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Indian Standard

CODE OF PRACrrICE FOR DESIGN AND CONSTRUCTION OF MACHINE FOUNDATIONS

PART II FOUNDATIONS FOR IMPACT TYPE MACHINES (HAMMER FOUNDATIONS)

(First Revision)

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CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF MACHINE FOUNDATIONS

PART II FOUNDATIONS FOR IMPACT TYPE MACHINES (HAMMER FOUNDATIONS)

(First Revision)

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AMENDMENT NO. 1 MAY 1984
TO
IS : 2974 (Part 2) - 1980 CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF MACHINE FOUNDATIONS

PART 2 FOUNDATIONS FOR IMPACT TYPE MACHINES (HAMMER FOUNDATIONS)

(First Revision)

Alterations

(*Page* 4, *clause* **1.1**) – Substitute the following for the existing:

'**1.1** This standard (Part 2) covers the design and construction of hammer foundation subject to repeated impacts.'

(*Page* 6, *clause* **2.4**):

a) *Line 1* – Add the words '(*see* Fig. 1)' after 'support'.

b) *Line 2* – Substitute the word 'soil' *for* 'ground'.

[*Pages* 7 *and* 8, *clause* **4.1**(c)] – Delete.

(BDC 43)

Indian Standard
CODE OF PRACTICE FOR DESIGN AND CONSTRUCTION OF MACHINE FOUNDATIONS
PART II FOUNDATIONS FOR IMPACT TYPE MACHINES (HAMMER FOUNDATIONS)
(First Revision)

0. FOREWORD

0.1 This Indian Standard (Part II) (First Revision) was adopted by the Indian Standards Institution on 31 July 1980, after the draft finalized by the Foundation Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The installation of heavy machinery involves careful design of their foundations taking into consideration the impact and vibration characteristics of the load and the condition of the soil on which the foundation rests. While many of the special features relating to the design and construction of such machine foundations will have to be as advised by the manufacturers of these machines, still most of the details will have to be according to general principles of design. This part (Part II) of the standard lays down the general principles with regard to foundations for impact type machines (hammer foundations). This standard was first published in 1966. This revision has been prepared based on experience gained in the implementation of this standard.

0.3 This standard on machine foundations is published in five parts. Other parts are:

- Part I Foundations for reciprocating type machines.
- Part III Foundations for rotary type machines (medium and high frequency).
- Part IV Foundations for rotary type machines of low frequency.
- Part V Foundations for impact type machines other than hammer (forging and stamping press, pig breaker, elevator and hoist towers).

0.4 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*.

*Rules for rounding off numerical values (*revised*).

The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

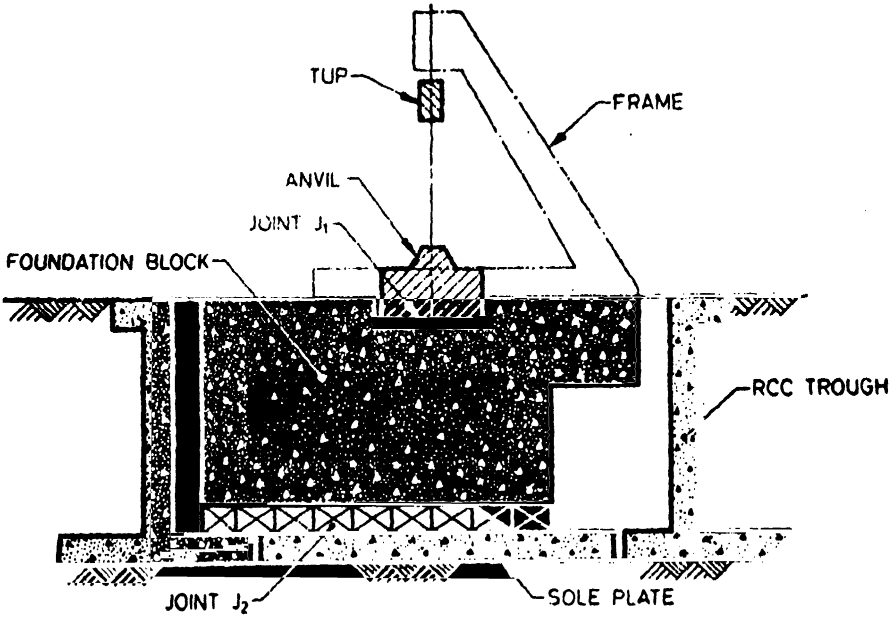
1. SCOPE

1.1 This standard (Part II) covers design and construction of hammer foundation subject to stray and repeated impacts and where the ratio of mass of anvil to foundation is high.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following and the relevant definitions in IS : 2974 (Part I)-1964*, shall apply.

2.1 Anvil — A base-block for a hammer on which material is forged into shape by repeated striking of the tup (*see* Fig. 1).

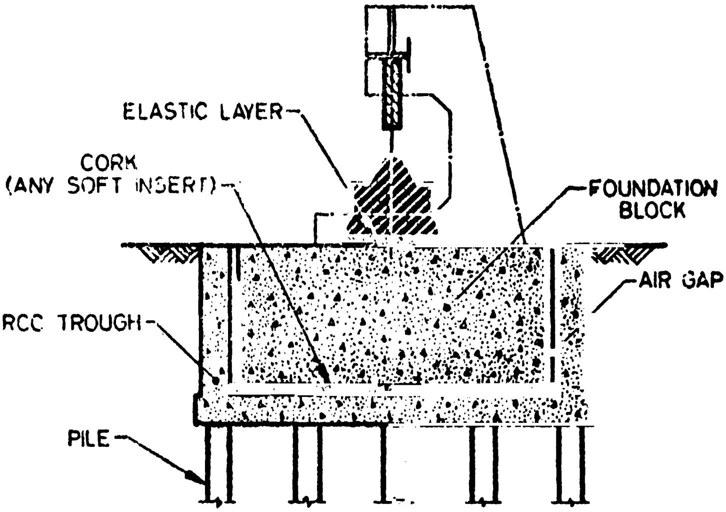


1A With Elastic Support

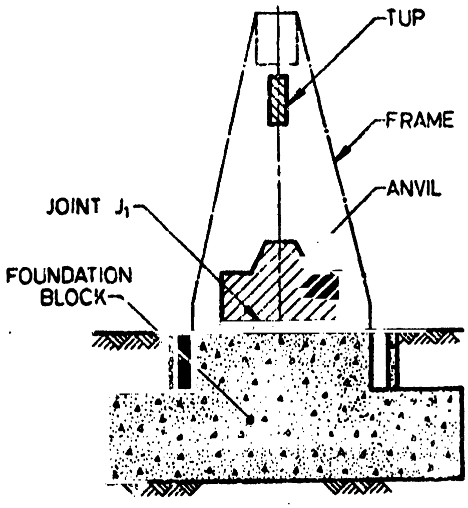
FIG. 1 DIFFERENT TYPES OF FOUNDATION SUPPORT—*Contd*

2.2 Capacity of Hammer — It is expressed as the mass of the falling tup.

*Code of practice for design and construction of machine foundations: Part I Foundations for reciprocating type machines (*first revision*).



1B Resting on Piles



1C Resting on Soil

FIG. 1 DIFFERENT TYPES OF FOUNDATION SUPPORT

2.3 Foundation Block — A mass of reinforced concrete on which the anvil rests (*see* Fig. 1).

2.4 Foundation Support — A support for resting the foundation block. The block may rest directly on ground or on a resilient mounting, such as timber sleepers, springs, cork layer, etc. The block may also be supported on pile foundations.

2.5 Impact Force (*F*) — The force produced when the falling tup strikes the material being forged on the anvil.

2.6 Coefficient of Restitution (*k*) — A coefficient used to determine the velocity of the anvil and the foundation block after the tup strikes. This coefficient is governed by the condition $0 < k < 1$ and its average value for design purposes may be taken up to 0·6. However, in specific known cases this value may be reduced.

2.7 Protective Cushioning Layer (Elastic Pad) — An elastic cushioning of suitable material and thickness provided between the anvil and the foundation block in order to prevent bouncing of anvil and creation of large impact stresses and consequent damage to the top surface of the concrete in the foundation block.

2.8 Tup — A weighted block which strikes the material being forged on the anvil (*see* Fig. 1).

3. NECESSARY DATA

3.1 Hammer Details

a) Total mass of hammer, that is, mass of frame and falling parts;
b) Mass of falling parts, that is, mass of tup and top die;
c) Mass of anvil (in case guide frame of the hammer is attached to the anvil, the mass of the frame should be added);
d) Energy of impact;
e) Number of blows per minute (this may vary depending on full stroke and short stroke);
f) Base dimensions of the anvil;
g) Manufacturer's drawing showing general cross section, plan, elevation of anvil, frame base, anvil base, etc, including details of anchor bolts; and
h) Coefficient of impact of anvil in extreme case for die to die blow.

3.2 Details of the Cushion Pad Between Anvil and Block

a) Material,
b) Elastic modulus,
c) Maximum allowable deformation, and
d) Allowable stress intensity.

3.3 Details of Cushioning Between Foundation Block and Soil, If Provided

a) If resilient pad is used:
   1) Material,
   2) Elastic modulus,
   3) Maximum allowable deformation, and
   4) Allowable stress intensity.

b) If springs and dampers are used:
   1) Maximum allowable spring deflections for normal working as well as for extreme conditions and also for static loads as well as for dynamic loads,
   2) Details of springs, and
   3) Details of dampers.

3.4 Soil Data

3.4.1 The sub-soil properties shall be determined according to IS : 1892-1979*.

3.4.2 The dynamic elastic properties of the soil shall be ascertained according to IS : 5249-1977†.

3.5 Information about the location of the hammer in the shop with respect to adjacent foundations; the dimensions, elevations and depth of these foundations as well as their tolerable amplitudes, shall be provided.

4. DESIGN CRITERIA

4.1 General Considerations — The hammer foundation shall satisfy the following requirements:

a) The design of the entire foundation system shall be such that the centres of gravity of the anvil and of the foundation block, as well as the resultants of the forces in the elastic pad and the foundation support, act as far as practicable so as to coincide with the line of fall of the hammer tup. While determining the centre of gravity of the foundation block the weight of the frame and of the tup shall also be considered.

b) The foundation shall be so designed that the induced vibrations in the structures nearby are within the safe limits fixed for them.

c) In case of hammers having continuous impacts, the design shall be such that the natural frequency of the foundation system will not be a whole number multiple of the operating frequency of impact. A natural frequency of the foundation system of two-and-a-half times the frequency of impact or more may be considered satisfactory. When the natural frequency is designed to be less than the frequency

*Code of practice for subsurface investigations for foundations (*first revision*).
†Method of test for determination of dynamic properties of soils (*first revision*).

of impact, it shall be 30 percent or more below than the frequenc of impact. For design, the combined natural frequency of th two-mass-spring system shall be considered.

4.2 Permissible Stresses

4.2.1 The total force acting on the pad and on the foundation suppor (*see* Fig. 1) shall be such that the deformation of the elastic material in ther are within the allowable limits.

4.2.2 The load intensity on the soil below the foundation shall not b more than 80 percent of the allowable bearing pressure of the soil or materia as the case may be.

4.3 Permissible Amplitudes

4.3.1 The permissible amplitudes which depend upon the mass of th tup shall be as follows:

	Mass of Tup		
	Up to 1 tonne	1 to 3 tonnes	More than 3 tonnes
For foundation block	1 mm	1·5 mm	2 mm
For anvil	1 mm	2 mm	3 to 4 mm

4.3.2 In case any important structure exists near the foundation, th amplitude of the foundation should be adjusted so that the velocity of th vibrations at the structure does not exceed 0·3 cm/s.

4.4 Dimensional Criteria

4.4.1 *Area* — The area of the foundation block at the base shall b such that the safe loading intensity of soil is never exceeded during th operation of the hammer.

4.4.2 *Depth* — The depth of the foundation block shall be so designe that the block is safe both in punching shear and bending. For the calcu lations the inertia forces developed shall also be included. Howeve the following minimum thickness of foundation block below the anvil sha be provided:

Mass of Tup	*Thickness (Depth) of Foundation Block, Min*
Tonnes	m
Up to 1·0	1·00
1·0 „ 2·0	1·25
2·0 „ 4·0	1·75
4·0 „ 6·0	2·25
Over 6·0	2·50

4.4.3 *Mass* — The mass of the anvil is generally 20 times the mass of the tup. The mass of the foundation block (W_b) shall be at least 3 times that of the anvil.

For foundations resting on stiff clays or compact sandy deposits, the mass of block should be from 4 to 5 times the mass of the anvil.

For moderately firm to soft clays and for medium dense to loose sandy deposits, the mass of the block should be from 5 to 6 times the mass of the anvil.

5. VIBRATION ANALYSIS

5.1 Drop and Forge Hammers — The machine foundation system shall be analysed as a 2-mass system, with anvil forming one mass and the foundation block as the second mass. The analysis of a two-mass system is suggested in Appendix A. For analysis the dynamic force is calculated on the basis of momentum equation. In case of stray or random impact hammers (when the operating frequency is less than 150 strokes per minute) the natural frequencies need not be calculated. The deflection of the foundation under a single impact should be calculated. This deflection should be within permissible amplitudes. In case of high speed hammers (whose operating frequency is more than 150 strokes per minute) the detailed analysis will have to be conducted to determine the natural frequencies as well as the amplitudes.

5.2 Counter-Blow Hammers — In these hammers as no dynamic force is transmitted to the foundation, detailed vibration analysis is unnecessary. Only the natural frequencies should be determined to avoid resonance of the system.

6. CONSTRUCTION

6.1 The foundation block should be made of reinforced concrete. The concrete used shall be of grade not less than M 15 conforming to IS : 456-1978*.

6.2 It is desirable to cast the entire foundation block in one operation. If a construction joint is unavoidable, the plane of joint shall be horizontal and measures shall be taken to provide a proper joint. The following measures are recommended.

6.2.1 Dowels of 12 to 16 mm diameter at 60 mm centres should be embedded to a depth of at least 30 cm on both sides of the joint. Before placing the new layer of concrete, the previously laid surface should be roughened, thoroughly cleaned, washed by a jet of water and then covered

*Code of practice for plain and reinforced concrete (*third revision*).

by a layer of rich 1 : 2 cement grout, 2 cm thick. Concrete should be placed not later than 2 hours after the grout is laid.

6.3 Reinforcement shall be arranged along the three axis and also diagonally to prevent shear (*see* Fig. 2). More reinforcement shall be provided at the topside of the foundation block than at the other sides. Reinforcement at the top may be provided in the form of layers of grills made of 16 mm diameter bars suitably spaced to allow easy pouring of concrete. The topmost layers of reinforcement shall be provided with a cover of at least 5 cm. The reinforcement provided shall be at least 25 kg/m³ of concrete.

6.4 Special care shall be taken to provide accurate location of holes for anchor bolts (if any) cut out for anvil, frame, etc. The bearing surface for anvil shall be strictly horizontal and no additional corrective pouring of concrete shall be permitted.

6.5 The protective layer between anvil and foundation block shall be safeguarded against water, oil scales, etc, and the material selected should withstand temperatures up to 100°C.

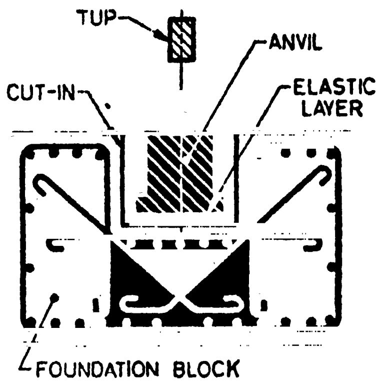


FIG. 2 TYPICAL REINFORCEMENT DETAIL

6.6 Air-gaps and spring elements provided for the purpose of damping vibrations shall be accessible in order to remove scales and enable inspection of springs and their replacement, if necessary.

6.7 Hammer foundations which are 'cut-in' by the anvil pits shall be made so deep that the parts which are weakened by the indent of 'cut-in' are of sufficient strength.

APPENDIX A

(*Clause* 5.1)

VIBRATION ANALYSIS OF A 2-MASS SYSTEM AND ITS APPLICATION TO DESIGN OF HAMMER FOUNDATIONS

A-1. ANALYSIS OF 2-MASS SYSTEM

A-1.1 The 2-mass system is represented by the model given in Fig. 3. The mass m_1 is subjected to a velocity of vibration of V_1. The two natural frequencies f_{n1} and f_{n2} of the system are given by the positive roots of the following expressions:

$$f_n^4 - (f^2_{na} + f^2_{nb})\,(1+\beta)\,f^2_n + (1+\beta)\,f^2_{na} f^2_{nb} = 0$$

where

$$f_{na} = \frac{1}{2\pi}\sqrt{\frac{k_1}{m_1}},$$

$$f_{nb} = \frac{1}{2\pi}\sqrt{\frac{k_2}{m_1+m_2}}, \text{ and}$$

$$\beta = \frac{m_1}{m_2}.$$

The amplitude of vibrations are given by:

$$a_1 = \frac{(f^2_{na} - f^2_{n2})\,(f^2_{na} - f^2_{n1})}{2\pi f^2_{na}\,(f^2_{n1} - f^2_{n2})\,f_{n2}} \cdot V_1, \text{ and}$$

$$a_2 = \frac{(f^2_{na} - f^2_{n1})}{2\pi\,(f^2_{n1} - f^2_{n2})\,f_{n2}} \cdot V_1$$

A-2. APPLICATION TO ANALYSIS OF HAMMER FOUNDATIONS

A-2.1 Notations

Mass of the tup	W_t kg
Mass of the anvil	W_a kg
Mass of the frame	W_f kg
Height of fall of tup	h cm
Frequency of impact	N blows/min
Area of piston	A cm^2
Area of anvil base	A_a cm^2
Elastic modulus of the pad between anvil and foundation	E_1 kg/cm^2

Thickness of pad	t_1 cm
Mass of foundation block	W_b kg
Area of foundation block	A_b cm^2
Equivalent radius of the base of foundation	r cm
Dynamic shear modulus of soil	G kg/cm^2
Coefficient of uniform elastic compression of soil	C_u kg/cm^3
Spring coefficient of pile foundations	K_p kg/cm
Elastic modulus of pile material	E_p kg/cm^2
Cross-sectional area of pile	A_p cm^2
Length of pile	l cm

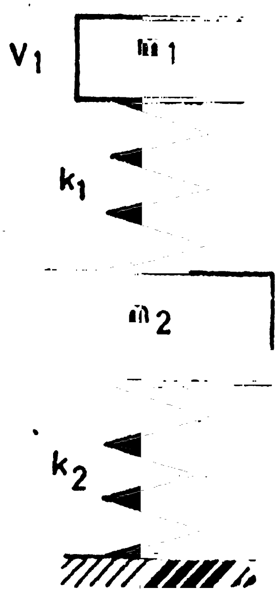


FIG. 3 MODEL SHOWING TWO-MASS SYSTEM

A-2.2 In a hammer foundation the first mass of the model corresponds to the anvil and the second mass to the foundation block. The mass of the frame will have to be added either to that of the anvil or to that of the foundation block depending upon whether the frame is attached to the anvil or to the block. The spring k_1 of the model corresponds to the elastic pad between the anvil and the block, while spring k_2 corresponds to the foundation support. The velocity V_1 is calculated on the basis of momentum equation.

A-2.2.1 These parameters can be calculated as below:

$$m_1 = \frac{W_a}{g}; \; m_2 = \frac{W_b}{g}$$

W_f will have to be added to either W_a or to W_b depending upon whether the frame is attached to anvil or to foundation block:

$$k_1 = \frac{E_1 \cdot A_a}{t_1} \text{ kg/cm,}$$

When the block is directly resting on soil:

$$k_2 = 7.6\, rG \text{ or } A_b \cdot C_u \text{ kg/cm,}$$

When the block is supported on short bearing piles:

$$k_2 = \frac{k_p \cdot k_s}{k_p + k_s},$$

where

$$k_s = 7.6\, rG \text{ or } A_b \cdot C_u, \text{ and}$$

$$k_p = \frac{n \cdot E_p \cdot A_p}{l}$$

For loose soils k_2 may be taken from settlement tests.

When springs are provided between the block and soil:

$$k_2 = \frac{k_{sp} \cdot k_s}{k_{sp} + k_s} \text{ kg/cm}$$

where

k_{sp} is the spring coefficient of springs,

$V_1 = V_{Aa}$ Velocity of the anvil after impact, and

$$V_{Aa} = V_{tb} \cdot \frac{1 + k}{1 + \dfrac{W_a}{W_t}}$$

where

$V_{tb} = \sqrt{2gh}$ for a freely falling tup type hammer, and

$= 0.65 \sqrt{2g \dfrac{(W_t + psA)\, h}{W_t}}$ for double acting steam hammer.

A-2.2.2 *Check on Design*

a) *Stability of the pad between anvil and block* — Total deflection of pad under impact $= \delta_1 = \delta_{1s} + \delta_{1d}$

where

$$\delta_{1s} = \frac{W_a}{k_1} \text{ cm}$$

NOTE — W_f will have to be added to W_a if the frame is attached to the anvil,

and $\delta_{1d} = \dfrac{V_{Aa}}{2\pi f_{na}}$

The loading intensity on the pad

$$\sigma_1 = \frac{k_1 \cdot \delta_1}{A_a} \text{ kg cm}^2$$

δ_1 and σ_1 should be less than the allowable values for the pad.

b) Stability of the soil below the foundation:

Loading intensity $\sigma_2 = \dfrac{W_a + W_b + W_f + k_z \measuredangle_\beta}{Ab}$

where

$$\measuredangle_\beta = \frac{V_{\beta a}}{2\pi f_{nb}}; \quad V_{\beta a} = V_{Aa} \frac{1+k}{1 + \dfrac{W_b}{W_a}}$$

(W_f will have to be added to W_b or to W_a depending upon whether the frame is attached to the block or to the anvil.)

σ_2 should be less than the allowable bearing pressure for the soil specified in **4.2.2**.

c) Maximum deflection of the foundation under a single impact:

Assuming the anvil and the foundation block to be a single monolithic unit, the velocity after the impact:

$$V'_a = V_{tb} \frac{1+k}{1 + \dfrac{W_a + W_b + W_f}{W_f}} \text{ cm/s}$$

The natural frequency of the system $= f_{nb} \cdot Hz$

The deflection of the block $\delta = \dfrac{V'_a}{2\pi f_{nb}}$

should be less than the permissible amplitude for the block.

(*Continued from page* 2)

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H. No. 15, Sector-3, PARWANOO, Distt. Solan (H.P.) 173220	235 436
Plot No A-20-21, Institutional Area, Sector 62, Goutam Budh Nagar, NOIDA 201307	240 2206
Patliputra Industrial Estate, PATNA 800013	226 2808
Plot Nos. 657-660, Market Yard, Gultkdi, PUNE 411037	2427 4804
"Sahajanand House" 3rd Floor, Bhaktinagar Circle, 80 Feet Road, RAJKOT 360002	237 8251
T.C. No. 2/275 (1 & 2), Near Food Corporation of India, Kesavadasapuram-Ulloor Road, Kesavadasapuram, THIRUVANANTHAPURAM 695004	255 7914
1st Floor, Udyog Bhavan, VUDA, Siripuram Junction, VISHAKHAPATNAM-03	271 2833

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