

SCOPE

- I 1.1 This practice covers the design and testing of supporting structures and foundations for heavy machinery. **Heavy machinery** is any equipment having reciprocating or rotary masses as the major moving parts (such as compressors, pumps, engines, and turbines), and having a total weight greater than 5,000 lbs (2270 kg).
- I 1.2 An asterisk (*) indicates that additional information from the Owner, or approval by the Owner, is required.

SUMMARY OF ADDITIONAL REQUIREMENTS

- I 2.1 **Table 1** lists the practices which shall be used as specified in this practice.
- I 2.2 **Table 2** lists the standard which shall be used with this practice as applicable.

TABLE 1

PRACTICES	
IP 4-1-1	Concrete Design and Construction
IP 4-6-1	Reinforced Concrete Foundations and Anchor Bolts

TABLE 2

STANDARD	
ACI Standard 207	Mass Concrete

DESIGN

GENERAL

- R 3.1 A dynamic analysis shall be performed on all foundations and structures supporting heavy machinery.
- R 3.2 **Dynamic analysis** shall be as follows:
 - a. For **shallow foundations** (slabs and mats), the **response of the soil subject to dynamic loadings** shall be based on "Elastic Half Space Model" theory.
 - * b. The method for determining the **response of piled foundations** subject to dynamic loadings shall be subject to the approval of the Owner.
 - c. The **dynamic modulus of elasticity** of concrete, E or E' , for use in dynamic analysis shall be:

$$E = 79,000 \sqrt{f'_c}$$
 where f'_c = 28 day standard cylinder compressive strength, psi

$$(E' = 6,550 \sqrt{f'_c}, \text{ for } f'_c \text{ in MPa})$$
 - d. **For analyses based on one or two degrees of freedom models**, all damped natural frequencies shall be out of the range of 0.8 to 1.2 times the machine operating speeds. **For multi-degrees of freedom analyses**, frequencies associated with modes with effective mass greater than 5% of the total mass of the model shall be out of the range of **0.8 to 1.2** times the operating speeds.
 - e. **Soil properties for use in the analysis** shall be based on the results of a soils investigation. The foundation system shall be analyzed considering a range of soil shear modulus values from 0.5 to 1.5 times the nominal value. If the nominal soil shear modulus is determined by a direct soil testing method acceptable to the Owner's Engineer such as a cross-hole field measurement or resonant column test, the range may be reduced to 0.75 to 1.25 times the nominal value.
 - f. **Geometric damping**, when used, shall not exceed 2/3 of the theoretical value nor 0.7 for all modes.

IP 4-6-2	Supporting Structures and Foundations for Heavy Machinery	 INTERNATIONAL PRACTICE
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- R 3.3 **Concrete design and construction** shall be per [IP 4-6-1](#) and [IP 4-1-1](#) and the following:
- The effects of **shrinkage and thermal expansion** shall be taken into account. To prevent cracking, minimum concrete reinforcing shall be 84 lb/cu yd (50 kg/m³), except for the foundation slab, which shall be at least 50 lb/cu yd (30 kg/m³). Reinforcing steel shall be placed on all faces of the foundation base slab and/or block. An intermediate layer of two-way reinforcing is required when the thickness exceeds 5 ft (1.5 m). Spacing between horizontal layers shall not exceed 3.25 ft (1 m). The interior of blocks with least horizontal dimension more than 5 ft (1.5 m) shall be reinforced with vertical bars spaced no more than 3.25 ft (1 m) between bars.
 - When the least dimension of a concrete foundation is greater than 4 ft (1.2 m), concrete construction and temperature control shall be per ACI 207, Mass Concrete, to prevent thermally induced cracking during hydration.

- R,O 3.4 **Foundation configuration** shall be as follows:
- Foundation design** shall consist of clean simple lines. Beams, columns and slabs shall be of uniform rectangular shapes. Pockets where vapors could accumulate are not permitted. Provision shall be made to drain oil and rainwater from under the equipment. Sufficient space shall be provided for installation, maintenance, operation, piping and anchor bolts.
 - The **thickness of the foundation slab** in feet (m), shall not be less than:

$$2 + \frac{L}{30} \left(0.6 + \frac{L}{30} \right)$$

where:

For one machinery train:

L = longest dimensions of the foundation slab, ft (m)

For two or more machinery trains supported off a common foundation:

L = greater of: **the least dimension** of the common slab, or,
the longest slab segment assigned to any one train, ft (m)

- The **height of support above grade** shall be the minimum required to accommodate suction and discharge piping configuration and shall be at least 8 inches (200 mm) above finished grade.
- Soil bearing pressure** shall not exceed 50 percent of the net allowable values for static loads. For piled foundations, no reduction in allowable pile capacity is required.
- All parts of machine supports shall be isolated from adjacent foundations and buildings to prevent vibration transmission.

Auxiliary structures such as access platforms and cranes shall be supported independently of the machine supports and foundations.

The machine foundation shall be spaced a minimum of 1/2 inch (12 mm) from adjacent foundations and floor slabs. The space between the two shall be filled with a flexible joint filler and sealer.

- R 3.5 **Shallow rigid (block-type) foundations** shall be as follows:
- The horizontal eccentricity, in any direction, between the centroid of mass of the machine-foundation system and the centroid of the base contact area, shall not exceed 5% of the respective base dimension.
 - The center of gravity of the machine foundation system shall be as close as possible to the lines of action of the unbalanced forces.

- R 3.6 **Elevated structures** for rotary machinery shall be designed as follows:
- The **upper table** and the **foundation slab** shall be rigid in the horizontal plane.
 - The **weight** of the upper table plus 1/2 of the weight of the columns shall be greater than the weight of the machine(s).
 - The foundation slab shall not weigh less than the combined supported weight of the upper table, columns or walls, and the machines (including baseplates).
 - The effects of short circuit couples, faulty synchronizing conditions, oil whirl frequency, rotor critical speeds, and background vibration shall be considered.