Short Communications

Settlement and allowable Pressures for Ring or Annular footings

by

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Introduction

With the present emphasis on provision of drinking water facility to the villages, a large number of overhead water tanks are being constructed all over the country. Ring or annular footing are ideally suited for foundations of overhead water, tanks, towers, silos, etc. Geotechnical design of these foundations has received relatively limited attention and the present work is an effort to fill the gap in our knowledge.

The Vankleek Hill Tower failure by rotation, reported by Bozozuk (1972) suggests that the General Shear Failure mechanism similar to that of circular footings is vaild for ring footings too.

The settlement, ρ, of a rigid ring footing, resting on a semiinfinite elastic continuum (Egorov, 1965) is

$$\rho = \frac{P\,(1 - v_s^2)}{E_s\, R_2}\; w\,(n) \qquad \ldots (1)$$

where P is the load on the footing, E_s and v_s—the modulus of deformation and Poisson's ratio of the soil, $w(n)$-influence factor, $n = R_1/R_2$, the ratio of inner (R_1) to outer (R_2) raddi. Values of $w(n)$ are listed in Table 1.

TABLE 1

Influence Factors

n	0	0.2	0.4	0.6	0.8	0.9	0.95
$w(n)$	0.5	0.5	0.51	0.52	0.57	0.6	0.65

(after EGOROV, 1965)

Using FEM, Milovic (1973) evaluated the stresses and displacements below a uniformly loaded ring footing (Figure 1) resting on a finite elastic

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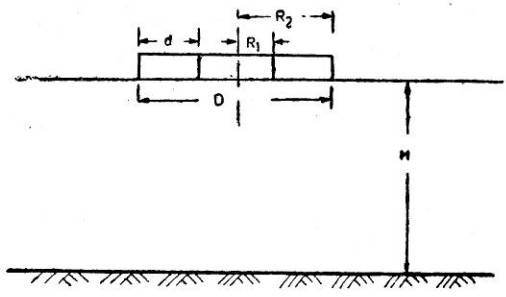

FIGURE 1 Rigid ring footing on finite layer

layer of thickness H. The surface settlement at a distance r from the centre is

$$\rho_r = \frac{q.\ D}{E_s}\ I_w(r) \qquad \ldots(2)$$

where, $D = 2R_2$, and $I_w(r)$—an influence coefficient dependent on ν_s, r/D, H/D, and $(R_1-R_2)/R_2$-ratios. Values of $I_w(r)$ are given in Milovic (1973).

Settlement of rigid ring footings

The results of Milovic (1973) for uniformly loaded ring footings resting on soil of finite thickness, can be used to calculate the settlement of rigid ring footings based on the approximation suggested by Poulos and Davis (1975),

$$\rho_{rigid} = \tfrac{1}{2}\,(\rho_c+\rho_e)_{fl} \qquad \ldots(3)$$

where ρ_c and ρ_e are the central and edge deflections of flexible circular or strip footings. As the settlement of inner (ρ_{ie}) and outer ($\rho_{o\epsilon}$) edge settlements of a flexible ring footing are not equal, Equation (3) is modified as

$$\rho_{rigid} = \tfrac{1}{4}\,(\rho_{ie}+2\rho_c+\rho_{oe})_{fl} \qquad \ldots(4)$$

$$= \frac{q_{av}\ D}{E}\ .\ I_R \qquad \ldots(5)$$

where q is the average pressure on the rigid footings. Approximation given by Equation (3) or (4) give errors which are less than 5 per cent. The influence coefficient I_R is calculated from the values given by Milovic (1973), for ρ_{ie}, ρ_c and ρ_{oe}, and are shown in Figure 2. The influence factor, I_R decreases with the ratio n, and Poisson's ratio, v_s. I_R as can be expected increases with H/D-ratio. For completeness the results of Egorov (1965) corresponding to $H/D \rightarrow \infty$ are also plotted in Figure 2, and this figure can be used to estimate settlements of rigid ring footing resting on finite layers. The results for a rigid circle resting on a finite layer are given in Poulos end Davis (1974).

Allowable Bearing Pressure

The safe or allowable bearing capacity of a footing can be arrived at from consideration of ultimate pressure and a factor of safety, or by

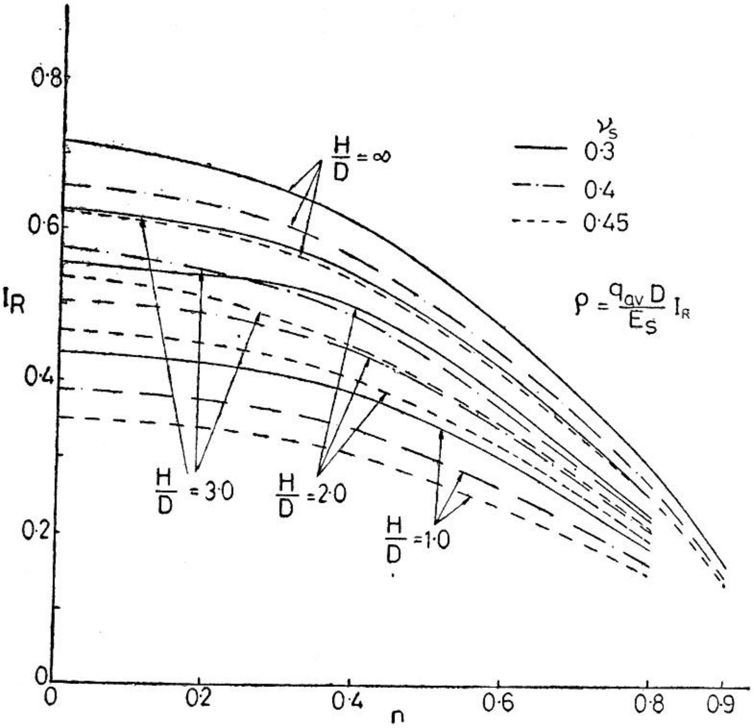

FIGURE 2 Influence factors for rigid ring footings

estimating these pressures for a given (safe) settlement. A method synthesising these two approaches is presented.

The ultimate bearing capacity, q_{ult}, of a circular footing is calculated (Vesic, 1975), as

$$q_{ult} = CN_c\, S_c + q_o\, N_q\, S_q + \tfrac{1}{2}\, \gamma\, D\, N_\gamma\, S_\gamma \qquad \ldots(6)$$

where N_c, N_q, N_γ and S_c, S_q, S_γ are the bearing capacity and shape factors respectively, dependent on the friction angle, ϕ, c-the cohesion and q_o the surcharge pressure.

The safe allowable (gross) pressurr, q_a, is

$$q_a = \frac{1}{F.S}\,(N_c\, S_c C + q_o\,(N_q - 1)\, S_q + \frac{1}{2}\,\gamma D\, N_\gamma\, S_\gamma\,) + q_o \qquad \ldots(7)$$

and the net bearing pressure, q_{nc} for circular footing

$$q_{nc} = q_a - q_o \qquad \ldots(8)$$

The settlement of a footing subjected to net bearing pressure can be estimated from Equation (5). Equating the settlement of ring and circular rigid footings, the allowable bearing pressure q_{nr} of a rigid ring as a ratio of rigid circular footing on a semi-infinite layer, is obtained as

$$\frac{q_{nr}}{q_{nc}} = \frac{1}{2(1-n^2)\, w(n)} \qquad \text{...(9)}$$

Equation (9) plotted in Figure 3 shows that the net allowable pressure on a ring increases with the ratio n. For $n = 0.5$ the increase is 50 per cent over that of a circular footing. In a similar manner, the ratio q_{nr}/q_{nc} is calculated for rigid rings on finite layers from the curves given in Figure 2. q_{nr} of ring footing resting on a finite layer varies in a very similar manner to that given by Equation (9) and is not dependent on the Poisson's ratio or on the layer depth (H/D-ratio). There is small difference between the curves corresponding to H/D equal to 1.0 and tending to infinity. The gross bearing pressure, q_{ar} for ring footing is now given as

$$q_{ar} = q_{nr} + q_o \qquad \text{...(10)}$$

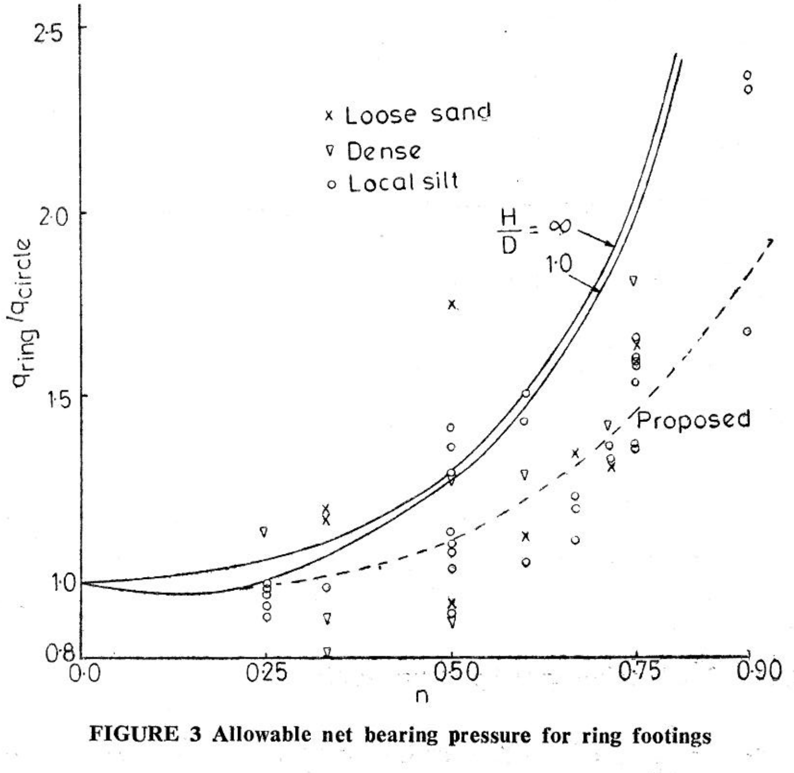

FIGURE 3 Allowable net bearing pressure for ring footings

Comparison with Model Tests

Tests on model ring footings conducted in the laboratory on loose (Raju, 1975), and dense sands (Karlekar, 1972), and laboratory and field tests on alluvial silt (Pathak, 1978) have been considered. Rings with outer diameter equal to 20 cm and with inner diameter varying from 0 to 15 cm were used. From the intensity of load versus settlement curves obtained, the ratio, q_{nr}/q_{nc} at settlements of 5 mm and 10 mm is calculated for different rings (n-values) and plotted in Figure 3. These points all lie below the theoretical lines obtained based on the elastic theory, The curve proposed (discontinuous line in Figure 3) also suggests increase of net bearing pressures with n, the order of increase being less than the ones from theoretical results. Settlement from larger pressures on ring footings could have led to plastic strains and thus, smaller ratios of q_{nr}/q_{nc} are obtained from model tests. This aspect needs further study with large scale *in-situ* tests.

Conclusions

Settlement of rigid ring footing resting on a finite soil layer can be estimated using Equation (5) and Figure 2. The net allowable pressure for a ring footing is obtained (Figure 3) as ratio of the net pressure of a circular footing having the same outer diameter for any given annular ratio (n). The gross bearing pressure is then obtained as the sum of the net pressure and the overburden pressure at the base of the ring.

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