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Indian Standard

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भू-संपर्कन के लिए रीति संहिता

(दूसरा पुनरीक्षण)

Code of Practice for Earthing

(Second Revision)

ICS 91.140.50

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Other factors that affect a decision whether to drive deep electrodes or to employ several rods or pipes in parallel are the steep rise in the energy required to drive them with increase in depth and the cost of couplings. The former can be offset by reducing the diameter of the rods, since a 13 mm diameter rod can be driven to considerable depths without deformation or bending if the technique of using a large number of comparatively light blows is adopted rather than a smaller number of blows with a sledge hammer. Power-driven hammers suitable for this purpose are available.

In cases where impenetrable strata or high resistivity soil occur at relatively small depths, considerable advantage may result from driving rods at an angle of about 30° to the horizontal, thus increasing the length installed for a given depth.

14.2.3 *Strip or Conductor Electrodes*

These have special advantages where high resistivity soil underlies shallow surface layers of low resistivity. The minimum cross-sectional area of strip electrodes shall be according to **12.1.1**. If round conductors are used as earth electrodes, their cross-sectional area shall not be less than the sizes recommended for strip electrodes. The resistance R is given by:

$$R = \frac{100\rho}{2\pi l}\log_e \frac{4l}{d} \text{ ohms}$$

where

ρ = resistivity of soil (Ω.m) (assumed uniform);

l = length of the strip in cm; and

d = width (strip) or twice the diameter (conductors); in cm.

Care should be taken in positioning these electrodes, especially to avoid damage by agricultural operations.

Figure 23 shows the variation of calculated earth-resistance of strip or conductor electrodes with length for a soil resistivity of 100 Ω.m. The effect of conductor size and depth over the range normally used is very small.

If several strip electrodes are required for connection in parallel in order to reduce the resistance, they may be installed in parallel lines or they may radiate from a point. In the former case, the resistance of two strips at a separation of 2.4 m is less than 65 percent of the individual resistance of either of them.

14.2.4 *Water Pipes*

Water pipes shall not be used as consumer earth electrodes.

NOTE — In urban districts and other areas where piped water supply is available the use of water pipes for consumers' earth electrodes has been common in the past. Though this was generally very effective when consumers' pipes and water mains to which they were connected were all metal-to-metal joints, the use of public water-pipes for this purpose has not been acceptable for many years because of the use of non-conducting material for pipes on new installations and for replacement purposes. Jointing techniques now being used do not ensure electrical continuity of metallic pipes.

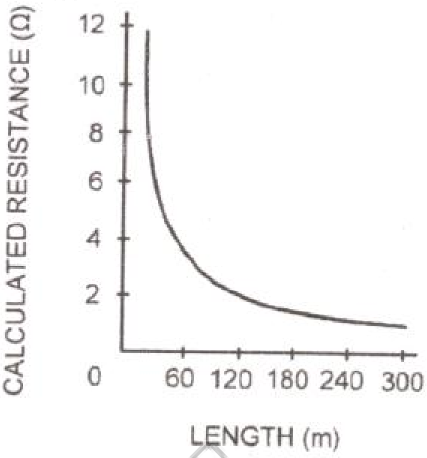

FIG. 23 EFFECT OF LENGTH OF STRIP OR CONDUCTOR ELECTRODES IN CALCULATED RESISTANCE FOR SOIL RESISTIVITY OF 100 Ω · m (ASSUMED UNIFORM)

For new installations, therefore, a public water pipe may not be used as a means of earthing. Metallic pipe systems of services other than water service (for example, for flammable liquids or gases, heating systems, etc) shall not be used as earth electrodes for protective purposes. Bonding of the water service with the exposed metalwork of the electrical installation (on the consumers' side of any insulating insert) and any other extraneous metalwork to the installation earthing terminal is, however, permissible and indeed necessary in most circumstances subject to the provision of earthing facilities that are satisfactory before these bonding connections are made.

For existing installations in which a water pipe is used as a sole earth electrode; an independent means of earthing should be provided at the first practicable opportunity.

14.2.5 *Resistance of an Electrode Encased in Low Resistivity Material, for Example, Conducting Concrete*

The resistance of a backfilled electrode R_b in ohms (Ω) may be calculated from:

$$R_b = \frac{1}{2\pi L}\{(\rho - \rho_c)\left[\log_e \left(\frac{8L}{d}\right) - 1\right] + \rho_c\left[\log_e \left(\frac{8L}{d}\right) - 1\right]\}$$

where

ρ = the resistivity of soil, in ohm metres (Ω.m);

ρ_c = the resistivity of the conducting material used for the backfill, in ohm metres (Ω.m);

L = the length of rod, in metres (m);

d = the diameter of the rod in metres (m).

14.2.6 *Cable Sheaths*

Where an extensive underground cable system is available, the lead sheath and armour form a most effective earth-electrode. In the majority of cases, the resistance to earth of such a system is less than 1 ΩA freshly installed jute or hessian served cable is insulated from earth, but the insulation resistance of the jute deteriorates according to the moisture content and nature of the soil. However, cable sheaths are more commonly used to provide a metallic path to the fault current returning to the neutral.

14.2.7 *Structural Steelwork*

The resistance to earth of steel frames or reinforced concrete buildings will vary considerably according to the type of soil and its moisture content, and the design of the stanchion bases. For this reason, it is essential to measure the resistance to earth of any structural steelwork that it is employing and at frequent intervals thereafter.

On the assumption that a representative value of a footing resistance can be obtained, the combined effect of all similar footings R_{tot} in ohms (Ω), assumed to be arranged in an approximately rectangular plan, may be obtained from the following:

$$R_{tot} = R_1 \times \frac{(1+\lambda\alpha)}{n}$$

in which $\alpha = \dfrac{\rho}{2\pi R_1 s}$

where

R_1 = the resistance of one footing, in ohms (Ω);

λ = the factor from Table 6;

ρ = the resistivity of the soil, in ohm metres (Ωm);

s = the spacing of footings, in metres (m);

n = the number of footings used as electrodes.

NOTE — This equation is based on the assumption that the spacing between adjacent electrodes is such that the ratio $\rho/2\pi R_1 s$ is less than approximately 0.2.

The larger proportion of the resistance is due to the concrete to earth immediately around the metal work and is dependent on its moisture content. After construction and with the passage of time this moisture content will approach equilibrium with that of the soil, and will usually be drier than when first laid.

Table 6 Factors for Vertical Electrodes Arranged in a Hollow Square

(*Clauses* 14.2.7 *and* 14.2.11.5)

Sl No. (1)	Number of Electrodes (n) Along the Side of the Square (2)	Factor λ (3)
i)	2	2.71
ii)	3	4.51
iii)	4	5.46
iv)	5	6.14
v)	6	6.63
vi)	7	7.03
vii)	8	7.30
viii)	9	7.65
ix)	10	7.90
x)	12	8.22
xi)	14	8.67
xii)	16	8.95
xiii)	18	9.22
xiv)	20	9.40

NOTE — The number of electrodes around the square is $4(n-1)$.

The resistance to earth of a reinforced concrete foundation R_r in ohms (Ω) may be estimated by assuming that only the vertical reinforcing rods are bonded to the building structure or to the earthing system. It may be assumed that the rods are equally spaced in symmetrical pattern.

$$R = \frac{1}{2\pi L}\left[\rho_c - \rho\right]\log_e\left(1+\frac{\delta}{z}\right) + \rho\log_e\left(\frac{2L}{z}\right)$$

where

ρ = the resistivity of the soil, in ohm metres (Ω.m);

ρ_c = the resistivity of the concrete, in ohm metres (Ω.m);

L = the length of reinforcing rod below ground level, in metres (m);

λ = the thickness of the concrete between rods and soil, in metres (m); and

z = the geometric mean distance of rod cluster, in metres (m) (*see* Table 7).

14.2.8 *Reinforcement of Piles*

At power stations and large substations, it is often possible to secure an effective earth-electrode by making use of the reinforcement in concrete piles. The earth strap should be bonded to a minimum of four piles and all the piles between the bonds should be bonded together. Each set of four piles should be connected to the main earthing-strap of the substation.