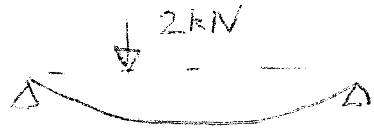
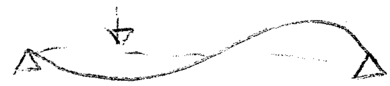
1. (a) SRSS = method of superposition based on taking the square root of the sum of the squares of the maximum response in each mode.
Unsafe if there is interaction between closely spaced natural frequencies
Alternatives are to i) superpose the absolute values of the maximum responses or ii) to superpose the actual complete time histories for each mode

(b) First two natural modes are given below:

Mode 1 $u_1 = \sin\frac{\pi x}{L}$

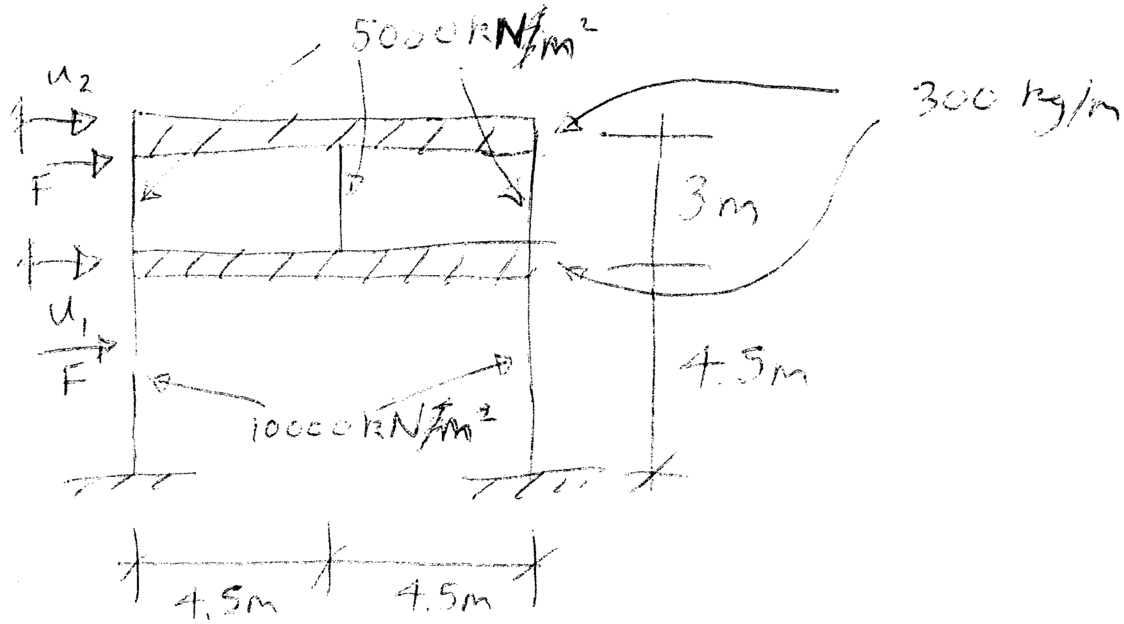


Mode 2 $u_2 = \sin\frac{2\pi x}{L}$

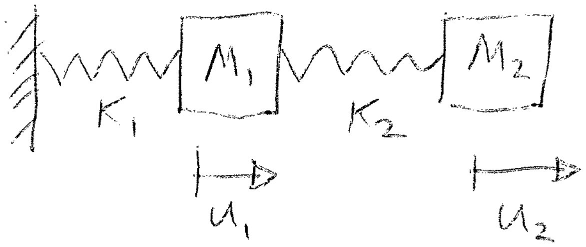


Properties of equivalent SDOF systems (Data Sheet)

	Mode 1	Mode 2
M_{ieq}	$=\frac{mL}{2} = \frac{300\times 6}{2} = 900\,kg$	$900\,kg$
K_{ieq}	$\frac{\pi^4 EI}{2L^3} = \frac{\pi^4\times 150}{2\times 6^3} = 33.8\,kN/m$	$\frac{(2\pi)^4 EI}{2L^3} = 541\,kN/m$
F_{ieq}	$Fu_{1B} = F\frac{\sin \pi L/4}{L} = \cancel{14.14\,kN}$ $1.414\,kN$	$Fu_{2B} = F\frac{\sin 2\pi L/4}{L} = \cancel{20\,kN}$ $2\,kN$
T_i	$2\pi\sqrt{\frac{M_{1eq}}{K_{1eq}}} = 1.03\,s$	$2\pi\sqrt{\frac{M_{2eq}}{K_{2eq}}} = 0.256$
t_d/T_i	$\frac{0.2}{1.03} = 0.097\times 2 = 0.19$	$\frac{0.2}{0.256} = 0.39\times 2 = 0.78$
DAF (data sheet)	$\cancel{1.95}$ 1.9	$\cancel{1.7}$ 1.3
Max. defl @ B	$\frac{F_{1eq}}{K_{1eq}} DAF\,u_{1B} = \cancel{0.\ldots m}$ $0.0562\,m$	$\frac{F_{2eq}}{K_{2eq}} DAF\,u_{2B} = 0.0048\,m$



Equivalent 2 DOF system



$M_1 = M_2 = 2700t$

$$K_1 = 2 \times \frac{12EI}{h^3} = 2 \times \frac{12 \times 10000}{(4.5)^3} = 2634 \text{ kN/m}$$

$$K_2 = 3 \times \frac{12EI}{h^3} = 3 \times \frac{12 \times 5000}{3^3} = 6667 \text{ kN/m}$$

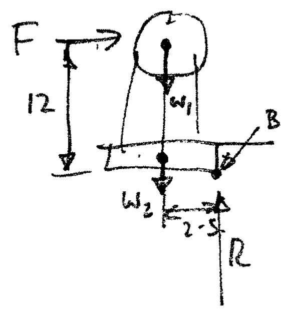
Static deflections:

$$u_1 = \frac{2F}{K_1} = \frac{2F}{2634} = \frac{F}{1317} \qquad u_2 = \frac{F}{K_2} + u_1 = \frac{F}{6667} + u_1$$

Normalising to a unit displacement of the top storey the following mode shape is assumed:

$$\begin{bmatrix} \bar{u}_1 \\ \bar{u}_2 \end{bmatrix} = \begin{bmatrix} 0.835 \\ 1 \end{bmatrix}$$

3 ~~(a)~~ i) Overturning stability



$F.12 = (W_1 + W_2)\,2.5$

$W_1\ min = 160\ kN$

$W_2 = 24\ kN/m^3 \times 25\,m^2 \times 0.5 = 300\ kN$

$W_1 + W_2 = 460\ kN.$

$F = 460 \times \frac{2.5}{12} = \underline{19.2\ kN}$

$\frac{1}{2}\rho V^2 C_D A = 19.2\ kN$

$A = \frac{\pi D^2}{4} = 19.6\ m^2$

$V^2 = \frac{2\,(19.2 \times 10^3\ N)}{1.2\,(0.8)(19.6)} = 2036$

$\therefore \underline{\underline{V = 45\ m/s}}$

ii) $V = \sqrt{\frac{G}{\rho}}$ shear wave velocity.

$G = \rho V^2 = 1800\,(120)^2 = 25.9\ MPa$

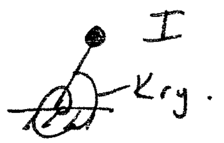
Need rotational inertia of system about base.

Raft inertia $\approx$ "$\left(\frac{bd^3}{12}\right)$" $\times\ l \times \rho$

$= \frac{0.5 \times 5^3 \times 5}{12} \times 2400 = 62\,500\ kg\,m^2$

Full tank inertia $\simeq 80{,}000\,kg \times (12\,m)^2 = 11.5 \times 10^6\ kg\,m^2$ + small terms.

Need K_{ry}



3 (cont'd)

$$K_{ry} = \frac{Gb^3}{1-\nu}\left[3.73 + 0.27\right]\left[1 + \frac{0.5}{2.5} + \frac{16}{(0.35+1)}\left(\frac{0.5}{2.5}\right)^2\right]$$

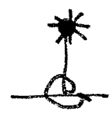
$$= \frac{G(2.5)^3}{0.7}\left[4\right]\underbrace{\left[1 + 0.2 + \frac{16}{1.35}(0.04)\right]}_{1.6741}$$

$$=$$

$$= \cancel{kg}\ \underline{149\,G} \qquad G = 25.92 \times 10^6\ N/m^2$$

$$= 3874 \times 10^6\ N/m^2 \times m^3$$

$$= \underline{3874 \times 10^6\ Nm} \quad = kg\,m^2 s^{-2}$$

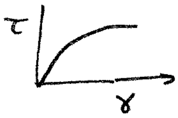


$$I = \cancel{kg\,m^2}\quad 11.5 \times 10^6\ kg.m^2.$$

$$\omega = \sqrt{\frac{K_{ry}}{I}} = \sqrt{\frac{3874 \times 10^6}{11.5 \times 10^6}} = 18.3\ rads/s.$$

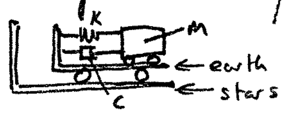
$$f = \frac{\omega}{2\pi} = \underline{2.92\ Hz}$$

May fall from this value due to i) degradation of sheer modulus under increasing sheer strain



(even if dry)

ii) decrease in effective stress due to contraction ~~...~~ of loose sand causing high pore water pressures which cannot dissipate on time-scale of earthquake.

4(a) Displacement response spectrum is peak response from set of oscillators 

subject to an earthquake (or a series of earthquakes) – each normalised to have peak ground acceleration of $1 m/s^2$ say. Peak response is plotted against natural frequency of system $\sqrt{k/m} \equiv \omega$.

Pseudo-velocity response spectrum is just displacement response spectrum × ω. (–and it is not actually the peak velocity (neither absolute nor relative) – (but probably close to each in some sense)).

–i.e. it is defined via displacement response spectrum,

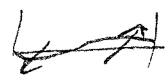
(b) In <u>loose</u> sandy soils, the application of shear strains and shaking can cause them to compact, thereby increasing soil pore water pressures in the voids which do not have time to dissipate. Stiffness and strength of soil depend on effective stress = total stress – pore water pressure. Therefore, for large pore water pressure effective stress can reach zero → soil has no stiffness and full. liquefies. Partial liquefaction is just when effective stress reduces sufficiently for stiffness to degrade a lot, but not fully to zero

c) Aerodynamic admittance is like an areal reduction factor which takes account of fact that pressure fluctuations are not fully correlated across ~~one~~ frontal area (of building, say). It is frequency-dependent, reflecting fact that low freq. eddies are larger, and may fully envelope building whereas high freq. pressure fluctuations come from small eddies which may average to close to zero over the frontal area.

Concept limits – takes no account of front and <u>rear</u> pressures (ie what's happening in bluff body wake).

– also assumes that the structural displacements are small and velocities are small cf. wind speed

– also really only applies to a rigid block – doesn't really apply when structure has a nontrivial mode shape

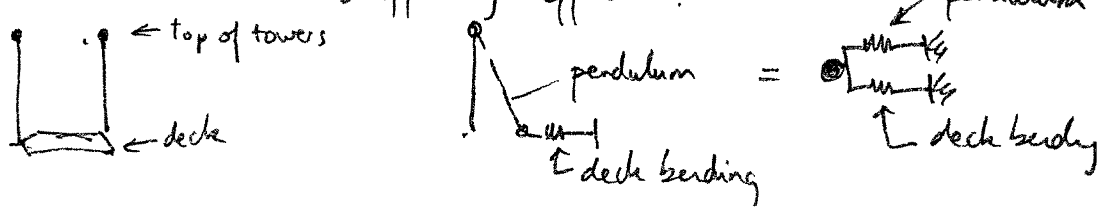
eg. suspension bridge 

Wind engineers do not use response spectrum because that can't take account of spatial decorrelation of pressure fluctuations.

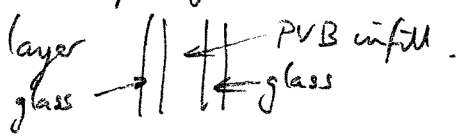
d) – Bridge decks are typically bluff, so have more complex wakes, separation/reattachment etc.

– quasistatic assumptions not always valid. Time-scale of oscillations comparable to time-scale for wind "particle" to pass across the structure (– hence "memory effects").

e) Many suspension bridges are mechanisms to 1st order structural analysis and obtain a significant part of their stiffness from "2nd order" tension-stiffening effects.



f). Stand-off distance for vehicles, sloping faces, reinforced concrete detailing of joints similar to seismic regions for robustness, etc.

~~Many~~ Main source of injuries in cities is flying glass, ~~so use~~ – many options, but best is three layer 

(– needs strong window panes
– structurally engineered).

g) Missiles puncture walls and shatter windows.

Dominant openings on ~~the~~ upwind side can lead to large positive internal pressures which, combined with suction pressures externally from flow over roof, can lift the roof off.