CEE 556

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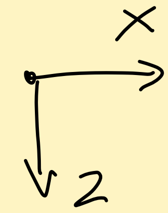
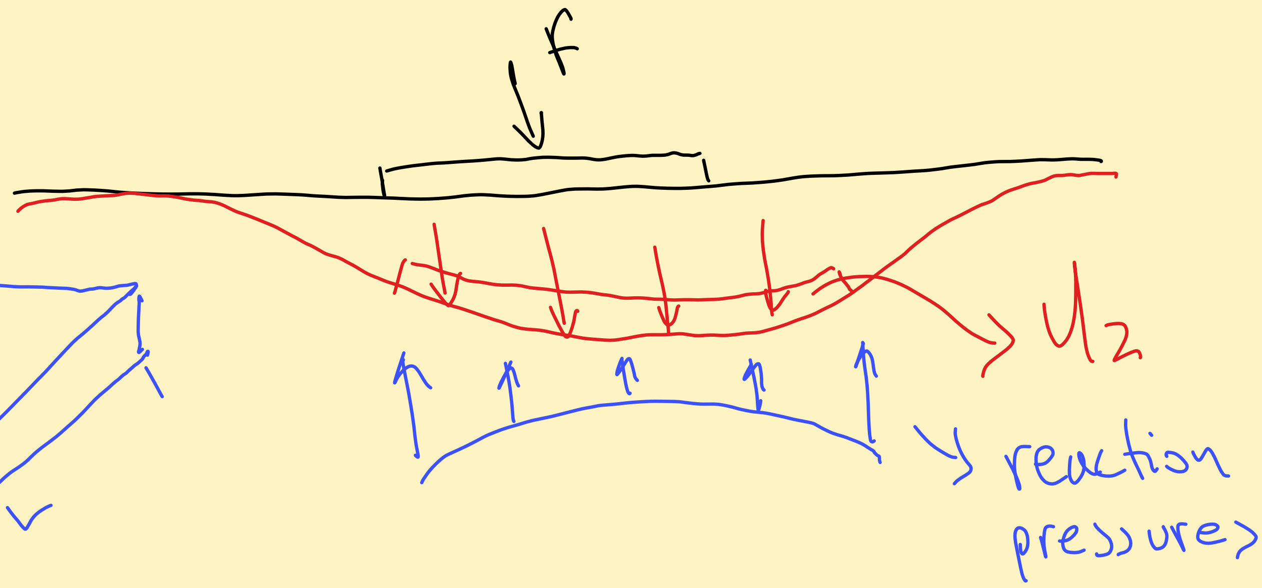
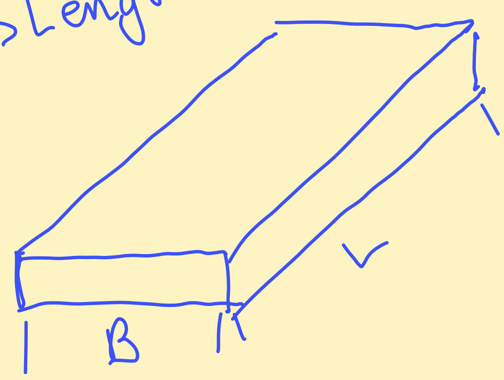


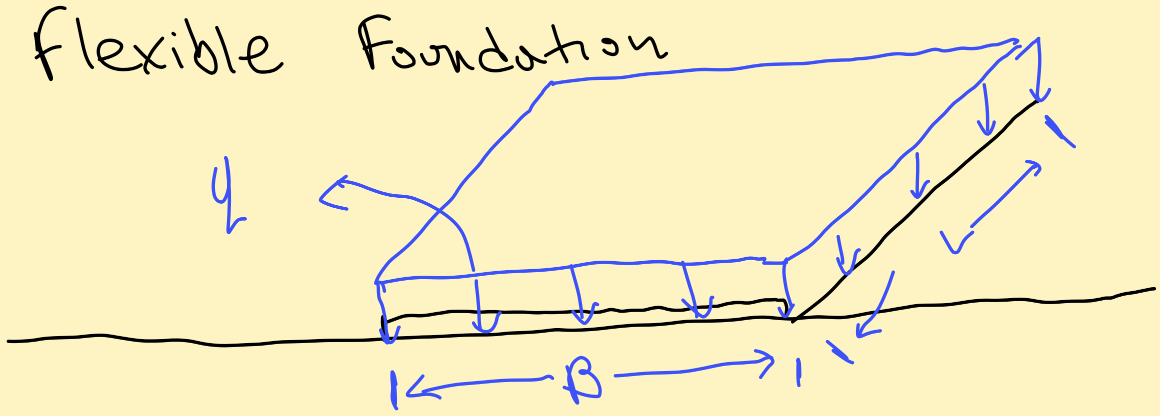


B -> width

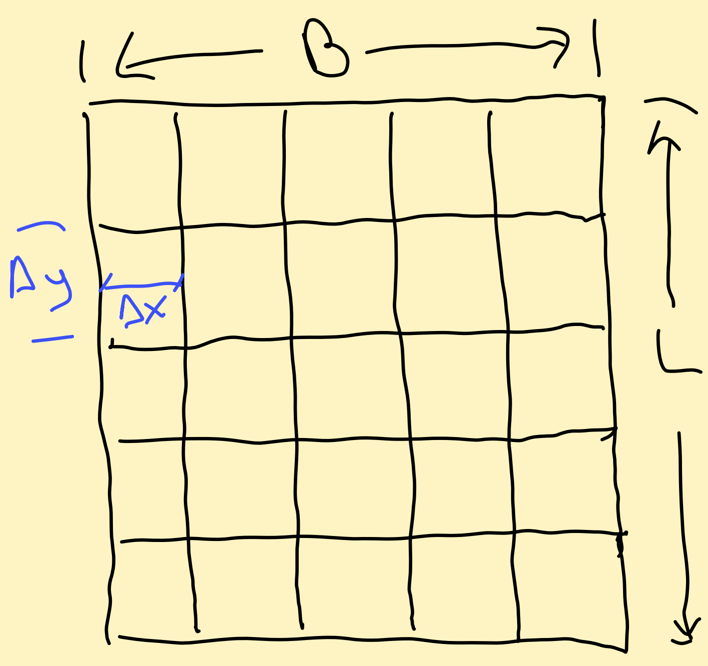
L -> Length



Extremelly Flexible Foundation

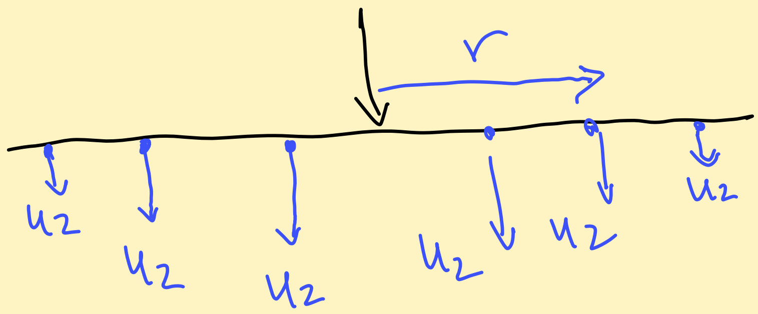


Plan View



Boussinesq Theory

Concentrated force $= P$



Settlement (u_z)

$$u_z(r) = \frac{P(1-\nu)}{2\pi G r}$$

G : shear modulus (Μέτρο Διάτμησης)

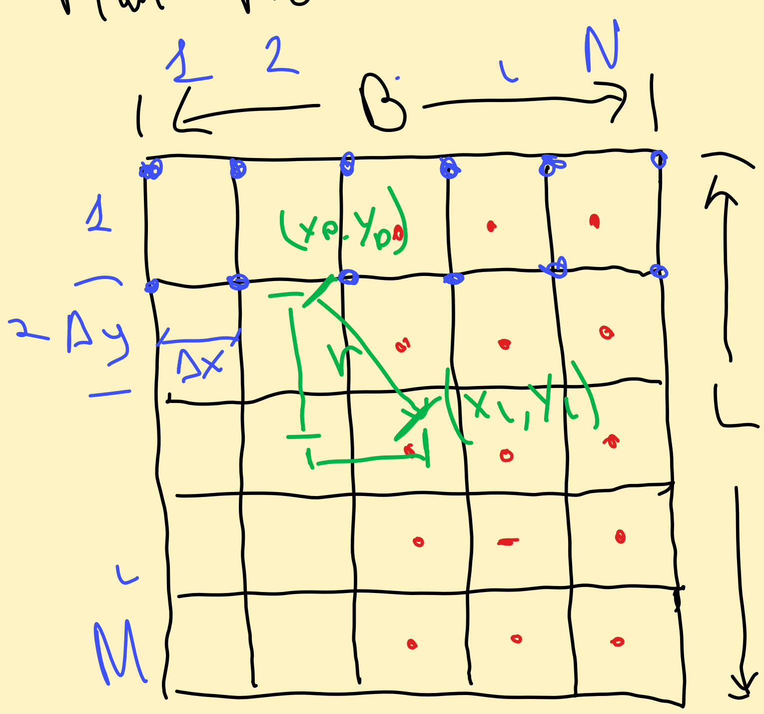
$$G = \frac{E}{2(1+\nu)}$$

ν = Poisson's ratio

Plan View

(• → concentrated force)

$P = q\,\Delta x\,\Delta y$



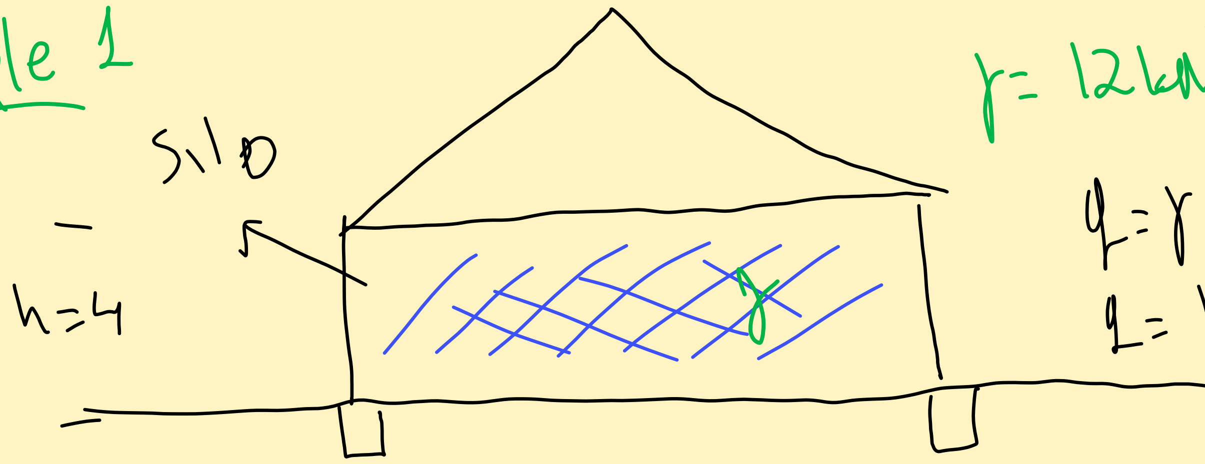
(• → nodes)

$$W(x,y) = \sum_{1}^{N} \sum_{1}^{M} \frac{P(1-\nu)}{2\pi G r}$$

$$r = \sqrt{(x_i - x_p)^2 + (y_i - y_p)^2}$$

$$\Rightarrow W(x,y) = \sum_{1}^{N} \sum_{1}^{M} \frac{q(1-\nu)}{2\pi G r}\,\Delta x\,\Delta y$$

Example 1

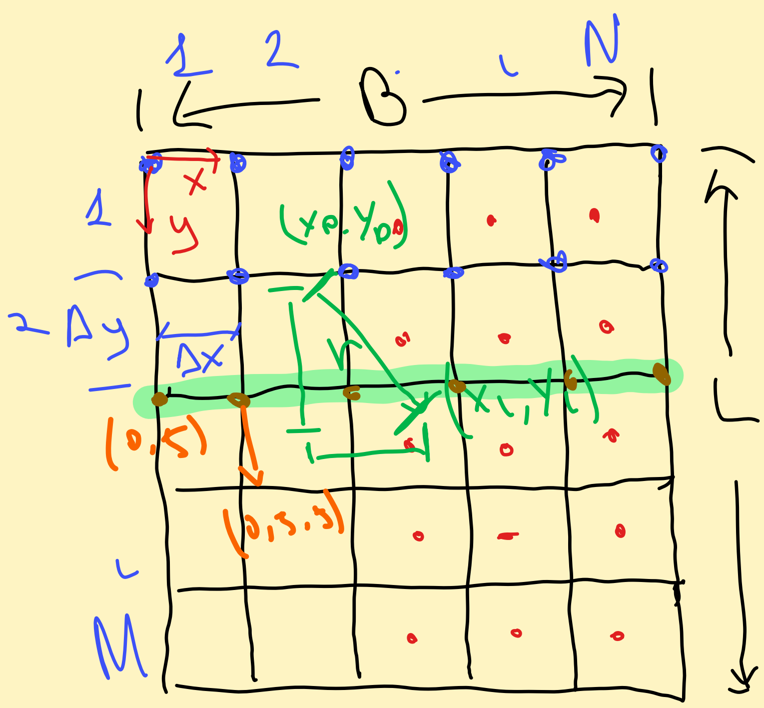


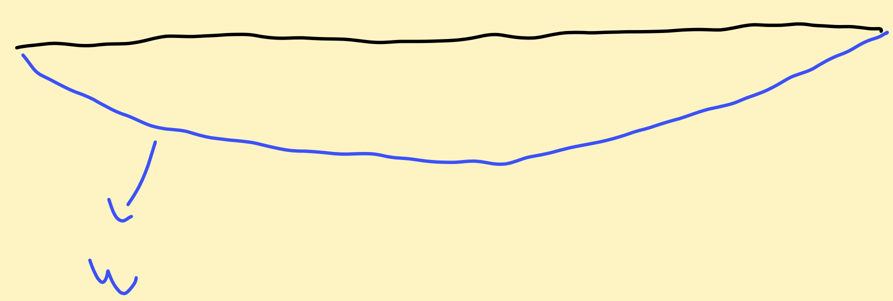
$\gamma = 12\,kN/m^3$

$q = \gamma H$

$q = 12 \cdot 4 \Rightarrow q = 48\,kPa$

$B = L = 10\,m$

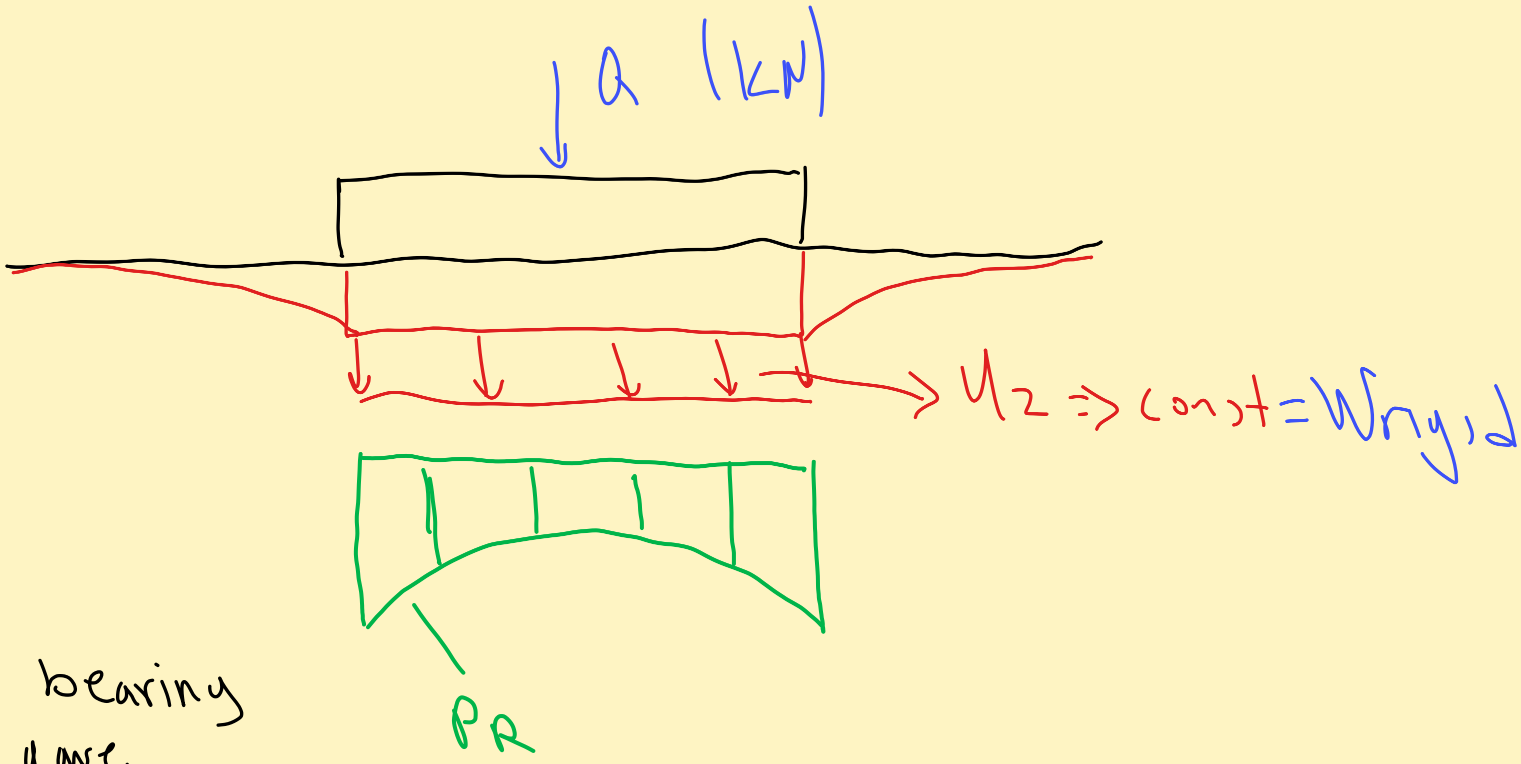




x	0	0.5	1.0	1.5	2	2.5	3	3.5	4	4.5	5.0
w	3.29	3.72	4.015	4.231	4.348	4.527	4.627	4.700	4.751	4.781	4.791

x	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
w	4.781	4.751	4.700	4.672	4.572	4.348	4.231	4.015	3.726	3.29

Example 2 Perfectly Rigid Foundation

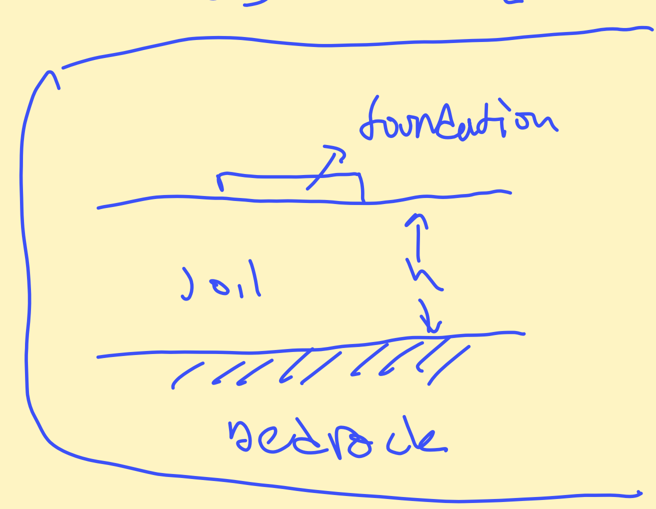


average bearing pressure

$$W_{rigid} = C_F \cdot \frac{\left(\frac{Q}{BL}\right) B (1-\nu^2)}{E}$$

$$C_F = \frac{0{,}85\left(\frac{L}{B}\right)^{0{,}45}}{\left[1 + 0{,}1\left(2+\frac{L}{B}\right)\frac{B}{H}\right]^{1+\exp(5\nu)}}$$

H -> thickness of soil



For B = L

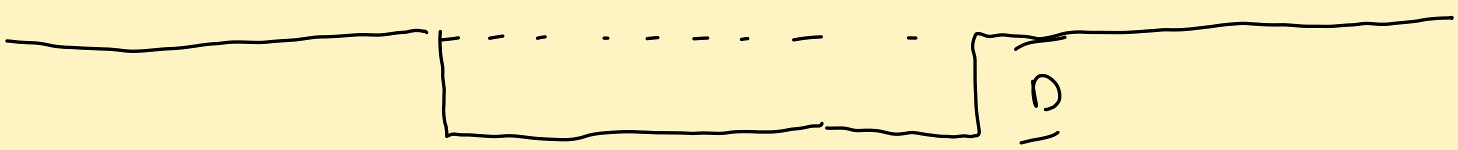
H → very large

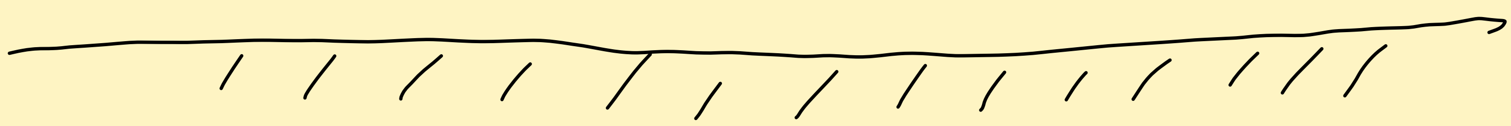
$$C_F = \frac{0{,}85\left(\frac{L}{B}\right)^{0{,}45}}{\Big[\underbrace{1 + \cancel{0{,}1\left(2+\frac{L}{B}\right)}}_{1{,}0}\underbrace{\cancel{\frac{B}{H}}}_{0}\Big]^{1+\exp(5\nu)}} \Rightarrow C_F = 0{,}85$$

$$W_{rigid} = C_f \, \frac{q_{ave} \, B(1-\nu^2)}{E \, D_f}$$ $\Rightarrow$ stiffer soil $\Rightarrow$ less W_{rigid}

$\Rightarrow$ $B\uparrow$ $\Rightarrow$ Large W_{rigid}

D -> embedment



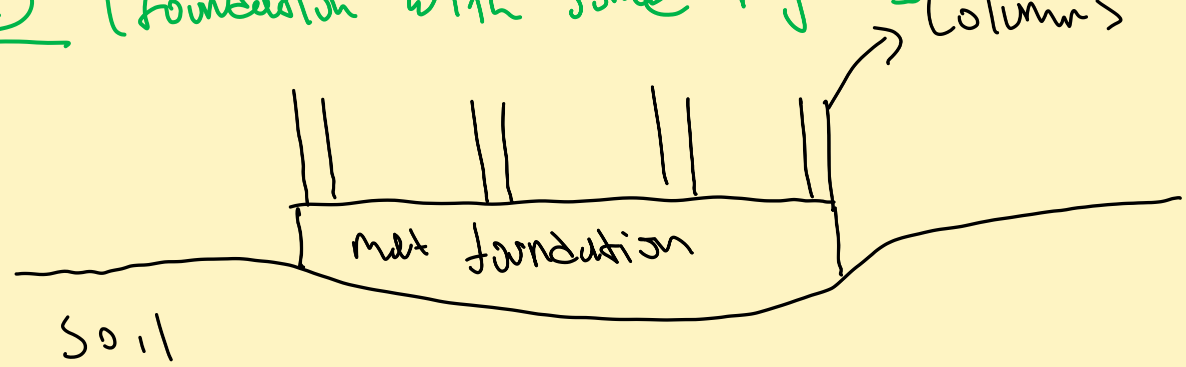


$$D_f = 1 + (0{,}27 - 0{,}12 \ln \nu)\left(1 - \exp\left(-0{,}83\left(\frac{D}{B}\right)^{0{,}83}\right)\right)$$

if $D = 0$

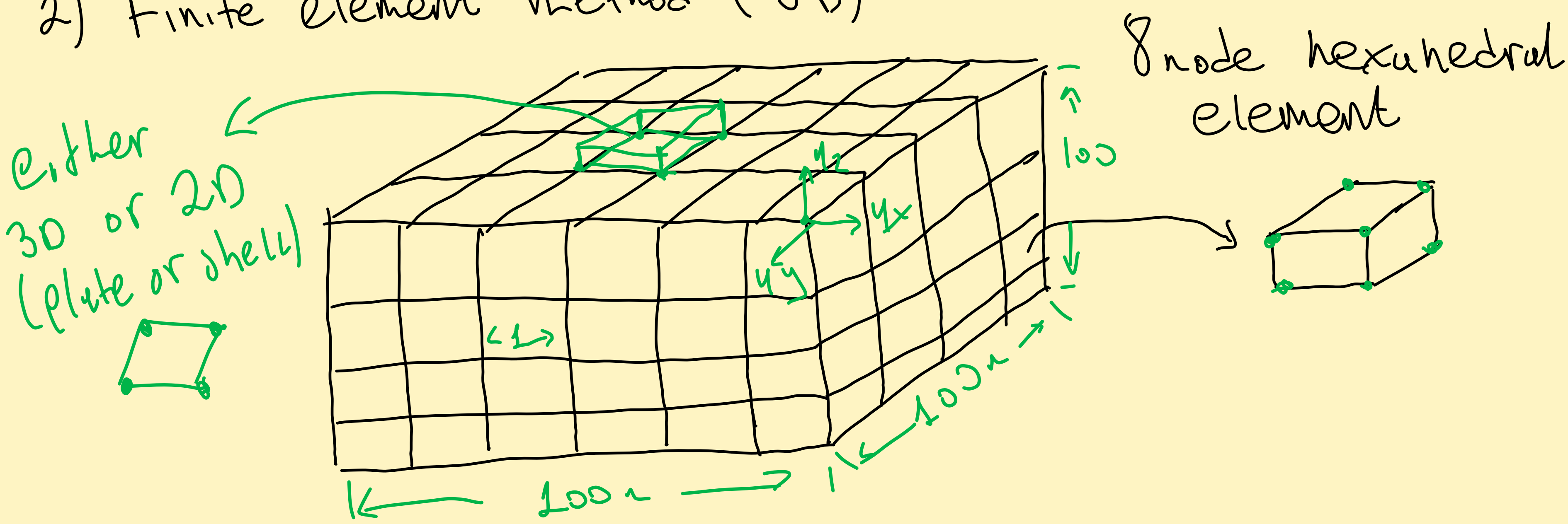
↳ $D_f = 1$

Example 3 (foundation with some rigitidy)



1) "Exact" semi-analytical methods
   - very complicated
   - not all input has physical meaning

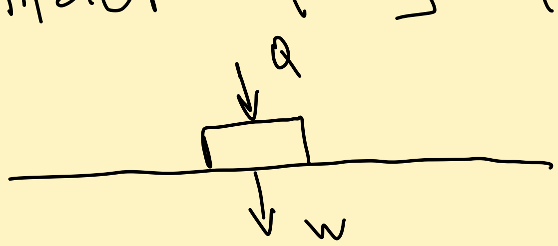
2) Finite element method (3D)



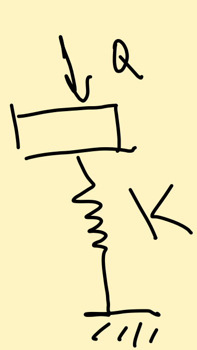
(Shell for modeling foundations in SAP 2000)

The FEM is very computationally costly

3) Winkler Spring Approach

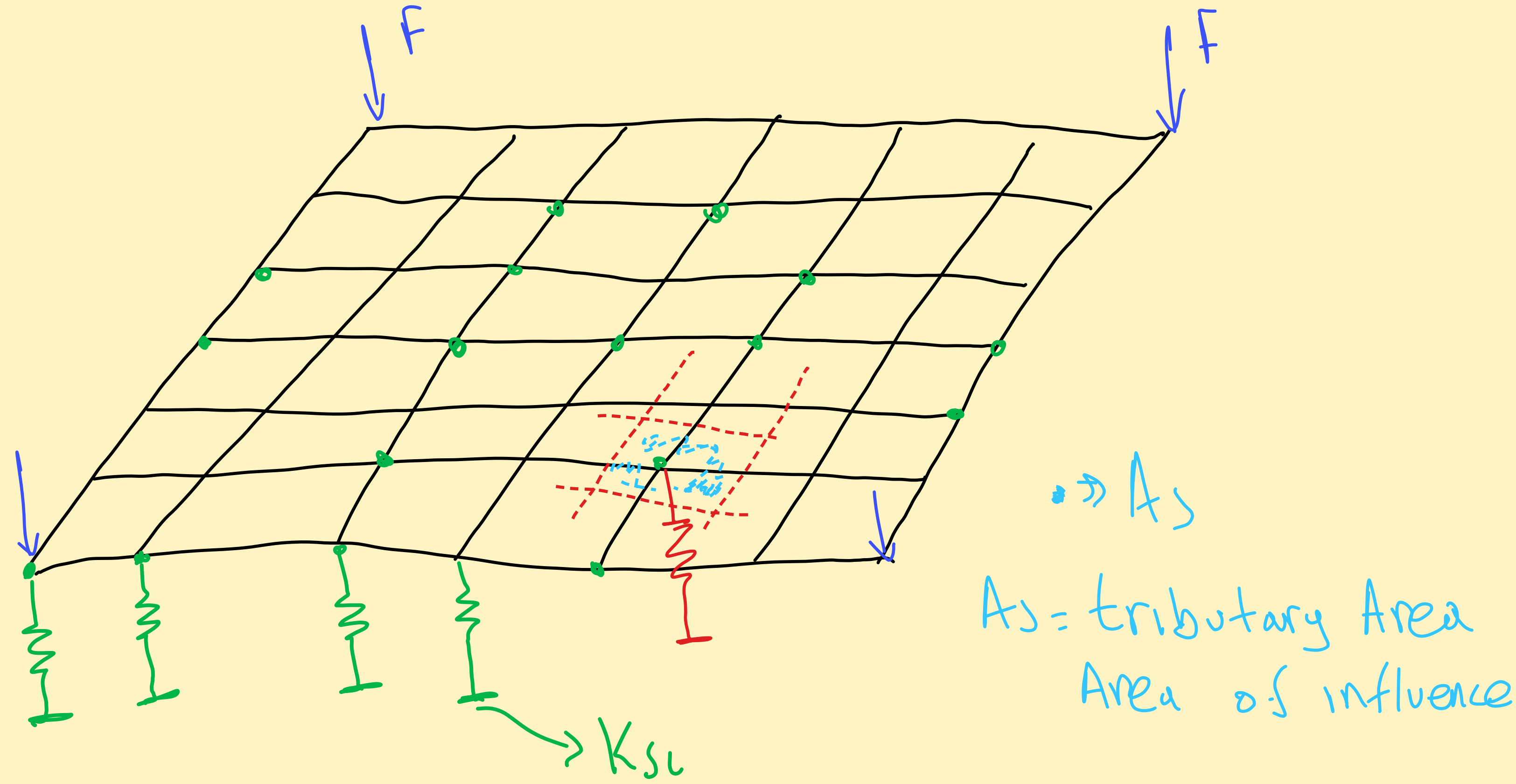


$\Downarrow$ equivalent static analog



$$W = \frac{Q}{K}$$

Mat Foundation



$$K_{si} = k_s \cdot A_s$$

$k_s \Rightarrow$ modulus of subgrade reaction (δείκτης εδάφους)

$\uparrow E \Rightarrow \uparrow k_s$ $\quad\quad$ $\uparrow \nu \Rightarrow \uparrow k_s$

$$w_{rigid} = \frac{q_{ave}\, B(1-\nu^2)}{E}$$

$k_s = \dfrac{E}{B(1-\nu^2)}$ $\quad\quad$ $k_s = \dfrac{q_{ave}}{w_{rigid}}$ $\quad\quad$ $q_{ave} = \dfrac{Q}{BL}$

$w_{rigid} \rightarrow$ calculated using geotech approaches

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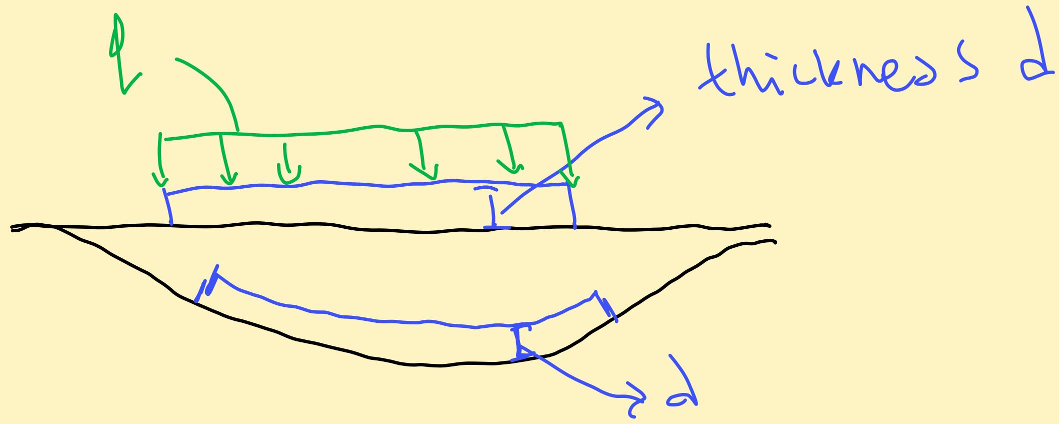
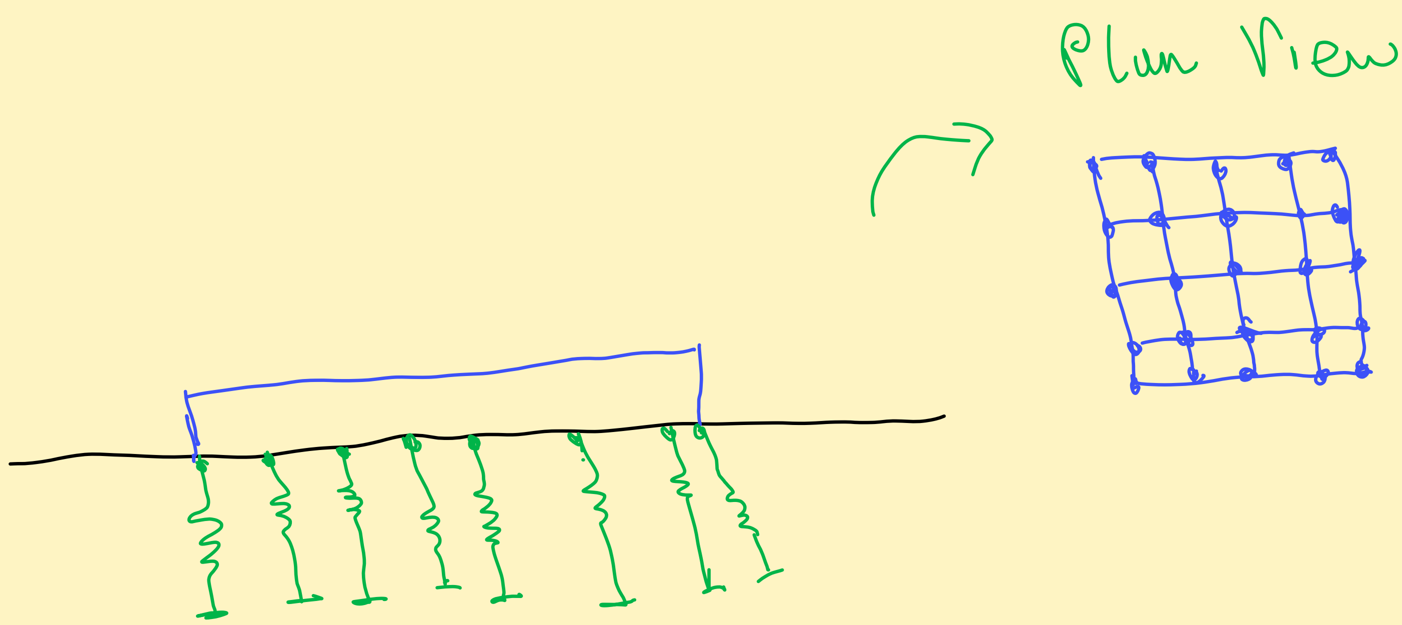


Solution methodologies

1) Semi-analytical methods

2) 3-dimensional methods
   - very expensive (too much time)

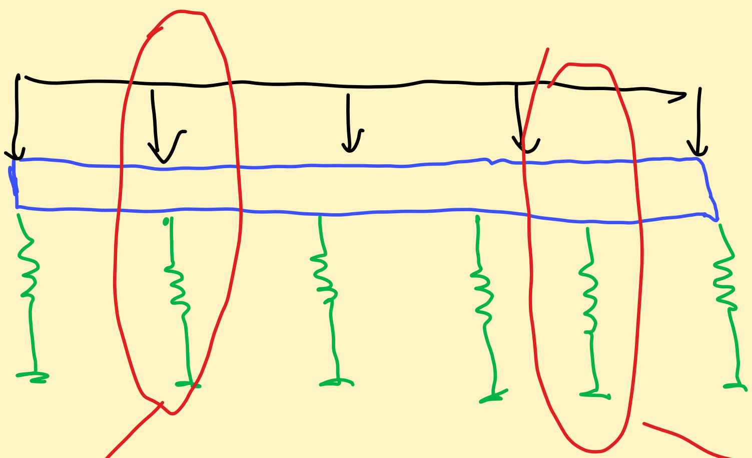
3) Winkel springs approach
   - what we use in practice



At each node we connect a spring, which has a Ks (spring coefficient)

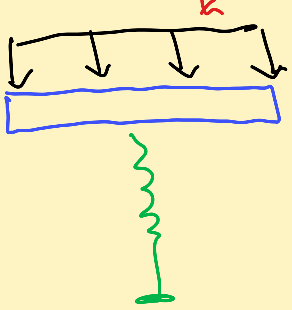
$K_s = k_s A$ A → area of influence

k_s → coefficient of subgrade reaction why we cant use the same ks for every spring, example



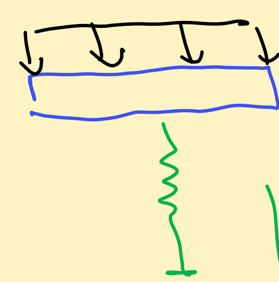
$d = 0$

$K_s = k_s A$



$q = 100$ kPa

$k_s = 1000$ kN/m

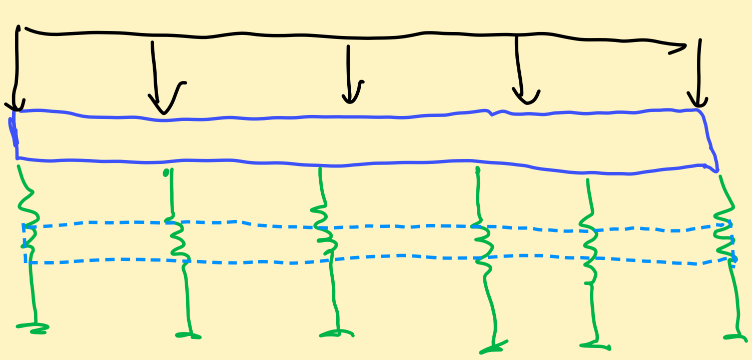


$q = 100$ kPa

$k_s = 1000$ kN/m

⇒ All spring will have the same displacements

⇒ The mat foundation will not bend (No moments will appear)

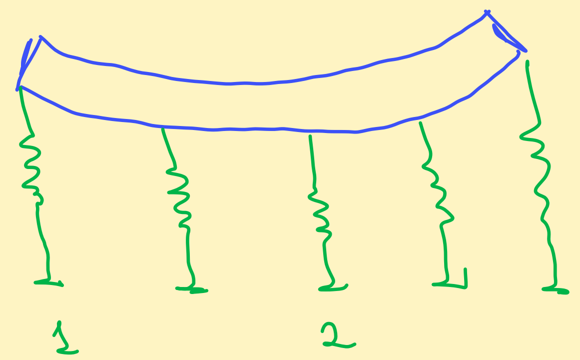


$\bar{u}$

Solution to this problem → Pseudo-coupled approach

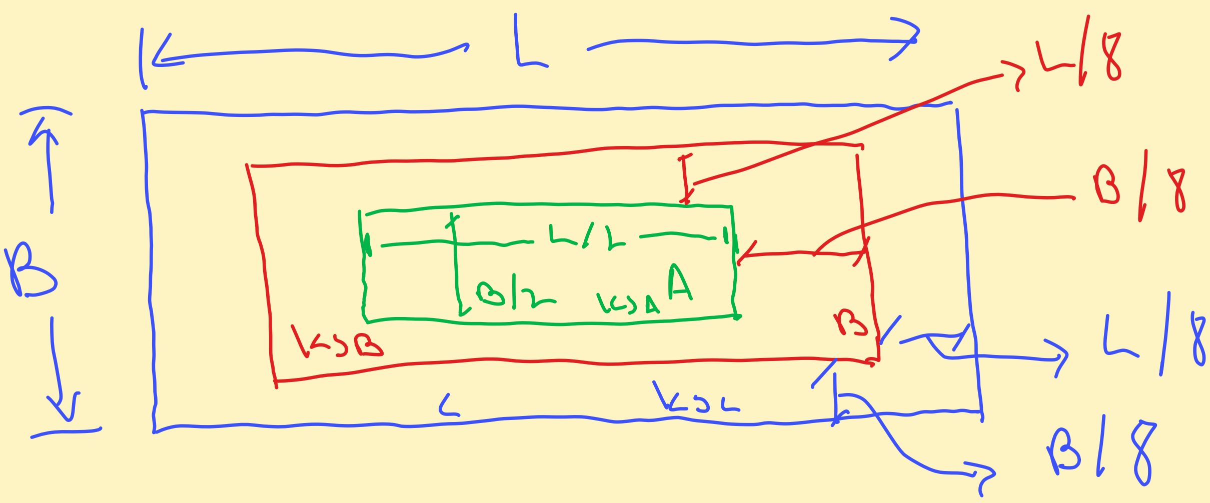
Large k_s → on the edges of the mat

Small k_s → in the middle of the mat



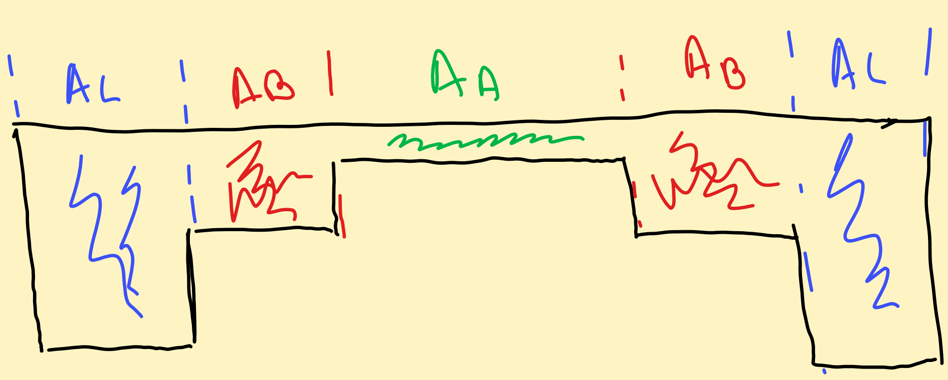
$k_{s1} > k_{s2}$

Conduto Approach



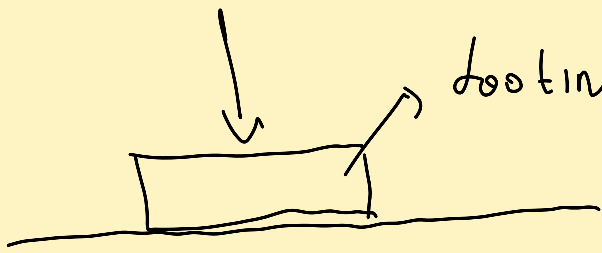
$k_{sC} > k_{sB} > k_{sA}$

Cross Section



$$\sum k_s = k_{sC} A_C + k_{sB} A_B + k_{sA} A_A$$

$$K = k_s A_s$$



footing

$$k_{s,rigid} = \frac{q_{ave}}{w_{rigid}}$$

$\downarrow$

$k_{s,average}$

$$q_{ave} = \frac{\sum Q}{A_{tot}}$$

$\sum Q \rightarrow$ column load

$A_{tot} \rightarrow$ Area of mat

$$\sum k_s = k_{s,rigid} \cdot A_{total}$$

$$k_{sC} A_C + k_{sB} A_B + k_{sA} A_A = k_{s,rigid} A_{tot}$$

$$A_{total} = B \cdot L$$

$$A_A = \frac{B}{2}\frac{L}{2} \Rightarrow A_A = \frac{BL}{4}$$

$$A_B = \left(\frac{4B}{8} + \frac{B}{8} + \frac{B}{8}\right)\left(\frac{4L}{8} + \frac{L}{8} + \frac{L}{8}\right) - \frac{BL}{4}$$

$$\frac{6B}{8} = \frac{3}{4}B \qquad \frac{3L}{4} \qquad \frac{BL}{4} \rightarrow \frac{4BL}{16}$$

$$\frac{9}{16}BL \qquad \frac{4BL}{16}$$

$A_B = \frac{5}{16} BL$

$A_L = BL - \frac{9}{16} BL \Rightarrow A_L = \frac{7}{16} BL$

$\Rightarrow k_{sL} \frac{7}{16} BL + k_{sB} \frac{5}{16} BL + k_{sA} \frac{4}{16} BL = k_{s,rigid} \frac{16 BL}{16}$

$\Rightarrow 7 k_{sL} + 5 k_{sB} + 4 k_{sA} = 16 k_{s,rigid}$

$\Rightarrow 0,4375 \, k_{sL} + 0,3125 \, k_{sB} + 0.25 \, k_{sA} = k_{s,rigid}$

Conduto Proposed.

$k_{sL} = 2 k_{sA}$

$k_{sB} = 1,5 k_{sA}$

$\Rightarrow 0,4375 \; 2 k_{sA} + 0,3125 \; 1,5 \, k_{sA} + 0,25 \, k_{sA} = k_{s,rigid}$

$\Rightarrow k_{sA} = \frac{k_{s,rigid}}{0.4375 \cdot 2 + 0.3125 \; 1,5 + 0,25}$

$$\left.\begin{aligned} \Rightarrow k_{sA} &= 0,627 \, k_{s,rigid} \\ k_{sB} &= 0,941 \, k_{s,rigid} \\ k_{sL} &= 1,255 \, k_{s,rigid} \end{aligned}\right\} \text{Conduto Approach (2001)}$$

$$W_{rigid} = \frac{C_f \; q_{ave} \, B (1-\nu^2)}{E \; D_f}$$

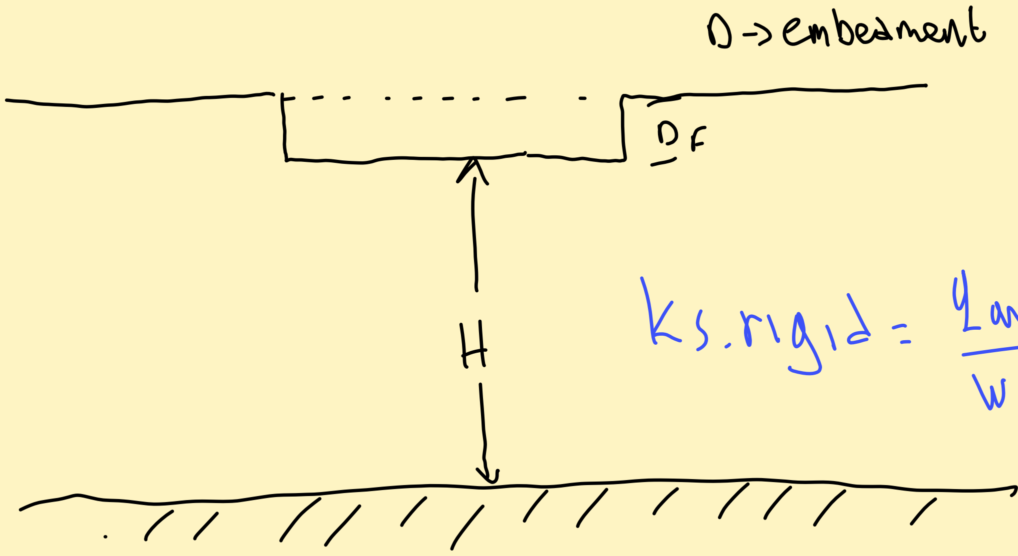
$C_f \rightarrow$ "Shape Factor"

$D_f \rightarrow$ Depth Factor

$B \rightarrow$ Width

$E \rightarrow$ Youn's modulus

$\nu \rightarrow$ Poissons Ratio



$$k_{s,rigid} = \frac{q_{ave}}{W_{rigid}}$$

$$C_f = \frac{0{,}85\left(\frac{L}{B}\right)^{0{,}45}}{\left[1 + 0{,}1\left(2+\frac{L}{B}\right)\frac{B}{H}\right]^{1+\exp(5\nu^3)}}$$

$$D_f = 1 + (0{,}27 - 0{,}12 \ln \nu)\left(1 - \exp\left(\cancel{-0{,}83}\left(\cancel{\frac{D}{B}}\right)^{0{,}83}\right)\right)$$

$\rightarrow 0$ $\quad \rightarrow 1$

if $D = 0$

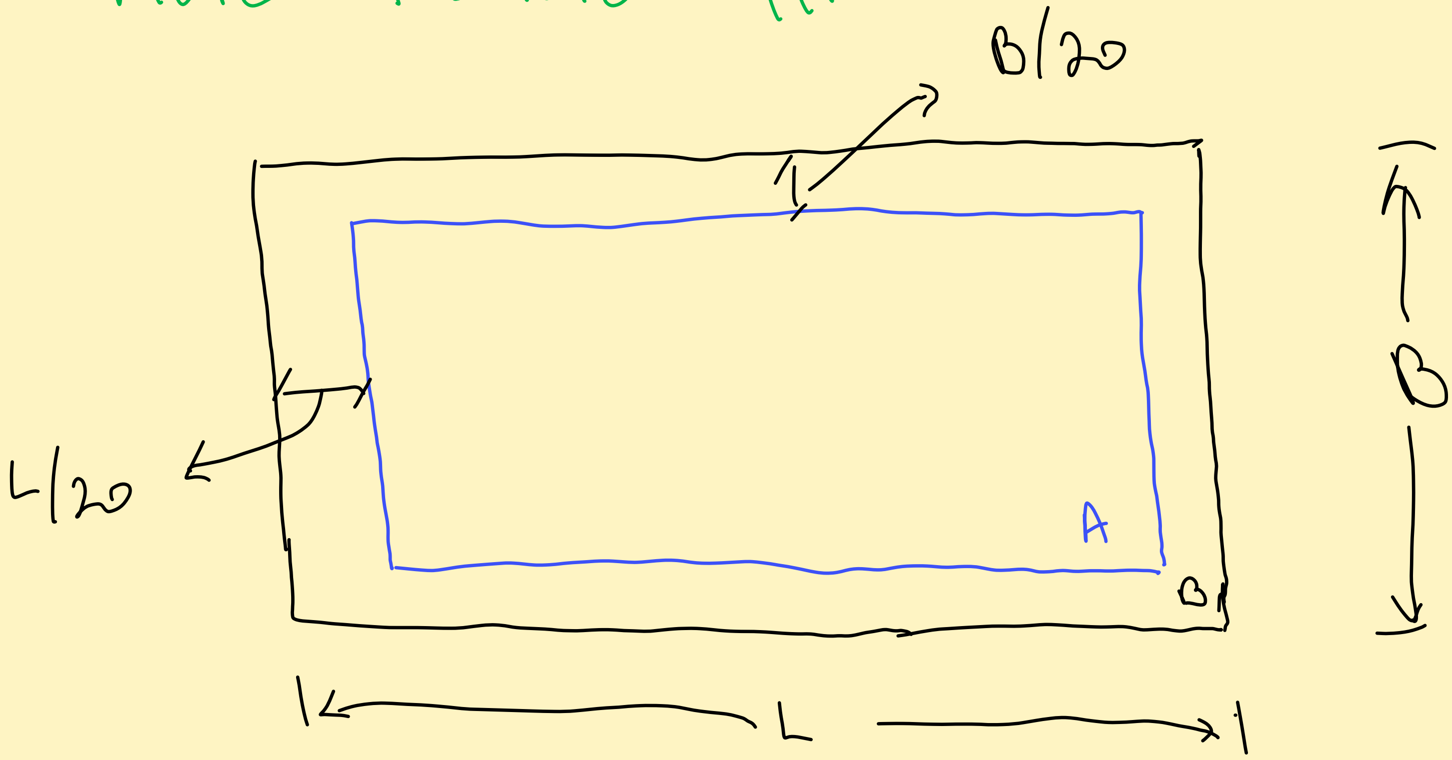
$\hookrightarrow$ $D_f = 1$

Conduto Approach

$\hookrightarrow$ Good for 2-5 storey building

$\hookrightarrow$ underestimates positive moments

More Accurate Approach



$k_s B = 4 k_s A$

EXAMPLE

$D = 0 \Rightarrow DF = 1$

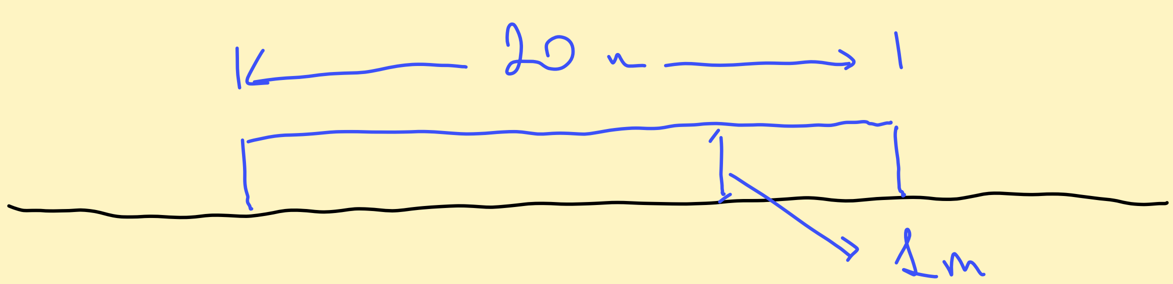
$E_s = 10000\,kPa$

$\nu_s = 0{,}3$

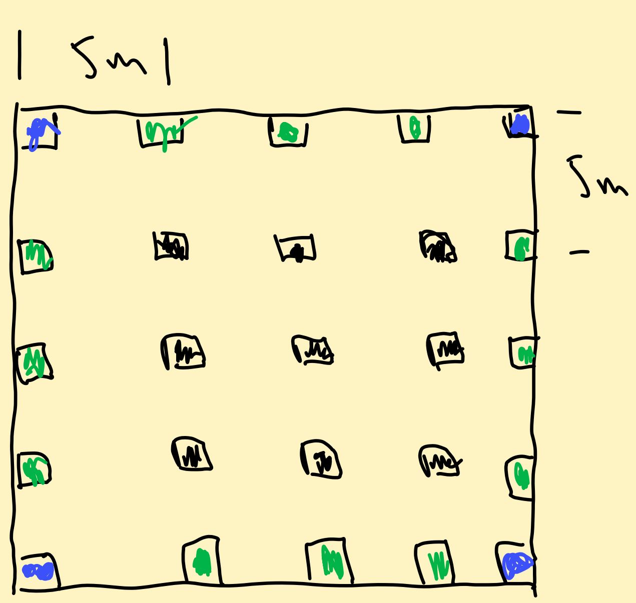
$B = L = 20\,m$

$H \to$ very large

$(H \to \infty)$



Plan View



Columns carry $\simeq 250\,kN/floor$

For 4 floors $\to$ 1000 kN
↳ interior columns

For columns on the side
↳ 500 kN (less Area)

For corner columns
↳ 250 kN (less Area)

$$q_{ave} = \frac{\Sigma Q}{A_{total}} = \frac{9 \cdot 1000 + 12 \cdot 500 + 4 \cdot 250}{20 \cdot 20}$$

$$q_{ave} = \frac{16000 \text{ kN}}{400 \text{ m}^2} \Rightarrow q_{ave} = 40 \text{ kPa}$$

$$C_f = \frac{0{,}85\left(\frac{L}{B}\right)^{0{,}45}}{\left[1 + 0{,}1\left(2 + \frac{L}{B}\right)\frac{B}{H}\right]^{1+\exp(5\nu)}} \Rightarrow C_f = 0{,}85$$

$$D_f = 1 + (0{,}27 - 0{,}12 \ln \nu)\left(1 - \exp\left(\cancel{-0{,}83}\left(\cancel{\frac{D}{B}}\right)^{0{,}83}\right)\right)$$

$\cancel{-0{,}83}\rightarrow 0$ $\quad \cancel{\frac{D}{B}} \rightarrow 1$

if $D = 0$

↳ $D_f = 1$

$$W_{rigid} = \frac{C_f \; q_{ave} \; B(1-\nu^2)}{E \; D_f} \Rightarrow W_{rigid} = 0{,}062 \text{ m}$$

$W_{rigid} = 62 \text{ cm}$

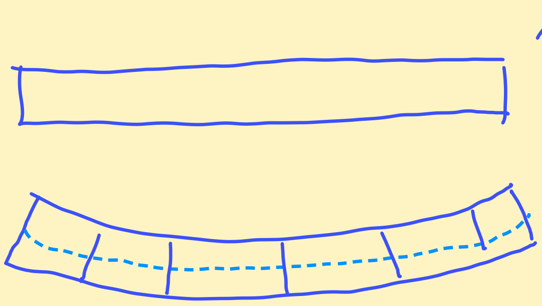
$$k_{s,rigid} = \frac{q_{ave}}{W_{rigid}} = \frac{40 \text{ kPa}}{0{,}062} \Rightarrow k_{s,rigid} = 645 \frac{\text{kPa}}{\text{m}}$$

$k_{sA} = 0{,}627 \, k_{s,rigid} \Rightarrow k_{sA} = 404 \text{ kPa/m}$

$k_{sB} = 0.941 \, k_{s\,rigid} \Rightarrow k_{sB} = 607 \text{ kPa/m}$

$k_{sC} = 1255 \, k_{s,rigid} \Rightarrow k_{sC} = 808 \text{ kPa/m}$

SAP 2000



⇒ Bernoulli Theory

	Beams	Plates / shell
Thin formulation	Euler	Bernoulli
Thick formulation	Timoshenko	Mindlin

Thin -> good for very flexible elements
-> does not take into account shear deformation

Thick -> takes account shear deformations

* On Mat foundations we select thick shell because we have many springs wich are close to each other therefore the mat foundation is not flexible

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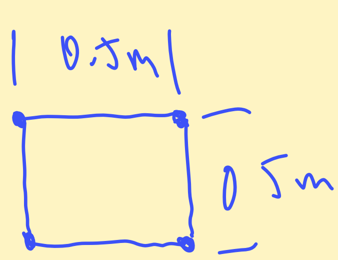
* -> The plates (foundation and slabs) we must always mesh our area SAP 2000

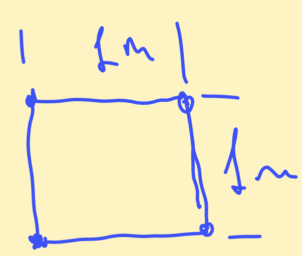
user FEM

using Assing Automatic Area Mesh

Proper Size of elements



or



for bigger structures

Case 1 ⇒ $k_{s,rigid}$ is uniform

$k_{s,rigid} = 645$ kPa/m

For the centre column (green color → positive M)

$m = 184$ kNm/m

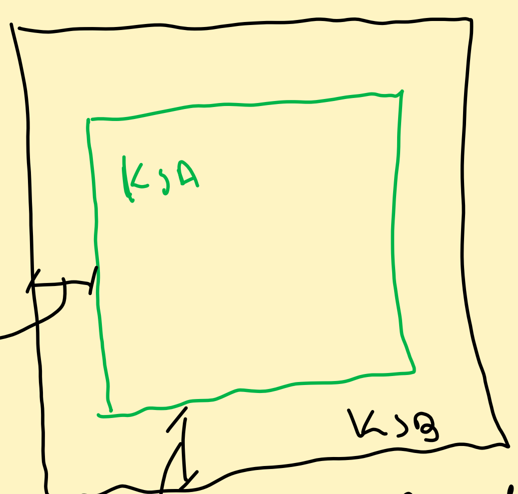
$v = 272$ kN/m

For the middle of the span

$m_{min} = 130$ kNm/m

Case 2 →

$B = L = 20$



$1 = B/20$

$L/20 = \frac{20}{20} = 1$

$k_{sA} = 0{,}66\, k_{s,rigid}$

$k_{sA} = 426$ kPa/m

$k_{sB} = 1{,}75\, k_{s,rigid}$

$k_{sB} = 1129$ kPa/m

For the centre column

$m = 521$ kNm/m

$m_{min} = -69$ kNm/m (at different position)

$v = 239$ kN/m

Eurocode 8

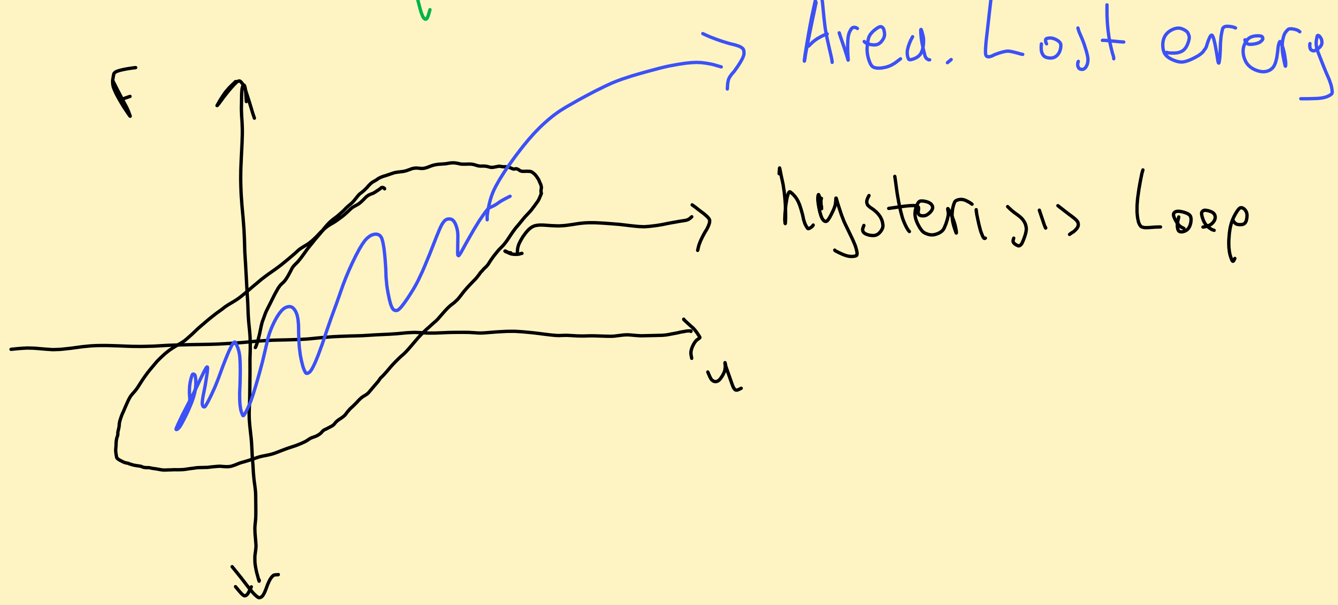
- shall → requirement
  (must)
- should → recomendation
- may → an option

- The natural T of a building is higher if I have SSI (soil structure interaction)

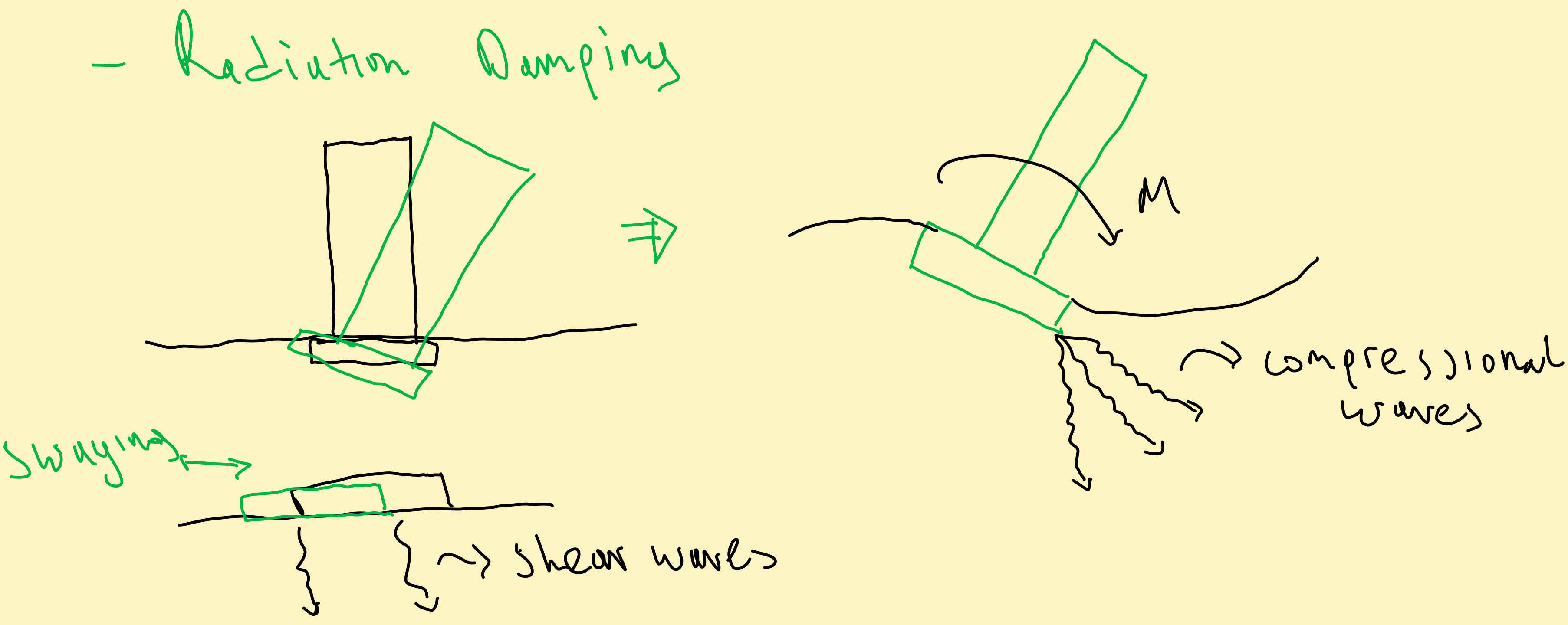
- SSI gives us higher damper

Two kinds of damping

- Hysteretic Damping



- Radiation Damping



Energy is lost due to the travelling of the waves

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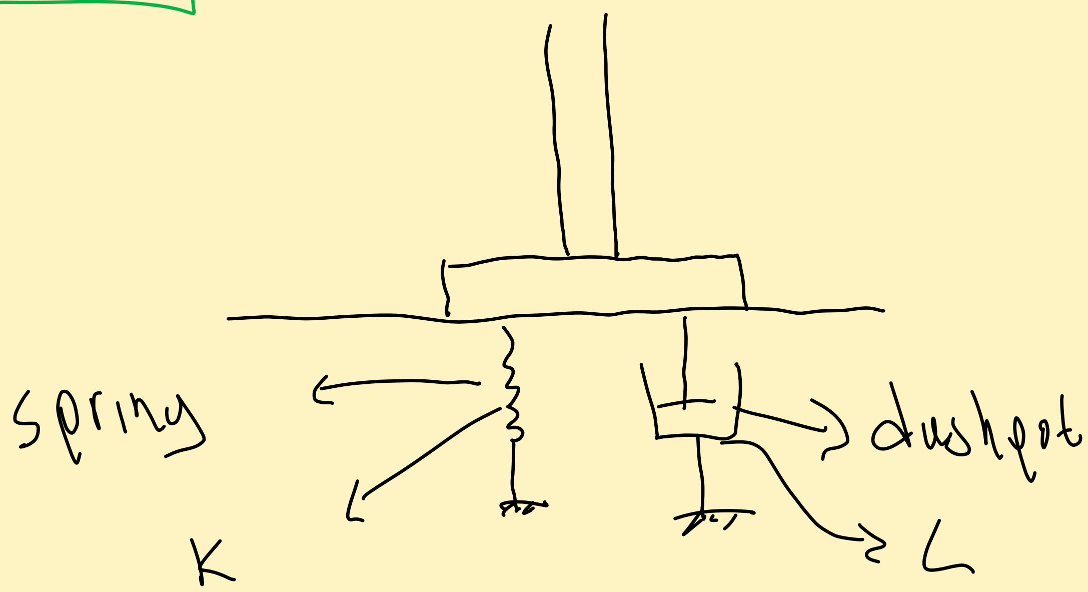


$K = K_{stat} \, k_{dyn}(\omega)$ → frequency of vibration

$\omega = \frac{2\pi}{T}$

$C = C_{rad} + C_{hyst}$

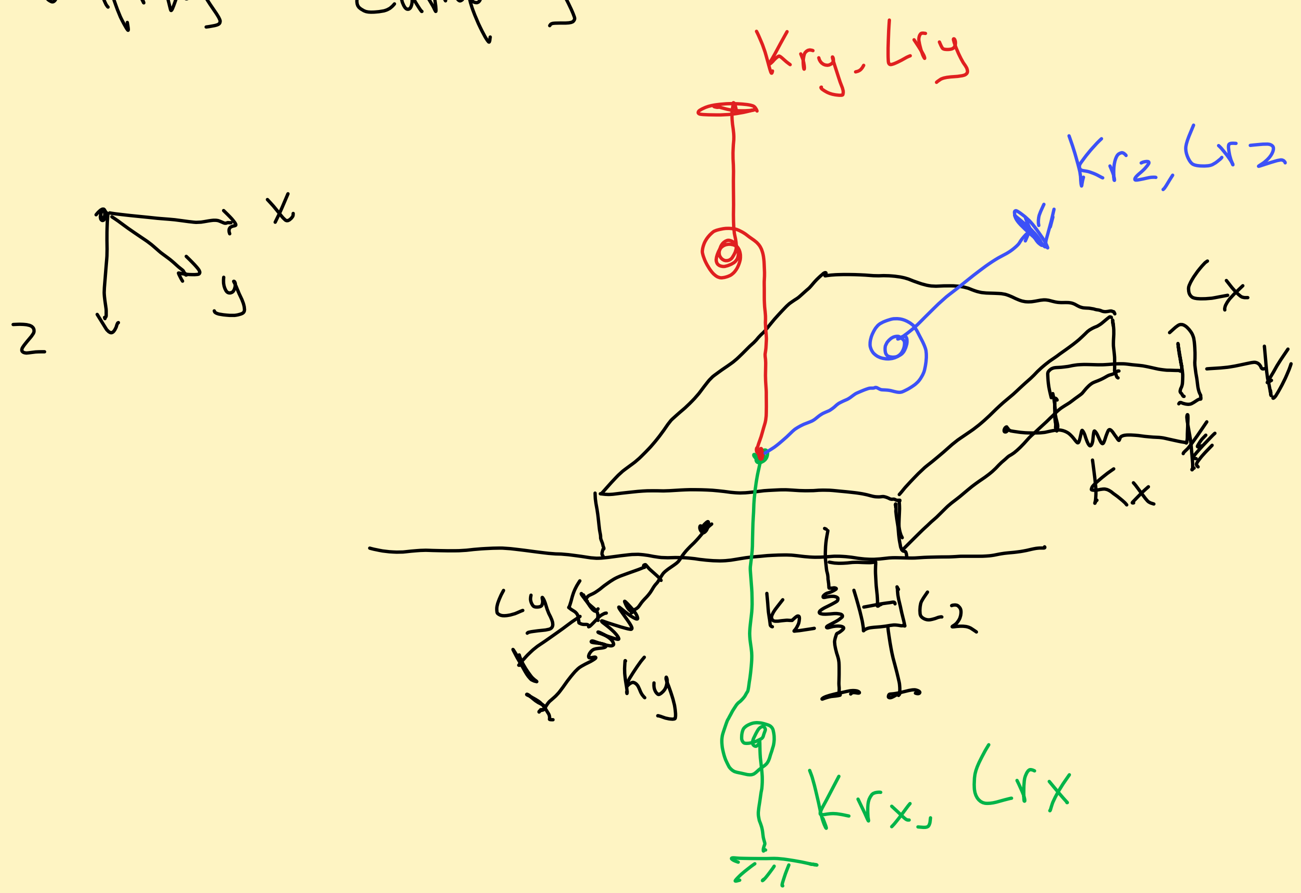
↓ radiation damping

↓ hysteretic damping

c → small → distributed

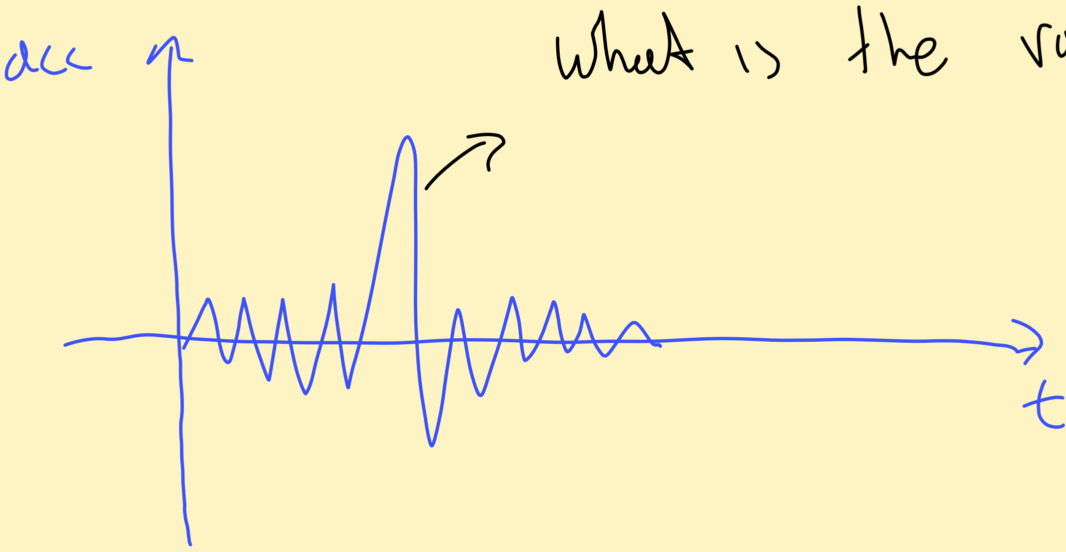
C → spring

↓ capital



$C_{hyst} = \frac{2K}{\omega} \cdot \xi_{hyst}$

$$a_0 = \frac{\omega \cdot \cancel{B^*} \rightarrow B/2}{V_s}$$

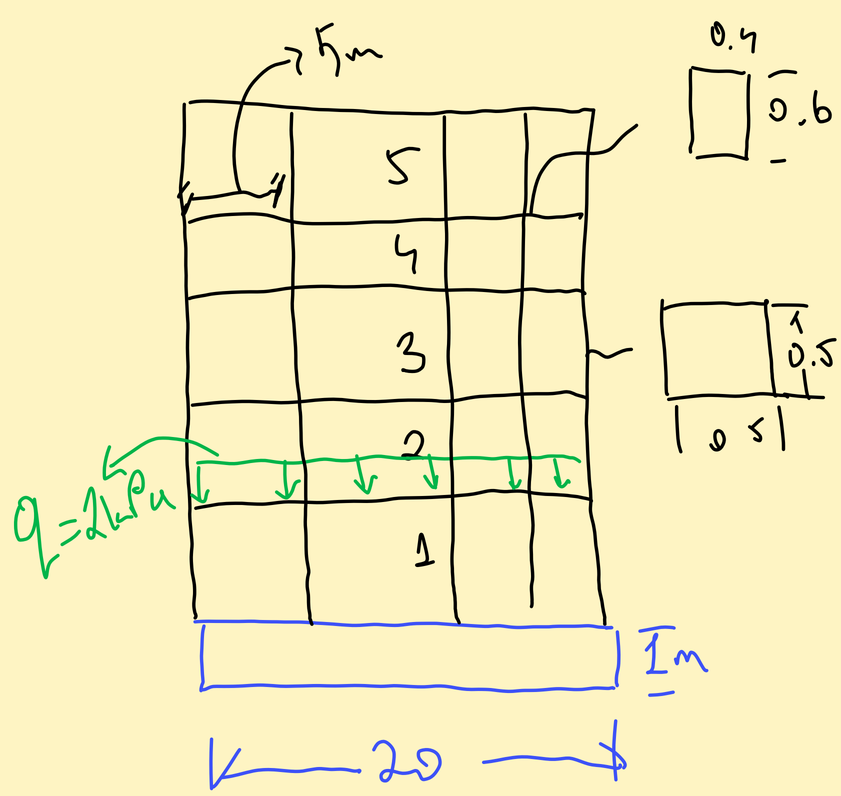


What is the value of ω?

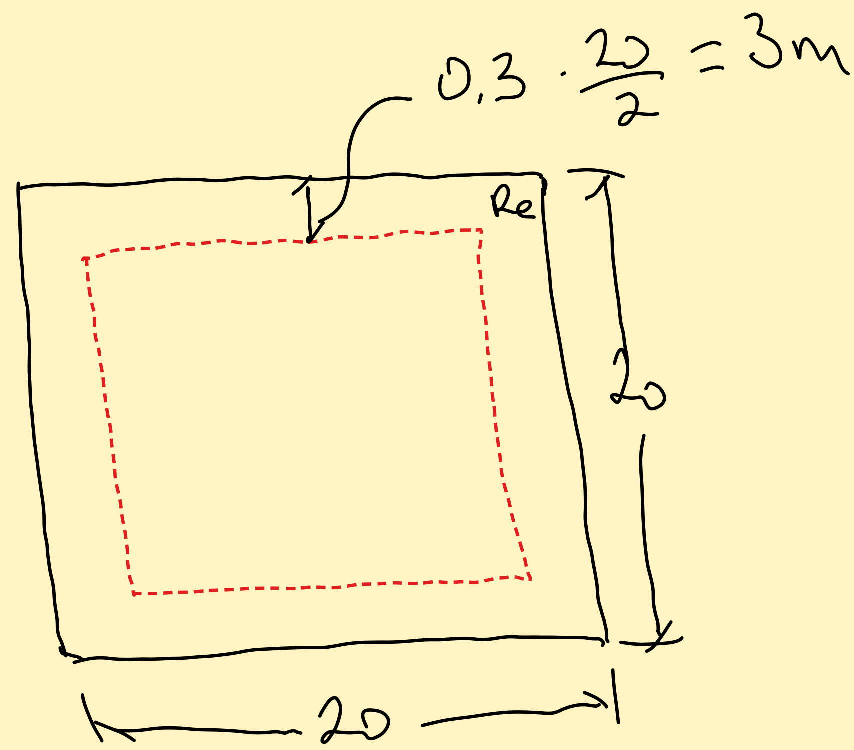
$$\omega_1 = \frac{2\pi}{T_1}$$

$T_1 \rightarrow$ fundametal period of the structure

Example 3 (SAP 2000)



Plan View



$S_u = 100$ kPa
$\rho = 2$ ton$/m^3$ } Soil category ↳ C

Thickness of slabs $= 0.2m$
↳ shell-thin

In Limassol $\rightarrow a = 0.25g$

$G + 0,3Q + E$

$\nu = 0,5$ (for clays)

G → dead

Q → live

E → Quake

For soil category C ⇒ S = 1,15

$a\,S = 0{,}25g \; 1{,}15$

$a \cdot S = 0{,}29g$

Soil $\xi = 0{,}10$

$V_s / V_{smax} = 0{,}6$

$G / G_{max} = 0{,}36$

⇒ EC8 §4.2.3 Table 4.1

$G_{max} = 1000\,S_u$

$G_{max} = 100000\,kPa \Rightarrow G = 0{,}36 \; 100000$

$G = 36000\,kPa$

Vertical

$$K_s = \frac{G}{(1-v)B}\left(0{,}73 + 1.54\left(\frac{B}{L}\right)^{0{,}75}\right) k_{dyn,2}$$

1 (B = L)

$$= \frac{36000}{(1-0{,}5)\;20}\,\big(\underbrace{0{,}73 + 1{,}54 \; 1}_{2{,}27}\big)\,k_{dyn,2}$$

→ Gazetas 1990

slides Kitpu απο SSI

$$a_o = \frac{\omega B^*}{V_s}$$

$$V_s = \sqrt{\frac{G}{\rho}} = \sqrt{\frac{36000}{2}} \Rightarrow V_s = 134\,m/s$$

$$w_1 = \frac{2\pi}{T_1} \qquad T_1 = 0{,}43\ s \quad (\text{from SAP 2000})$$

Gazetas

$B = B^* = B/2$

$$w_1 = \frac{2\pi}{0{,}43} \Rightarrow w_1 = 14{,}6\ rad/sec$$

$$a_0 = \frac{w\,B^*}{V_s} \Rightarrow a_0 = 1.1 \qquad B^* = B/2$$

Gazetas Tables (Page 21) Table 15.1

$\Rightarrow$ using a_0 and B/L $\Rightarrow$ graph (a) Gazetas

$\Rightarrow k_{dyn,z} = 0{,}9$

Vertical (z)

$$k_z = \frac{G}{(1-v)B}\left(0{,}73 + 1{,}54 \cdot 1\right) \cdot 0{,}9$$

$$k_z = 7355\ kPa/m$$

$$k_y = \frac{G}{(2-v)}\left[2 + 2.5\left(\cancel{\frac{B}{L}}\right)^{\cancel{0{,}85}\ 1}\right] k_{dyn,y}$$ → slide κάτω από SSI

Gazetas Table (15.1)

$k_{dyn,y} = 0{,}95$

$\hookrightarrow k_y = 5130\ kPa/m$

$k_x = k_y \Rightarrow k_x = 5130\ kPa/m$

NIST Approach (Calculation of R_k, R_c) →

Formulas according to Gazetas (1990) for shallow foundation on soil layer of large thickness (no influence of bedrock)

$$k_s = \frac{K_s}{BL} = \frac{G}{(1-\nu)B}\left(0.73+1.54\left(\frac{B}{L}\right)^{0.75}\right)k_{dyn,z} \qquad c_z = \rho\frac{3.4}{\pi(1-\nu)}V_s\tilde{c}_z$$

$$K_{rx} = \frac{G}{(1-\nu)}\left(\frac{LB^3}{12}\right)^{0.75}\left(\frac{L}{B}\right)^{0.25}\left(2.4+0.5\frac{B}{L}\right)k_{dyn,rx} \qquad C_{rx} = \rho\frac{3.4}{\pi(1-\nu)}V_s\frac{LB^3}{12}\tilde{c}_{rx}$$

$$K_{ry} = \frac{G}{(1-\nu)}\left(\frac{BL^3}{12}\right)^{0.75}3\left(\frac{L}{B}\right)^{0.15}k_{dyn,ry} \qquad C_{ry} = \rho\frac{3.4}{\pi(1-\nu)}V_s\frac{L^3B}{12}\tilde{c}_{ry}$$

$$k_y = \frac{K_y}{BL} = \frac{G}{(2-\nu)B}\left(2+2.5\left(\frac{B}{L}\right)^{0.85}\right)k_{dyn,y} \qquad c_x = \rho V_s$$

$$k_x = k_y - \frac{0.1G}{(0.75-\nu)B}\left(1-\frac{B}{L}\right) \qquad c_y = \rho V_s\tilde{c}_y$$

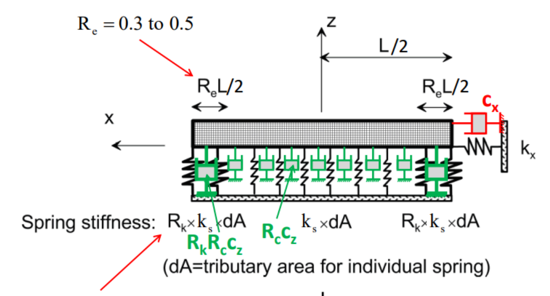
Using Gazetas (Torsional)

$$\hookrightarrow K_{ry} = \frac{3.6 G B^{*3}}{1-\nu}$$

$$K_{ry} = \frac{3.6 \cdot 36000 \left(\frac{20}{2}\right)^3}{1-0.5} \Rightarrow kPa\ m^3 \to \frac{kN}{m^2}\ m^3 \to kN\,m$$

$$K_{ry} = 25920000\ kN\,m$$

NIST approach (2012)



For the longitudinal direction (along the length L)

$$R_k = \frac{\left(\frac{K_{ry}}{k_s(BL^3/12)}\right)-(1-R_e)^3}{1-(1-R_e)^3}$$

$$R_c = \frac{\left(\frac{C_{ry}}{c_z(BL^3/12)}\right)}{R_k(1-(1-R_e)^3)+(1-R_e)^3}$$

For the transvers direction (along the width B)

$$R_k = \frac{\left(\frac{K_{rx}}{k_s(LB^3/12)}\right)-(1-R_e)^3}{1-(1-R_e)^3}$$

$$R_c = \frac{\left(\frac{C_{rx}}{c_z(B^3L/12)}\right)}{R_k(1-(1-R_e)^3)+(1-R_e)^3}$$

$$R_k = \frac{\left(\frac{K_{Ry}}{k_s(BL^3/12)}\right)-(1-R_e)^3}{1-(1-R_e)^3}$$

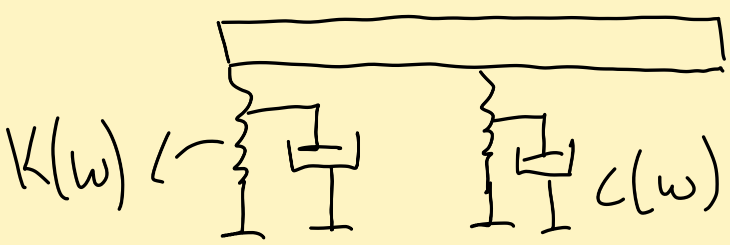
$R_e = 0,3$

$R_k = 3,5$

$k_s = 7355\ kPa/m$

5/10/23 example 3 συνέχεια

$kN/m/s \to kNs/m$



$$C_z = (\rho\ V_{La}\ A_b)\,\tilde{c}_z$$

Table Gazeta

$$a_0 = \frac{\omega B^*}{V_s} = 1,1\ m/s^2$$

$* \to B/L$

$V_s = 134\ m/s$

$A_b = 20^2 = 400m$

Lysmer's velocity

$$V_{La} = \frac{3.4}{\pi(1-\nu)}V_s \Rightarrow V_{La} = 290 m/s$$

$F = C\,v$

$\hookrightarrow C = \frac{F}{v} = \frac{kN}{m/s}$

$$\tilde{c}_z = 0,95 \cdot 1,01 \Rightarrow \tilde{c}_z = 0,95$$

↳ Από graph Gazeta (c)

Graph C μικρο τιμη

$$\frac{\tilde{c}_z\ (\nu=0.5)}{\tilde{c}_z\ (\nu=0,4)}$$

$C_z = (2 \; 290 \; 400) \cdot 0{,}95$

$C_z = 220400 \; \frac{kNs}{m}$

Small c

↳ μικρό damping ratio (ξ)

→ μικρή κατανάλωση ενέργειας

→ μεγαλύτερες δυνάμεις

graph d

$C_x = C_y = \rho \, V_s \, A_b \; 0{,}95$

$= 2 \cdot 134 \; 400 \; 0{,}95$

$C_x = C_y = 101840 \; kNs/m$

$c_z = \frac{C_z}{A_b} = \frac{220400}{400} \Rightarrow c_z = 551 \; kNs/m^3$

$c_x = c_y = \frac{C_x}{A_b} = \frac{C_y}{A_b} = \frac{101840}{400} \Rightarrow c_x = c_y = 255 \; kNs/m^3$

slides

$C_{ry} = \rho \frac{3{,}4}{\pi(1-v)} V_s \frac{LB^3}{12} \tilde{c}_{ry}$ $\quad \tilde{c}_{ry} = 0{,}4$ → Gazetas graph f

$C_{ry} = 2 \; \frac{3{,}4}{0{,}5\pi} \; 134 \; \frac{20^4}{12} \; 0.4 \Rightarrow C_{ry} = 3051912{,}5 \; kNms$

↳ kNms

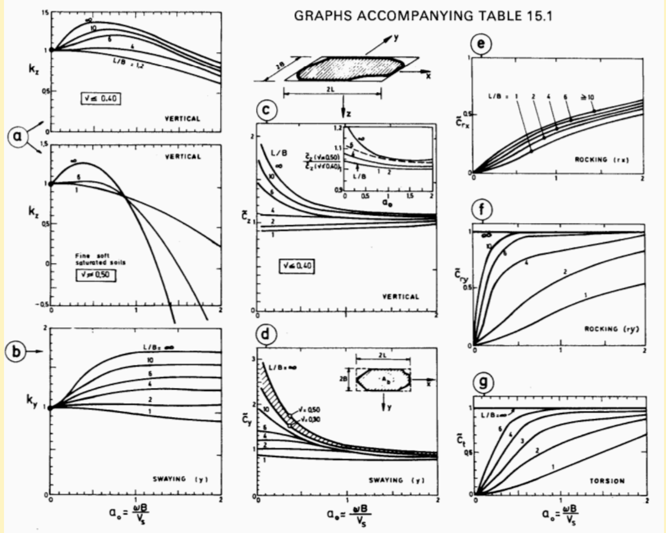
$R_L = \frac{\left(\frac{C_{ry}}{c_z (BL^3/12)}\right)}{R_k\left(1-(1-R_e)^3\right) + (1-R_e)^3} = \frac{\frac{3051912{,}5}{551(20^4/12)}}{3{,}5\left(1-(1-0.3)^3\right)+(1-0{,}3)^3}$

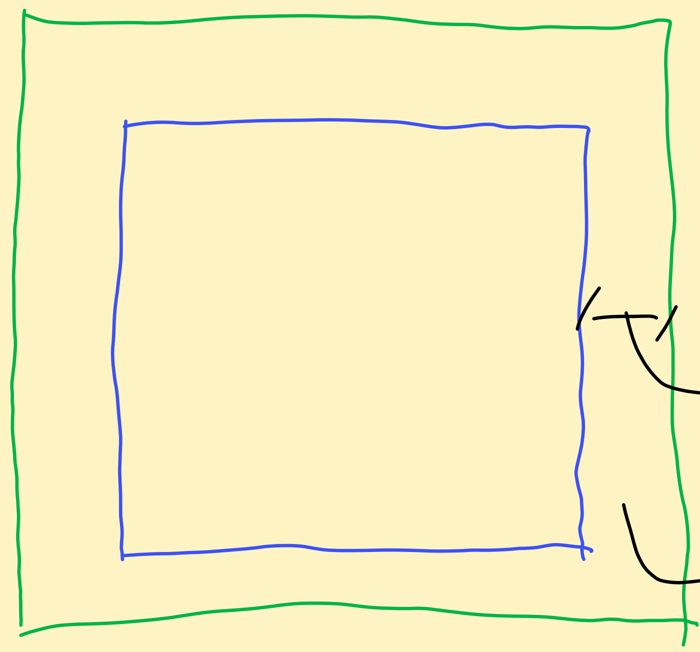
$R_L = 1{,}57$

TABLE 15.1 DYNAMIC STIFFNESSES AND DASHPOT COEFFICIENTS FOR ARBITRARILY SHAPED FOUNDATIONS ON THE SURFACE OF A HOMOGENEOUS HALFSPACE.

Vibration Mode	Dynamic Stiffness $\bar{K} = K \cdot k(\omega)$ — Static Stiffness K — General Shape (foundation–soil contact surface is of area A_b and has a circumscribed rectangle $2L$ by $2B$; $L > B$)*	Square $L = B$	Dynamic Stiffness Coefficient k (General shape; $0 \leqslant a_0 \leqslant 2$)†	Radiation Dashpot Coefficient C (General Shapes)
Vertical, z	$K_z = \frac{2GL}{1-\nu}(0.73 + 1.54\chi^{0.75})$ with $\chi = \frac{A_b}{4L^2}$	$K_z = \frac{4.54GB}{1-\nu}$	$k_z = k_z\left(\frac{L}{B}, \nu; a_0\right)$ is plotted in Graph a	$C_z = (\rho V_{La} A_b) \cdot \tilde{c}_z$; $\tilde{c}_z = \tilde{c}_z(L/B, \nu; a_0)$ is plotted in Graph c
Horizontal, y (in the lateral direction)	$K_y = \frac{2GL}{2-\nu}(2 + 2.50\chi^{0.85})$	$K_y = \frac{9GB}{2-\nu}$	$k_y = k_y\left(\frac{L}{B}; a_0\right)$ is plotted in Graph b	$C_y = (\rho V_s A_b) \cdot \tilde{c}_y$; $\tilde{c}_y = \tilde{c}_y(L/B; a_0)$ is plotted in Graph d
Horizontal, x (in the longitudinal direction)	$K_x = K_y - \frac{0.2}{0.75-\nu} GL\left(1 - \frac{B}{L}\right)$	$K_x = K_y$	$k_x \simeq 1$	$C_x \simeq \rho V_s A_b$
Rocking, rx (around longitudinal x axis)	$K_{rx} = \frac{G}{1-\nu} I_{bx}^{0.75}\left(\frac{L}{B}\right)^{0.25}\left(2.4 + 0.5\frac{B}{L}\right)$ with $I_{bx}(I_{by})$ area moment of inertia of the foundation–soil contact surface around the $x(y)$ axis	$K_{rx} = \frac{3.6GB^3}{1-\nu}$	$k_{rx} \simeq 1 - 0.20a_0$	$C_{rx} = (\rho V_{La} I_{bx}) \cdot \tilde{c}_{rx}$; $\tilde{c}_{rx} = \tilde{c}_{rx}(L/B; a_0)$ is plotted in Graphs e and f
Rocking, ry (around lateral axis)	$K_{ry} = \frac{G}{1-\nu} I_{by}^{0.75}\left[3\left(\frac{L}{B}\right)^{0.15}\right]$	$K_{ry} = K_{rx}$	$\nu < 0.45$: $k_{ry} \simeq 1 - 0.30a_0$; $\nu \simeq 0.50$: $k_{ry} \simeq 1 - 0.25a_0\left(\frac{L}{B}\right)^{0.30}$	$C_{ry} = (\rho V_{La} I_{by}) \cdot \tilde{c}_{ry}$; $\tilde{c}_{ry} = \tilde{c}_{ry}(L/B; a_0)$ is plotted in Graph g
Torsional	$K_t = GJ_b^{0.75}\left[4 + 11\left(1 - \frac{B}{L}\right)^{10}\right]$ with $J_b = I_{bx} + I_{by}$ being the polar moment of the soil–foundation contact surface	$K_t = 8.3GB^3$	$k_t \simeq 1 - 0.14a_0$	$C_t = (\rho V_s J_b) \cdot \tilde{c}_t$; $\tilde{c}_t = \tilde{c}_t(L/B; a_0)$

* Note that as $L/B \to \infty$ (strip footing) the theoretical values of K_z and $K_y \to 0$; the values computed from the two given formulas correspond to a footing with $L/B \approx 20$.
† $a_0 = \omega B / V_s$.





$R_e \frac{L}{2} = 0.3 \cdot \frac{20}{2} = 3m$

Perimeter Zone
enchanced springs

Για dashpots → Βάζω Links (SAP 2000)

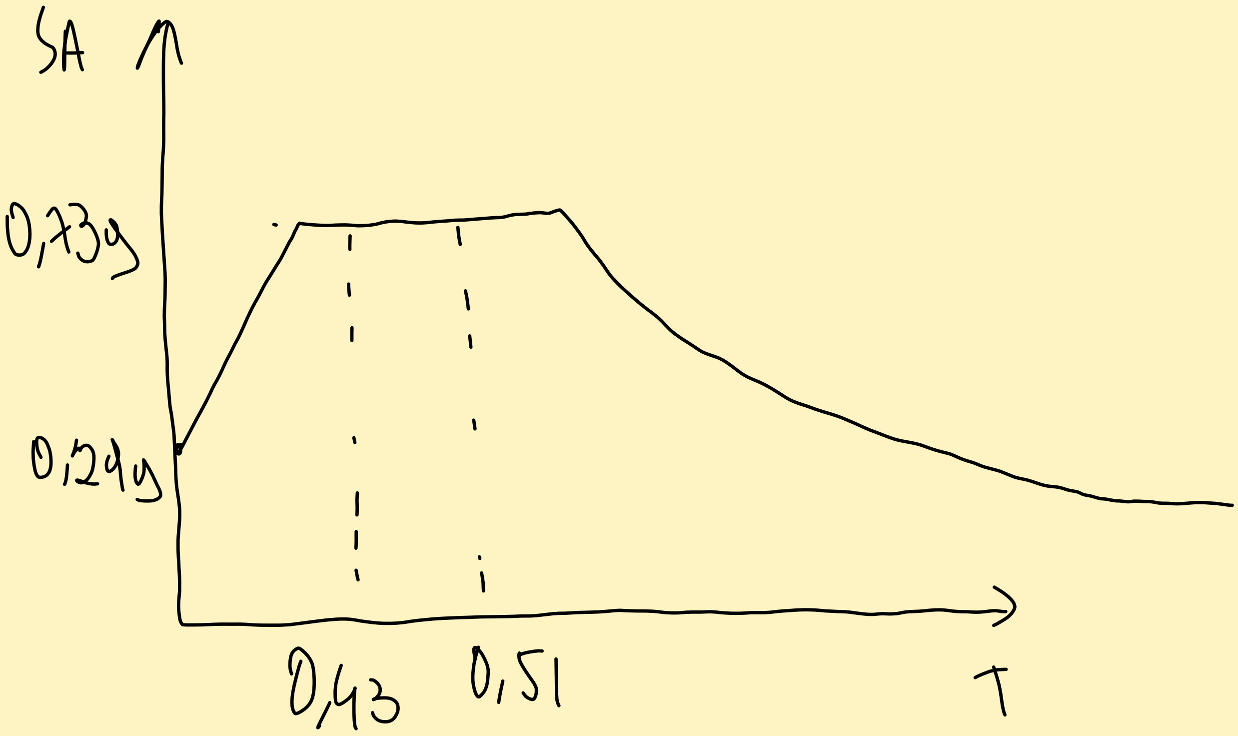
Βάζω τα μέτρα k και c που υπολόγισα πριν
k_x, k_y, k_z c_x c_y c_z

For the central zone	For the perimeter zone
$k_z = 7355$ kPa/m	$k_z^* = R_k k_z$
$c_z = 551$ kPas/m	$= 3.5 \cdot 7355$
	$k_z^* = 25743$ kPa/m
$c_x^* = c_x$	$c_z^* = R_c R_k c_z$
$c_y^* = c_y$	$= 1.57 \cdot 3.57 \cdot 551$
$k_x^* = k_x$	$c_z^* = 3028$ kNs/m³
$k_y^* = k_y$	↓ kPas/m

$*$ → perimeter zone

Με αλληλεπίδραση εδάφους πάντα έχω μεγαλύτερο T_1

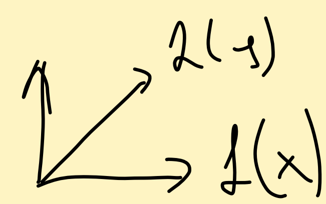
SSI $\Rightarrow T_1 = 0,51$ sec

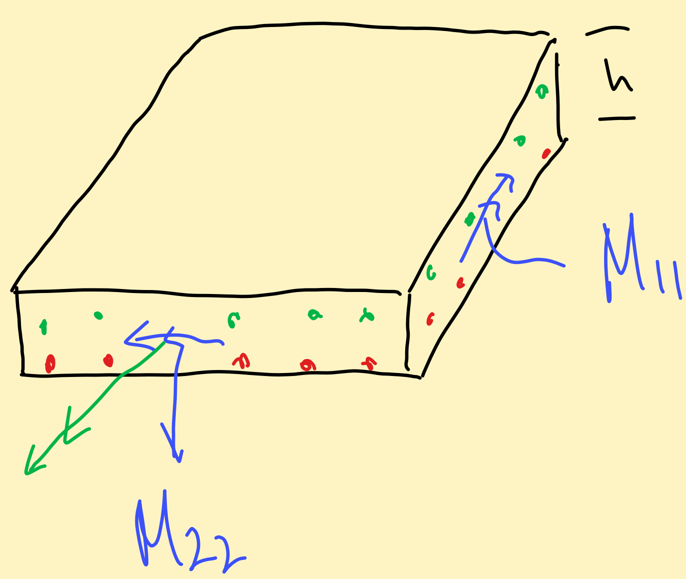


Σεισμικοί Συνδυασμοί

↳ $G + 0.3L + E$

12/10/23/ SAP 2000 Example 3

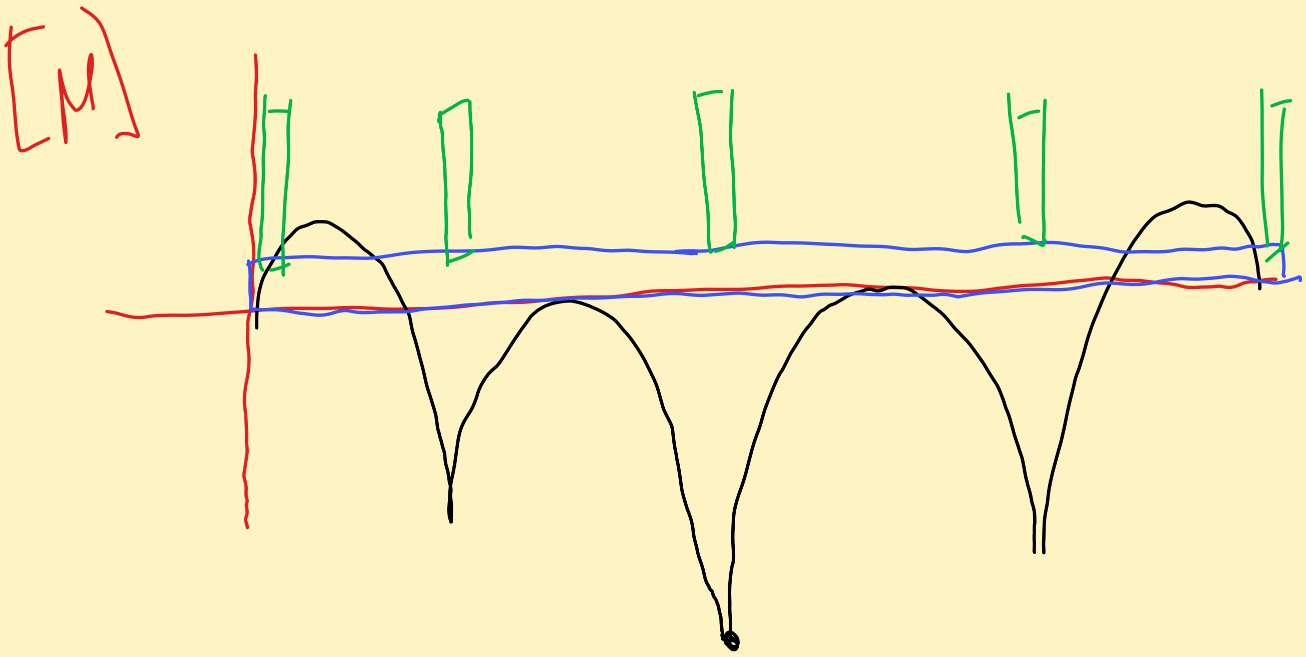




$$\left.\begin{array}{l} m_x = M_{11} + |M_{12}| \\ m_y = M_{22} + |M_{12}| \end{array}\right\} \Rightarrow$$ Οπλισμός κάτω (bottom reinforcement)

$$\left.\begin{array}{l} m_x = M_{11} - |M_{12}| \\ m_y = M_{22} - |M_{12}| \end{array}\right\} \Rightarrow \text{οπλισμός πάνω (top reinforcement)}$$

COMB1 G + 0.3L + E



$M_{11} = 2200 \text{ kNm/m}$

$M_{22} = 130 \text{ kNm/m}$

$m_x = 2200 + 130$

$m_x = 2330 \text{ kN/m}$

$$k = \frac{M}{b \cdot d^2 \cdot f_{ck}} = \frac{2330 \text{ kNm/m}}{1\text{m} \; 0.95^2 \; 30 \; 1000 \text{ kPa}}$$

(b = 1m)

cover = 5cm

d = h − cover

$\rightarrow k = 0{,}086$

$$z = \frac{d}{2}\left[1 + \sqrt{1 - 3.53K}\right] \leq 0.95\,d$$

$$z = \frac{0,95}{2}\left[1 + \sqrt{1 - 3\,53\;0,086}\right] \Rightarrow z = 0,871$$

$$A_s = \frac{M}{f_{yd}\,z} = \frac{2330\ \text{kNm/m}}{\frac{500}{1,15} \cdot 0,95} \Rightarrow A_s = 0,0062\,m^2$$

$A_{s\,min} = 0,00015\ \cancel{A}_c^{\;1\times 1}$

$\hookrightarrow A_{s\,min} = 0,00015 < 0.0062\ m^2$

$A_{s\,max} = 0,04\,A_c$

$= 0,04 > 0,0062\ m^2$

$$\rho = \frac{A_{s\,min}}{b \cdot d} \quad (b = 1,\ d = h - \text{cover}, d = 0,95)$$

$\phi 16$

$D = 16\ mm \quad A_b = \pi\,\frac{0,016^2}{4} \Rightarrow A_b = 0,0002\,m^2$

$$N = \frac{A_s}{A_b} = \frac{0,0062}{0,0002} \Rightarrow N = 31$$

$$\text{spacing} = \frac{1m}{31} = 0,0032 \to 32\,cm$$

$\phi 30$

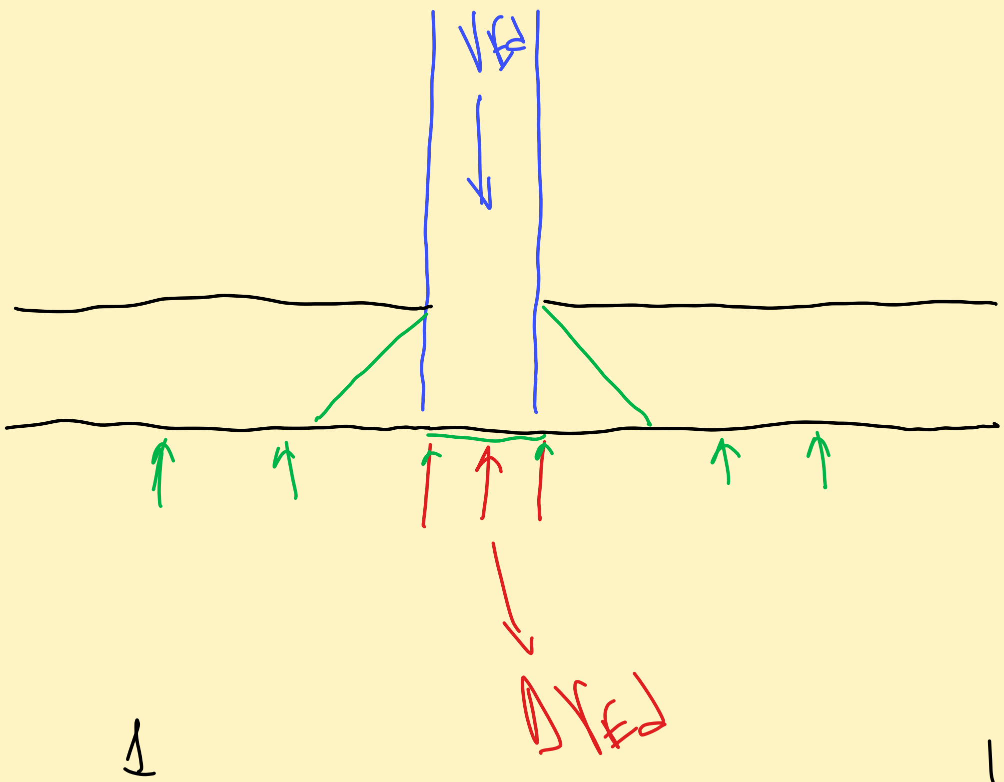
$D = 30\ mm \quad A_b = \frac{0,03^2\,\pi}{4} \Rightarrow A_b = 0,0007\,m^2$

$$N = \frac{0,0062}{0,0007} \Rightarrow N = 9 \qquad \text{spacing} = \frac{1m}{9} = 11\,cm$$

$\hookrightarrow \phi 30/10$

Διάτρηση Punching Calculations

$V_{Ed} = 3743\,kN$

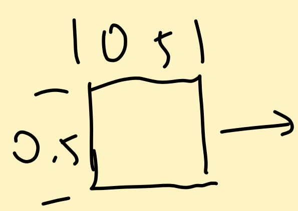


$$V_{Ed\,max} = \frac{\cancel{\beta}^{\,1}(V_{Ed} - \Delta V_{Ed})}{u_0 \cdot d_{eff}}$$

περίμετρος u_{out}

$d_{eff} = h - (cover + \phi)$

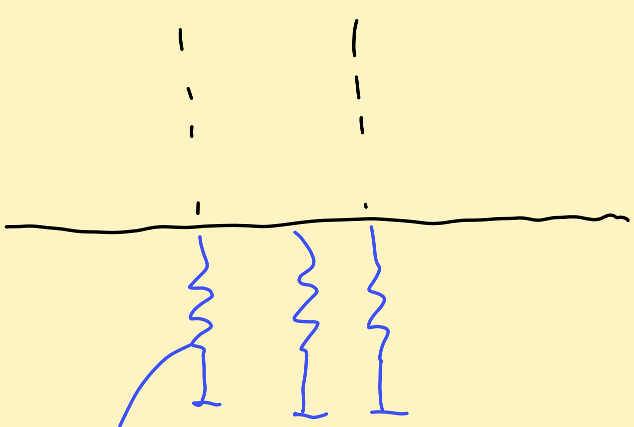
$d_{eff} = 0{,}92\,m$



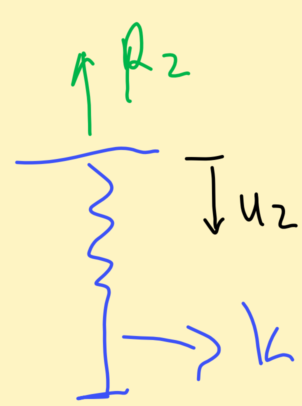
$\to u_0 = 4.05$

$u_0 = 2m$

β → εξαρτάται από τη θέση του υποστυλώματος
Figure 7
β = 1 (όταν M=0



$\to K_s = k_s A_s$



$R_z = k\, u_z$

$\Delta V_{Ed} = \sum R_z = \sum k_s A u_z$

$\Delta V_{Ed} = u_z k_s \underbrace{\sum A}_{0.5^2}$

$k_s = 7355 \frac{kPa}{m}$

$u_z = 0{,}025\ m$

$\Delta V_{Ed} = 0{,}025\ m \cdot 7355 \cdot 0.5^2$

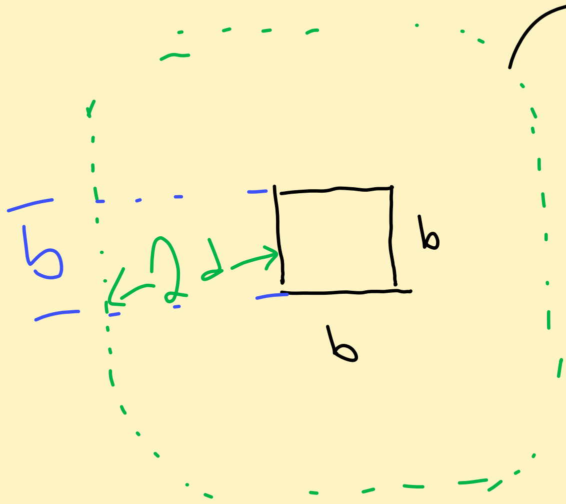
$\Delta V_{Ed} = 46\ kN$

$V_{Ed,max} = \frac{(3743-46)}{0.025 \cdot 0{,}92} \Rightarrow V_{Ed,max} = 2009\ kPa$
$= 2\ MPa$

$V_{Rd,max} = 5{,}28\ MPa > V_{Ed,max}$
↓
table 7

$V_{Ed} < V_{Rd}$ (Περίμετρος για 2d)

→ u_1 — Περίμετρος



$d = d_{eff}$

$2d = 2 \cdot 0{,}92$

$2d = 1{,}84\ m$

$r = 2d$

$u_1 = 4 \cdot 0{,}5 + \frac{2\pi r}{4} \cdot 4$

$u_1 = 13{,}60\ m$

$v_{Ed} = \frac{V_{Ed} - \Delta V_{Ed}}{u_1\ d_{ef}}$

$\Delta V_{Ed} = u_2 k_0 A$

$= 0{,}024 \; 7335 \; 14{,}60$

$\Delta V_{Ed} = 2570 \text{ kN}$

$A = 0{,}5^2 + 4\,(0{,}5 \; 1{,}84) + 4\frac{\pi r^2}{4}$

$A = 0{,}5^2 + 4(0.5 \cdot 1.84) + \pi \, 1{,}84^2$

$A = 14{,}60 \text{ m}^2$

$V_{Ed} = \frac{3743 - 2570}{13.60 \cdot 0{,}92} \Rightarrow V_{Ed} = 93.75 \text{ kPa}$

$V_{Ed} = 0{,}094 \text{ MPa}$

Table 6

$\Phi 30$

$\rho_L = \frac{9 \; \frac{\pi \; 0\,03^2}{4}}{1 \times 1} \Rightarrow \rho_L = 0{,}63\%$

Απο table 6 $\Rightarrow V_{R,c} = 0{,}45 \text{ MPa} > V_{Ed} = 0{,}094 \text{ MPa}$

Ιδιος ελεγχος για περιμετρο d ($V_{Rd} = ?$)

$\Rightarrow V_{Rd} = 2 V_{Rdc}$ ($V_{Rd} = \frac{2d}{d} V_{Rdc}$)

19/10/23 Homework hardcopy στις 2/11

Midterm 9/11

Homework 1

Άσκηση 1

$k_{sand} = \frac{100MN}{5cm}$

Άσκηση 2

Φασματική Ανάλυση

Gazzetas Tables

Nist Approach

Ύψος ορόφου 3m

Δεν βάζω 50% K

Ενδιάμεση

→ Καταστρώσεις

NIST

εφαρμογή κρίσεων Φασματικής Ανάλυσης

→ Ίσως Παρασκευή

ΠΑΣΣΑΛΟΙ

Settlements of Pile Foundations

Πλευρική δύναμη

$Q_{s,i} = q_{s,i} A_{s,i}$ $\quad$ $A_{s,i} \Rightarrow$ εμβαδόν πλευρικής επιφάνειας

$q_{s,i} \Rightarrow$ αντίσταση (kPa)

$Q_{b,ult} \rightarrow$ οριακή αντίσταση αιχμής (στο 0.1 B)

$Q_{sL} \rightarrow$ οριακή αντίσταση πλευρικής τριβής

$G_i \rightarrow$ μέτρο διάτμησης

$r_m \rightarrow$ ακτίνα επιρροής πασσάλου (radius of influence)

$$r_m = \left[0.25 + \left(2.5(1-v)\frac{G_{ave}}{G_L} - 0.25\right)\frac{G_L}{G_{Base}}\right] L$$

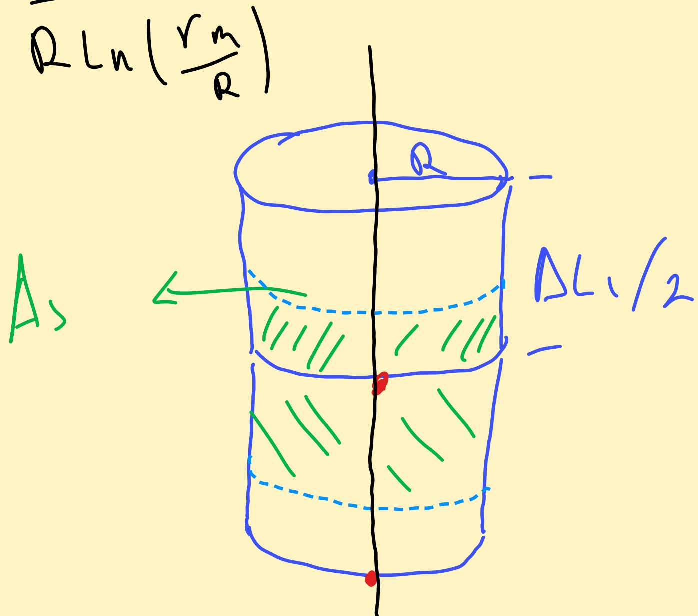
Αν παντού ομοιόμορφο έδαφος $G_{ave} = G_L = G_{Base}$

↳ ομοιόμορφη άργιλος $(v=0.5)$

$$r_m = \left[0.25 + \left(2.5(1-0.5)\ 1 - 0.25\right)\ 1\right] L$$

$$r_m = 1.25\,L$$

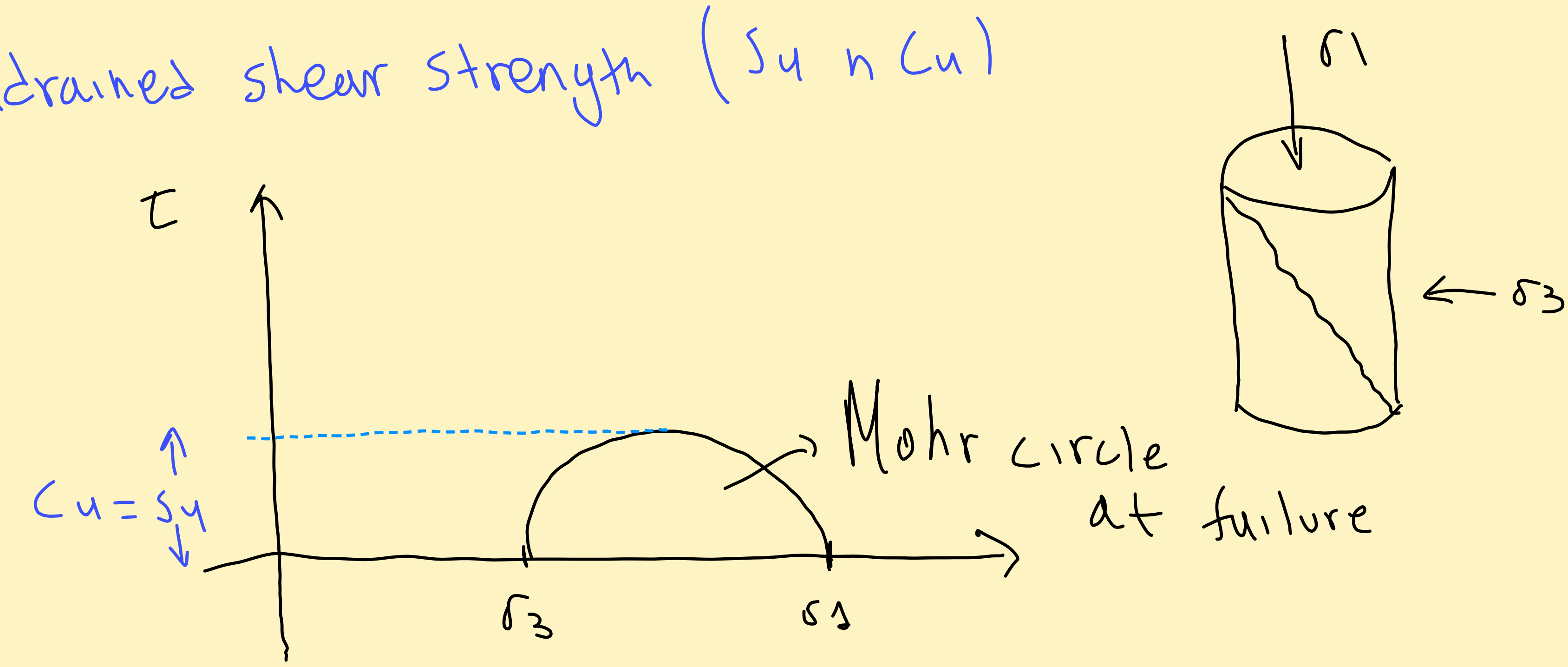
$$k_s = \frac{G}{R \ln\left(\frac{r_m}{R}\right)} \qquad K_s = k_s A_s$$



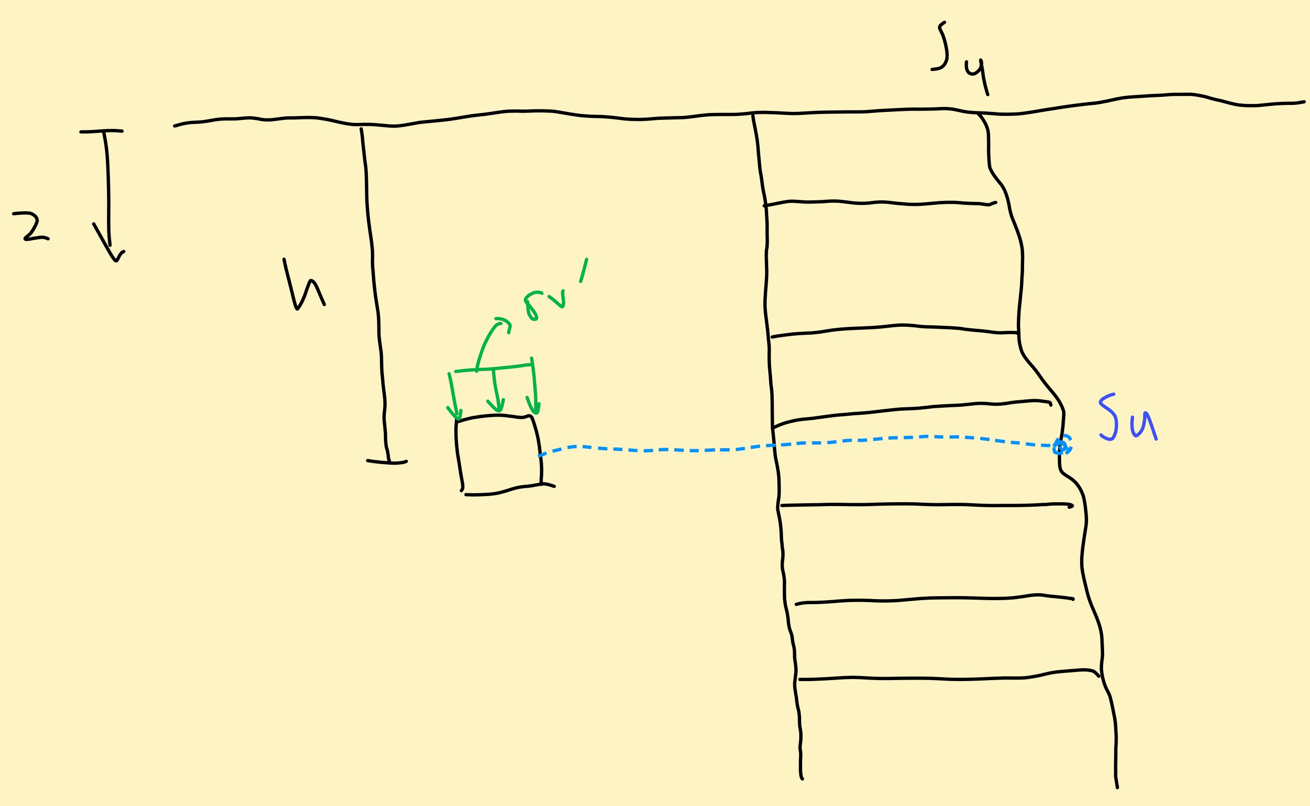
$$A_s = 2\pi R \frac{\Delta L_i}{2}$$

$$K_s = \frac{G}{R \ln\left(\frac{r_m}{R}\right)} 2\pi R \frac{\Delta L_i}{2} \Rightarrow K_s = \frac{2\pi}{\ln\left(\frac{r_m}{R}\right)} G \; 0.5 \Delta L_i$$

Undrained shear strength (S_u n C_u)



Driven Piles $\quad q_{sL} = \alpha S_u \quad q_{bL} = 9 S_u$



9,81 kN/m³

$$\sigma_v' = \gamma h - \gamma_w h$$

$$\alpha = \left(\frac{S_u}{\sigma_v'}\right)_{NC}^{0.5} \left(\frac{S_u}{\sigma_v'}\right)^{-0.5} \quad \text{for} \quad \frac{S_u}{\sigma_v'} \leq 1$$

$$\alpha = \left(\frac{S_u}{\sigma_v'}\right)_{NC}^{0.5} \left(\frac{S_u}{\sigma_v'}\right)^{-0.25} \quad \text{for} \quad \frac{S_u}{\sigma_v'} > 1$$

$$\left(\frac{S_u}{\sigma_v'}\right)_{NL} = 0{,}11 + 0{,}0037\, PI \qquad PI = LL - PL$$

If the clay is currently NC

$$a = \left(\frac{S_u}{\sigma_v'}\right)^{0,5}_{NL} \left(\frac{S_u}{\sigma_v'}\right)^{-0,5}_{NL} \Rightarrow a = 1$$

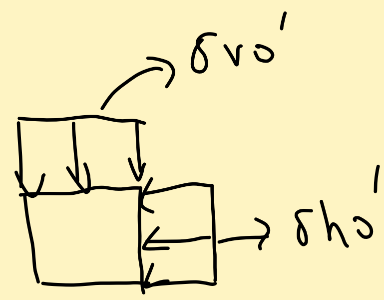
$D_R \rightarrow$ σχετική πυκνότητα (Relative density)

$$D_R = \frac{e_{max} - e}{e_{max} - e_{min}} \qquad e \rightarrow \text{δείκτης πόρων}$$

From SPT $\qquad N_{SPT} \rightarrow N_{60}$

$$D_R\,(\%) = \sqrt{\frac{N_{60}}{36{,}5 + 27\,\frac{\sigma_{vo}'}{P_A}}} \qquad P_A = 100\,kPa$$

$$K_o = \frac{\sigma_{ho}'}{\sigma_{vo}'} = 1 - \sin\phi$$



26/10/23

- Στους πασσάλους χρησιμοποιώ thick formulation
- Non Linear analysis στο SAP 2000 (για σπίτι)

SAP 2000 Example 4

Drillet shaft C30/37

clay (αργιλος)

OCR = 2-6 (overconsolidated)

$S_u = 200\,kPa$

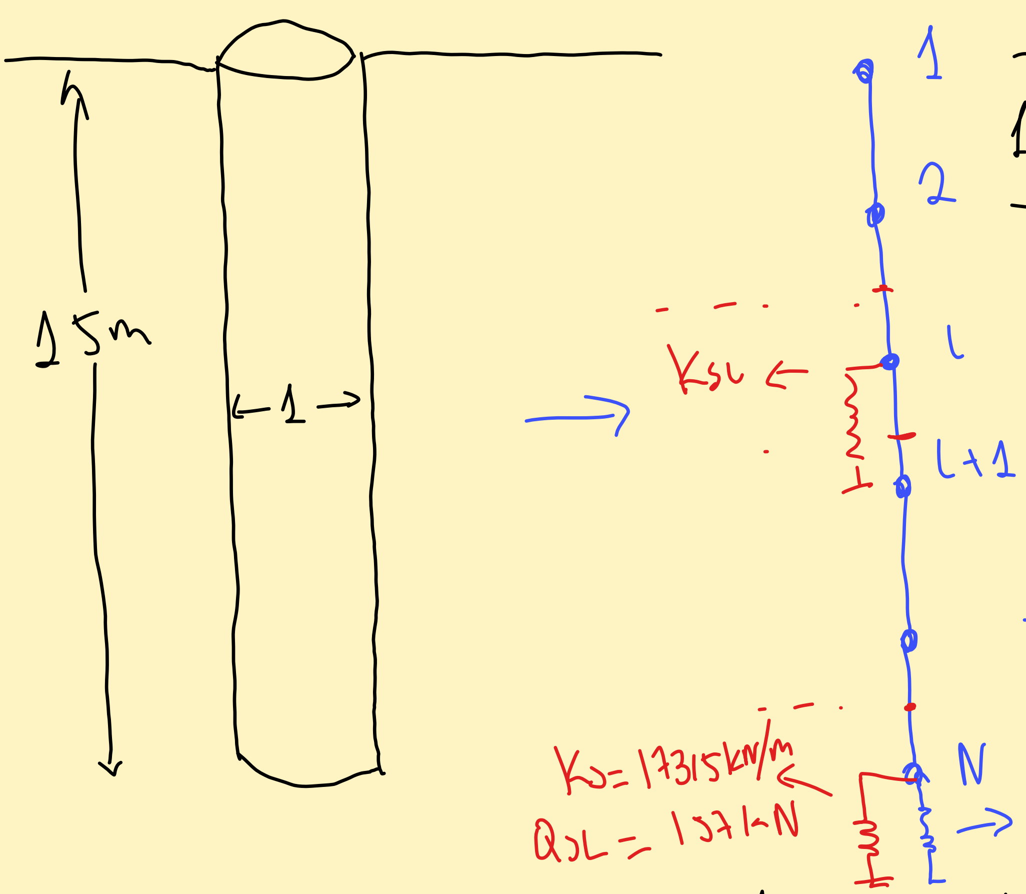
$D = 1m \quad R = 0.5m$

$\nu = 0.5 \quad \gamma = 18\,kN/m^3$

WT → very deep, $u_w = 0$

$\sigma_{vo}' = \sigma_{vo} - u_w \Rightarrow \sigma_{vo}' = \sigma_{vo}$

$\sigma_{vo}' = \gamma \cdot z$



⇒ στοιχεία 1m ⇒ L = 1m

N = 16 (κόμβοι)

→ $K_b = 108254\,kN/m$

$Q_{bL} = 1413\,kN$

$$K_{sl} = \frac{2\pi}{\ln\left(\frac{r_m}{R}\right)} \underbrace{\left(0.5\,\overset{1}{\cancel{L}}\,G + 0.5\,\overset{1}{\cancel{L}}\,G\right)}_{\hookrightarrow\ G}$$

$G = 100\,S_u$

$= 100 \cdot 200\,kPa$

$G = 20000\,kPa$

$\hookrightarrow G = G_L = G_{ave} = G_{BASE}$

$$r_m = \left[0.25 + \left(2.5(1-\nu)\,\overset{1}{\cancel{\frac{G_{ave}}{G_L}}} - 0.25\right)\overset{1}{\cancel{\frac{G_L}{G_{BASE}}}}\right]\overset{15}{\cancel{L}}$$

$r_m = 1.25 \cdot 15 \Rightarrow r_m = 18.8\,m$

$$K_{sl} = \frac{2\pi}{\ln\left(\frac{18.8}{0.5}\right)}\,20000 \Rightarrow K_{sl} = 34729\,kN/m$$ → inner nodes

$$K_{s1}=K_{sN}=\frac{2\pi}{\ln\left(\frac{r_m}{R}\right)}(0.5\,L\,G)$$

$$K_{s1}=K_{sN}=\frac{34729}{2} \Rightarrow \left.\begin{array}{l} K_{s1}=17315\ kN/m \\ K_{sN}=17315\ kN/m \end{array}\right\} \text{outer nodes}$$

Υπολογισμός $Q_{sL,i}$ → Αντίσταση ολίσθησης

$q_{sL}=\alpha\, S_u$

$\frac{S_u}{P_A}=\frac{200}{100}=2$

$q_{sL}=0.5\ 200kPa$

$\hookrightarrow \alpha=0.55-0.1\left(\overset{\to 2}{\frac{S_u}{P_A}}-1.5\right)$

$q_{sL}=100kPa$

$\alpha=0.5$

↓ εδάφους

$$Q_{sL,i}=2\pi R\,(0.5\,L\,q_{sL}+0.5\,L\,q_{sL})$$

$$Q_{sL,i}=2\pi\ 0.5\,(0.5\ 1\ 100+0.5\ 1\ 100)$$

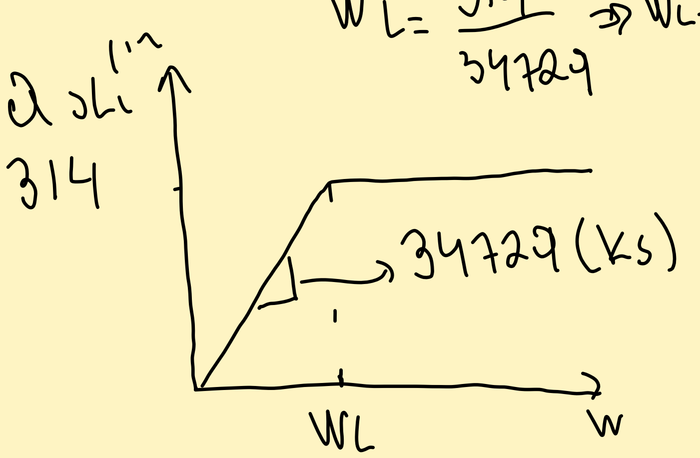
$Q_{sL,i}^{(in)}=314\ kN$ → inner nodes

$$Q_{sL,i}^{(out)}=\frac{314}{2}$$

$Q_{sL,i}^{(out)}=157\ kN$ → outer nodes

Inner

$W_L=\frac{314}{34729} \Rightarrow W_L=0.009\,m$



$\frac{W_L}{D}=0.9\%$

Υπολογισμός K_b και Q_{bL} (στη βάση του πασσάλου στον N node)

$$K_b = \frac{4RG}{1-v}(1,27 - 0,12 \ln v)$$

$$K_b = \frac{4 \; 0.5 \; 20000}{1-0.5}(1,27 - 0.12 \ln 0.5) \Rightarrow K_b = 108254 \text{ kN/m}$$

$$q_{bL} = 9 \; s_u$$
$$= 9 \; 200 \text{ kPa} \Rightarrow q_{bL} = 1800 \text{ kPa}$$

$$Q_{bL} = q_{bL} \; A_b$$
$$= 1800 \; \pi \; 0.5^2 \Rightarrow Q_{bL} = 1413 \text{ kN}$$

Υπολογισμός R (horizontal Non-linear model)

↳ Διάλεξη Lateral response of pile foundations

Υπολογισμός R στο excel

$$E_p = 210000000 \text{ kPa}$$

$$I_p = \frac{\pi r^4}{4} = \frac{\pi \; 0.5^4}{4} \Rightarrow I_p = 0,0491 \text{m}^4$$

↓

second moment area (κυκλικής διατομής)

$$E_{εδάφους} = G \; 2(1+v)$$
$$= 20000 \text{ kPa} \; 2(1+0.5)$$

$$E_{εδάφους} = 60000 \text{ kPa}$$

$$K_{rel} = \frac{E_p \; I_p}{E_s \; L^4}$$ $L = 15$

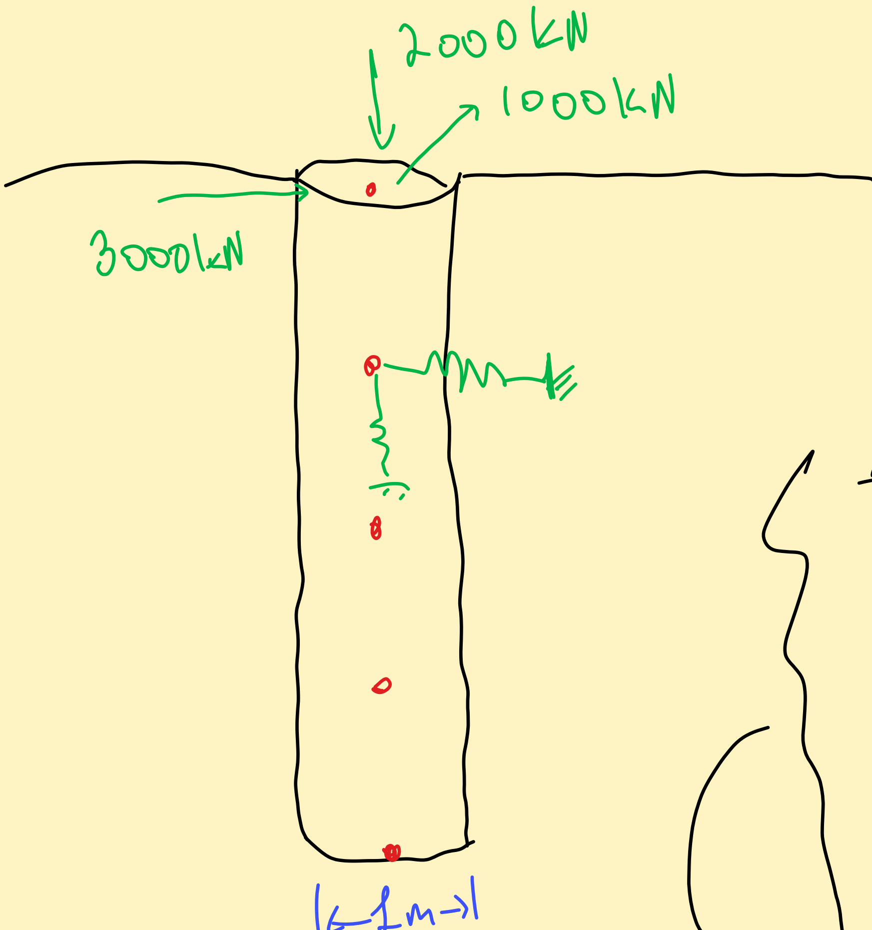
$$= \frac{210000000 \;\; 0,0491}{60000 \;\; 15^4}$$

$$K_{rel} = 0,0034$$

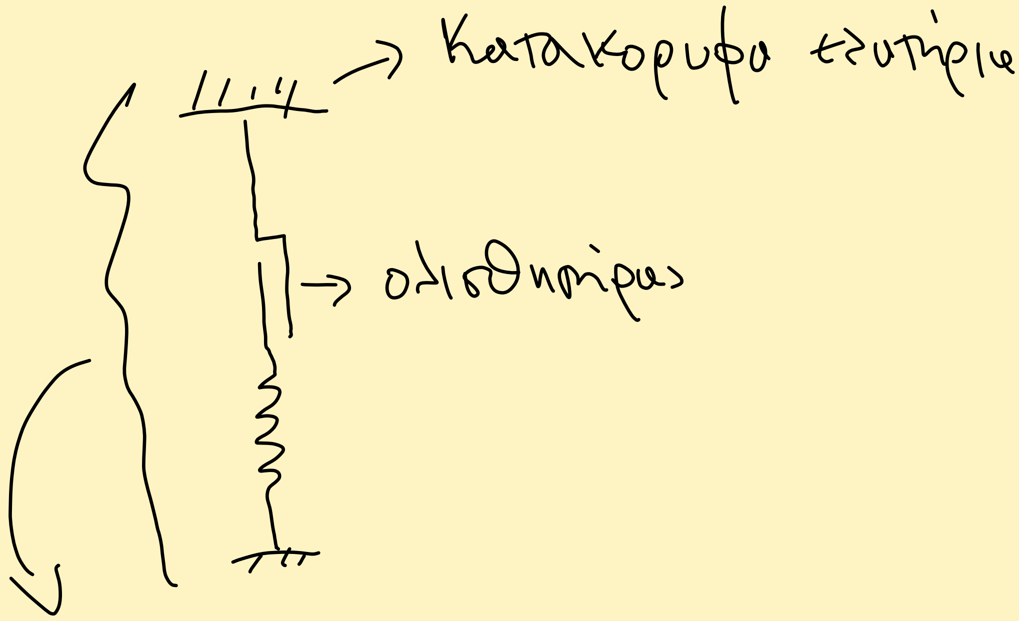
2/11/23

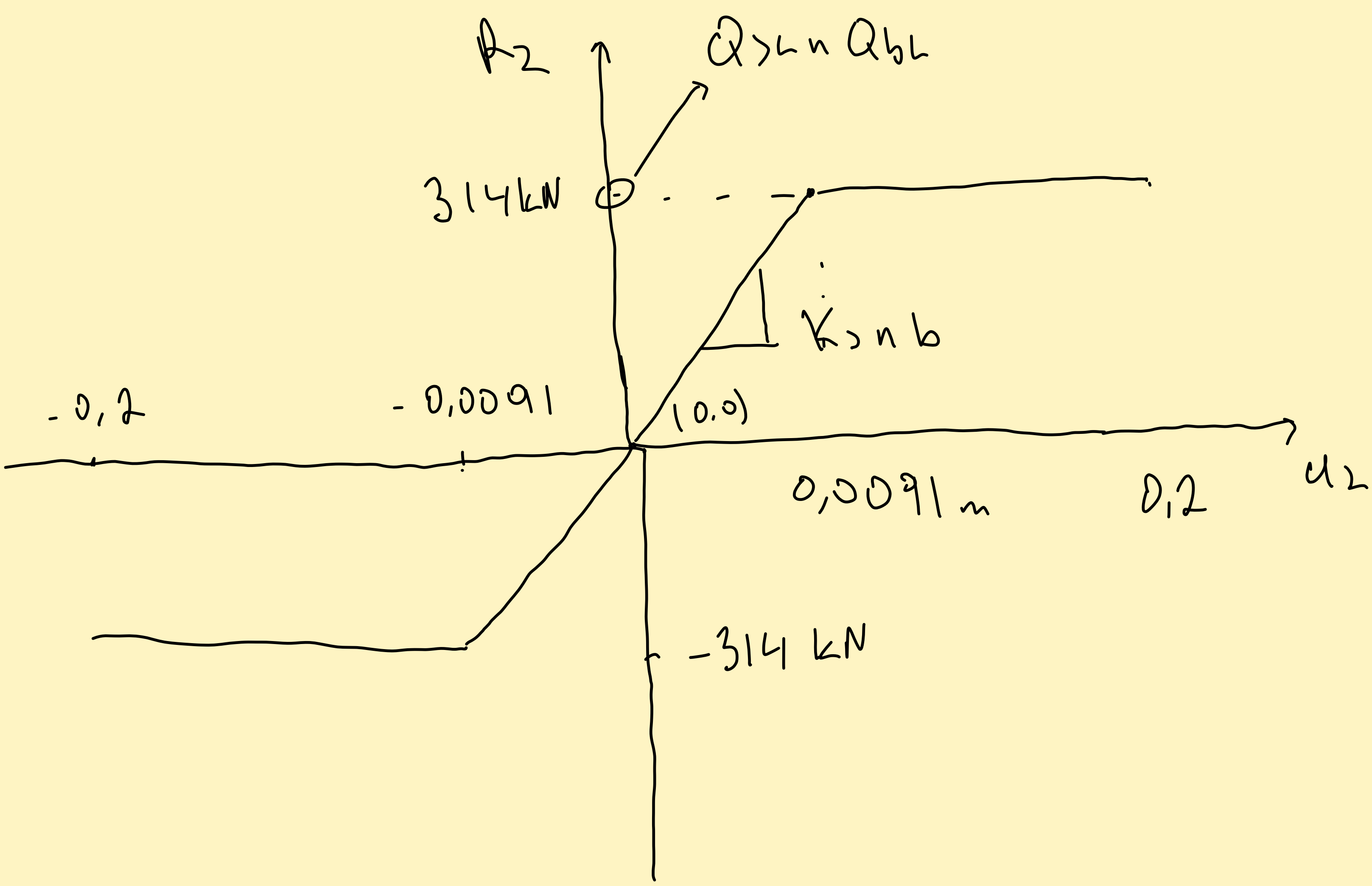
Συνέχεια Παραδείγματος

Midterm
- ↳ έξω οι πρόοδοι
- ↳ ερωτήσεις κρίσεως
- ↳ multiple choice
- ↳ γενικά EC8



Clay (OC)





SAP 2000

↳ Δεν βάζω αποσβεστήρες στηρίξεις βάζω link support properties

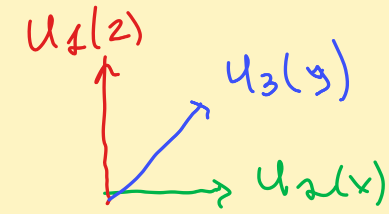
Link support properties

↳ multilinear Plastic

- ☑ U1
- ☑ U2
- ☑ U3

} Non linear

Local axis



modify για U1 (κατακόρυφο Local axes)

Kinematic

Disp	Force
-0.2	-157
-0,0091	-157
0	0
0,0091	157
0.2	157

Κατακόρυφο ελατήριο ⇐

157 για το κόμβο στη κορυφή του πασσάλου και τον κόμβο στη βάση του πασσάλου

314 για τους ενδιάμεσους

Για να βάλω το Link

draw joint Link και διαλέγω το joint

→ U2 και U3 βάζω τους αριθμούς του excel

η στήλη Disp → u (του excel)

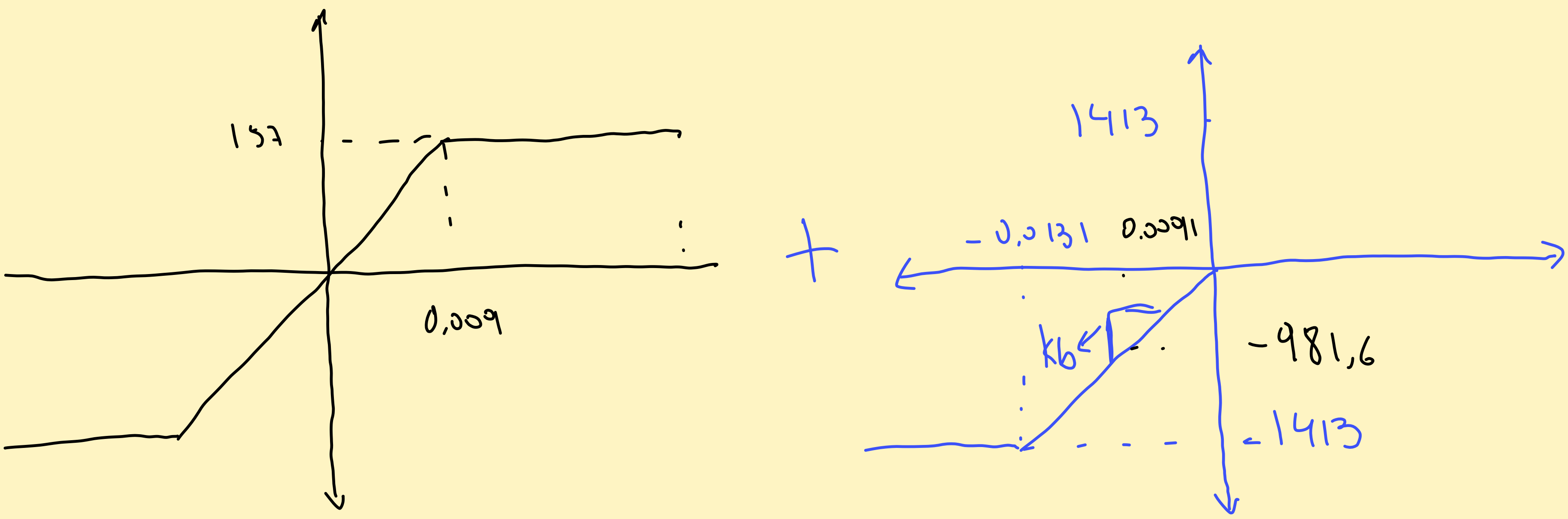
στήλη Force → z (1 ή 2 ή 3) Από excel

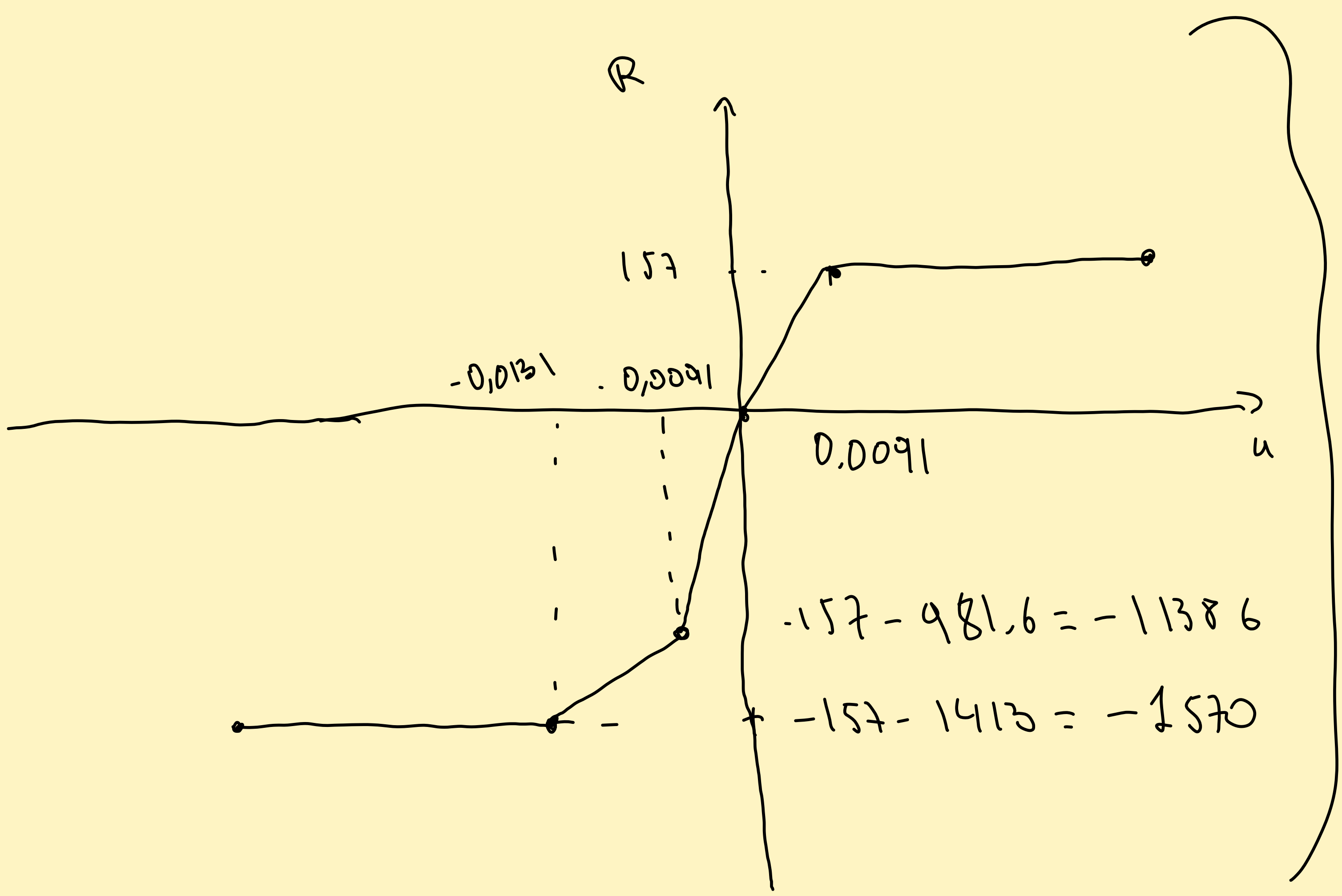
Επαναλαμβάνω τη διαδικασία για όλους τους κόμβους

Από βάθος 6 - 14 ίδιο Link

Για node 15

↳ πρέπει να βάλω και το ελατήριο της βάσης





⇒ U_1

Μη γραμμική ανάλυση

↳ new case pattern → Static Nonlinear

↳ Add φορτία

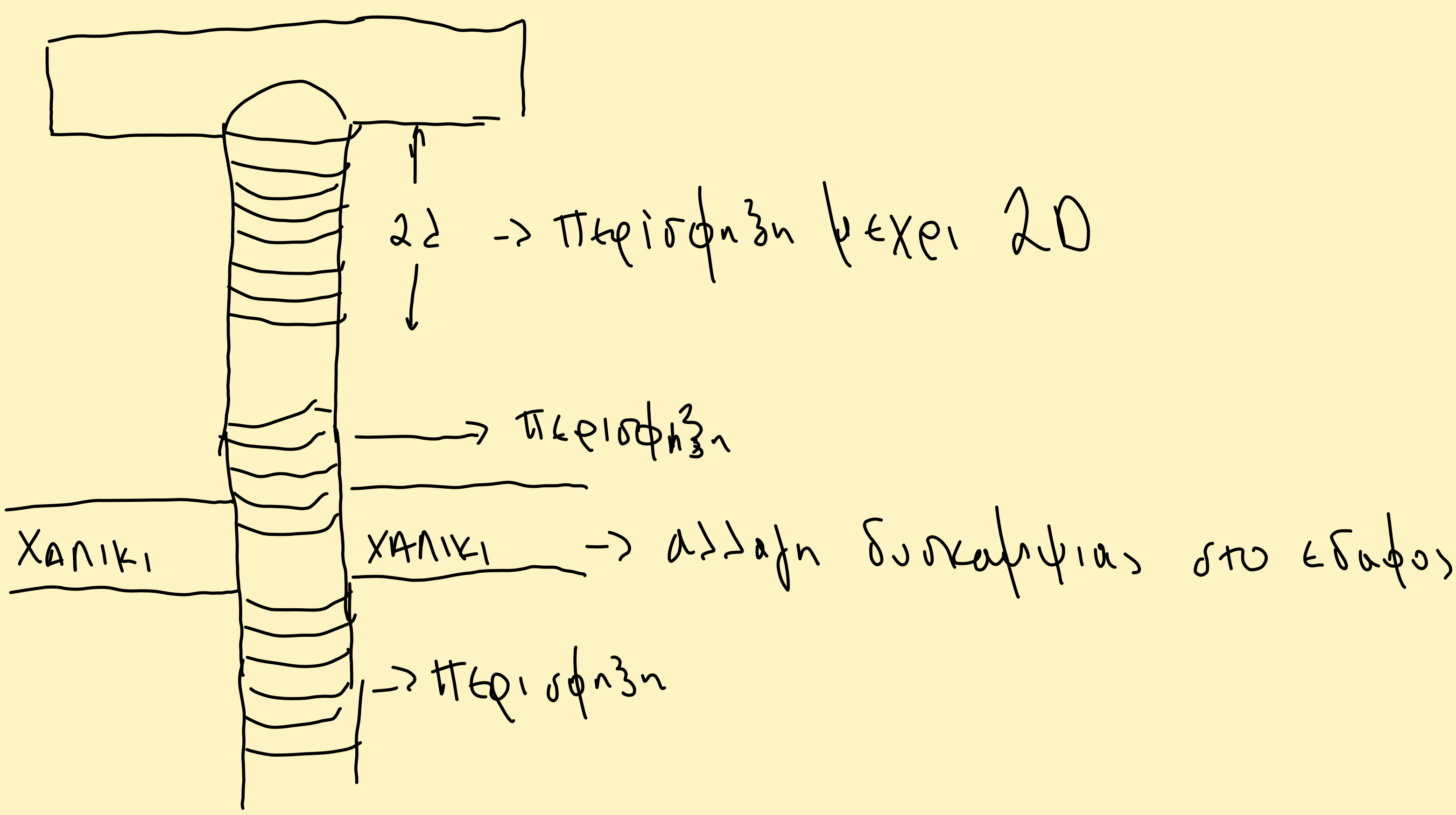
Set analyse options

☐ R_2 → πρέπει να είναι ελεύθερος

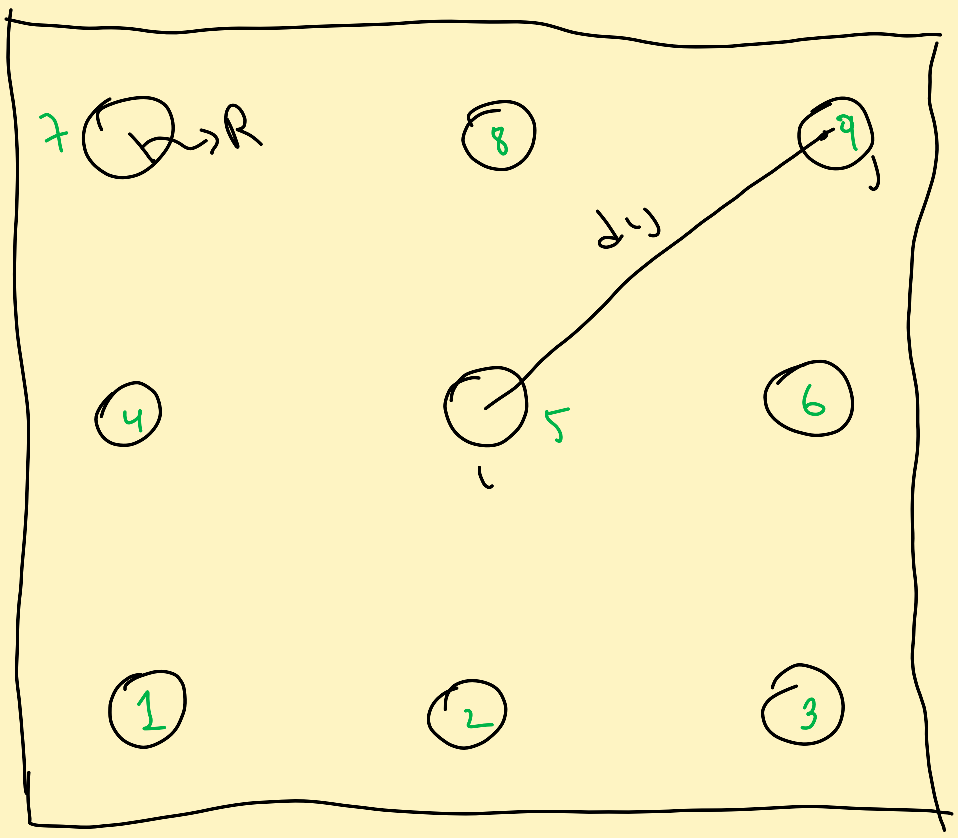
Run μόνο την ACASE 1 (τη μη-γραμμική)

Desing of Pile

Cyprus ⇒ DCM ή DCH



Settlement of Pile Groups

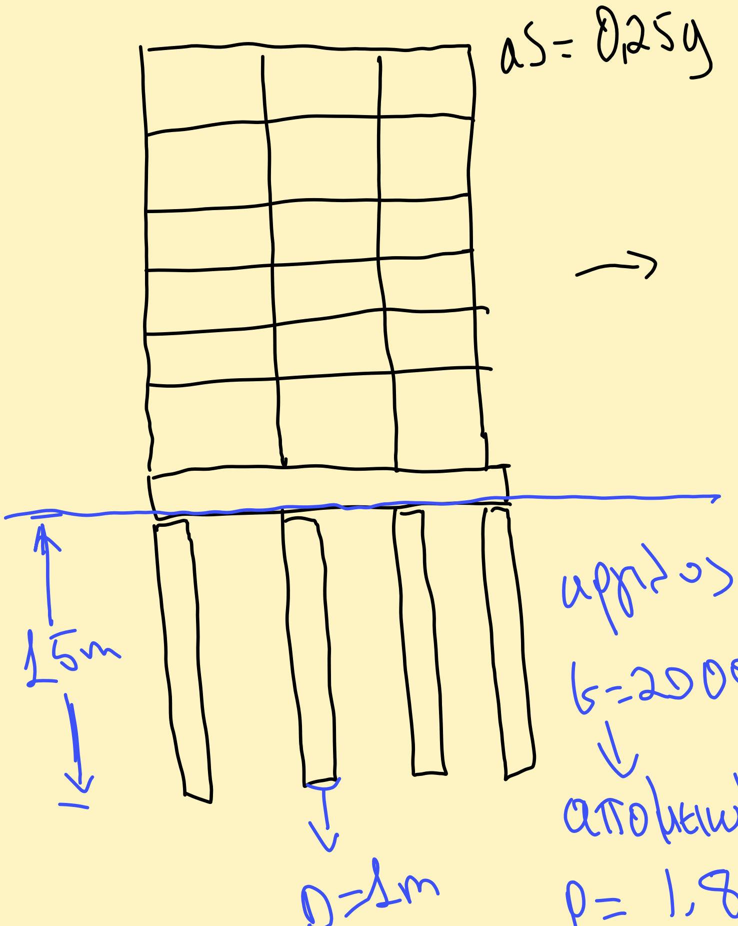


→ excel

9/11/23 Example_pile_group_class (SAP FILE)

C30/37

as = 0,25g



αργιλος

E=20000kPa

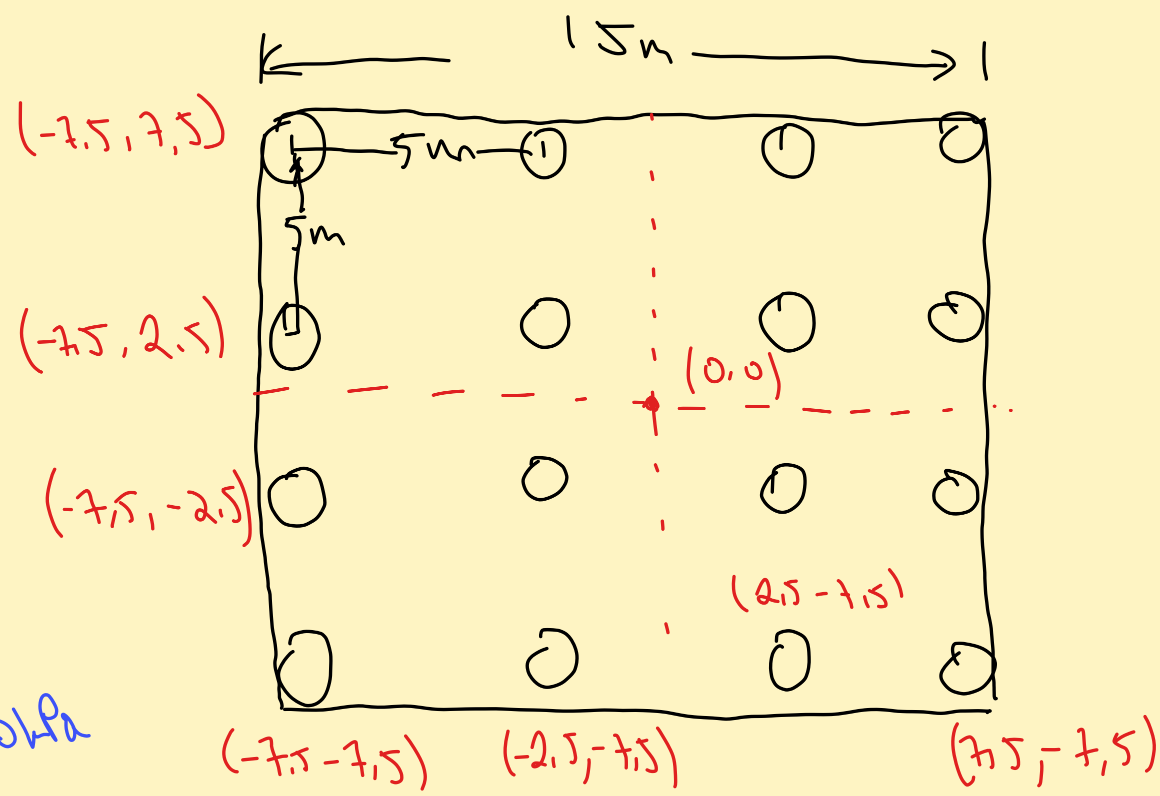
↓

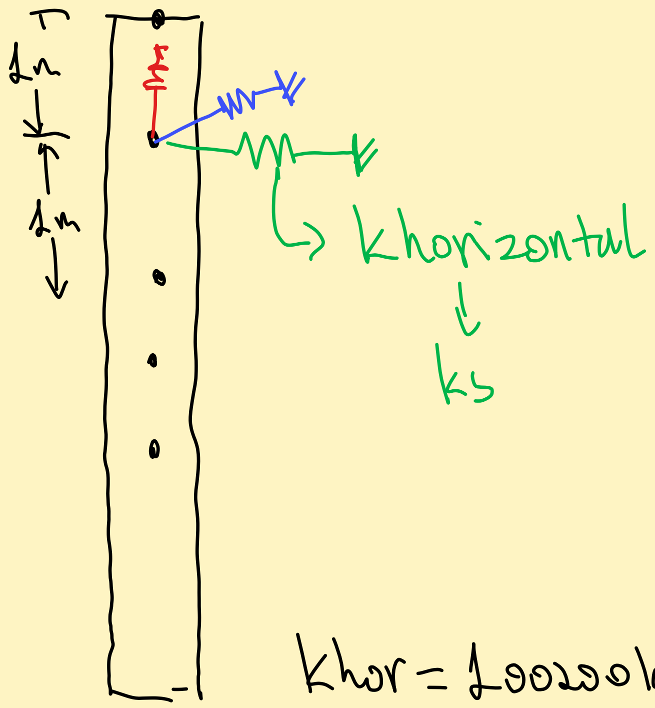
απομειωμένο

$\rho = 1,8\,t/m^3$

$\nu = 0,5$

→





$$k_s = \frac{1{,}67\,E}{D}$$

$$E = 2\,G(1+v)$$

$$E = 20000\ 2(1+0{,}5)$$

$$E = 60000\,kPa$$

$$k_s = \frac{1.67\ 60000}{1m} \Rightarrow k_s = 100200\,kPa/m$$

$$k_{hor} = 100200\,kN/m \Rightarrow (0{,}5\ 1\ 100200 + 0{,}5\ 1\ 100200)$$
↳ inner

$$k_{hor}(out) = 50100\,kN/m$$

$$C_s = 2\rho V_s$$

$$V_s = \sqrt{\frac{G}{\rho}} = \sqrt{\frac{20000}{1{,}8}} \Rightarrow V_s = 105\,m/s$$

$$C_s = 2 \cdot 1.8\ 105 \Rightarrow C_s = 378\,kPa\,s/m$$

$$C_{hor} = \pi\,C_s$$

$$C_{hor,rad} = 3{,}14\ 378 \Rightarrow C_{hor} = 1187\,kN\,s/m$$

$$C_{hor,tot} = C_{hor,rad} + \frac{2K_{hor}}{\omega} \cdot \zeta$$

$$\zeta = 8\%$$

$$\omega = \frac{2\pi}{T} \Rightarrow \omega = \frac{2\pi}{0{,}7} \Rightarrow \omega = 9\,rad/sec$$

$T = 0.7$

$$C_{hor,tot} = 1187 + \frac{2\ 100200}{9}\ 0{,}08 \Rightarrow C_{hor,tot} = 2968\,kN\,s/m$$
↳ inner

$$C_{hor,total} = 2968/2 = 1484\,kNs/m$$
↳ outer

Καρακορυφο Εδαφιο (settlements of pile foundations)

$R = D/2 = 0.5m$

$r_m = \left[0{,}25 + (2{,}5(1-0{,}5)\frac{G}{G} - 0{,}25)\frac{G}{G}\right] L$

vertical

$r_m = 1{,}25 L = 1{,}25 \cdot 15$

$r_m = 18.8m$

$K_{sv} = \frac{2\pi}{\ln\left(\frac{18.8}{0.5}\right)} (0.5 \cdot 1 \cdot 20000 + 0.5 \cdot 1 \cdot 20000)$

$K_s = 34600 \, kN/m$ ↳ inner

$K_s = 17300 \, kN/m$ ↳ outer

$K_b = \frac{4RG}{1-v}(1{,}27 - 0{,}12 \ln(0.5))$

$= \frac{4 \cdot 0.5 \cdot 20000}{1-0.5}(1{,}27 - 0{,}12 \ln 0.5) \Rightarrow K_b = 108240 \, kN/m$ ↳ base

$C_s = \rho V_s = 1{,}8 \cdot 105 \Rightarrow C_s = 189 \, kPa\frac{s}{m}$

$C_{s,inner} = \pi \cdot 189 \Rightarrow C_{s,inner} = 593 \, kN\frac{s}{m}$

$C_{s,outer} = 593/2 \Rightarrow C_{s,outer} = 297 \, kN\frac{s}{m}$

$C_{s,tot,inner} = 593 + \frac{2 \cdot \overset{k_s}{34600}}{9} 0{,}08 \Rightarrow C_{s,tot,inner} = 1208 \, kN\frac{s}{m}$

$C_{s,tot,outer} = 604 \, kN\frac{s}{m}$

$\overset{base}{C_b} = \frac{3.4R^2}{1-v}\sqrt{\rho G} = \frac{3.4 \cdot 0.5^2}{1-0.5}\sqrt{1.8 \cdot 20000}$

$C_b = 323 \, kN\frac{s}{m}$

Vertical $\rightarrow e_g = 0{,}43$

$F_L = 0{,}64 + 0{,}06\ \frac{5}{1} \le 1 \Rightarrow F_L = 0.94$

$F_{T1} = 0{,}34 + 0{,}11\ \frac{5}{1} \le 1 \Rightarrow F_{T1} = 0.89$

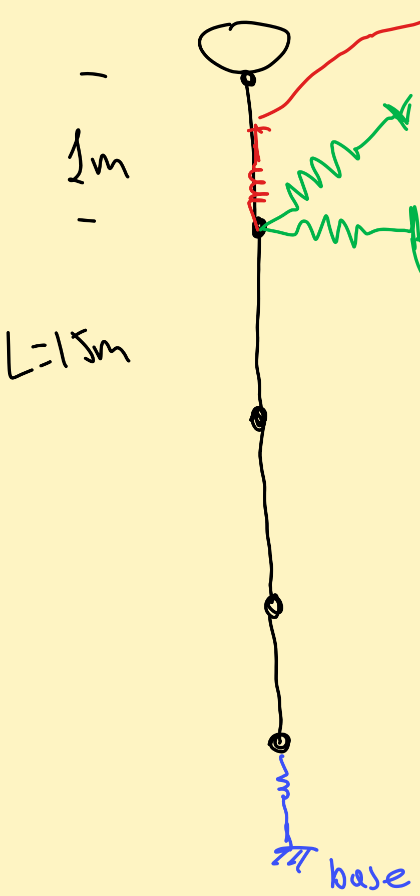
$F_{T2} = 0{,}16 + 0{,}14\ \frac{5}{1} \le 1 \Rightarrow F_{T2} = 0.86$

$F_{T3} = 0{,}04 + 0{,}16\ \frac{5}{1} \le 1 \Rightarrow F_{T3} = 0.84$

$$\left.\begin{array}{l} F_{green} = \frac{0{,}89 + 0.86}{2} \Rightarrow F_{green} = 0.875 \\ F_{red} = \frac{0.94 + 0.84}{2} \Rightarrow F_{red} = 0{,}84 \end{array}\right\} \Rightarrow F = 0{,}88$$

16/11/23

$e_g = 0{,}43 \qquad f = 0{,}88 \qquad (e_g, f \to$ αλληλεπίδραση πασσάλων$)$



$K^{(in)}_{ovr} = 34600$ kN $\to$ 14878 $\to$ outer 17300 kN $\to$ 7439

$C^{(in)}_{ovr,tot} = 1208\ \frac{kNs}{m}$ $\to$ 519 $\to$ 604 $\frac{kNs}{m}$ $\to$ 302

$\Big\}\times e_g$

$K^{(in)}_{hor} = 100200\ kN/m$ $\to$ 88176 $\to$ outer 50100 kN/m $\to$ 49088

$C^{(in)}_{hor,tot} = 2968\ \frac{kNs}{m}$ $\to$ 2612 $\to$ 1484 $\frac{kNs}{m}$ $\to$ 1306

$\Big\} \times 0{,}88$

$$\left.\begin{array}{l} K_b = 108240\ kN/m \\ C_{b,tot} = 323\ \frac{kNs}{m} \end{array}\right) \times e_g$$

SAP file → example_pile_group_class

Base: $K_b = 108240 \cdot 0{,}43 + 7343 = 53982$ kN/m

$C_{b,tot} = 323 \cdot 0{,}43 + 302 = 441$ kNs/m

↳ ορίζοντας τιμές ίδιες αλλαγή μόνο στο U1

Draw 1 joint link

<u>Nicosia</u>

$a_{gR} = 0.205$

$\frac{G}{G_{max}} = 0{,}43$

$G = 20000$ kPa

$G_{max} = \frac{20000}{0.43} \Rightarrow G_{max} = 46512$ kPa

$V_{s,max} = \sqrt{\frac{G_{max}}{\rho}} = \sqrt{\frac{46512}{1.8}} \Rightarrow V_{s,max} = 161$ m/s

↳ D ground type

$S = 1{,}35$

συνδυασμός D + 0,3L + E

Define Mass Source

Define εκκεντρότητα μαζών (5%)

↳ Load case του seismic

Define διαφράγματα

FINAL
13/12/23
6.00 – 9.00 greenPark

23/11/23

Wind Loads

- Νέο Load pattern
- Load Case

30/11/23

Final

↳ multiple choice

↳ Ότι άσκηση δεν έχει SAP

Kinematic Interaction ⇒ μόνο θεωρία

↳ true or false