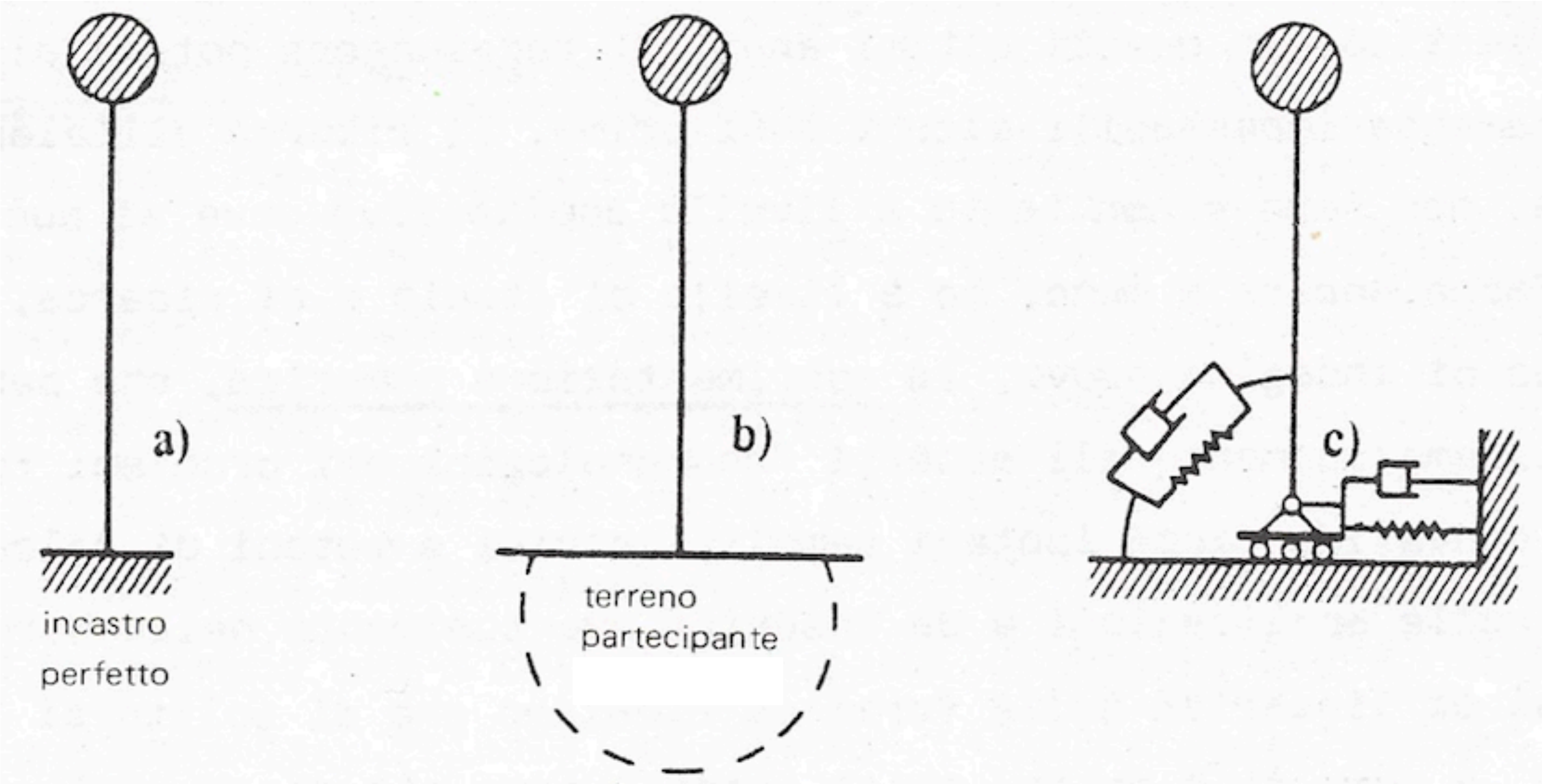
STRUTTURE DI FONDAZIONE E FONDAZIONI

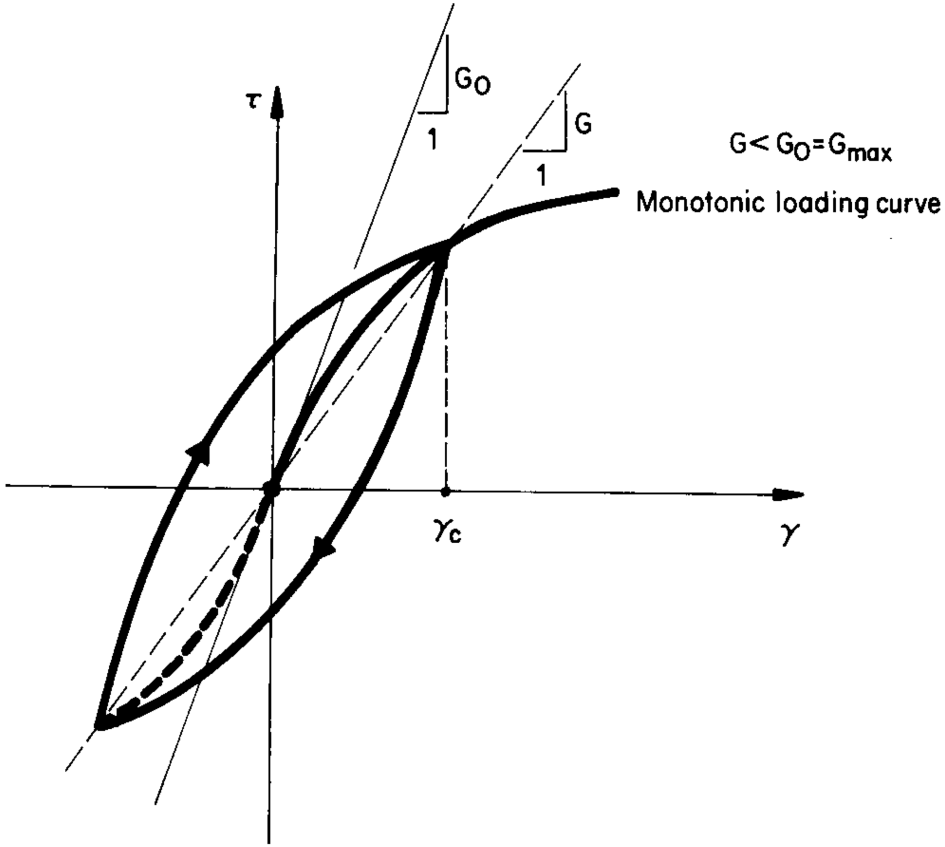
ing. Nunziante Squeglia

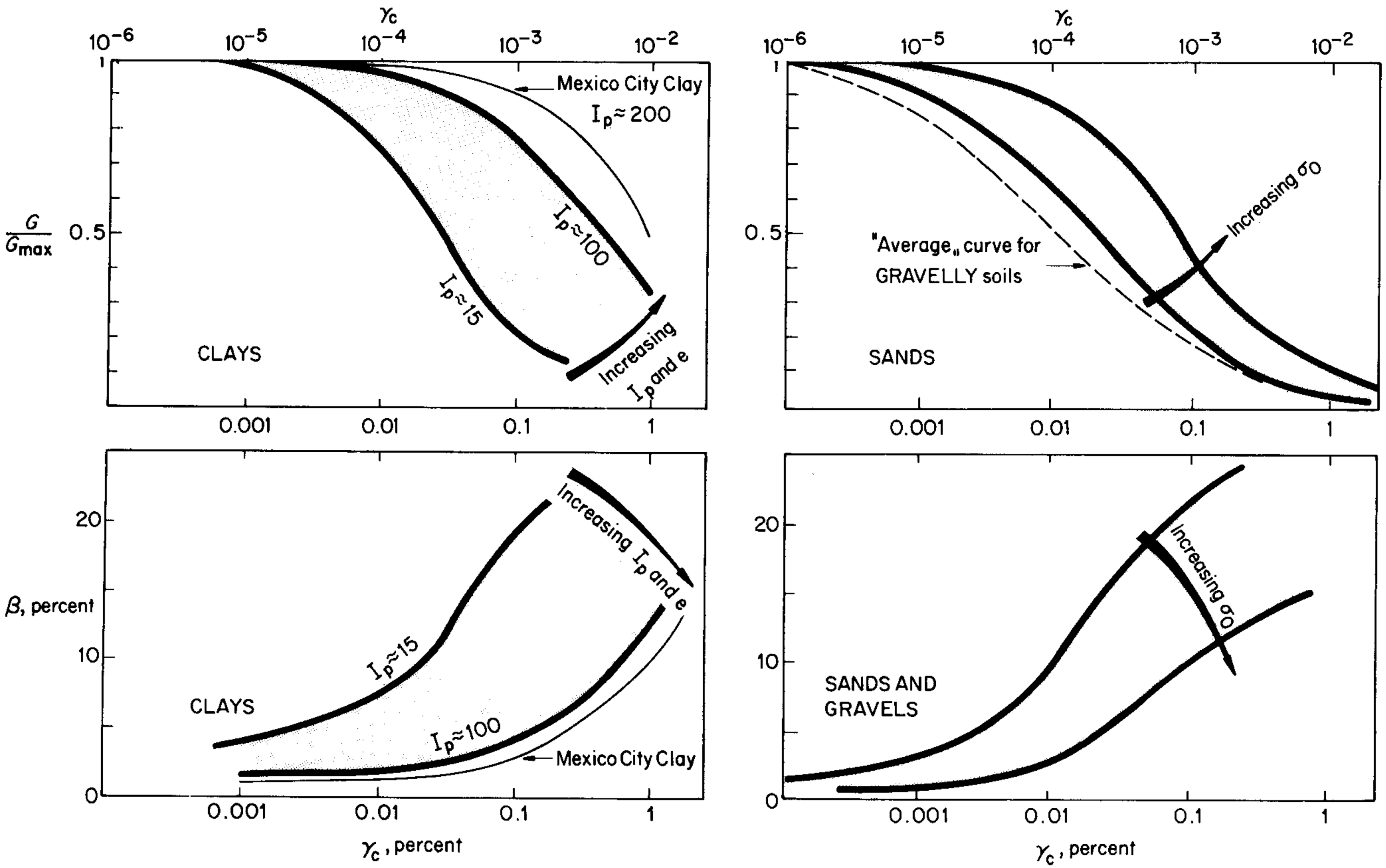
FONDAZIONI SUPERFICIALI
Interazione in campo dinamico

DEFINIZIONE DEL PROBLEMA



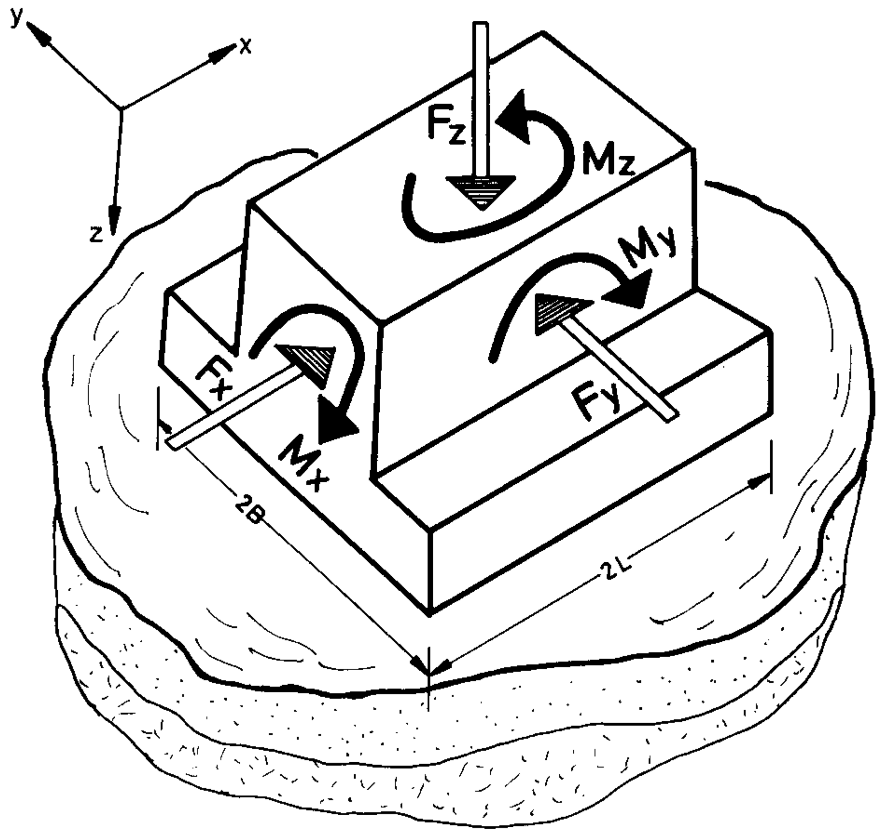
COMPORTAMENTO CICLICO DEL TERRENO



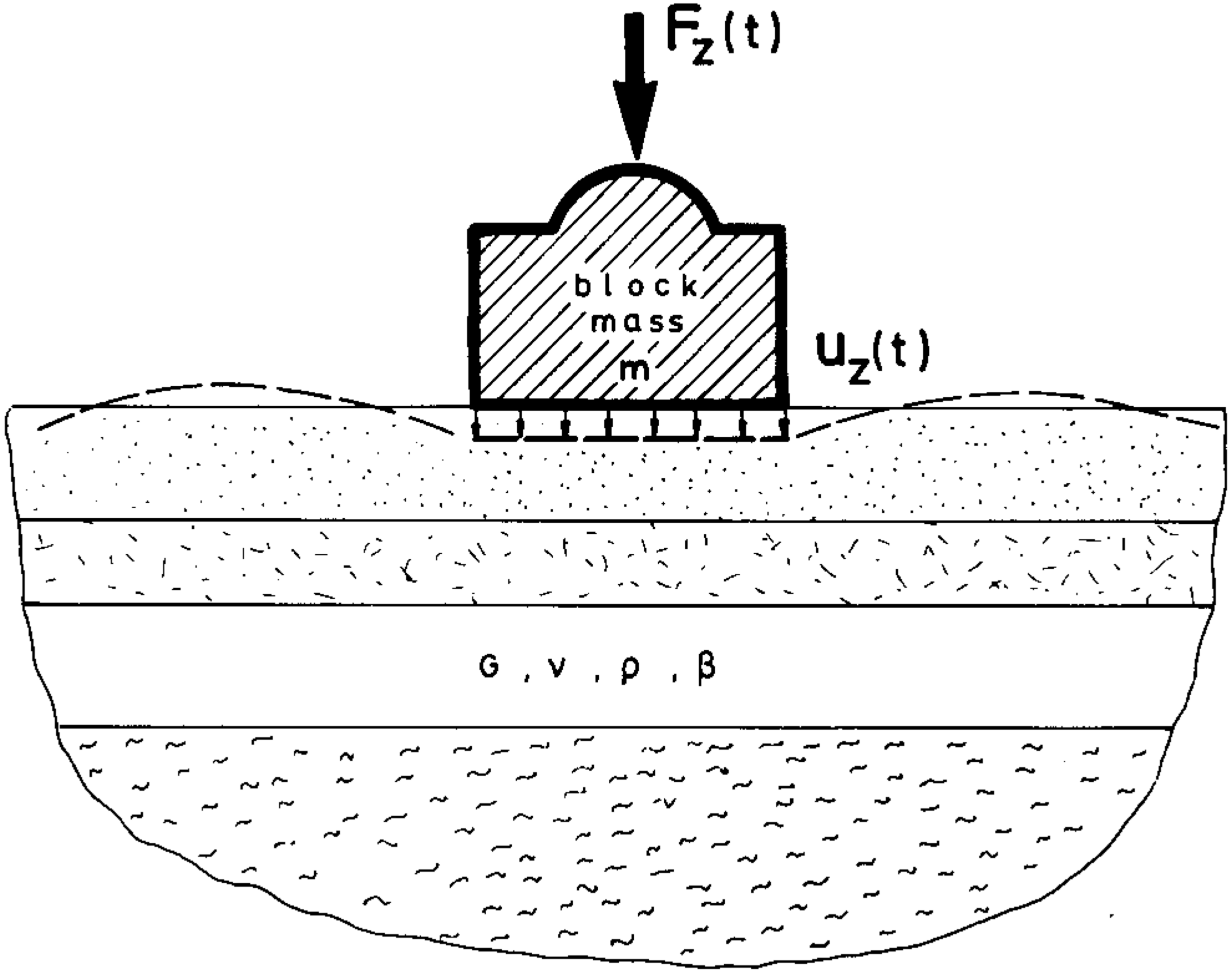


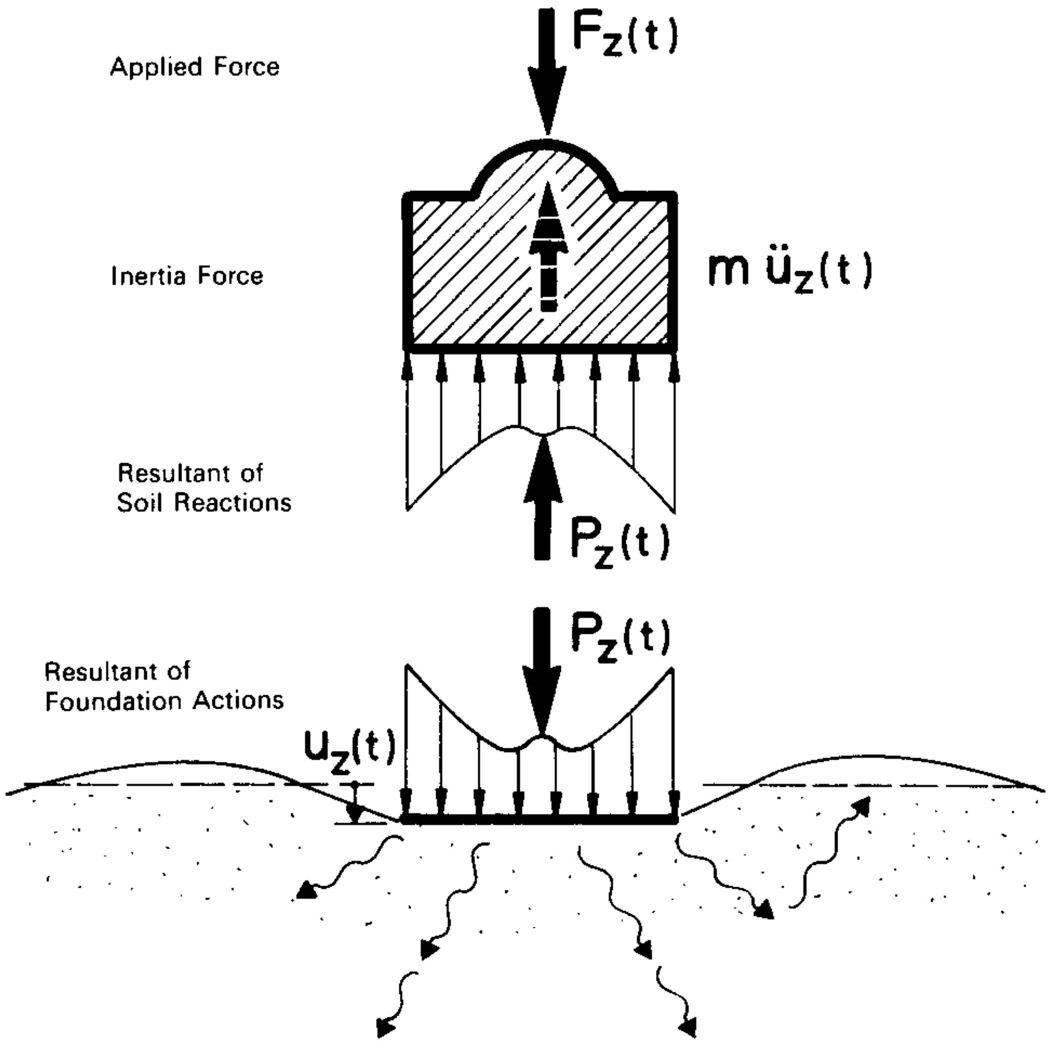
γ_c
10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2}
Mexico City Clay
$I_p \approx 200$
$I_p \approx 100$
$I_p \approx 15$
CLAYS
Increasing I_p and e
$\frac{G}{G_{max}}$
0.5
1
0.001 0.01 0.1 1
"Average" curve for
GRAVELLY soils
Increasing σ_0
SANDS
β, percent
20
10
0
CLAYS
Increasing I_p and e
$I_p \approx 15$
$I_p \approx 100$
Mexico City Clay
SANDS AND
GRAVELS
Increasing σ_0
γ_c, percent

FONDAZIONE RIGIDA E GRADI DI LIBERTA’



CASO DI FORZA VERTICALE




Applied Force
$F_z(t)$
Inertia Force
$m\,\ddot{u}_z(t)$
Resultant of
Soil Reactions
$P_z(t)$
$P_z(t)$
Resultant of
Foundation Actions
$u_z(t)$

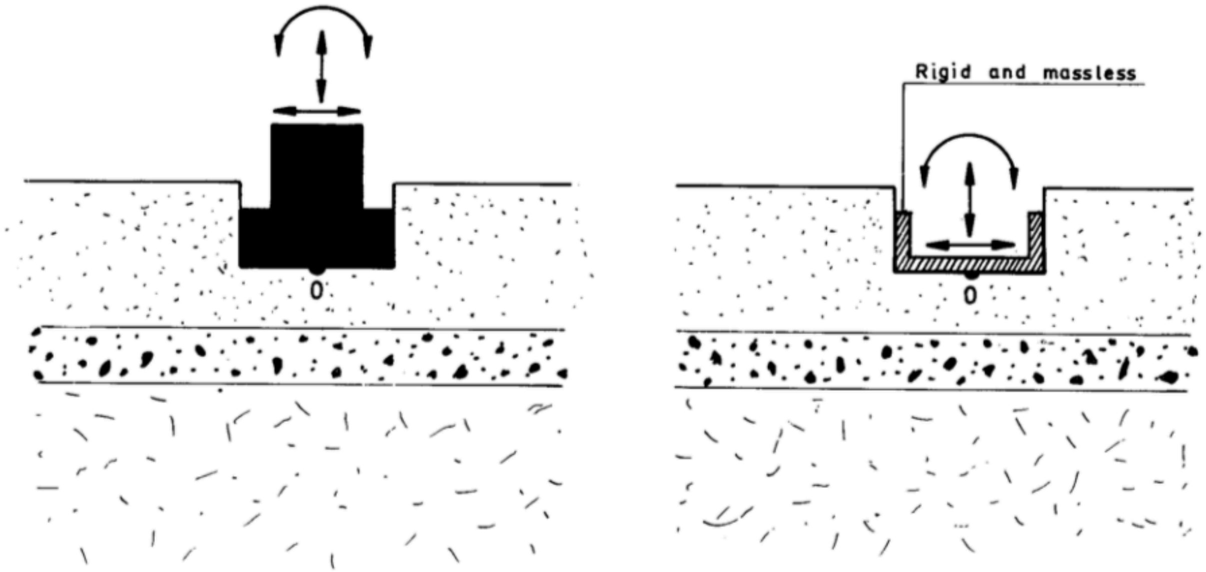
$$P_z(t) + m\ddot{u}_z(t) = F_z(t)$$

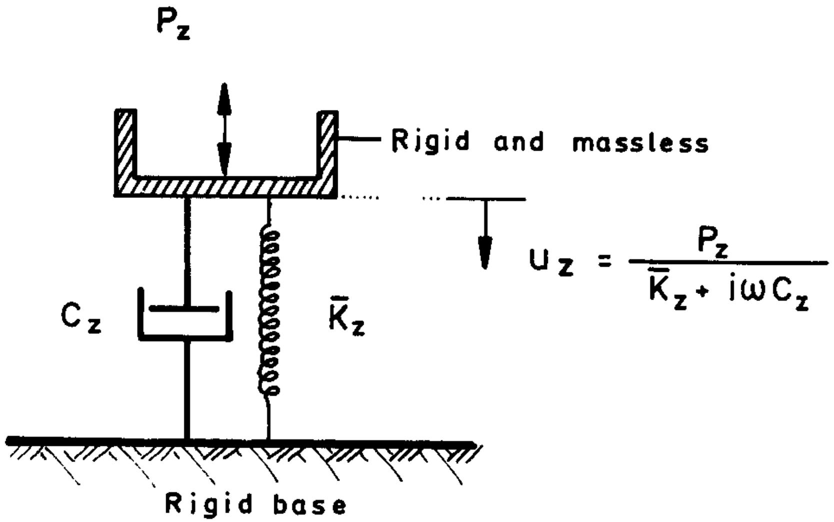
$$P_z(t) = \mathcal{K}_z u_z(t)$$

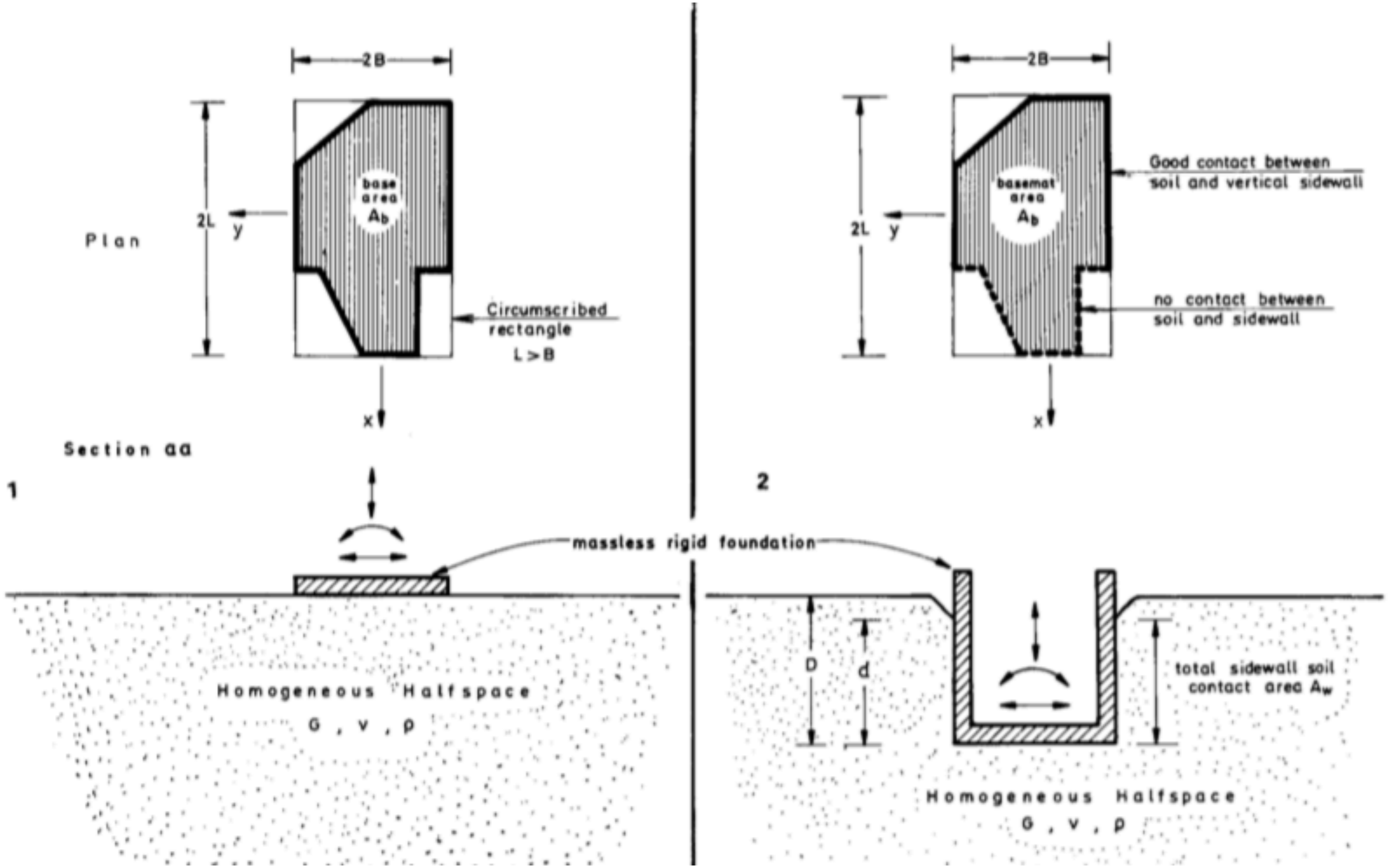
$$\mathcal{K}_z = \bar{K}_z + i\omega C_z$$

$$m\ddot{u}_z(t) + C_z\dot{u}_z(t) + \bar{K}_z u_z(t) = F_z(t)$$

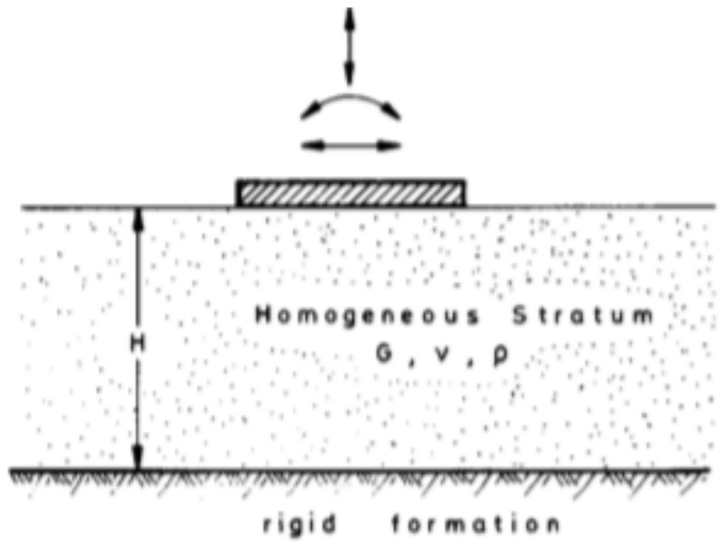
$$[(\bar{K}_z - m\omega^2) + i\omega C_z]\bar{u}_z = F_z$$


0
Rigid and massless
0

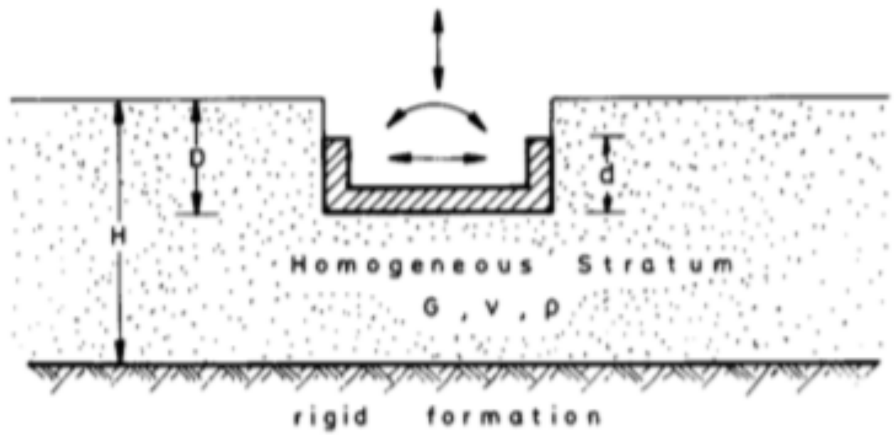

P_z
Rigid and massless
C_z
$\bar{K}_z$
$u_z = \frac{P_z}{\bar{K}_z + i\omega C_z}$
Rigid base

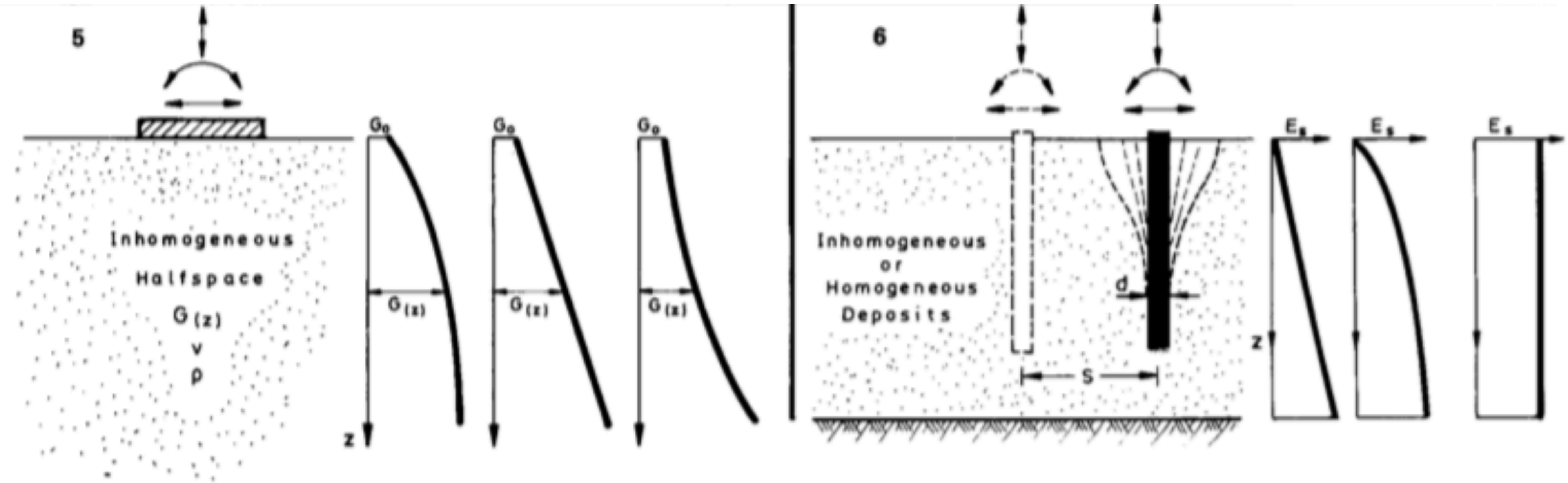

2B
2L
Plan
y
base area A_b
Circumscribed rectangle L > B
x
Section aa
1
massless rigid foundation
Homogeneous Halfspace
G , ν , ρ
2B
2L
y
basemat area A_b
Good contact between soil and vertical sidewall
no contact between soil and sidewall
x
2
D
d
total sidewall soil contact area A_w
Homogeneous Halfspace
G , ν , ρ

3


H
Homogeneous Stratum
G , ν , ρ
rigid formation

4


D
d
H
Homogeneous Stratum
G , ν , ρ
rigid formation



$$G = G_0(1 + \alpha\zeta)^n \qquad \zeta = \frac{z}{B}$$

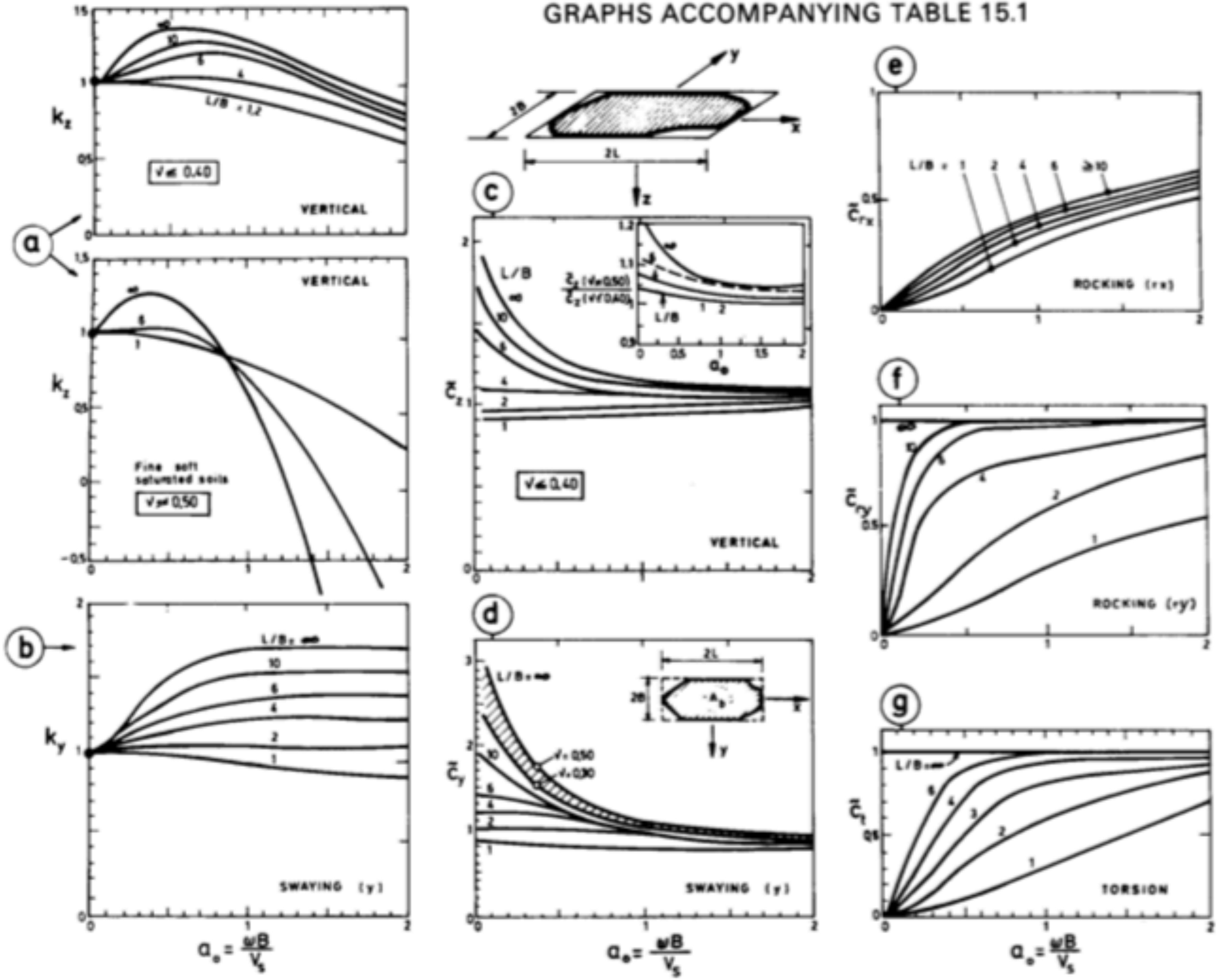
TABLE 15.1 DYNAMIC STIFFNESSES AND DASHPOT COEFFICIENTS FOR ARBITRARILY SHAPED FOUNDATIONS ON THE SURFACE OF A HOMOGENEOUS HALFSPACE.

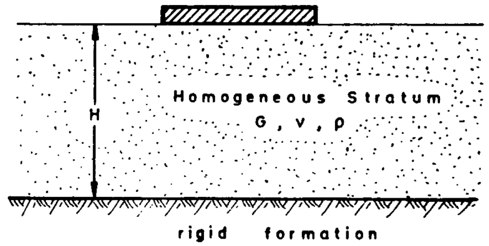
Vibration Mode	Dynamic Stiffness $\bar{K} = K \cdot k(\omega)$ — Static Stiffness K — General Shape (foundation–soil contact surface is of area A_b and has a circumscribed rectangle $2L$ by $2B$; $L > B$)*	Static Stiffness K — Square $L = B$	Dynamic Stiffness Coefficient k (General shape; $0 \leq a_0 \leq 2$)†	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 $L/B \approx 20$.

† $a_0 = \omega B/V_s$.

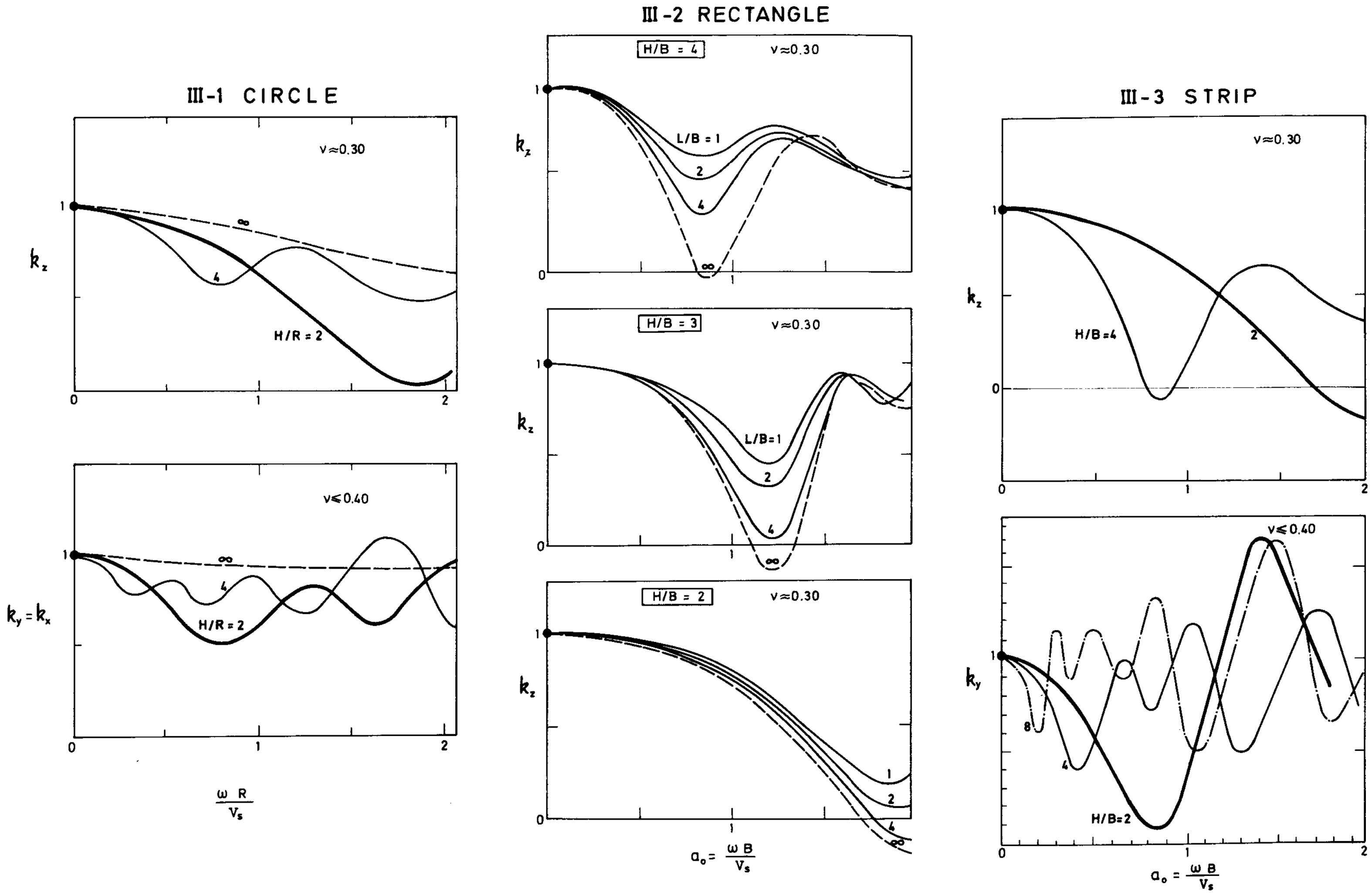
GRAPHS ACCOMPANYING TABLE 15.1





	Foundation Shape	*Circular Foundation of Radius* $B = R$	*Rectangular Foundation 2B by 2L* $(L > B)$	*Strip Foundation* $2L \to \infty$
Static stiffnesses, K	Vertical, z	$K_z = \frac{4GR}{1-\nu}\left(1 + 1.3\frac{R}{H}\right)$	$K_z = \frac{2GL}{1-\nu}\left[0.73 + 1.54\left(\frac{B}{L}\right)^{3/4}\right]\left(1 + \frac{\frac{B}{H}}{0.5 + \frac{B}{L}}\right)$	$\frac{K_z}{2L} \simeq \frac{0.73G}{1-\nu}\left(1 + 3.5\frac{B}{H}\right)$
	Lateral, y	$K_y = \frac{8GR}{2-\nu}\left(1 + 0.5\frac{R}{H}\right)$	*	$\frac{K_y}{2L} \simeq \frac{2G}{2-\nu}\left(1 + 2\frac{B}{H}\right)$
	Lateral, x	$K_x = K_y$	*	—
	Rocking, rx	$K_{rx} = \frac{8GR}{3(1-\nu)}\left(1 + 0.17\frac{R}{H}\right)$	*	$\frac{K_{rx}}{2L} = \frac{\pi G B^2}{2(1-\nu)}\left(1 + 0.2\frac{B}{H}\right)$
	Rocking, ry	$K_{ry} = K_{rx}$	*	—
	Torsional, t	$K_t = \frac{16}{3}GR^3\left(1 + 0.10\frac{R}{H}\right)$	*	—
Dynamic stiffness coefficients, $k(\omega)$	Vertical, z	$k_z = k_z(H/R, a_0)$ is obtained from Graph III-1	$k_z = k_z(H/B, L/B, a_0)$ is plotted in Graph III-2 for rectangles and strip	
	Horizontal, y or x	$k_y = k_y(H/R, a_0)$ is obtained from Graph III-1	*	$k_y = k_y(H/B, a_0)$ is obtained from Graph III-3
	Rocking, rx or ry; Torsional	$k_\alpha(H/R) \simeq k_\alpha(\infty)$, $\alpha = rx, ry, t$	* *	$k_{rx}(H/R) \simeq k_{rx}(\infty)$
Radiation dashpot coefficients, $C(\omega)$	Vertical, z	$C_z(H/B) \simeq 0$ at frequencies $f < f_c$, regardless of foundation shape $C_z(H/B) \simeq 0.8C_z(\infty)$ at $f \geqslant 1.5f_c$ At intermediate frequencies: interpolate linearly. $f_c = \frac{V_{La}}{4H}$, $V_{La} = \frac{3.4V_s}{\pi(1-\nu)}$		
	Lateral, y or x	$C_y(H/B) \simeq 0$ at $f < \frac{3}{4}f_s$; $C_y(H/B) \simeq C_y(\infty)$ at $f > \frac{4}{3}f_s$ At intermediate frequencies: interpolate linearly. $f_s = V_s/4H$. Similarly for C_x		
	Rocking, rx or ry	$C_{rx}(H/B) \simeq 0$ at $f < f_c$; $C_{rx}(H/B) \simeq C_{rx}(\infty)$ at $f > f_c$. Similarly for C_{ry}		
	Torsional, t	$C_t(H/B) \simeq C_t(\infty)$		

* Not available.


III-1 CIRCLE
III-2 RECTANGLE
III-3 STRIP
ν≈0.30
ν≤0.40
H/R = 2
H/B = 4
H/B = 3
H/B = 2
L/B = 1
H/B=4
H/B=2
k_z
$k_y = k_x$
k_y
ωR/Vs
$a_o = \frac{\omega B}{V_s}$

Annex D (Informative)

Dynamic soil-structure interaction (SSI). General effects and significance

D.l As a result of dynamic SSI, the seismic response of a flexibly-supported structure, i.e. a structure founded on deformable ground, will differ in several ways from that of the same structure founded on rigid ground (fixed base) and subjected to an identical free-field excitation, for the following reasons:

a) the foundation motion of the flexibly-supported structure will differ from the free-field motion and may include an important rocking component of the fixed-base structure;

b) the fundamental period of vibration of the flexibly-supported structure will be longer than that of the fixed-base structure;

c) the natural periods, mode shapes and modal participation factors of the flexibly-supported structure will be different from those of the fixed-base structure;

d) the overall damping of the flexibly-supported structure will include both the radiation and the internal damping generated at the soil-foundation interface, in addition to the damping associated with the superstructure.

D.2 For the majority of common building structures, the effects of SSI tend to be beneficial, since they reduce the bending moments and shear forces in the various members of the superstructure. For the structures listed in Section **6** the SSI effects might be detrimental.

6 SOIL-STRUCTURE INTERACTION

(l)P The effects of dynamic soil-structure interaction shall be taken into account in:

a) structures where P-δ (2nd order) effects play a significant role;

b) structures with massive or deep-seated foundations, such as bridge piers, offshore caissons, and silos;

c) slender tall structures, such as towers and chimneys, covered in EN 1998-6:2004;

d) structures supported on very soft soils, with average shear wave velocity $v_{s,max}$ (as defined in Table 4.1) less than 100 m/s, such as those soils in ground type S_1.

Parametri del terreno: $G\max = \rho \cdot V_S^2$

influenza del livello deformativo: curva di decadimento EC8-5

Accelerazione di picco $a_{g,max}$	Rapporto di smorzamento	$\frac{v_s}{v_{s,\max}}$	$\frac{G}{G_{\max}}$
0,10	0,03	$0{,}9(\pm 0{,}07)$	$0{,}80(\pm 0{,}10)$
0,20	0,06	$0{,}7(\pm 0{,}15)$	$0{,}50(\pm 0{,}20)$
0,30	0,10	$0{,}6(\pm 0{,}15)$	$0{,}35(\pm 0{,}20)$

Bisogna tenere conto di

- **smorzamento meccanico (material damping)**
- **smorzamento geometrico (radiation damping)**