



**Earthquake Engineering Research Centre**  
**International Institute of Information Technology**  
**Gachibowli, Hyderabad – 500 032, India**

**Theory:**

Equation of motion excluding damping forces

$$m\ddot{u} + ku = -m\ddot{u}_g$$

For two way unsymmetrical system;

$$\begin{pmatrix} m & 0 & 0 \\ 0 & m & 0 \\ 0 & 0 & I_o \end{pmatrix} \begin{Bmatrix} \ddot{u}_x \\ \ddot{u}_y \\ \ddot{u}_\theta \end{Bmatrix} + \begin{pmatrix} k_{xx} & 0 & k_{x\theta} \\ 0 & k_{yy} & k_{y\theta} \\ k_{\theta x} & k_{\theta y} & k_{\theta\theta} \end{pmatrix} \begin{Bmatrix} u_x \\ u_y \\ u_\theta \end{Bmatrix} = - \begin{Bmatrix} m\ddot{u}_{gx}(t) \\ m\ddot{u}_{gy}(t) \\ I_o\ddot{u}_{g\theta}(t) \end{Bmatrix}$$

Where

$$I_o = \frac{m(b^2 + d^2)}{12}$$

$$k_{xx} = k_1 + k_3$$

$$k_{yy} = k_2 + k_4$$

$$k_{x\theta} = k_{\theta x} = (k_3x_3 - k_1x_1)$$

$$k_{y\theta} = k_{\theta y} = (k_4x_4 - k_2x_2)$$

$$k_{\theta\theta} = k_3x_3^2 + k_1x_1^2 + k_4x_4^2 + k_2x_2^2$$

If the system is symmetric about x-axis then  $k_{x\theta} = k_{\theta x} = 0$

If the system is symmetric about y-axis then  $k_{y\theta} = k_{\theta y} = 0$