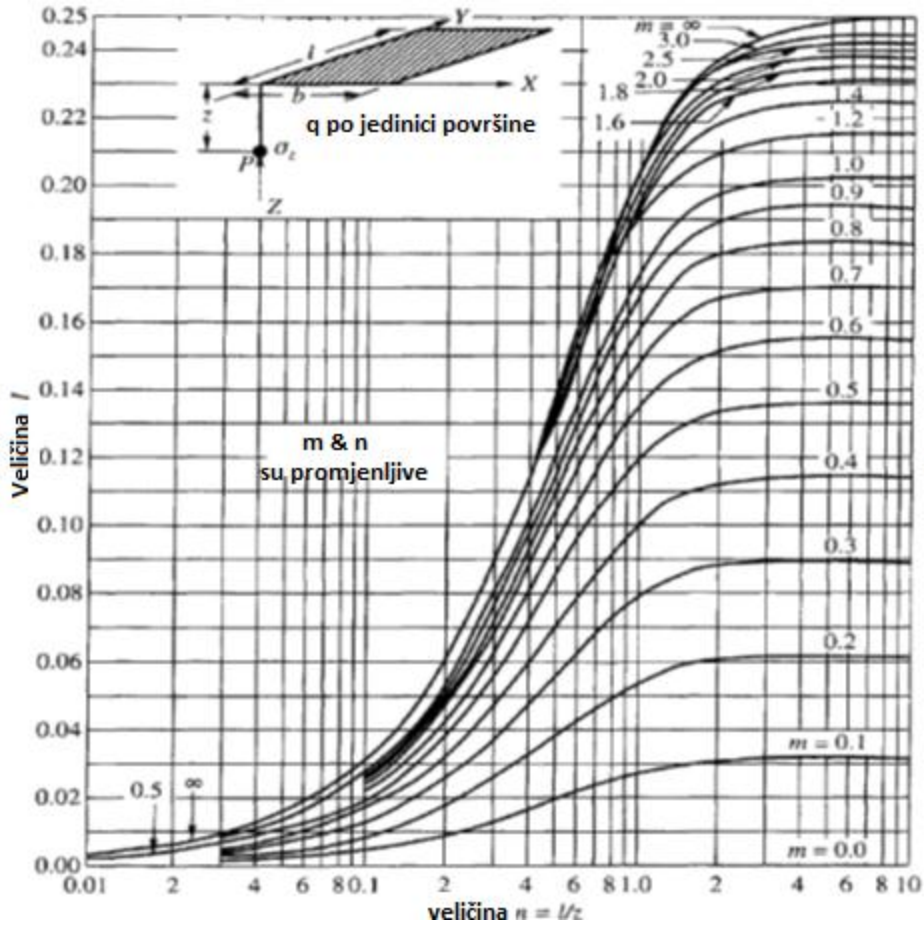
5.14



Slika:5.7 Dijagram za računanje σ_z ispod ugla pravougaonog temelja (po: Steinbrenner-u,1934)

$$\sigma_z = q (I_1 + I_2 + I_3 + I_4) \quad 5.15$$

$$ABCD = OB_1CD_1 - OB_1BD_2 - OD_1DA_1 + OA_1AD_2 \quad 5.16$$



Slika:5.8 Dijagram za određivanje uticajnih veličina za vertikalno naprezanje σ_z u tački P lociranoj ispod jednog ugla ravnomjerno opterećene pravougaone površine (prema: Fadum, 1948)

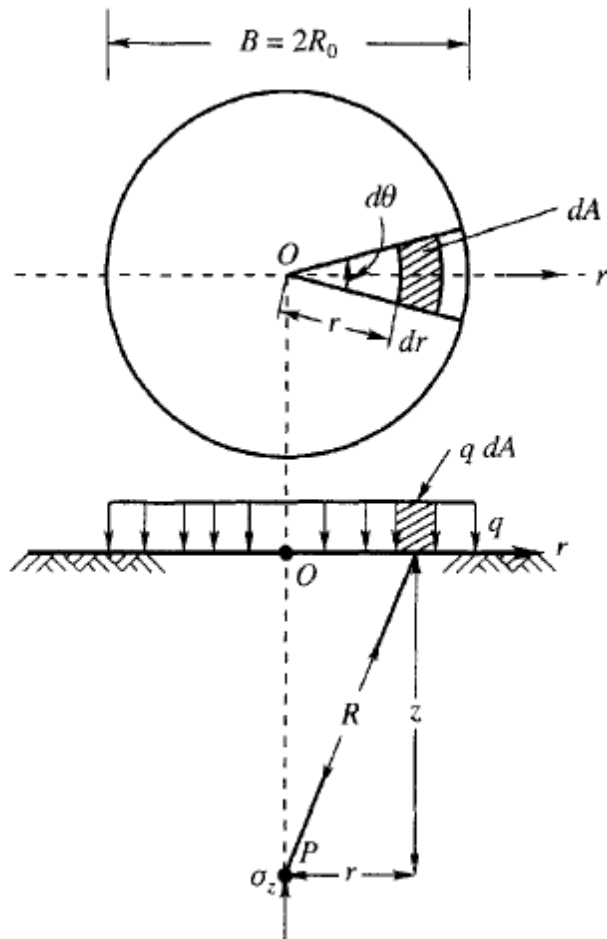
5.7 NAPON ISPOD RAVNOMJERNO OPTEREĆENOG KRUŽNOG TEMELJA

$$dQ = q dA = qr d\theta dr \quad 5.17$$

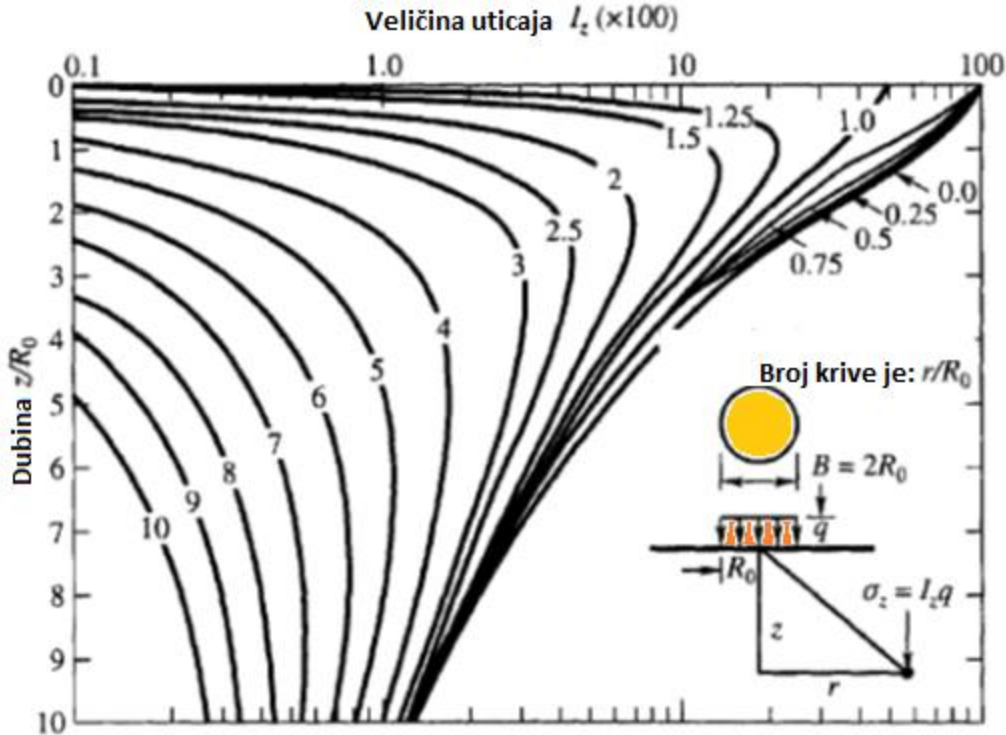
$$d\sigma_z = \frac{3q}{2\pi} \frac{z^3 r d\theta dr}{(r^2 + z^2)^{5/2}} \quad 5.18$$

$$\sigma_z = \int_{\theta=0}^{\theta=2\pi} \int_{r=0}^{r=R_0} d\sigma_z = \frac{3qz^3}{2\pi} \int_{\theta=0}^{\theta=2\pi} \int_{r=0}^{r=R_0} \frac{rd\theta dr}{(r^2 + z^2)^{5/2}} \quad 5.19$$

$$\sigma_z = q \left[1 - \frac{z^3}{(R_0^2 + z^2)^{3/2}} \right] \quad 5.20$$



Slika: 5.9 Vertikalni napon ispod ravnomjerno opterećene kružne površine



Slika: 5.10 Dijagram uticajnih veličina za vertikalne normalne napone za tačke unutar elastičnog poluprostora ispod kružne ravnomjerno opterećene površine (prema: Foster & Ahlvin, 1954)

$$\sigma_z/q = 1 - \left[\frac{1}{1 + (R_0/z)^2} \right]^{3/2} = I_z \quad 5.21$$

5.8 VERTIKALNI NAPON ISPOD OPTEREĆENE POVRŠINE NEPRAVILNOG OBLIKA

$$\Delta\sigma_z = Cq \quad 5.22$$

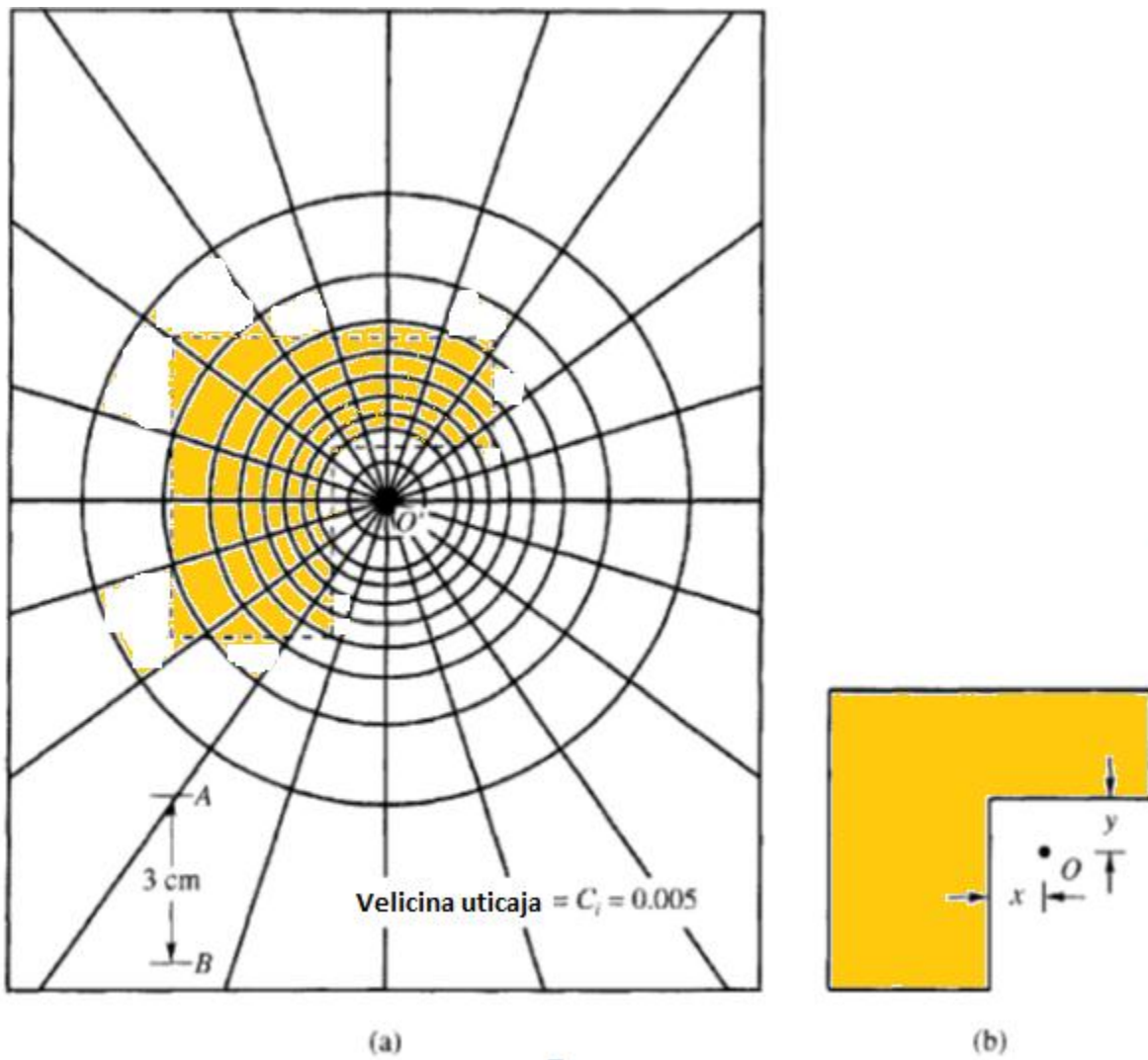
Tabela: 5.1 Vrijednosti R/z za različite veličine σ_z/q

σ_z/q	R/z	σ_z/q	R/z
0.00	0.000	0.80	1.387
0.10	0.270	0.90	1.908
0.20	0.401	0.92	2.094
0.30	0.518	0.94	2.351
0.40	0.637	0.96	2.748
0.50	0.766	0.98	3.546
0.60	0.917	1.00	∞
0.70	1.110	-	-

$$\frac{\Delta\sigma_z}{n} = \frac{C}{n} q = C_i q \quad 5.23$$

$$\frac{\Delta\sigma_z}{n} = C_i$$

$$\sigma_z = C_i N q \quad 5.24$$



Slika: 5.11 Dijagram uticaja prema Newmark-u

5.9 OPTEREĆENJA OD NASIPA

Vertikalno opterećenje linearno se povećava

$$dq = (q/a) b db$$

$$d\sigma_z = \left(\frac{1}{a}\right) \left(\frac{2q}{\pi}\right) \frac{z^3 b db}{[(x-b)^2 + z^2]^2}$$

$$\sigma_z = \int d\sigma_z = \left(\frac{1}{a}\right) \left(\frac{2q}{\pi}\right) \int_{b=0}^{b=a} \frac{z^3 b db}{[(x-b)^2 + z^2]^2}$$

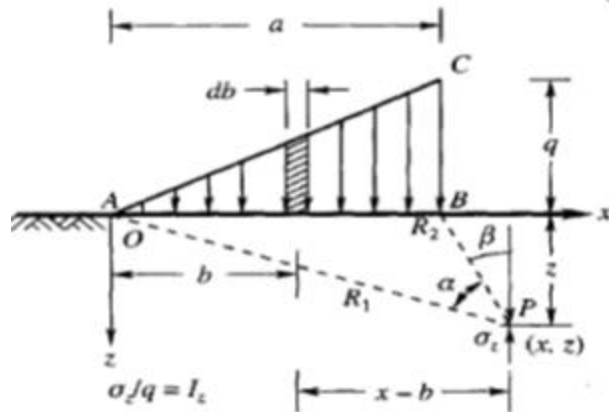
$$\sigma_z = \frac{q}{2\pi} \left(\frac{2x}{a} \alpha - \sin 2\beta \right) = qI_z \quad 5.25$$

$$\sigma_z = \frac{q}{\pi} (\alpha) \quad 5.26$$

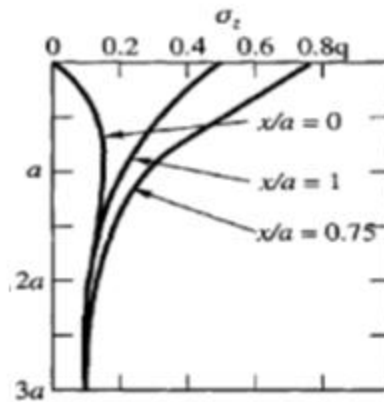
Vertikalni napon od opterećenja nasipom

Tabela: 5.2 I_z za trouglasto opterećenje (jednačina: 5.25)

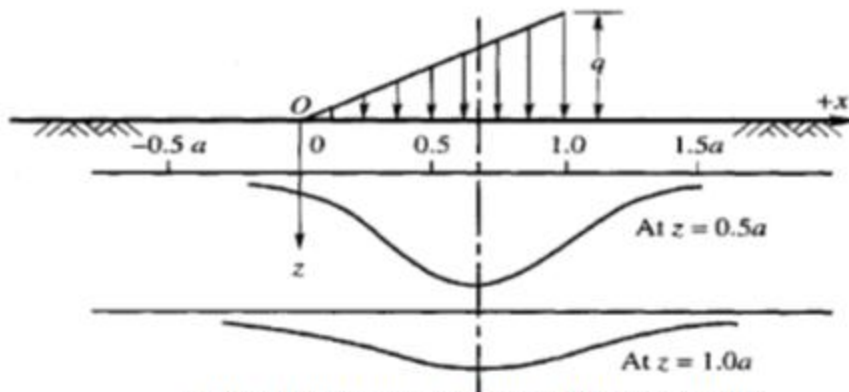
x/a	z/a						
	0.00	0.5	1.0	1.5	2	4	6
-1.500	0.00	0.002	0.014	0.020	0.033	0.051	0.041
-1.00	0.00	0.003	0.025	0.048	0.061	0.060	0.041
0.00	0.00	0.127	0.159	0.145	0.127	0.075	0.051
0.50	0.50	0.410	0.275	0.200	0.155	0.085	0.053
0.75	0.75	0.477	0.279	0.202	0.163	0.082	0.053
1.00	0.50	0.353	0.241	0.185	0.153	0.075	0.053
1.50	0.00	0.056	0.129	0.124	0.108	0.073	0.050
2.00	0.00	0.017	0.045	0.062	0.069	0.060	0.050
2.50	0.00	0.003	0.013	0.041	0.050	0.049	0.045



(a) Troglasto opterećenje



(b) Vertikalni napon na vertikalnom presjeku



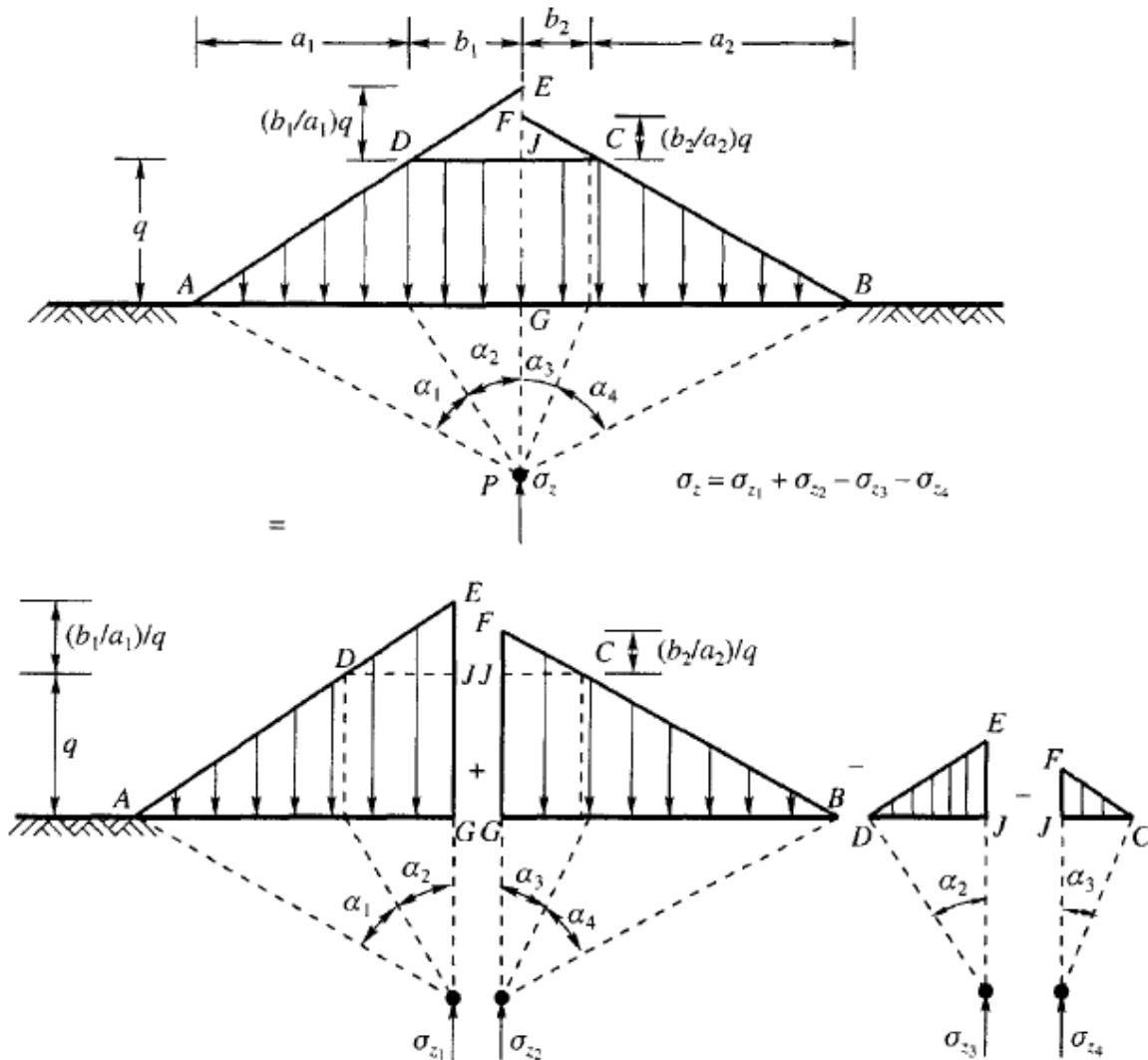
(c) Vertikalni napon na horizontalnom presjeku

Slika: 5.12 Naponi u polu-beskonačnoj masi od opterećenja trouglastog oblika na površini

 σ_z – Metodom superpozicije

$$ABCD = AGE + FGB - EDJ - FJC \quad 5.27$$

$$\sigma_z = \sigma_{z_1} + \sigma_{z_2} - \sigma_{z_3} - \sigma_{z_4} \quad 5.28$$



Slika: 5.13 Vertikalni naponi od nasipa

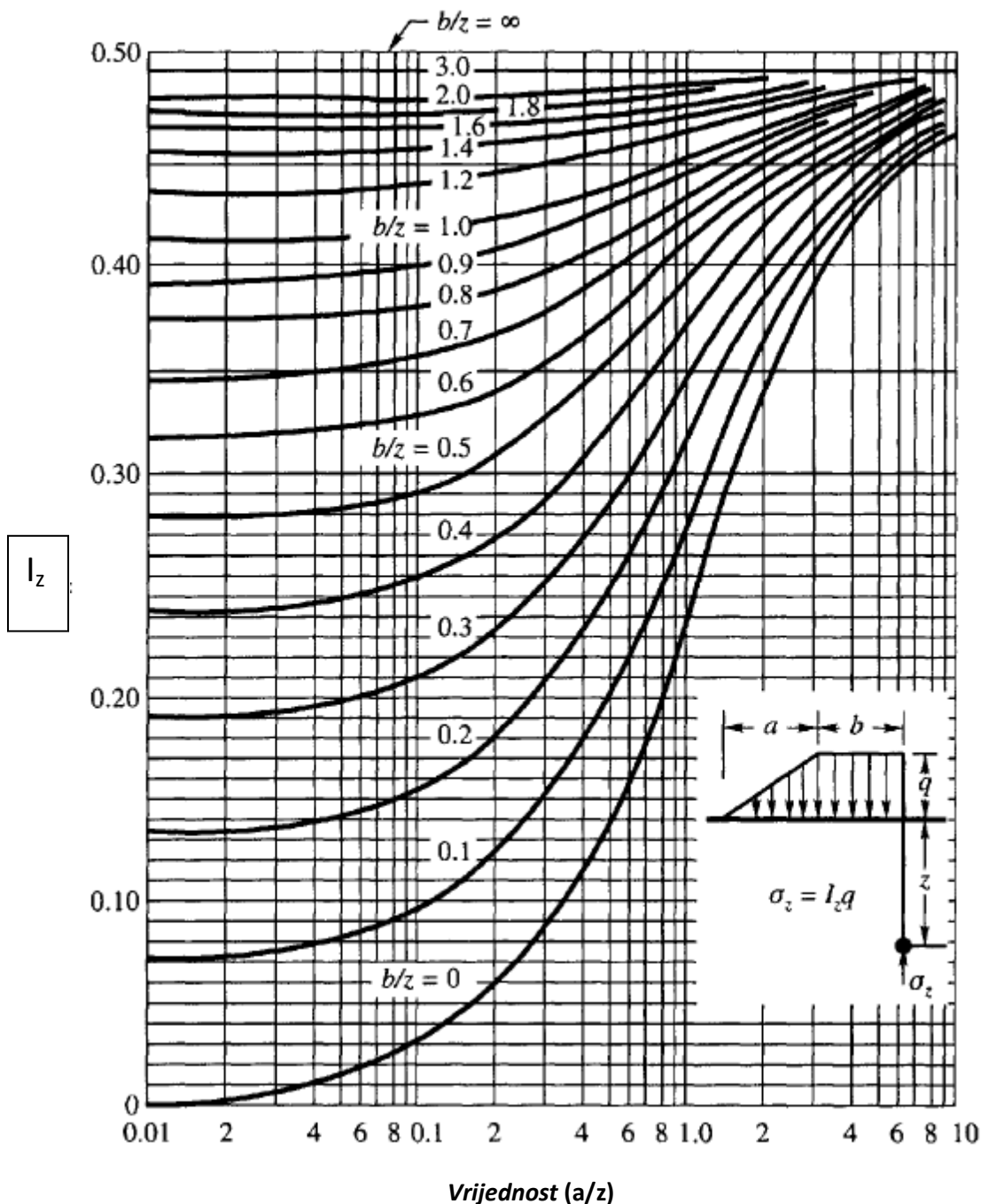
$$\sigma_z = \frac{q}{\pi} \left[(\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4) + (b_1 / a_1) \alpha_1 + (b_2 / a_2) \alpha_4 \right] \quad 5.29$$

$$\sigma_z = q l_z = \frac{q}{\pi} f(a/z, b/z) \quad 5.30$$

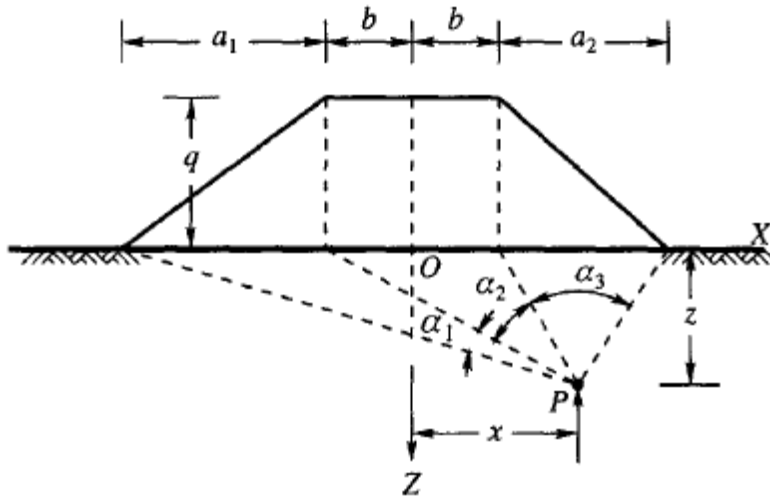
σ_z formule za nesimetrično trapezasto opterećenje

$$\sigma_z = \frac{q}{\pi} \left[(\alpha_1 + \alpha_2 + \alpha_3) + \frac{b}{a_1} (\alpha_1 + R\alpha_3) + \frac{x}{a_1} (\alpha_1 - R\alpha_3) \right]$$

5.31



Slika: 5.14 Dijagram za određivanje napona pritiska od opterećenja promjenljivog po linearnom zakonu (prema: Osterberg,1957)



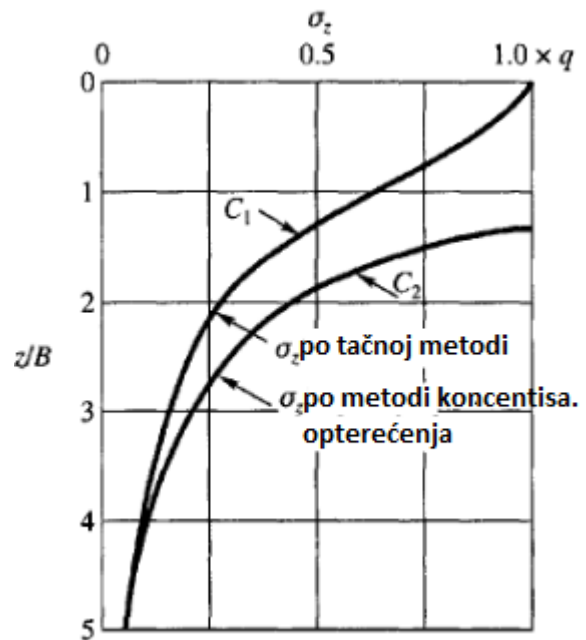
Slika: 5.15 Trapezasto opterećenje

$$\sigma_z = \frac{q}{\pi} \left[(\alpha_1 + \alpha_3) + \frac{x}{a_1} (\alpha_1 - R\alpha_3) \right]$$

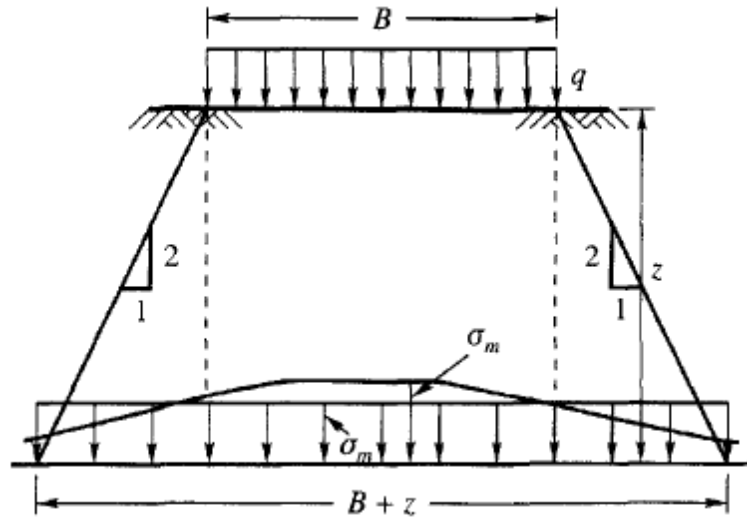
5.32

5.10 PRIBLIŽAN METOD ZA RAČUNANJE σ_z

Metod koncentrisanog opterećenja

Slika: 5.16 σ_z prema koncentrisanom opterećenju

2 : 1 Metod

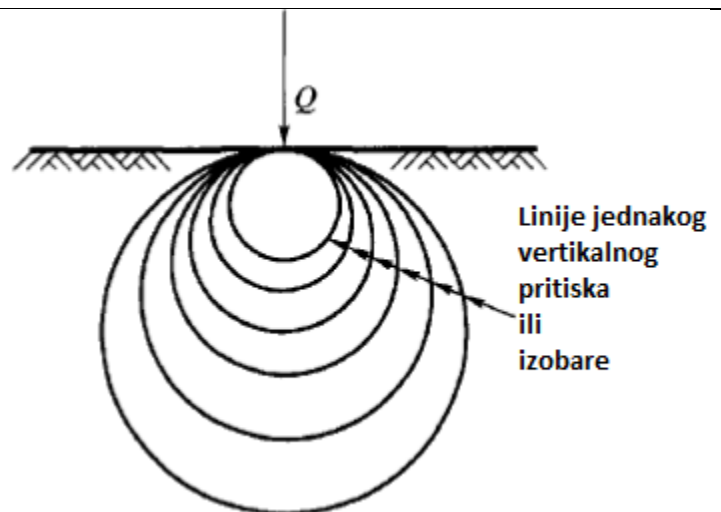


Slika: 5.17 σ_m 2 : 1 Metod

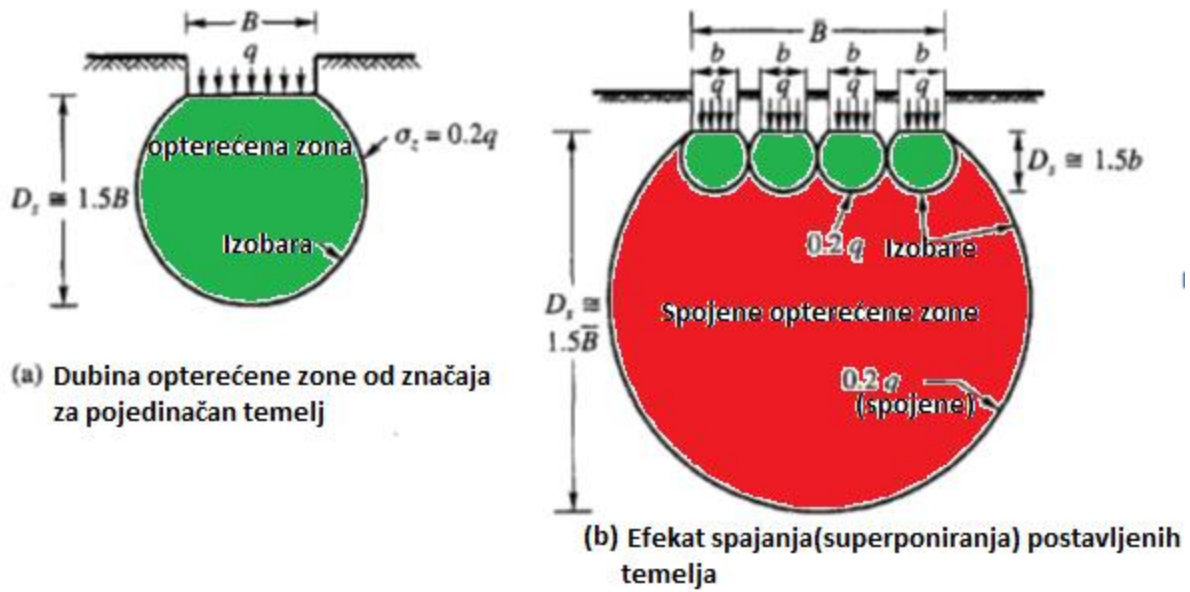
$$\sigma_a = \frac{Q}{(B+z)(L+z)}$$

5.33

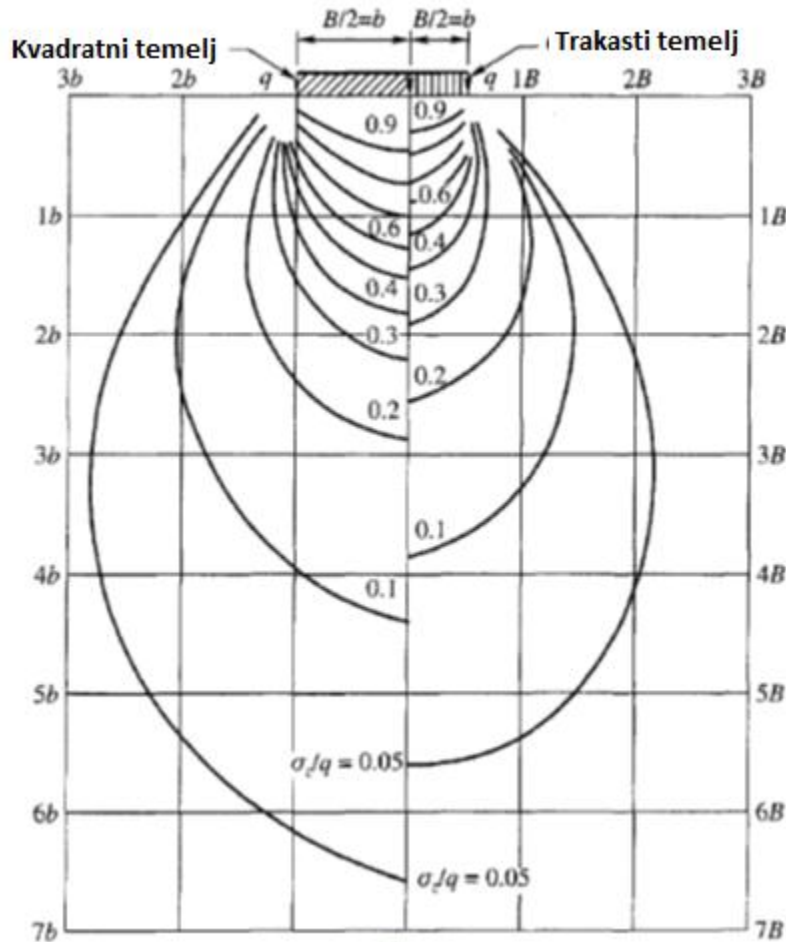
5.11 IZOBARE PRITISKA



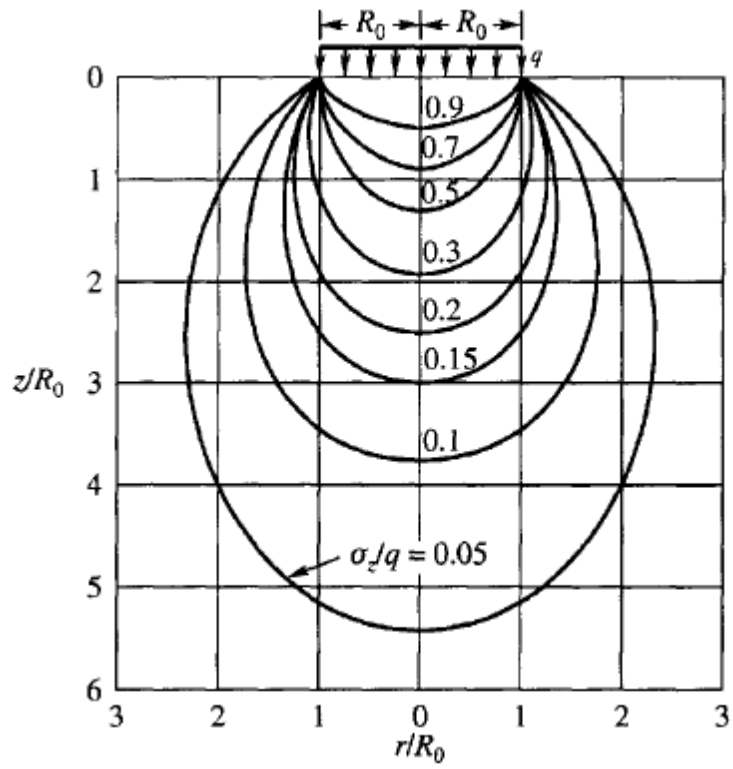
Slika: 5.18 Prostor naprezanja



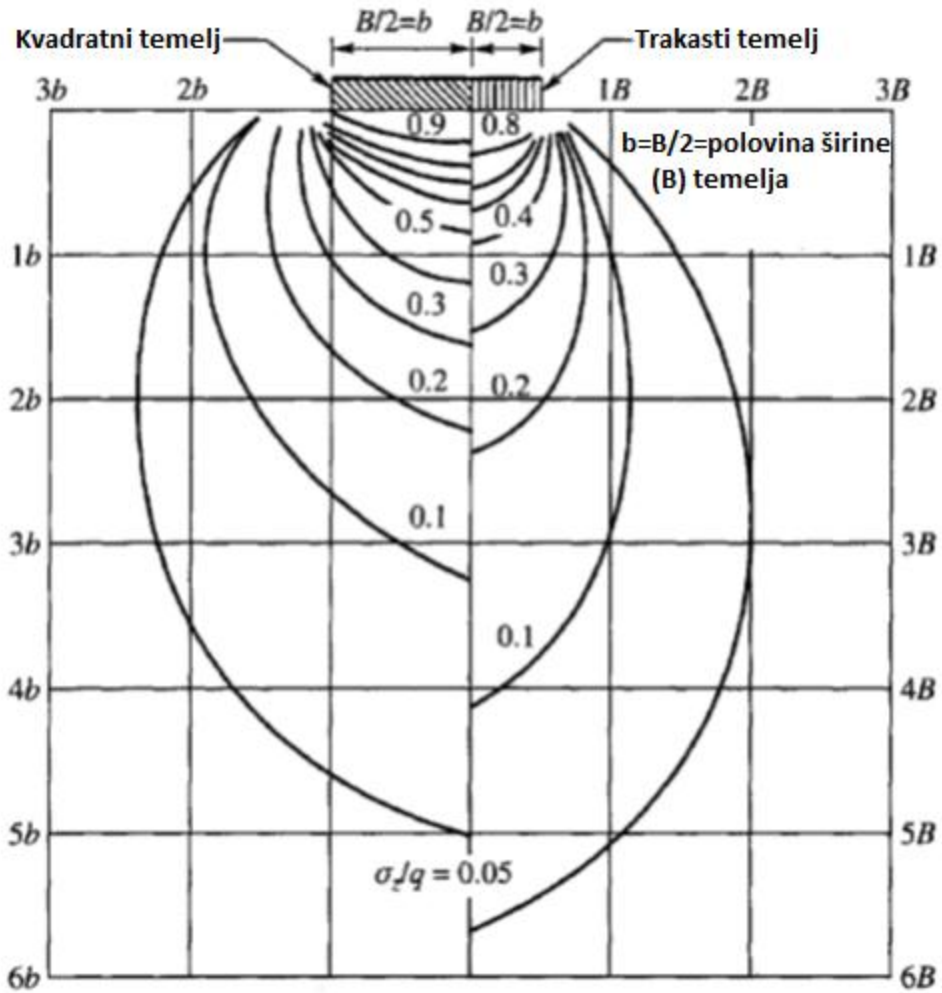
Slika: 5.19 Značajna dubina opterećene (napregnute) zone



Slika: 5.20 Izobare pritiska po Boussinesque-ovim jednačinama za kvadratne i trakaste temelje



Slika:5.21 Izobare pritiska po Boussinesque-ovim jednačinama za ravnomjerno opterećen kružni temelj



Slika: 5.22 Izobare pritiska prema Westergaardeovim jednačinama za kvadratni i trakasti temelj