Module 7 : Design of Machine Foundations

Lecture 32 : Machine foundation [Section 32.1 : Introduction]

Objectives

In this section you will learn the following

- Categories of machine foundations
- Types of Machine Foundations
- Criteria for the Design of Machine Foundations

Categories of machine foundations

- **Reciprocating machines:**

  It produces periodic unbalanced force and operating frequency is 600rpm. For designing unbalanced force is taken as varying sinusoidally.

- **Impact machines**

  It produces impact loads at an operating frequency of 60-150 blows/min. Dynamic load attends the peak within short duration and then die out quickly. Designed as over tuned.

- **Rotary machines:**

  These are high speed machines with high operating frequency. Hence the foundations are designed as under tuned.

Types of Machine Foundations

- Block type
- Caisson type
- Wall type

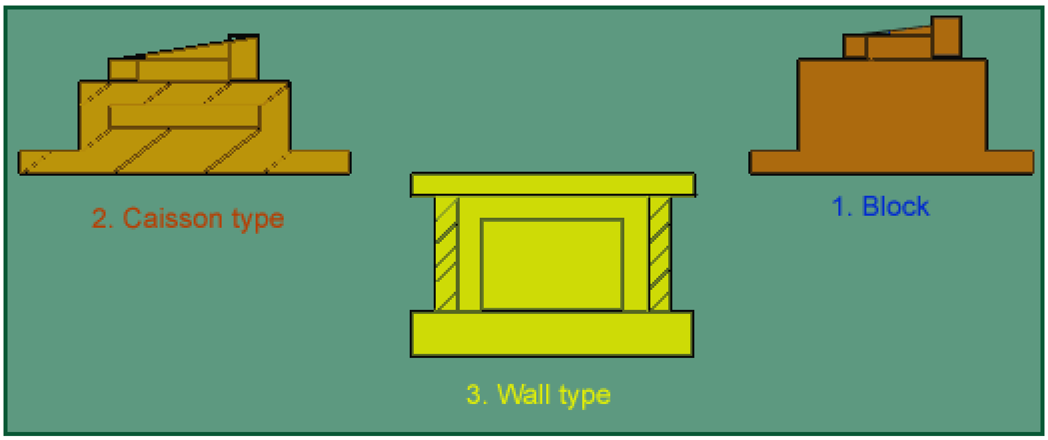


Figure 8.14 Types of Machine Foundations

Criteria for the Design of Machine Foundations

1. **Static Loading**

   Without shear failure

   Without any excessive settlement

2. **Dynamic loading**

- No resonance

  As per 2974 part1, $r<0.5$ (under tuned)
  $r>0.5$ (over tuned)

- The amplitude of motion should not exceed limiting amplitude. Permissible amplitude is 0.2mm.
- Vibrations must not be annoying to the persons working in factory or surroundings.

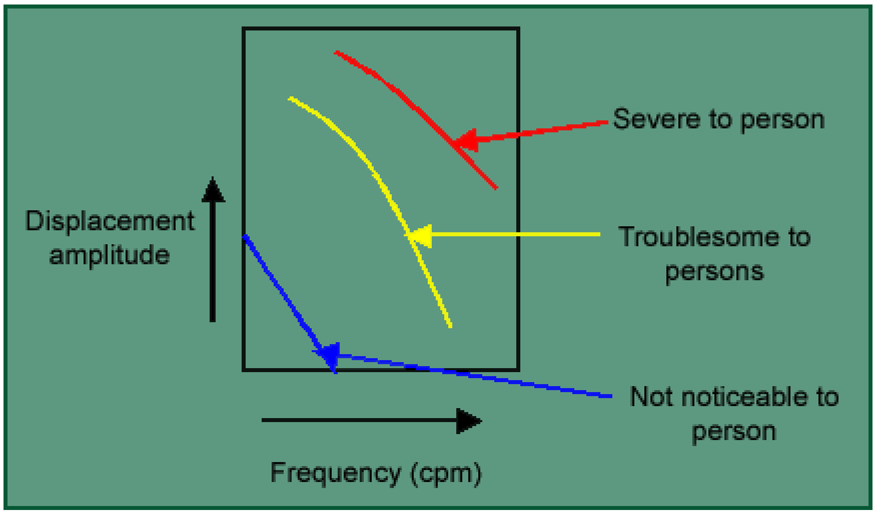


Fig. 8.15 Displacement amplitude vs. frequency (Richard 1962)

Recap

In this section you have learnt the following.

- Categories of machine foundations
- Types of Machine Foundations
- Criteria for the Design of Machine Foundations

Objectives

In this section you will learn the following

- Linear elastic weightless spring MSD model
- Linear elastic theory

Method of Analysis

1. linear elastic weightless spring MSD model
2. linear elastic theory

Degrees of freedom for block type foundation

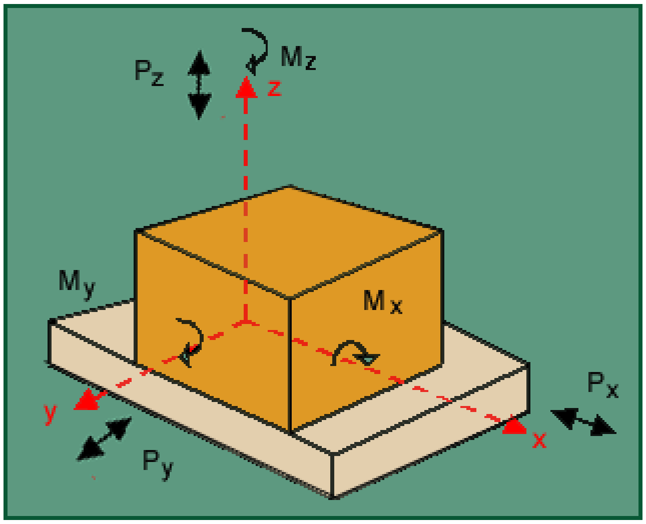
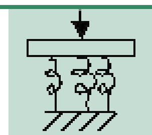
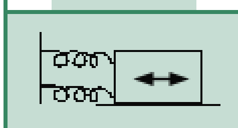
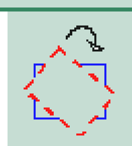
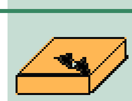


Figure 8.16 Degrees of freedom for block type foundation

Linear Elastic Weightless Spring MSD Model

	$\omega_{nz} = \sqrt{\frac{k_z}{m}}$	Vertical vibration
	$\omega_{nx} = \sqrt{\frac{k_x}{m}}$	Horizontal vibration
	$\omega_{n\phi} = \sqrt{\frac{k_{n\phi}}{Mm_0}}$	Rocking
	$\omega_{n\psi} = \sqrt{\frac{k_{n\psi}}{Mm_z}}$	Yawing

Coefficient of uniform elastic compression C_u

$$C_u = \frac{P}{S_e}, \; k_z = C_u A$$

A=area of test plate

Coefficient of linear elastic shear C_i

$$C_i = \frac{\tau}{S_e'}, \; k_x = C_\tau A$$

Barken (1962) proposed the following values:

C_u =2 C_z, C_ϕ =2 C_u, $C_\tau = 1.5 C_\psi$

According to IS: 5249:

$C_u = 1.73 C_\tau$, C_ϕ =2 C_u

Vertical Vibration of the Block

$$P_z = P_0 \sin \omega t$$

$$m\ddot{z} + k_z z = P_0 \sin \omega t$$

$$\omega_{nz} = \sqrt{\frac{C_u A}{m}}$$

$A = \dfrac{P_z \sin \omega t}{m(\omega_{nz}^2 - \omega^2)}$, maximum amplitude $A_z = \dfrac{P_z}{m(\omega_{nz}^2 - \omega^2)}$

Sliding Vibration of the Block

$$P_x = P_0 \sin \omega t$$

$$m\ddot{x} + k_x x = P_0 \sin \omega t$$

$$\omega_{nx} = \sqrt{\frac{C_x A}{m}}$$

$A_x = \dfrac{P_x \sin \omega t}{m(\omega_{nx}^2 - \omega^2)}$, maximum amplitude $A_x = \dfrac{P_x}{m(\omega_{nx}^2 - \omega^2)}$

Linear Elastic Theory

Table 8.2 Analysis by Lysmer and Richart (1966)

Mode of vibration	Mass ratio	Damping factor/ratio	Spring constant
Vertical	$B_z = \dfrac{1-\nu}{4}\dfrac{m}{\rho r_0^3}$	$\xi_z = \dfrac{0.425}{\sqrt{B_z}}$	$k_z = \dfrac{4Gr_0}{1-\nu}$
Sliding	$B_x = \dfrac{7-8\nu}{32(1-\nu)}\dfrac{m}{\rho r_0^3}$	$\xi_x = \dfrac{0.2875}{\sqrt{B_x}}$	$k_x = \dfrac{32(1-\nu)Gr_0}{7-8\nu}$
Rocking	$B_\phi = \dfrac{3(1-\nu)}{8}\dfrac{I}{\rho r_0^3}$	$\xi_x = \dfrac{0.15}{(1+\beta_\phi)\sqrt{\beta_\phi}}$	$k_\phi = \dfrac{8Gr_0^3}{3(1-\nu)}$
Torsional	$B_\psi = \dfrac{J_z}{\rho r_0^5}$	$\xi_\psi = \dfrac{0.5}{(1+2\beta_\psi)}$	$k_\psi = \dfrac{16}{3Gr_0^3}$

r 0= radius of equivalent circular area of the foundation

Shear wave velocity $v_s = \sqrt{\dfrac{G}{\rho}}$

Vertical Vibration of the Block

$$b = \frac{m}{\rho r_0^3} = \frac{W}{\rho r_0^3 g}, \quad a_0 = \omega_n r_0 \sqrt{\frac{\rho}{G}} = \frac{2\pi f_n r_0}{v_s}$$

Vertical Vibration of the Block

$$b = \frac{m}{\rho r_0^3} = \frac{W}{\rho r_0^3 g}, \quad a_0 = \omega_n r_0 \sqrt{\frac{\rho}{G}} = \frac{2\pi f_n r_0}{v_s}$$

Equation of Vertical Motion:

$$m\ddot{z} + \left[\frac{3.4}{1-\nu} r_0^2 \sqrt{G\rho}\right]\dot{z} + \left(\frac{4Gr_0}{1-\nu}\right) z = P_0(t)$$

$$C_c = 2\sqrt{km} = 2\sqrt{\frac{4Gr_0}{1-\nu} m}$$

$$\xi_z = \frac{c}{C_c} = \frac{0.85}{\sqrt{1-\nu}} = \frac{1}{\sqrt{b}}$$

Sliding Vibration of the Block

$$k_x = \frac{32(1-\nu)Gr_0}{7-8\nu}$$

$$c = \frac{18.4(1-\nu)r_0^2}{7-8\nu}\sqrt{\rho g}$$

Recap

In this section you have learnt the following.

- Linear elastic weightless spring MSD model
- Linear elastic theory