Apr 29th - May 4th

Seismic Bearing Capacity of Strip Footing Resting on Reinforced Earth Bed

Apoorva Agarwal
Inderprastha Engineering College, India

Swami Saran
IIT Roorkee, India

S. Mukerjee
IIT Roorkee, India

Commemorate the Legacy of Ralph B. Peck
Seventh International Conference on
Case Histories in Geotechnical Engineering
and Symposium in Honor of Clyde Baker
April 29 - May 4, 2013 CHICAGO

SEISMIC BEARING CAPACITY OF STRIP FOOTING RESTING ON REINFORCED EARTH BED

Apoorva Agarwal
Lecturer, Department of Civil Engineering,
Inderprastha Engineering College, Ghaziabad, India.
Contact number: +91- 07669465029
Email id: apoorvaagarwal6@gmail.com

Swami Saran (Retired Professor)
S. Mukerjee(Associate Professor)
Department of Earthquake Engineering,
IIT Roorkee, Roorkee – 247667, India.

ABSTRACT

With an increase in demand for construction the use of poor soils becomes imperative. Soil bearing capacity and settlement play an important role in the design of foundations. Seismicity of the site is another important parameter in the design of the foundation for a structure. Hence seismic bearing capacity of soil becomes an important component in the design. In weak soils often deep foundations are recommended on account of the low soil bearing capacity available. In poor soils, ground improvement techniques are commonly used to improve the soil bearing capacity. Reinforcing earth with geo synthetic is one such technique adopted in practice. This is preferred due to its cost effectiveness as in most of the engineering projects economy plays an important role. If the weak soil is improved by using geo synthetic, then it becomes feasible to use shallow foundations instead of deep foundations for the same structure, thus effecting economy. Shallow foundations still remain the most used foundation type in construction due to its economy and ease in construction.

In this paper an attempt has been made to develop an analytical approach to obtain the seismic bearing capacity of a strip footing resting on reinforced earth. The approach is based on the analysis proposed by Binquet and Lee (1975b) for a strip footing subjected to static load. Both vertical and horizontal accelerations have been considered in terms of seismic coefficients, αh and αv. Results have been presented in the form of non - dimensional charts from which seismic bearing capacity can be obtained, conveniently. Both rupture strength and frictional resistance criteria, have been taken into account in preparing these charts. Charts incorporate horizontal seismic acceleration coefficient, $\alpha h = 0.0$ and 0.10. The value of vertical seismic acceleration coefficient, αv, is taken as $2/3\alpha h$. An illustrative example has been included for a lucid understanding.

INTRODUCTION

Reinforced soil foundations are used where low bearing capacity and excessive settlements are prevalent. The traditional options that were available to overcome the problem in unreinforced soil were pile foundation being placed through a weak soil, excavation and replacement with suitable soil, stabilizing the soil with injected additives, pre – consolidation of soil deposits, applying techniques for densification of soil, increasing the dimensions of footing etc.

But the methods listed above are expensive and time taking and requires skilled labour. An alternative solution to this problem was to reinforce the soil with appropriate reinforcing material. Vidal (1966) was the first person in modern times to come up with the idea of reinforcing soil. He used this concept to improve the bearing capacity of footings.

A reinforced earth bed is a soil foundation system containing horizontally bedded thin flat metal strips or ties. Free draining granular soils are considered as good frictional bond is needed between the ties and the soil. The strips are placed horizontally. Geo-synthetic is used for reinforcing the soil. Many investigators have studied experimentally the behaviour of footings resting on reinforced soil such as Binquet and Lee(1975 a and b), Akinmusuru and Akinbolade(1981),Saran and Talwar(1981), Fragszy and Lawton(1984), Saran et al.(1985), Guido et al.(1985,1986), Dembicki et al.(1986), Sridharan et al.(1988), Sreekanieth (1987,1990), Samtani and Sonpal(1989), Huang and Tatsuoka(1990), Mandal et al.(1990,1992) Shankriah(1991), Dixit (1978), Khing et al.(1993,1994), Rao et al.(1994) and helped in understanding the behaviour of reinforced soil foundations. The common findings of these investigators were that by preparing a suitable reinforced soil bed, the ultimate bearing capacity of the footing can be increased by 3 to 4 times and the settlement/tilt can be brought down to 30% for the same footing resting on unreinforced soil bed.

Bearing capacity and settlement play an important role in designing any structure as these factors decide the nature and depth of the foundation. Seismicity of the place also plays an important role in the designing criteria. With this, there arises a need for knowing the seismic bearing capacity of the soil.

In this paper an attempt has been made to develop an analytical approach to obtain the seismic bearing capacity of a strip footing resting on reinforced earth. The approach is based on the analysis proposed by Binquet and Lee (1975b) for a strip footing subjected to static load. Both vertical and horizontal accelerations have been considered in terms of seismic coefficients, α_h and α_v. Results have been presented in the form of non - dimensional charts from which seismic bearing capacity can be obtained, conveniently. Charts incorporate horizontal seismic acceleration coefficient, α_h = 0.0 and 0.10. The value of vertical seismic acceleration coefficient, α_v, is taken as $2/3\alpha_h$.

ANALYSIS

Assumptions

The analysis is based on the following assumptions:

a. The central soil zone moves down with respect to the outer zones. The boundary between the downward moving and outward moving zones has been assumed as a locus of points of maximum shear stress at every depth *z*.

b. At the plane separating the downward and lateral movements, the ties are assumed to undergo two right angled bends around two frictionless rollers and T_D is a vertically acting tensile force (Fig. 1).

c. The tie-soil friction coefficient has been assumed to vary with depth as per following equation:

$$f_e = m.f \qquad (1)$$

where, *m* = mobilization factor given by

$$m = \left[\left(1-\frac{z}{B}\right)0.7+0.3\right] \quad \text{for } z/B < 1.0 \qquad (2a)$$

$$m = \left[\left(2-\frac{z}{B}\right)0.3\right] \quad \text{for } z/B > 1.0 \qquad (2b)$$

d. For N_R number of reinforcing layers provided in the foundation soil, developed tie force has been assumed to be in the proportion of m_1: m_2: ..... : m_N such that, $m_1 + m_2 + ... + m_N = 1$ and failure has been assumed for various combinations of tie-pull-out and tie breakage at different levels.

e. The forces evaluated in the analysis are for the same size of footing and same settlement for a footing on reinforced and unreinforced soil.

f. Elastic theory is applied to estimate the stress distribution inside the soil mass.

g. Principle of superposition is applied for calculating the forces on the reinforced as well as the unreinforced soil element.

Developed Tie Force (T_D)

To evaluate the forces developed in the ties due to applied load on the footing, it was assumed that the plane separating the downward and lateral moving zones is the locus of points of maximum shear stress $\tau_{xz\,max}$ at every depth *z*. This $\tau_{xz\,max}$ is the net result of $(\tau_{xz\,max})_{ver}$ due to vertical loading and $(\tau_{xz\,max})_{hor}$ due to horizontal loading. In Figure 1, *ac* and *a'c'* are assumed as separating planes. Fig. 2 shows the separating planes for α_h = 0.0 and α_h = 0.10.

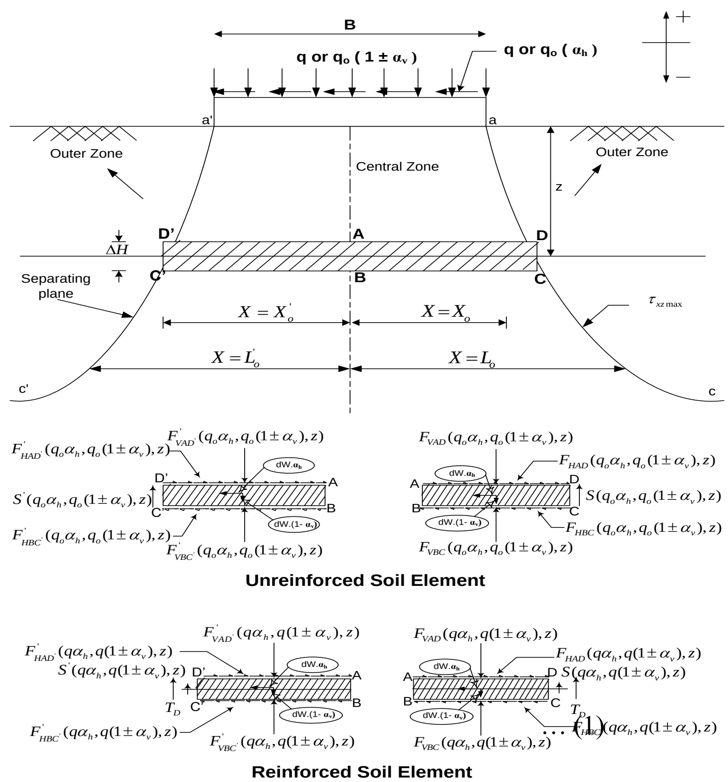

Fig.1: Assumed separating planes and components of forces for pressure ratio calculation of isolated strip foundation on reinforced soil. (unsymmetrical)

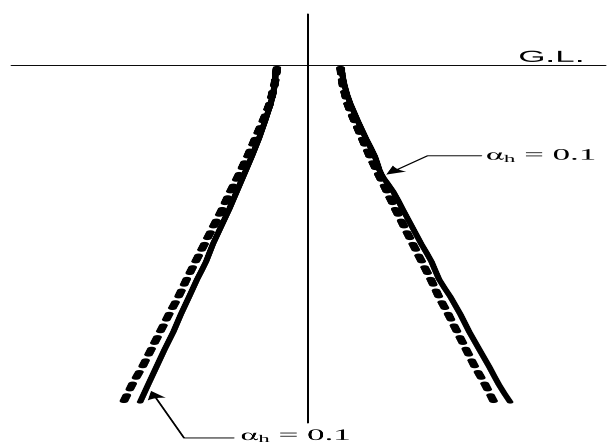

Fig.2: Assumed separating planes for α_h = 0.0 and α_h = 0.10.

Considering elements *ABCD* and *ABC'D'* at depth *z* (Fig.1) which represent the volume of soil lying between two adjacent layers of reinforcement. The forces acting on elements are shown in the fig.1 for unreinforced and reinforced foundation soil. $F_{VAD}(q_o\alpha_h, q_o(1\pm\alpha_v), z)$, $F'_{VAD}(q_o\alpha_h, q_o(1\pm\alpha_v), z)$, $F_{VBC}(q_o\alpha_h, q_o(1\pm\alpha_v), z)$ and $F'_{VBC}(q_o\alpha_h, q_o(1\pm\alpha_v), z)$ are the normal forces and $S(q_o\alpha_h, q_o(1\pm\alpha_v), z)$ and $S'(q_o\alpha_h, q_o(1\pm\alpha_v), z)$ are the vertical shear forces acting on the boundaries of the element of unreinforced soil. These forces are due to normal and shear stresses at depth z, due to vertical and horizontal loading caused by the applied bearing pressure q_o on the footing. A similar set of forces also exist for the reinforced soil foundation which is caused by applied bearing pressure q. In addition, there will be a force developed in the tie, T_D. Considering vertical equilibrium as bearing capacity needs to satisfy vertical equilibrium only.

$$\sum V = 0$$

Equilibrium of the element, $D'C'CD$, in the unreinforced soil may be expressed as

$$\begin{aligned}&F_{VAD}(q_o\alpha_h, q_o(1\pm\alpha_v), z) + F'_{VAD'}(q_o\alpha_h, q_o(1\pm\alpha_v), z)\\ &-F_{VBC}(q_o\alpha_h, q_o(1\pm\alpha_v), z) - F'_{VBC'}(q_o\alpha_h, q_o(1\pm\alpha_v), z)\\ &-S(q_o\alpha_h, q_o(1\pm\alpha_v), z) - S'(q_o\alpha_h, q_o(1\pm\alpha_v), z) +\\ &dW.(1\pm\alpha_v) = 0\end{aligned} \tag{3}$$

For single layer of reinforcement in the foundation soil at depth z, the equilibrium of the element $D'C'CD$ may be expressed as

$$\begin{aligned}&F_{VAD}(q\alpha_h, q(1\pm\alpha_v), z) + F'_{VAD'}(q\alpha_h, q(1\pm\alpha_v), z)\\ &-F_{VBC}(q\alpha_h, q(1\pm\alpha_v), z) - T_D - F'_{VBC'}(q\alpha_h, q(1\pm\alpha_v), z)\\ &-S(q\alpha_h, q(1\pm\alpha_v), z) - S'(q\alpha_h, q(1\pm\alpha_v), z) - T_D\\ &+dW.(1\pm\alpha_v) = 0\end{aligned} \tag{4}$$

It has been assumed in the analysis that forces are evaluated for the same size of footing, B, and the same settlement, Δ, for the footing on reinforced and unreinforced soil, so F_{VBC} and $F'_{VBC'}$ shall be same for reinforced and unreinforced soil. The additional load (q - q_o) shall be taken by the reinforcement above the level $C'C$. Therefore,

$$\begin{aligned}&F_{VBC}(q_o\alpha_h, q_o(1\pm\alpha_v), z) - F'_{VBC'}(q_o\alpha_h, q_o(1\pm\alpha_v), z)\\ &= F_{VBC}(q\alpha_h, q(1\pm\alpha_v), z) - F'_{VBC'}(q\alpha_h, q(1\pm\alpha_v), z)\end{aligned} \tag{5}$$

Combining equations 3, 4 and 5, we get

$$\begin{aligned}&F_{VAD}(q\alpha_h, q_o(1\pm\alpha_v), z) + F'_{VAD'}(q\alpha_h, q(1\pm\alpha_v), z)\\ &-F_{VAD}(q_o\alpha_h, q_o(1\pm\alpha_v), z) - F'_{VAD'}(q_o\alpha_h, q_o(1\pm\alpha_v), z)\\ &= S(q\alpha_h, q(1\pm\alpha_v), z) + S'(q\alpha_h, q(1\pm\alpha_v), z) -\\ &S(q_o\alpha_h, q_o(1\pm\alpha_v), z) - S'(q_o\alpha_h, q_o(1\pm\alpha_v), z) + 2T_D\end{aligned} \tag{6}$$

where, for reinforced soil

$$F_{VAD}(q\alpha_h, q(1\pm\alpha_v), z) = \int_0^{X_o} \sigma_z(q\alpha_h, q(1\pm\alpha_v), x, z)dx \tag{7}$$

$$F'_{VAD'}(q\alpha_h, q(1\pm\alpha_v), z) = \int_{X'_o}^{0} \sigma'_z(q\alpha_h, q(1\pm\alpha_v), x, z)dx \tag{8}$$

$$S(q\alpha_h, q(1\pm\alpha_v), z) = \tau_{xz}(q\alpha_h, q(1\pm\alpha_v), X_o, z).\Delta H \tag{9}$$

$$S'(q\alpha_h, q(1\pm\alpha_v), z) = \tau'_{xz}(q\alpha_h, q(1\pm\alpha_v), X'_o, z).\Delta H \tag{10}$$

where X_o and X'_o are the values of X at which τ_{xz} is maximum. Similarly, for unreinforced soil

$$\begin{aligned}&F_{VAD}(q_o\alpha_h, q_o(1\pm\alpha_v), z) =\\ &\int_0^{X_o} \sigma_z(q_o\alpha_h, q_o(1\pm\alpha_v), x, z)dx\end{aligned} \tag{11}$$

$$\begin{aligned}&F'_{VAD'}(q_o\alpha_h, q_o(1\pm\alpha_v), z)\\ &= \int_{X'_o}^{0} \sigma'_z(q_o\alpha_h, q_o(1\pm\alpha_v), x, z)dx\end{aligned} \tag{12}$$

$$\begin{aligned}&S(q_o\alpha_h, q_o(1\pm\alpha_v), z) =\\ &\tau_{xz}(q_o\alpha_h, q_o(1\pm\alpha_v), X_o, z).\Delta H\end{aligned} \tag{13}$$

$$\begin{aligned}&S'(q_o\alpha_h, q_o(1\pm\alpha_v), z) =\\ &\tau'_{xz}(q_o\alpha_h, q_o(1\pm\alpha_v), X'_o, z).\Delta H\end{aligned} \tag{14}$$

Equations 7 to 14 may also be written in the dimensionless form as below:

$$F_{VAD}(q\alpha_h, q(1\pm\alpha_v), z) = J_z qB \tag{15}$$

in which $$J_z = \frac{\int_0^{X_o} \sigma_z(q\alpha_h, q(1\pm\alpha_v), x, z)dx}{qB} \tag{16}$$

$$F'_{VAD'}(q\alpha_h, q(1\pm\alpha_v), z) = J'_z qB \tag{17}$$

in which $$J'_z = \frac{\int_{X'_o}^{0} \sigma_z(q\alpha_h, q(1\pm\alpha_v), x, z)dx}{qB} \tag{18}$$

$$S(q\alpha_h, q(1\pm\alpha_v), z) = I_z q.\Delta H \tag{19}$$

$$I_z = \frac{\tau_{xz\max}(q\alpha_h, q(1\pm\alpha_v), x_o, z)}{q} \tag{20}$$

$$S'(q\alpha_h, q(1\pm\alpha_v), z) = I'_z q.\Delta H \tag{21}$$

$$I'_z = \frac{\tau'_{xz\max}(q\alpha_h, q(1\pm\alpha_v), x'_o, z)}{q} \tag{22}$$

Similarly,

$$F_{VAD}(q_o\alpha_h, q_o(1\pm\alpha_v), z) = J_z q_o B \tag{23}$$

where $$J_z = \frac{\int_0^{X_o} \sigma_z(q_o\alpha_h, q_o(1\pm\alpha_v), x, z)dx}{q_o B} \tag{24}$$

$$F'_{VAD'}(q_o\alpha_h, q_o(1\pm\alpha_v), z) = J'_z q_o B \tag{25}$$

in which $$J_z^{'} = \frac{\int_{X_o^{'}}^{0} \sigma_z(q_o\alpha_h, q_o(1\pm\alpha_v), x, z)dx}{q_o B} \qquad (26)$$

$$S(q_o\alpha_h, q_o(1\pm\alpha_v), z) = I_z q_o.\Delta H \qquad (27)$$

where, $$I_z = \frac{\tau_{xz\max}(q_o\alpha_h, q_o(1\pm\alpha_v), x_o, z)}{q_o} \qquad (28)$$

$$S'(q_o\alpha_h, q_o(1\pm\alpha_v), z) = I_z^{'} q_o.\Delta H \qquad (29)$$

where, $$I_z^{'} = \frac{\tau_{xz\max}^{'}(q_o\alpha_h, q_o(1\pm\alpha_v), x_o^{'}, z)}{q_o} \qquad (30)$$

The values of X_o/B corresponding to z/B values can be taken from the non-dimensional chart as shown in Fig. 3.

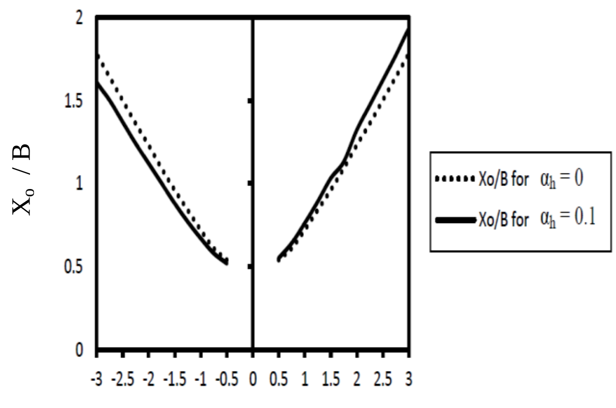

Fig.3: Non dimensional length for pressure ratio calculation of isolated strip footing on reinforced soil for α_h = 0.0 and α_h = 0.10.

In above equations J_z and I_z are dimensionless quantities whose values can be calculated at different depths under the footing using Boussinesq equations for normal and shear stresses. Substituting equation 15, 17, 19, 21, 23, 25, 27 and 29 in equation 7.

$$2T_D = \left[(J_z + J_z^{'})B - (I_z + I_z^{'})\Delta H\right](q - q_o) \qquad (31)$$

which may be expressed in terms of pressure ratio (p_r) as

$$2T_D = \left[(J_z + J_z^{'})B - (I_z + I_z^{'})\Delta H\right]q_o(p_r - 1) \qquad (32)$$

The values of J_z and I_z for different *z/B* values can be represented in form of non-dimensional charts. In these charts values of seismic coefficient i.e., α_h is varied for 0.0and 0.10. *q* is assumed as 10 kN/m^2, though the charts prepared are non-dimensional and does not depend on the value of *q*. The value of *q* was just considered to make the calculations easy. The Fig. 4 shown below are the different values of I_z and J_z for different α_h values.

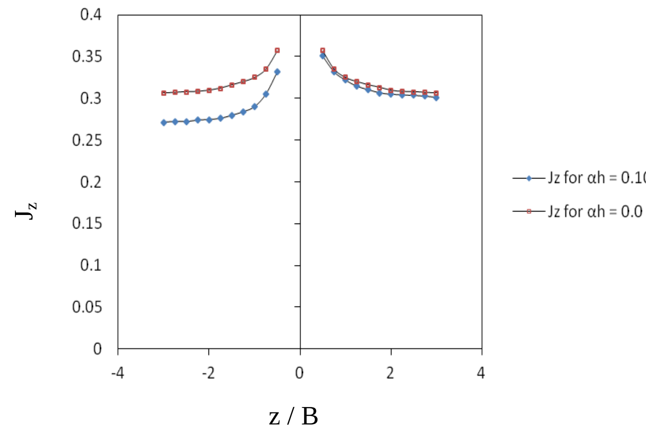

Fig. 4a: Values for J_z

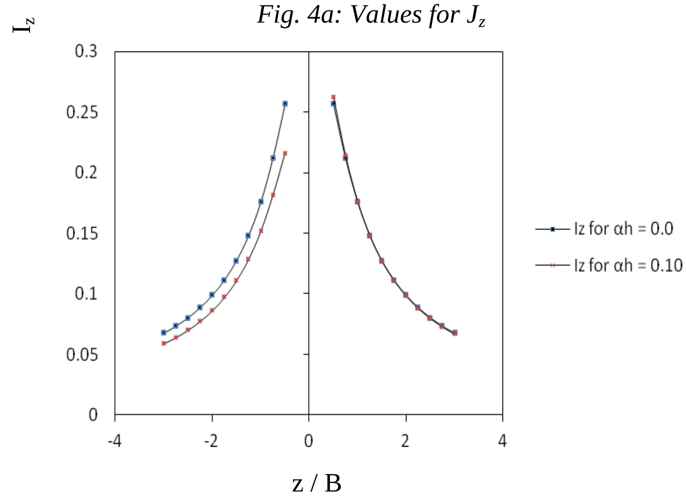

Fig.4b: Values for I_z

Fig.4: Non-Dimensional force components for pressure ratio calculation of isolated strip footing on reinforced soil. (I_z and J_z)

<u>Tie-Pull-Out Frictional Resistance (T_f)</u>

The tie-pull-out resistance is due to the normal force acting on the length of the tie which is outside the assumed plane separating downward and outward moving zones *a-c* (Figure 1). The normal force is consisting of two components. One is due to the applied bearing pressure and the other is due to the normal overburden pressure of soil.

The force due to applied pressure *q* is given by

$$F_{V1}(q\alpha_h, q(1\pm\alpha_v), z) = L_{DR}\int_{X_o}^{L_o} \sigma_z(q\alpha_h, q(1\pm\alpha_v), x, z)dx \qquad (33)$$

$$F_{V1}^{'}(q\alpha_h, q(1\pm\alpha_v), z) = L_{DR}\int_{L_o^{'}}^{X_o^{'}} \sigma_z(q\alpha_h, q(1\pm\alpha_v), x, z)dx \qquad (34)$$

where,

$$L_o = 0.5B + L_x = L_r / 2 \qquad (35)$$

L_x = Extension of reinforcement on either side of footing beyond the edge of the footing

L_r = Length of the reinforcement

L_{DR} = Linear Density of Reinforcement

= (Length of footing covered with reinforcement) / (Length of footing)

= 1 for geogrids / mats / sheets

Equation 33 and 34 may be written in dimensionless form as

$$F_{V1}(q\alpha_h, q(1\pm\alpha_v), z) = L_{DR}B.M_z q \quad (35)$$

$$F_{V1}^{'}(q\alpha_h, q(1\pm\alpha_v), z) = L_{DR}B.M_z^{'} q \quad (36)$$

in which
$$M_z = \frac{\int_{X_o}^{L_o} \sigma_z(q\alpha_h, q(1\pm\alpha_v), z)dx}{qB} \quad (37)$$

and
$$M_z^{'} = \frac{\int_{L_o^{'}}^{X_o^{'}} \sigma_z(q\alpha_h, q(1\pm\alpha_v), z)dx}{qB} \quad (38)$$

The figures shown below are the different values of M_z for different α_h values.

The force due to overburden pressure on the ties at depth z is given by

$$F_{V2} = L_{DR}\gamma(L_o - X_o)(z) \quad (39)$$

$$F_{V2}^{'} = L_{DR}\gamma(X_o^{'} - L_o^{'})(z) \quad (40)$$

where γ = Unit weight of the overburden soil.

The vertical normal force is given by

$$F_{VT} = F_{V1} + F_{V1}^{'} + F_{V2} + F_{V2}^{'} \quad (41)$$

The soil tie coefficient of friction is defined by f_e , where

$$f_e = m.f \quad (42a)$$

$$f = \tan\phi_f \quad (42b)$$

ϕ_f = Soil- reinforcement friction angle

The tie-pull-out frictional resistance, T_f, per unit length of strip footing at depth z in terms of pressure ratio may be written by combining Eqs. 35, 36, 39, 40, 41 and 42.

$$\begin{aligned} &2.f_e L_{DR}\left[M_z Bq_o p_r + \gamma(L_o - X_o)(z)\right] + \\ &2.f_e^{'} L_{DR}\left[M_z^{'} Bq_o p_r + \gamma(X_o^{'} - L_o^{'})(z)\right] = 2T_f \end{aligned} \quad (43)$$

For footing at depth D_f

$$\begin{aligned} &2.f_e L_{DR}\left[M_z Bq_o p_r + \gamma(L_o - X_o)(z + D_f)\right] + \\ &2.f_e^{'} L_{DR}\left[M_z^{'} Bq_o p_r + \gamma(X_o^{'} - L_o^{'})(z + D_f)\right] = 2T_f \end{aligned} \quad (44)$$

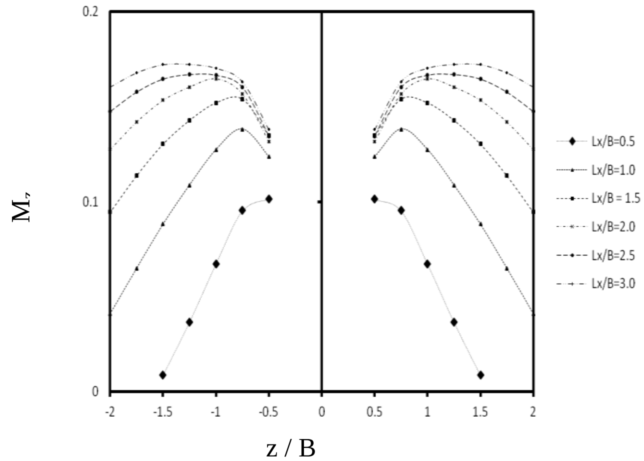

Fig. 5a: Value of M_z for α_h = 0.0

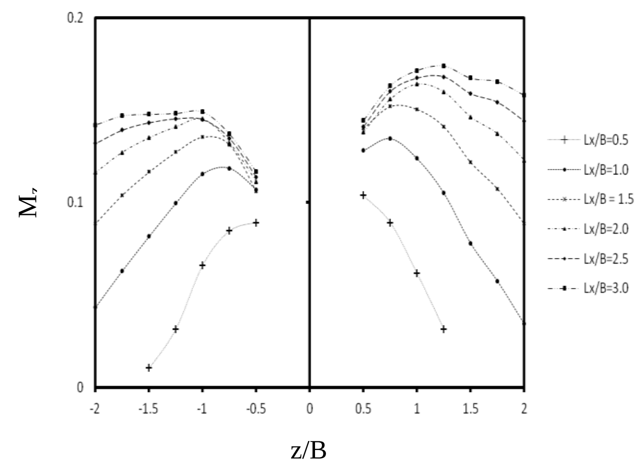

Fig.5b: Value for M_z for α_h = 0.10

Fig.5: Non-Dimensional force components for pressure ratio calculation of isolated strip footing on reinforced soil. (M_z)

DETERMINATION OF PRESSURE RATIO (p_r)

The pressure ratio p_r for a strip footing has been computed by applying the following conditions:

(a) The developed tie force in any layer should not exceed the tie- pull – out frictional resistance, in the same layer, i.e.,

$$m_i T_{Di} \le T_{fi} \quad (45)$$

where i = 1, 2… N

(b) The developed tie force in any layer should not exceed the tie breaking strength of the same layer. i.e.,

$$m_i T_{Di} \le T_{RF} \quad (46)$$

where,

T_{RF} = Total breaking force in that layer

= R_T X length of reinforcement along which breakage may take place. (47)

R_T = Allowable tensile strength of reinforcement per unit length

As mentioned earlier, m_i's are the distribution factors assumed for the distribution of the tie force in N- layers, such that $m_1 + m_2 + ... + m_N = 1$. The check is applied for different combinations of tie – pull – out and breaking failures. The minimum value shall be the critical p_r value.

ULTIMATE BEARING CAPACITY OF FOOTINGS ON REINFORCED EARTH BED

Applying the approach discussed herein, it is possible to calculate the pressure intensity of a footing on reinforced soil for a settlement Δ, corresponding to the given pressure intensity obtained for the same footing resting on unreinforced soil and for the same settlement Δ. Therefore, the pressure settlement values of reinforced soil can be computed upto the ultimate bearing capacity of the unreinforced soil. The experimental results show that this does not give the ultimate bearing capacity of the reinforced soil (Kumar, 1997).

It is observed that when footing length reinforcement layers are placed beneath the footing upto a depth D_R the bearing capacity increases and the effect is similar to that of unreinforced sand with the footing located at depth D_R. This is applicable upto 1.0B (Singh, 1988; Huang and Tatsuoka, 1990; Kumar, 1997). Now, if q_r is the pressure intensity of reinforced soil for a settlement corresponding to ultimate bearing capacity of unreinforced soil q_u, then ultimate bearing capacity of the reinforced soil (q_{ur}) is being given by:

$$q_{ur} = q_r + \gamma D_R N_{qE} \tag{48}$$

where, q_r and q_{ur} are as shown in Fig. 6

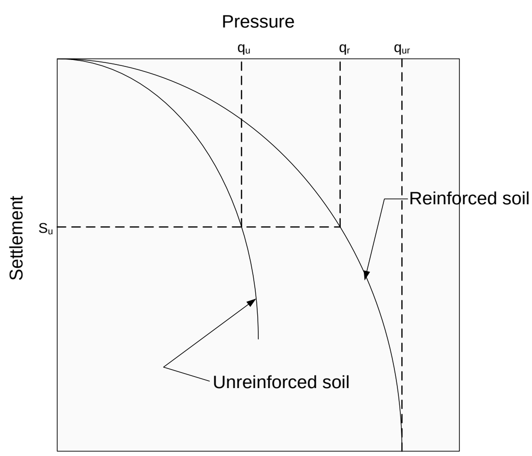

Fig.6: General nature of pressure-settlement curves for unreinforced and reinforced sand supporting a footing

D_R is the depth of lowermost layer of reinforcement from ground level

N_{qE} is seismic bearing capacity factor for a surcharge (Budhu and Al – Karni,1993)

Values of q_r can be obtained from the pressure ratio corresponding to the ultimate pressure of the actual footing i.e., q_u. Let this pressure ratio be p_{ru}.

Then,

$$q_r = q_u . p_{ru} \tag{49}$$

ILLUSTRATIVE EXAMPLE

The ultimate static bearing capacity for a 1 m wide strip footing founded 1 m below a homogenous soil with φ = 30° and a unit weight of 15.8 kN/m^3 is 859.284 kN/m^2 for single layer of reinforcement. The ultimate seismic bearing capacity for a horizontal acceleration of 0.1g and a vertical acceleration of 0.067g works out as 534.593 kN/m^2 for single layer of reinforcement.

Total of three layers of reinforcement are considered. Also no reinforcement layer condition is also considered (Table 1).

Table 1: Net increment in bearing capacity for different α_h values

No. of reinforcement layers	Static Case	Dynamic Case
	α_h = 0.0	α_h = 0.10
	q_{uS}	q_{uE}
None	466.89	268.205
Single	859.284	534.493
Two	930.81	590.987
Three	1006.40	652.66
Net Increment	2.15	2.43

CONCLUSIONS

From the study carried out to determine the ultimate seismic bearing capacity of strip footing resting on reinforced earth bed following conclusions can be drawn:

(1) Non Dimensional charts have been developed for obtaining seismic bearing capacity of a strip footing resting on reinforced earth bed.

(2) The ratio of the bearing capacity of a footing resting on reinforced earth slab in seismic condition to the bearing capacity of the same footing in static condition decreases with increase in horizontal seismic coefficient (α_h) for particular number of reinforcing layers.

(3) The ratio of the bearing capacity of a footing resting on reinforced earth slab in seismic condition to the

bearing capacity of the same footing in static condition increases with increase in number of reinforcement layers for a particular value of horizontal seismic coefficient (α_h).

REFERENCE

1. Akinmusuru J.O. and Akinbolande J.A. (1981). “Stability of Loaded Footings on Reinforced Soil.” *Journal of Geotechnical Engineering Division, ASCE,* Vol.107, GT6, pp.819-827.
2. Binquet J. and Lee K.L. (1975a). “Bearing Capacity Tests on Reinforced Earth Slabs.” *Journal of Geotechnical Engineering Division, ASCE,* Vol. 101, No.GT12, pp. 1241-1255.
3. Binquet J. and Lee K.L. (1975b). “Bearing Capacity Analysis of Reinforced Earth Slabs.” *Journal of Geotechnical Engineering Division, ASCE,* Vol. 101, No.GT12, pp. 1257-1276.
4. Budhu, M. and Al- Karni, A.A. (1993). “Seismic Bearing Capacity of Soils.” *Geotechnique,* 43 (I), pp. 181 – 187.
5. Dembicki E., Jermolomicz P. And Niemunis A. (1986). “Bearing Capacity for Strip Foundations of Soft Soil Reinforced by Geotextiles.” *Proc. Third International Conference on Geotextiles,* Vienna, Austria, Vol.2A/6, pp. 205-208.
6. Dixit A.M. (1978). “Interaction of Different Types of Footing on Sand.” *Indian Geotechnical Journal,* Vol.8 (4), pp.193-204.
7. Fragaszy R.J. and Lawton E. (1984). “Bearing Capacity of Reinforced Sand Subgrade.” *Journal of Geotechnical Engineering Division, ASCE,* Vol.110, No.10, pp.1500-1507.
8. Guido V.A., Biesiadecki G.L. and Sullivan M.J. (1985). “Bearing Capacity of Geotextile-Reinforced Foundation.” *Proc. 11th International Conference on Soil Mechanics and Foundation Engineering,* San Francisco, Calf, Vol. 5/c/3, pp. 1777-1780.
9. Huang C.C. and Tatsuoka F. (1990). “Bearing Capacity of Reinforced Horizontal Sandy Ground.” *Geotextiles and Geomembranes,* Vol.9, pp. 51-82.
10. Khing K.H., Das B.M., Puri V.K., Cook E.E. and Yen S.C. (1993). “The Bearing Capacity of a Strip Foundation on Geogrid- Reinforced Sand.” *Geotextiles and Geomembranes,* Vol.12, pp.351-361.
11. Khing K.H., Das B.M., Puri V.K., Cook E.E. and Yen S.C. (1994). “Foundation on Strong Sand Underlain by Weak Clay with Geogrid at the Interface.” *Geotextiles and Geomembranes,* Vol.13, pp.199-206.
12. Kumar A. (1997). *Interaction of Footing Resting on Reinforced Sand,* at Indian Institute of Technology Roorkee, at Roorkee, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.
13. Mandal J.N. and Manjunath V.R. (1990). “Bearing Capacity of Single Layer of Geosynthetic Sand Subgrade.” *Proc. IGC-90,* Bombay, India, Vol.1, pp.7-10.
14. Mandal J.N. and Shah H.S. (1992). “Bearing Capacity Tests of Geogrid Reinforced Clay.” *Technical Note, Geotextiles and Geomembranes,* Vol.11, pp.327-333.
15. Rao G.V., Kate J.M. and Shamsher F.H. (1994). “Soil Improvement with Geosynthetics.” *XIII ICSMFE,* New Delhi, India, pp. 1237-1240.
16. Samtani N.C. and Sonpal R.C. (1989). “Laboratory Tests of Strip Footing on Reinforced Cohesive Soil.” *Journal of Geotechnical Engineering Division, ASCE,* Vol.115, No.9, pp.1326-1330.
17. Saran S., Rao A.S.R. and Singh H. (1985). “Behaviour of Eccentrically Loaded Footings on Reinforced Earth Slab.” *IGC-85*, Roorkee, Vol.1, pp.117-122.
18. Shankariah B. (1991). “Effect of Size and Type of Reinforcement on Bearing Capacity of Reinforced Sand Subgrade.” *IGC-91*, Surat, India, pp. 95-98.
19. Singh H.R. (1998). *Bearing Capacity of Reinforced Soil Beds* at Indian Institute of Science, at Bangalore, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.
20. Sreekanieth H.R. (1987). “An Investigation of a Rectangular Footing on Reinforced Sand.” *IGC-87,* Bangalore, Vol.1, pp.121-124.
21. Sreekanieth H.R. (1990). “Loaded Footing on Geotextile Reinforced Sand Bed.” *IGC-90,* Bombay, Vol. 1, pp.73-77.
22. Sridharan A., Murthy B.R.S. and Singh H.R. (1988). “Shape and Size Effects of Foundations on the Bearing Capacity of Reinforced Soil Beds.” *IGC-88,* Allahabad, Vol. 1, pp.205-210.
23. Vidal H. (1966). *La Terre Armee, Annales de l’Institut Technique du Batiment et des Travaux Publics*, pp.888-938