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DETERMINATION OF SEISMIC BEARING CAPACITY FACTOR $N_{\gamma e}$ USING MODIFIED PSEUDO-DYNAMIC METHOD

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ABSTRACT

Estimating the seismic bearing capacity of soil under shallow foundation is important for seismically active areas. A new approach is suggested for the computation of bearing capacity factor, $N_{\gamma e}$ considering logspiral failure mechanisms. This paper uses modified pseudo-dynamic method to estimate the dimensionless seismic bearing capacity factor $N_{\gamma e}$ for dry sand underlying a surface strip footing. Soil amplification is considered inherently in this method and seismic acceleration is found to have significant effect on $N_{\gamma e}$. The present study shows that the value of $N_{\gamma e}$ considering $k_h = 0.1$, $k_v = 0$, decreases by 86% as compared to the static condition for Φ=30°. The vertical seismic acceleration coefficient also significantly affects the seismic bearing capacity factor. It was found that $N_{\gamma e}$ decreased by 84% when k_h increased from 0.1 to 0.2 for $k_v = 0$ and it decreased by 95% when $k_v = k_h$ for Φ =30°. With decrease in Φ from 40° to 30°, $N_{\gamma e}$ decreased by 68% for $k_h = k_v = 0.1$. The proposed method can be used for seismic design of shallow strip foundations in sand.

METHODOLOGY

The present study estimates the seismic bearing capacity factor $N_{\gamma e}$ of dry cohesionless soil beneath a surface strip footing. One sided non-symmetrical failure mechanism is considered (see Figure 1) with radial shear zone of shape of a log spiral having focus at the edge of the footing. The seismic forces are computed using the more realistic and accurate modified pseudo-dynamic method and both horizontal and vertical seismic accelerations have been considered in the analysis. Using the limit equilibrium method, the seismic bearing capacity factor $N_{\gamma e}$ is obtained for various values of soil friction angles. The equation of motion of seismic waves travelling through a Kelvin-Voigt visco-elastic material is given by Yuan et al. (2006).

$$\rho\frac{\partial^2\vec{u}}{\partial t^2}=\left(\left(\lambda+G\right)+\left(\eta_l+\eta_s\right)\frac{\partial}{\partial t}\right)grad\left(div\left(\vec{u}\right)\right)+\left(G+\eta_s\frac{\partial}{\partial t}\right)\nabla^2\vec{u} \tag{1}$$

where ρ is density of the soil, G is shear modulus, η is viscosity, λ is Lame's constant, and u is displacement vector, *grad* is gradient and *div* is divergence. Vertical acceleration can be obtained as:

$$a_2\left(z,t\right)=\frac{k_v g}{C_2^2+S_2^2}[\left(C_2C_p+S_2S_p\right)cos\left(2\pi\frac{t}{T}\right)+\left(S_2C_p-C_2S_p\right)sin\left(2\pi\frac{t}{T}\right) \tag{2}$$

Figure (1) shows the assumed one-sided failure mechanism considered in the present study. AC represents the base of strip footing of width B resting on the surface of dry cohesionless soil of unit weight γ and internal friction angle Φ. The active wedge (zone 1) is denoted by triangle ACD and passive wedge (zone 3) is triangle CFE. The radial shear zone (zone 2) CDE is a log spiral with focus at the edge of the footing (point C). The initial and final radial, r_0(CD) and r_f(CE) respectively, of the log spiral constitutes an internal angle Φ.

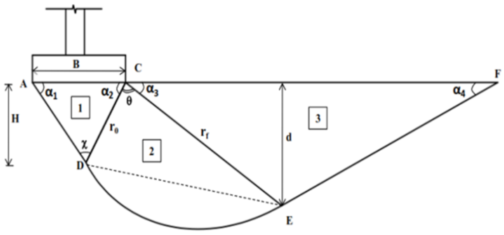

Figure 1. One-sided failure mechanism with composite failure surface (log spiral + planar).

Considering modified pseudo-dynamic method, the inertia forces in each failure zone are computed. The most critical directions of seismic inertia forces are considered for finding the minimum seismic.

RESULTS AND DISCUSSIONS

The results of seismic bearing capacity factor Nγe are presented graphically for various input parameters. The modified pseudo-dynamic method inherently accounts for the soil amplification and so a specific value of amplification factor is not needed. The input parameters used for the present study are as follows: Φ=25°, 30°, 35°, 40°; k_h = 0.0, 0.1, 0.2, 0.3; k_v = 0.0, 0.5 k_h, k_h; T = 0.33s; V_s = 200 m/s; V_p / V_s =1.87; Φ=10%.

The present results are higher by 17.8% to 36.6% as compared to values by Meyerhof (1963) and lower by 16.2% to 29% as compared to values by Chen (1975) while those are close to values reported by Soubra (1999) (0.5% to 8.1% variation), Vesic (1973) (1.2% to 4%) and Terzaghi (9.1% to 11.9%). The present study assumes the footing to be resting on the surface and hence large variation observed in Nγe obtained when compared to values given by Meyerhof (1963).

Table 1. Comparison for static bearing capacity factor $N_{\gamma e}$.

Φ°	Present Paper	Terzaghi (1943)	Meyerhof (1963)	Vesic (1973)	Chen (1975)	Soubra (1999)
25	10.67	9.7	6.77	10.88	12.4	9.81
30	22.13	19.7	15.67	22.4	26.7	21.51
35	48.76	42.4	37.15	48.03	60.2	49.0
40	113.97	100.4	93.69	109.41	147	119.84

The variation in $N_{\gamma e}$ with soil friction angle is studied and shown in Figure (2). The seismic bearing capacity factor $N_{\gamma e}$ increases with increase in soil friction angle. For example, $N_{\gamma e}$ decreased by 68% when the friction angle decreased from 40° to 30° for k_v=k_h=0.1. This is because higher soil friction angle indicates higher soil strength and hence the failure surfaces are pushed deeper from the ground surface, causing an increase in size and hence weight of the failure zones.

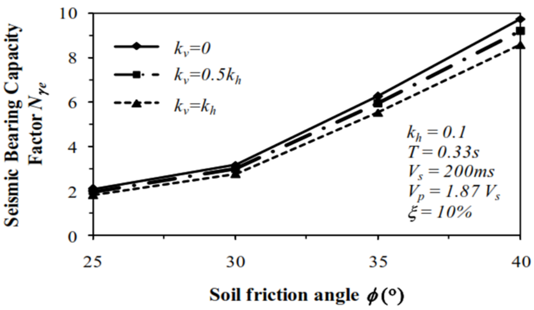

Figure 2. Variation of $N_{\gamma e}$ with soil friction angle Φ for different vertical seismic acceleration coefficients (k_v).

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