ZEMİNDE GERİLMELER ve DAĞILIŞI

ea

ZEMİNDE GERİLMELER

$$s = \frac{P}{A}$$

A) Doğal Gerilmeler: Özağırlık, suyun etkisi ve sonradan edinilen gerilmeler,

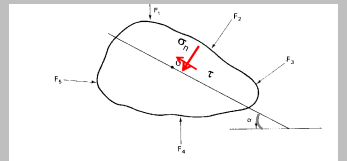
B) Taban Basınçları: Temel (dış yük)-Zemin arayüzeyinde beliren gerilmeler,

C) Kitle Gerilmeleri: Dış yüklemeden dolayı zemin kitlesi içinde beliren gerilmelerdir.

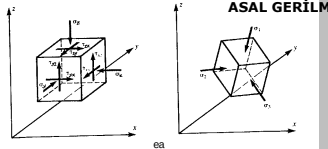
ea

ZEMİNE ETKİ EDEN KUVVET VE GERİLMELER

(a) Kuvvetler sistemi (b) gerilemeler (c) asal gerilmeler

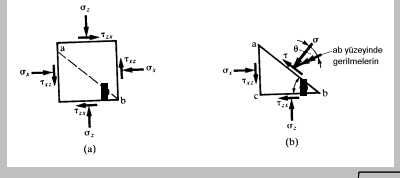


ASAL GERİLMELER



ea

iki boyutlu elemanda gerilmeler



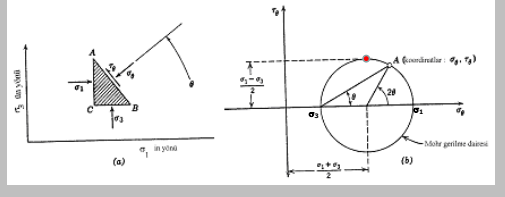
$$\left[s - \frac{1}{2}\left(s_x + s_z\right)\right]^2 + t^2 = \left[\frac{1}{2}\left(s_x - s_z\right)\right]^2 + t_{xz}^2$$

$$\sqrt{\left[\frac{1}{2}\left(s_x - s_z\right)\right]^2 + t_{xz}^2}$$

$$\frac{1}{2}\left(s_x + s_z\right)$$

ea

İKİ BOYUTLU GEERİLME ANALİZİ: Mohr Gerilme Dairesi



Gerilmelerin Mohr Dairesinde Gösterilmesi
(a) Gerilmelerin yönü (b) Dairenin özellikleri

A noktasında $t_q = \left(s_1 - s_3\right)\sin q \cos q = \frac{s_1 - s_3}{2}\sin 2q$

ea

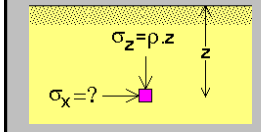
YÜK ALTINDA HERHANGİ BİR DÜZLEM ÜZERİNDE GERİLMELER

$$s_q = s_1 \cos^2 q + s_3 \sin^2 q = \frac{s_1 + s_3}{2} + \frac{s_1 - s_3}{2}\cos 2q$$

$$t_q = \left(s_1 - s_3\right)\sin q \cos q = \frac{s_1 - s_3}{2}\sin 2q$$

ea

A) DOĞAL GERİLMELER



$$\sigma_x = \sigma_z \cdot \left(\frac{\nu}{1-\nu}\right)$$

$$\nu = \frac{\varepsilon_x}{\varepsilon_z}$$

$$\sigma_v = \sigma_z = \rho.z$$

$$\sigma_x = K_0 \cdot \sigma_z$$

K_0:Sükunette toprak basıncı katsayısı

$$K_0 = \frac{\sigma_x}{\sigma_z}$$

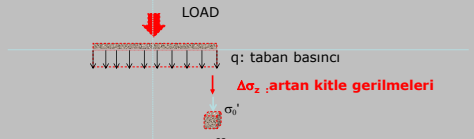
$$K_0 = \frac{\nu}{1-\nu}$$

ea

B) TABAN BASINÇLARI

Üstyapı yükleri zemine 'temel' denilen yapı elemanları aracılığıyla aktarılır.

Günümüzde temeller betonarme olarak imal edilmektedir . Betonarmenin rijitliği zemininkinden çok farklı olduğundan temel - zemin arayüzeyinde beliren gerilme (q) sadece temelin aşırı **esnek** olduğu özel durumlarda yük şiddeti P/A'ya eşit ve üniform olur.



ea

Bunun dışındaki tüm durumlarda "taban basıncı" olarak anılan Zemin-Temel arayüzeyinde oluşan gerilmeler

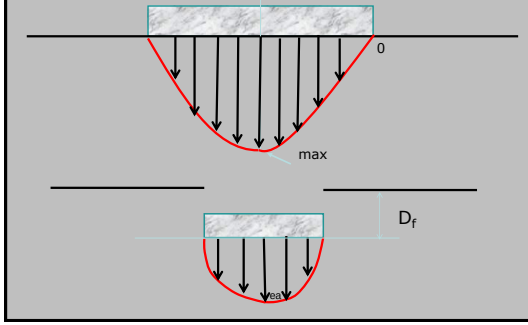
-Yükün şiddeti (temelin son taşıma gücü)
-Zemin tipi
-Poisson oranı
-Temelin esnekliği
-Yükün şekli
-Gömme derinliğine

bağlı olarak taban boyunca polinom eğrisi tipinde değişir.

-

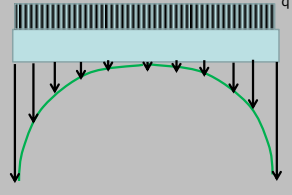
ea

KUM
Rijit Temeller Altında Taban Basıncı Dağılımı



ea

KİL
Rijit Temeller Altında Taban Basıncı Dağılımı



ea

ELASTİK MALZEME

"**ELASTİK**"; yükün kaldırılmasıyla orjinal şekle dönüşü ifade eder.
*Elastik bir malzeme Hook Kanunu' na uyar.
*Buna göre zorlanma (deformasyon) gerilme ile orantılı olarak değişir.



$$\varepsilon_z = \frac{\Delta H}{H_0} \qquad \varepsilon_x = \frac{\Delta D}{D_0}$$

Hooke Kanunu

$$E = \frac{\sigma}{\varepsilon}$$

Poisson Oranı

$$\upsilon = \frac{\varepsilon_x}{\varepsilon_z}$$

mantar ν=0
zeminler ν~0.3

ea

C) KİTLE GERİLMELERİ

Normal Gerilme ve Kayma Gerilmesi, Temelin uyguladığı taban basıncıyla oluşur.

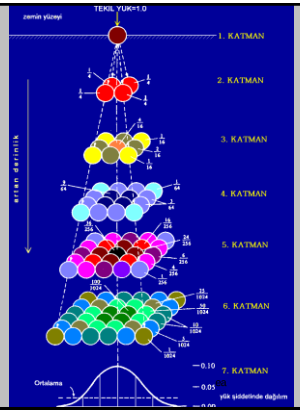
-Yükün şiddeti
- Yükün uygulandığı yere olan uzaklık
- Temelin zemin içine gömülme derinliğine bağlıdır.

ea

KİTLE GERİLMELERİNİN HESAPLAMA YÖNTEMLERİ

1) Boussinesq (1865)
2) Newmark
3) Westergaard
4) Jurgenson
5) Sayısal Analiz (FEM)

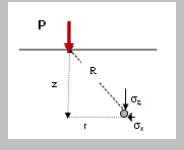
ea



KİTLE GERİLMELERİ

Daneli Ortamda Düşey Gerilmelerin Yayılışı

TEKİL YÜK ETKİSİYLE OLUŞAN KİTLE GERİLMESİ ARTIŞI



Boussinesque

- ✓Homojen zemin
- ✓Eşyönlü
- ✓Ağırlıksız
- ✓Düzlem yüzeyli

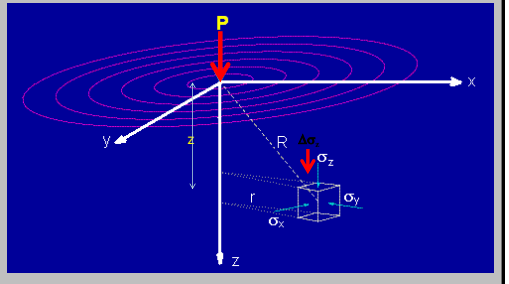
$$\Delta\sigma_z = \frac{3Pz^2}{2\pi R^5} \quad \text{or}$$

$$\Delta\sigma_z = -\frac{P}{2\pi R^2}\left[\frac{3r^2 z}{R^3} + \frac{(1-2\nu)R}{R+z}\right]$$

$$\tau_{rz} = \frac{3Prz^2}{2\pi R^5}$$

ea

DÜŞEY GERİLME ARTIŞI KAVRAMI

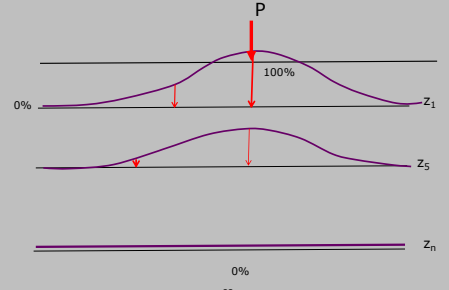


Varsayım : $\sigma_x = \sigma_y$

ea $\Delta\sigma_z = \frac{3Pz^2}{2\pi R^5}$

BASINÇ ÇANI

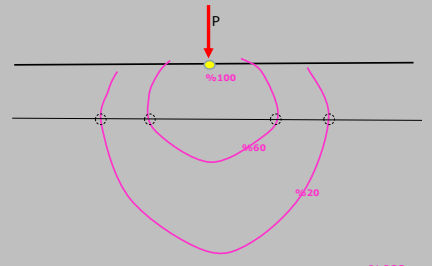
Herhangi bir XX düzlemine belirli bir z derinliğinde etki eden temsili eğri



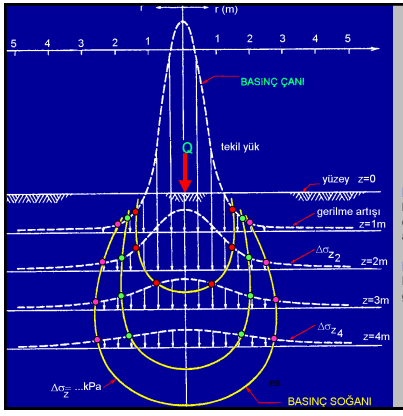
ea

BASINÇ SOĞANI

Eşit gerilmelerden geçen temsili eğrileri



ea



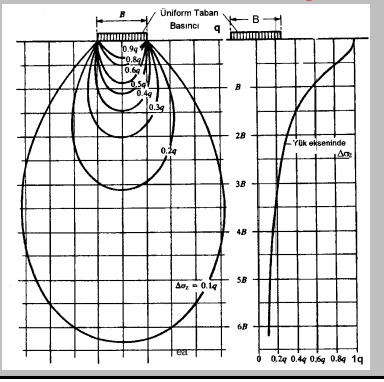
ea

Basınç Çanı ve Basınç Soğanı Kavramı

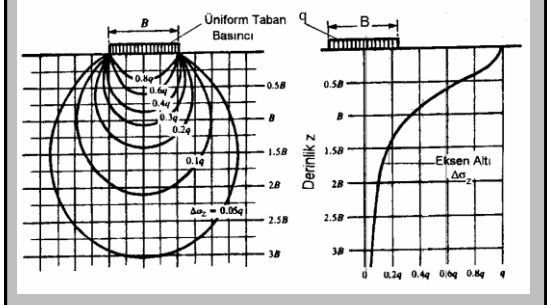
Basınç Çanı
Herhangi bir düzleme gelen gerilme artışlarıdır.

Basınç Soğanı:
Eş basınç noktalarından geçirilen eğrilerdir.

Şerit Yükler Altında Basınç Soğanları



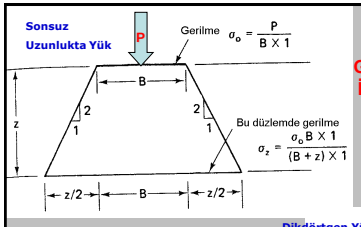
Kare Yükler Altında Basınç Soğanları



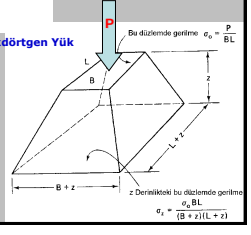
ea

Gerilme Artışı Hesabı İçin Yaklaşık Yöntem

Sonsuz Uzunlukta Yük

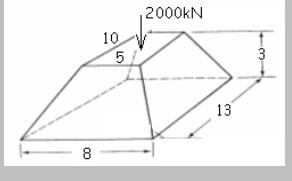


Dikdörtgen Yük



ea

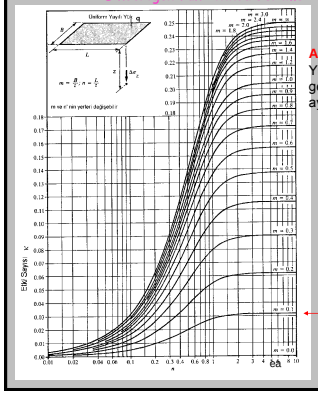
PROBLEM 1[k]: Zemin yüzeyinde 5x10 m boyutlarında bir alana 2000 kN yük gelmiştir. Bu yükten dolayı 3 m derinlikte yatay düzleme gelecek ortalama gerilme artışı ne olabilir?



$$\sigma_z = \frac{P}{A} = \frac{2000}{(5+3)\cdot(10+3)} = 19.23 \ \frac{kN}{m^2} = 19.23 \ kPa$$

ea

Dikdörtgen Yük Altında Gerilme Artışı için Etki Sayısı

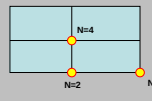


Boussinesq

ANA KURAL:
Yüzeydeki yükün bir köşesi ile gerilme artışı hesaplanacak nokta aynı düşey eksende olmasıdır

$$\Delta\sigma_z = N.q.\kappa$$

N=Simetri Katsayısı



κ = Etki Katsayısı(Grafikten)

$$m = \frac{B}{z}, \quad n = \frac{L}{z}$$

ea

DÖRTGEN ALANLAR İÇİN ETKİ KATSAYILARI, κ

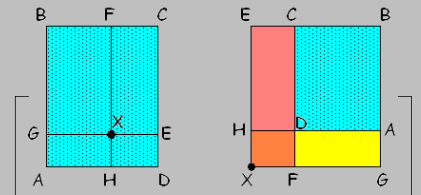
m \ n	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4
0.1	.00470	.00917	.01323	.01678	.01978	.02223	.02420	.02576	.02698	.02794	.02926	.03007
0.2	.00917	.01790	.02585	.03280	.03866	.04348	.04735	.05042	.05283	.05471	.05733	.05894
0.3	.01323	.02585	.03735	.04742	.05593	.06294	.06858	.07308	.07661	.07938	.08323	.08561
0.4	.01678	.03280	.04742	.06024	.0714	.08009	.08734	.09314	.09770	.10129	.10631	.10941
0.5	.01978	.03866	.05593	.07011	.08403	.09473	.10340	.11035	.11584	.12018	.12626	.13003
0.6	.02223	.04348	.06294	.08009	.09473	.10688	.11679	.12474	.13105	.13605	.14309	.14749
0.7	.02420	.04735	.06858	.08734	.10340	.11679	.12772	.13653	.14356	.14914	.15703	.16199
0.8	.02576	.05042	.07308	.09314	.11035	.12474	.13653	.14607	.15371	.15978	.16843	.17389
0.9	.02698	.05283	.07661	.09770	.11584	.13105	.14356	.15371	.16185	.16835	.17766	.18357
1.0	.02794	.05471	.07938	.10129	.12018	.13605	.14914	.15978	.16835	.17522	.18508	.19139
1.2	.02926	.05733	.08323	.10631	.12626	.14309	.15703	.16843	.17766	.18508	.19584	.20278
1.4	.03007	.05894	.08561	.10941	.13003	.14749	.16199	.17389	.18537	.19139	.20278	.21020
1.6	.03058	.05994	.08709	.11135	.13241	.15028	.16515	.17739	.18737	.19546	.20731	.21510
1.8	.03090	.06058	.08804	.11260	.13395	.15207	.16720	.17967	.18986	.19814	.20731	.21836
2.0	.03111	.06100	.08867	.11342	.13496	.15326	.16856	.18119	.19152	.19994	.21032	.22058
2.5	.03138	.06155	.08948	.11450	.13628	.15483	.17036	.18321	.19375	.20236	.21235	.22364
3.0	.03150	.06178	.08982	.11495	.13684	.15550	.17113	.18407	.19470	.20341	.21512	.22499
4.0	.03158	.06194	.09007	.11527	.13724	.15598	.17168	.18469	.19540	.20417	.21633	.22600
5.0	.03160	.06199	.09014	.11537	.13737	.15612	.17185	.18488	.19561	.20440	.21722	.22632
6.0	.03161	.06201	.09017	.11541	.13741	.15617	.17191	.18496	.19569	.20449	.21749	.22644
8.0	.03162	.06202	.09018	.11543	.13744	.15621	.17195	.18500	.19574	.20455	.21760	.22652
10.	.03162	.06202	.09019	.11544	.13745	.15622	.17196	.18502	.19576	.20457	.21767	.22654
∞	.03162	.06202	.09019	.11544	.13745	.15623	.17197	.18502	.19577	.20458	.21769	.22656

ea

DÖRTGEN ALANLAR İÇİN ETKİ KATSAYILARI, κ (Devam)

m \ n	1.6	1.8	2.0	2.5	3.0	4.0	5.0	6.0	8.0	10.0	∞
0.1	.03058	.03090	.03111	.03138	.03150	.03158	.03160	.03161	.03162	.03162	.03162
0.2	.05994	.06058	.06100	.06155	.06178	.06194	.06199	.06201	.06202	.06202	.06202
0.3	.08709	.08804	.08867	.08948	.08982	.09007	.09014	.09017	.09018	.09019	.09019
0.4	.11135	.11260	.11342	.11450	.11495	.11527	.11537	.11541	.11543	.11544	.11544
0.5	.13241	.13395	.13496	.13628	.13684	.13724	.13737	.13741	.13744	.13745	.13745
0.6	.15028	.15207	.15326	.15483	.15550	.15598	.15612	.15617	.15621	.15622	.15623
0.7	.16515	.16720	.16856	.17036	.17113	.17168	.17185	.17191	.17195	.17196	.17197
0.8	.17739	.17967	.18119	.18321	.18407	.18469	.18488	.18496	.18500	.18502	.18502
0.9	.18737	.18986	.19152	.19375	.19470	.19540	.19561	.19569	.19574	.19576	.19577
1.0	.19546	.19814	.19994	.20236	.20341	.20417	.20440	.20449	.20455	.20457	.20458
1.2	.20731	.21032	.21235	.21512	.21633	.21722	.21749	.21760	.21767	.21769	.21770
1.4	.21510	.21836	.22058	.22364	.22499	.22600	.22632	.22644	.22652	.22654	.22656
1.6	.22025	.22372	.22610	.22940	.23088	.23200	.23236	.23249	.23258	.23261	.23263
1.8	.22372	.22736	.22986	.23334	.23495	.23617	.23656	.23671	.23681	.23684	.23686
2.0	.22610	.22986	.23247	.23614	.23782	.23912	.23954	.23970	.23981	.23985	.23987
2.5	.22940	.23334	.23614	.24010	.24196	.24344	.24392	.24412	.24425	.24429	.24432
3.0	.23088	.23495	.23782	.24196	.24394	.24554	.24608	.24630	.24646	.24650	.24654
4.0	.23200	.23617	.23912	.24344	.24554	.24729	.24791	.24817	.24836	.24842	.24846
5.0	.23236	.23656	.23954	.24392	.24608	.24791	.24857	.24885	.24916	.24939	.24946
6.0	.23249	.23671	.23970	.24412	.24630	.24817	.24885	.24916	.24939	.24946	.24952
8.0	.23258	.23681	.23981	.24425	.24646	.24836	.24907	.24939	.24964	.24973	.24980
10.	.23261	.23684	.23985	.24429	.24650	.24842	.24914	.24946	.24973	.24981	.24989
∞	.23263	.23686	.23987	.24432	.24654	.24846	.24919	.24952	.24980	.24989	.25000

ea

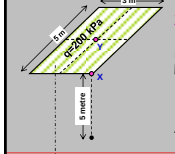


$$\kappa_{ABCD} = \kappa_{XEDH} + \kappa_{XECF} + \kappa_{XFBG} + \kappa_{XHAG}$$

$$\kappa_{ABCD} = \kappa_{XGBE} - \kappa_{XECF} - \kappa_{XGAH} + \kappa_{XFDH}$$

ea

PROBLEM 2: Planı verilen 3x5 m² lik dikdörtgen temelin üniform olan taban basıncı 200 kPa'dır. Temel yükünden meydana gelen düşey gerilme artışlarını temelin merkezi altında ve bir köşesinden 5 m derinlikte Boussinesq yöntemini kullanarak hesaplayınız.

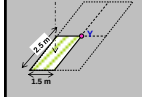


X noktasından 5 m derinlikte gerilme artışı;

B=3 m=B/Z=3/5=0.6 n=L/Z=5/5=1
L=5 m=0.6
n=1 Boussinesq abağından κ=0.13605

$\Delta\sigma_v = q \times \kappa = 200 \times 0.13605 = 27.21$ kPa

Y noktasından 5 m derinlikteki gerilme artışı;

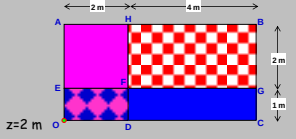


B=1.5 m=B/Z=1.5/5=0.3 n=L/Z=2.5/5=0.5
L=2.5 m=0.3
n=0.5 Boussinesq abağından κ=0.05593

$\Delta\sigma_v = 4 \times q \times \kappa = 4 \times 200 \times 0.05593 = 44.744$ kPa

ea

PROBLEM 3*: 2 m x 4 m' lik dikdörtgen temel zemine 210 kPa' lık üniform taban basıncı uygulamaktadır. Bu temelin O noktasından 2 m düşey derinlikte oluşturacağı gerilme artışını bulunuz.



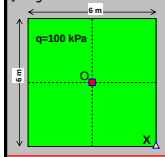
$$\kappa_{HBGF} = \kappa_{OABC} - \kappa_{OAHD} - \kappa_{OEGC} + \kappa_{OEFD}$$

ALAN	L	B	m = L/z	n = B/z	κ
+OABC	6	3	6/2=3	3/2=1.5	+0.22794
-OAHD	2	3	2/2=1	3/2=1.5	-0.19343
-OEGC	6	1	6/2=3	1/2=0.5	-0.13648
+OEFD	2	1	2/2=1	1/2=0.5	+0.12018
				Toplam:	+0.01821

$\Delta\sigma z = q \cdot \kappa = 210 \cdot 0.01821 = 3.82$ kPa

ea

PROBLEM 4ᵏ: Üzerinde 100 kPa eşdeğeri yük olan 6x6 m boyutlarında kare temelin (a) O merkezi ve (b) X köşesi altında gerilme artışı ($\Delta\sigma$) – derinlik (z) eğrilerini Boussinesq çizelgelerini kullanarak bulunuz.



O Noktası Altında

m= B /z = 3/z = n = L/ z

$\Delta\sigma_z$ = N.q.κ = 4.100.κ = 400 κ

z	0	1	2	3	5	7	9
m = n	∞	3	1.5	1	0.6	0.43	0.33
κ	0.25	0.24394	0.21517	0.17522	0.10688	0.07169	0.04364
$\Delta\sigma_z$	100	98	86	70	43	29	17

X Noktası Altında

m=n= 6/z

$\Delta\sigma_z$ = N.q.κ = 1.100.κ = 100 κ (kPa)

z	0	1	2	3	5	7	9
m = n	∞	6	3	2	1.2	0.86	0.67
κ	0.25	.249	0.24	0,23	0.20	0.16	0.14
$\Delta\sigma_z$	25	25	24	23	20	16	14

