Effect of shape on bearing capacity of embedded footings on reinforced foundation beds over soft non-homogeneous ground

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ABSTRACT

The paper presents the effect of shape on bearing capacity of footings on reinforced foundation bed over soft non-homogeneous ground. The model considered for study consists of a two-layered system of granular fill over soft non-homogeneous ground with a single horizontal layer of geosynthetic reinforcement in the granular fill. Meyerhof’s punching mode of failure for footings on dense sand overlying soft homogeneous clay is extended to include the effects of non-homogeneity of soft ground and the axial resistance of the reinforcement to pullout. Shape of footing is an important parameter that influences the ultimate bearing capacity of ground/soil. Solutions are given for strip, square, circular and rectangular footings on both unreinforced as well as reinforced granular beds. A parametric study quantifies the contributions of various parameters on the improved bearing capacity of footings upon consideration of non-homogeneity, embedment and reinforcement. Predictions compare well with experimental results in literature.

Keywords: non-homogeneity, bearing capacity ratio (BCR), granular fill, geosynthetic reinforcement, axial resistance

1 INTRODUCTION

Most naturally deposited clays exhibit undrained strength increasing linearly with depth. Davis and Booker (1973) presented solutions for bearing capacity of a strip footing resting on a non-homogeneous deposit whose undrained shear strength increases with depth and detailed possible strength variations as shown in Fig. 1. Despite the fact that majority of field conditions indicate non-homogeneity, most solutions for bearing capacity of footings in soft clay consider only homogeneous deposits, neglecting natural or stress induced non-homogeneity.

Hu and Randolph (1999) compared the bearing response of strip and circular footings penetrating deeply into non-homogeneous cohesive soil from finite element method, with lower and upper bound plasticity solutions. Rethaliya and Verma (2009) considered contributions from stress distribution through sand layer, shear layer effect and membrane action of reinforcement, on the bearing capacity of a strip footing on geotextile reinforced sand over soft homogeneous clay. Rajyalakshmi et al. (2012) presented a method for estimation of bearing capacity of a strip footing on a geosynthetic reinforced foundation bed overlying soft non-homogeneous clay, whose undrained shear strength increases linearly with depth.

Fig. 1. Idealized undrained strength versus depth profiles: a) Normally consolidated deposit, b) Aged deposit and c) Normally consolidated deposit with crust (after Davis and Booker 1973).

2 PROBLEM DEFINITION & FORMULATION

Figure 2 shows a footing of width/diameter, B, embedded at a depth, Df, below the ground surface in a reinforced granular fill of thickness, H, over soft non-homogeneous ground whose undrained shear strength, $s_u$, increases from a value, $s_{u0}$, at the granular fill-soft non-homogeneous ground interface, linearly with depth, z, at a rate, $\rho$. A single layer of geosynthetic reinforcement of length, $L_r$, is placed just above the granular fill-soft non-homogeneous ground interface, but within the granular fill itself.
The angle of shearing resistance and unit weight of the granular fill are $\phi$ and $\gamma$ respectively. The interface/bond resistance between the reinforcement and the fill is $\phi_r$ and the axial tension developed in the reinforcement is $T_r$.

Davis and Booker (1973), using the method of characteristics, obtained plasticity solution for the bearing capacity of smooth and rough footings on a non-homogeneous deposit (Fig. 1), which is significantly different from those on a homogeneous deposit. The ultimate bearing capacities, $q_{nc}$, of strip, square, circular and rectangular footings on the surface of a deposit whose undrained shear strength increases linearly with depth are

$$q_{nc(strip)} = \frac{F}{B} \left[ s_{u0} N_c + \frac{1}{4} \rho B \right]$$

$$q_{nc(square/circle)} = 1.2 F \left[ s_{u0} N_c + \frac{1}{4} \rho B \right]$$

$$q_{nc(rectangle)} = \left( 1 + 0.2 \frac{B}{L} \right) F \left[ s_{u0} N_c + \frac{1}{4} \rho B \right]$$

where $N_c = (2+\pi)$ is a bearing capacity factor; $s_{u0}$ - the undrained shear strength of the deposit at the granular fill-non-homogeneous ground interface; $\rho = ds_{u}/dz$ - the rate of increase of undrained shear strength, $s_u$, of the deposit with depth, $z$; $B$ - the least lateral dimension of the footing and $F = f(\rho B/s_{u0})$ - a correction factor.

Meyerhof (1974) proposed a punching mode of failure for footing of width/diameter, $B$, and depth $D$, resting on a relatively thin, dense sand stratum of thickness, $H$ with angle of shearing resistance, $\phi$ and unit weight, $\gamma$, overlying thick soft clay with undrained cohesion, $c$ (Fig. 3). A total passive force, $P_p$, inclined at an angle, $\delta$, acts on a vertical plane through the footing edge. The possible failure modes of the footing, namely, punching shear through a relatively thin sand layer (Fig. 3a) and general shear failure within a thick sand layer alone (Fig. 3b) are shown.

Fig. 2. Definition sketch of footing on reinforced granular bed over soft non-homogeneous ground.

As the footing punches through the sand layer into soft clay, shear stresses are developed on either sides of the sand column. The ultimate bearing capacities, $q_u$, of strip, square, circular and rectangular footings in dense sand over soft clay are

$$q_{u(strip)} = c N_c + \frac{\gamma H^2}{B} \left( 1 + \frac{2D}{H} \right) K_p \tan \phi + \gamma D$$

$$q_{u(square)} = 1.2 c N_c + \frac{2\gamma H^2}{B} \left( 1 + \frac{2D}{H} \right) K_p \tan \phi + \gamma D$$

$$q_{u(circle)} = 1.2 c N_c + \frac{2\gamma H^2}{B} \left( 1 + \frac{2D}{H} \right) s_k \tan \phi + \gamma D$$

$$q_{u(rectangle)} = \left( 1 + 0.2 \frac{B}{L} \right) c N_c + \left( 1 + \frac{B}{L} \right) \frac{\gamma H^2}{B} \left( 1 + \frac{2D}{H} \right) K_p \tan \phi + \gamma D$$

where $s$ is the shape factor governing the passive earth pressure on a cylindrical wall; $K_p$ is the coefficient of punching shearing resistance; $N_c$ (equal to 5.14 for soft clay with $\phi_u = 0$), $N_q$ and $N_\gamma$ are Meyerhof’s bearing capacity factors. The ultimate bearing capacities, $q_u$, of strip, square, circular and rectangular footings in dense sand over soft clay are limited by that of a thick deposit of sand.

2.1 Bearing capacity of footing on granular bed over soft non-homogeneous ground

Normalizing Eqs. (1), (2) and (3) with the undrained shear strength of soft ground, $s_{u0}$, the normalized ultimate bearing capacities, $N_{nc}$, of strip, square, circular and rectangular footings installed at depth, $D_f$, in soft non-homogeneous ground alone, are

$$N_{nc(strip)} = F \left[ N_c + \frac{1}{4} \left( \frac{\rho B}{s_{u0}} \right) \right] + \left( \frac{\gamma B}{s_{u0}} \right) \left( \frac{D_f}{B} \right)$$

$$N_{nc(square/circle)} = 1.2 F \left[ N_c + \frac{1}{4} \left( \frac{\rho B}{s_{u0}} \right) \right] + \left( \frac{\gamma B}{s_{u0}} \right) \left( \frac{D_f}{B} \right)$$

Fig. 3. Failure mechanism for footing in dense sand over soft clay (after Meyerhof 1974).
The ultimate bearing capacities, \( q_{\text{ncb}} \), of strip, square, circular and rectangular footings in a two-layered system of granular fill over soft non-homogeneous ground are obtained by incorporating Davis and Booker’s theory in Meyerhof’s solution, as

\[
N_{\text{ncb(rectangle)}} = \left(1 + \frac{0.2B}{L}\right)F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\( \gamma \) H

The ultimate bearing capacities, \( q_{\text{ncb}} \), of strip, square, circular and rectangular footings in a two-layered system of granular fill over soft non-homogeneous ground are obtained by incorporating Davis and Booker’s theory in Meyerhof’s solution, as

\[
q_{\text{ncb}} = F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
q_{\text{ncb(square)}} = 1.2F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
q_{\text{ncb(circular)}} = 1.2F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
q_{\text{ncb(rectangular)}} = \left(1 + \frac{0.2B}{L}\right)F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

where \( K_s \) is the coefficient of punching shearing resistance-a function of the angle of shearing resistance of the granular fill, \( \phi \), and the ratio \( q_2/q_1 \), where \( q_1 \) and \( q_2 \) are the ultimate bearing capacities of footing on the surface of thick granular bed and soft non-homogeneous ground respectively. Considering the total thickness of the granular fill as \( H \) (Fig. 2) and normalizing Eqs. (11), (12), (13) and (14) with the undrained shear strength of soft ground, \( s_u \), the normalized ultimate bearing capacities, \( N_{\text{ncb}} \), of strip, square, circular and rectangular footings in a two-layered system of granular fill over soft non-homogeneous ground, are

\[
N_{\text{ncb(rectangle)}} = \left(1 + \frac{0.2B}{L}\right)F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
N_{\text{ncb(square)}} = 1.2F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
N_{\text{ncb(circular)}} = 1.2F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
N_{\text{ncb(rectangular)}} = \left(1 + \frac{0.2B}{L}\right)F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

where \( K_s \) is the coefficient of punching shearing resistance-a function of the angle of shearing resistance of the granular fill, \( \phi \), and the ratio \( q_2/q_1 \), where \( q_1 \) and \( q_2 \) are the ultimate bearing capacities of footing on the surface of thick granular bed and soft non-homogeneous ground respectively. Considering the total thickness of the granular fill as \( H \) (Fig. 2) and normalizing Eqs. (11), (12), (13) and (14) with the undrained shear strength of soft ground, \( s_u \), the normalized ultimate bearing capacities, \( N_{\text{ncb}} \), of strip, square, circular and rectangular footings in a two-layered system of granular fill over soft non-homogeneous ground, are

\[
N_{\text{ncb(rectangle)}} = \left(1 + \frac{0.2B}{L}\right)F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
N_{\text{ncb(square)}} = 1.2F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
N_{\text{ncb(circular)}} = 1.2F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

\[
N_{\text{ncb(rectangular)}} = \left(1 + \frac{0.2B}{L}\right)F \left[N_c + \frac{1}{4} \left(\frac{\rho B}{s_u}\right)\right] + \left(\frac{yB}{s_u}\right)\left(\frac{D_f}{B}\right)
\]

2.2 Bearing capacity of footing on reinforced granular bed over soft non-homogeneous ground

Fig. 4. Stresses on (a) reinforced granular column and (b) geosynthetic reinforcement.

The ultimate bearing capacities, \( q_{\text{ncb}} \), of strip, square, circular and rectangular footings in a two-layered system of granular fill over soft non-homogeneous ground (Fig. 2), are obtained by incorporating the contribution of the axial resistance of the geosynthetic reinforcement to pull-out. The axial tension developed in the reinforcement layer of length, \( L_r \), is due to interface shear resistance mobilized over the surface of the reinforcement. Figs. 4a & b depict the stresses developed in the reinforced granular column and the geosynthetic reinforcement respectively, due to punching of the footing through the reinforced granular bed into underlying soft non-homogeneous ground. The length of the reinforcement beyond the edge of the footing, \( L_r - B \), is considered to be effective in contributing to axial resistance and bearing capacity improvement. The axial tension, \( T_R \), developed in the reinforcement due to shear stresses over the surface of the reinforcement at the granular fill-soft non-homogeneous ground interface is

\[
T_{R(\text{strip})} = \gamma H \tan \phi_r (L_r - B)
\]

\[
T_{R(\text{square})} = \gamma H \tan \phi_r (L_r^2 - B^2)
\]

\[
T_{R(\text{rectangle})} = \gamma H \tan \phi_r (L_r^2 - LB)
\]

Figure 5 shows the geosynthetic reinforcement of diameter, \( L_r \), under a circular footing of diameter \( B \). The axial resistance mobilized by the reinforcement beneath a circular footing is as considered by Rethalliya and Verma (2009). Considering an elemental area of the reinforcement \( \Delta A = \pi r \Delta \theta \Delta r \) under the circular footing and integrating, the axial tension, \( T_R \), developed in the reinforcement layer due to shear stresses over the surface of the reinforcement at the granular fill-soft non-homogeneous ground interface is

\[
T_{R(\text{circle})} = \frac{\pi}{2} \gamma H \tan \phi_r (L_r^2 - B^2)
\]

The ultimate bearing capacities, \( q_{\text{ncb}} \), of strip, square, circular and rectangular footings in a two-layered system of reinforced granular fill over soft non-homogeneous ground, thus becomes
Fig. 5. Geosynthetic reinforcement of diameter, \( L_r \), under circular footing of diameter, \( B \).

Normalizing Eqs. (23), (24), (25) and (26) with the undrained shear strength of soft ground, \( s_{u0} \), the normalized ultimate bearing capacities, \( N_{ncbr} \), of strip, square, circular and rectangular footings in a two-layered system of reinforced granular fill over soft non-homogeneous ground are

\[
N_{ncbr(\text{strip})} = \left( 1 + 0.2 \frac{B}{L} \right) F \left[ \frac{N_c}{L} + \frac{1}{4} \left( \frac{\rho B}{s_{u0}} \right) \right] + \frac{\gamma B}{L} \left( \frac{H}{B} - \frac{D_f}{B} \right) K_t \tan \varphi \left( \frac{L_r}{L} \right)^2 - 1 \tag{27}
\]

\[
N_{ncbr(\text{square})} = 1.2 F \left[ \frac{N_c}{L} + \frac{1}{4} \left( \frac{\rho B}{s_{u0}} \right) \left( \frac{H}{B} - \frac{D_f}{B} \right)^2 \right] + \frac{\gamma B}{L} \left( \frac{H}{B} - \frac{D_f}{B} \right) K_t \tan \varphi \left( \frac{L_r}{L} \right)^2 - 1 \tag{28}
\]

\[
N_{ncbr(\text{circle})} = 1.2 F \left[ \frac{N_c}{L} + \frac{1}{4} \left( \frac{\rho B}{s_{u0}} \right) \left( \frac{H}{B} - \frac{D_f}{B} \right)^2 \right] + \frac{\gamma B}{L} \left( \frac{H}{B} - \frac{D_f}{B} \right) K_t \tan \varphi \left( \frac{L_r}{L} \right)^2 - 1 \tag{29}
\]

\[
N_{ncbr(\text{rectangle})} = \left( 1 + \frac{\rho B}{s_{u0}} \right) F \left[ \frac{N_c}{L} + \frac{1}{4} \left( \frac{\rho B}{s_{u0}} \right) \left( \frac{H}{B} - \frac{D_f}{B} \right)^2 \right] + \frac{\gamma B}{L} \left( \frac{H}{B} - \frac{D_f}{B} \right) K_t \tan \varphi \left( \frac{L_r}{L} \right)^2 - 1 \tag{30}
\]

Bearing capacities ratios, \( BCR \), are defined to quantify the degrees of improvement as:

\[
(BCR)_{ncb} = \frac{N_{ncb}}{N_{nc}} \text{ is the ratio of the normalized ultimate bearing capacity of footing in an unreinforced two-layered system of granular fill over soft non-homogeneous ground, to that in soft non-homogeneous ground alone. The ratio (BCR)_{ncb} quantifies the contribution of the granular fill.}
\]

\[
(BCR)_{ncbr} = \frac{N_{ncbr}}{N_{nc}} \text{ is the ratio of the normalized ultimate bearing capacity of footing in a reinforced two-layered system of granular fill over soft non-homogeneous ground, to that in soft non-homogeneous ground alone. The ratio (BCR)_{ncbr} quantifies the contribution of both the granular fill as well as the geosynthetic reinforcement.}
\]

\[
(BCR)_{ncbr}^{*} = \frac{N_{ncbr}}{N_{ncb}} \text{ is the ratio of the normalized ultimate bearing capacity of footing in a reinforced two-layered system of granular fill over soft non-homogeneous ground, to that of an unreinforced system. The ratio (BCR)_{ncbr}^{*} quantifies the contribution of the reinforcement alone.}
\]

3 RESULTS AND DISCUSSION

The ultimate bearing capacity of strip, square, circular and rectangular footings, in a two-layered system of granular fill over soft non-homogeneous ground, depends on the normalized foundation depth, \( D_f/B \), angle of shearing resistance of the granular material, \( \varphi \), normalized fill thickness, \( H/B \), \( \rho B/s_{u0} \) related to the non-homogeneity of soft ground and \( \gamma B/s_{u0} \), related to the unit weight of the granular fill, least lateral dimension of the footing and undrained shear strength of soft non-homogeneous ground at the interface with the granular fill. If the granular fill is reinforced with a layer of geosynthetic, parameters \( L_r/B \) and \( \varphi_r/\varphi \) also influence the bearing capacity of the two-layered system. A parametric study quantifies the effects of \( B/L \) and \( \rho B/s_{u0} \) on the normalized ultimate bearing capacity and bearing capacity ratio of strip, square, circular and rectangular footings.

Figures 6 and 7 present the variations of the normalized bearing capacities, \( N_{nc} \) and \( N_{ncbr} \), of strip, square, circular and rectangular footings in a two-layered system of unreinforced and reinforced granular fill over soft non-homogeneous ground, respectively, with \( \rho B/s_{u0} \), for \( \varphi = 35^\circ \), \( D_f/B \) of 0.5, \( H/B \) of 1.0, \( \varphi_r/\varphi \) of 0.75 (reinforced case) and \( L_r/B \) of 3.0 (reinforced case).
Fig. 6. $N_{ncb}$ versus $\rho B/s_{u0}$ – effect of shape of footing.

$N_{ncb}$ and $N_{ncbr}$ increase non-linearly with $\rho B/s_{u0}$ due to enhanced contribution from inherent non-homogeneity of soft ground, towards the bearing capacity of the footing. Square and circular footings display relatively higher normalized ultimate bearing capacities than strip and rectangular footings due to all-round passive resistance, against punching, mobilized by the granular fill. Strip footing, being a plane-strain problem, yields the lowest normalized bearing capacity due to passive resistance mobilized, only along the length of the footing, by the granular fill. Similar behavior is observed when the granular fill is reinforced with a layer of geosynthetic, in this case, the mobilization of interface shear resistance over the effective surface area of the reinforcement. $N_{ncbr}$ values are greater than $N_{ncb}$ due to additional contribution from the axial resistance to pullout mobilized by the reinforcement towards the ultimate bearing capacity of the footing. Tables 1 and 2 present the values of $N_{ncb}$ and $N_{ncbr}$ for different $\rho B/s_{u0}$ and shapes of footing.

Figures 8, 9 and 10 present the variations of the bearing capacity ratios, $(BCR)_{ncb}$, $(BCR)_{ncbr}$ and $(BCR)_{ncbr}^*$, of strip, square, circular and rectangular footings in a two-layered system of unreinforced and reinforced granular fill over soft non-homogeneous ground, respectively, with $\rho B/s_{u0}$, for $\phi$ of 35°, $D_y/B$ of 0.5, $H/B$ of 1.0, $\phi_r/\phi$ of 0.75 (reinforced case) and $L_r/B$ of 3.0 (reinforced case). $(BCR)_{ncb}$, $(BCR)_{ncbr}$ and $(BCR)_{ncbr}^*$ decrease non-linearly with $\rho B/s_{u0}$ due to increase in undrained shear strength of soft ground with depth. Square and circular footings project higher BCR than rectangular and strip footings. Moreover, the difference between the relative improvement of bearing capacity of a square and a circular footing on an unreinforced/reinforced granular fill over soft non-homogeneous ground is significant. Tables 3, 4 and 5 present the values of $(BCR)_{ncb}$, $(BCR)_{ncbr}$ and $(BCR)_{ncbr}^*$ for different $\rho B/s_{u0}$ and shapes of footing.
Fig. 9. (BCR)$_{ncbr}$ versus $\rho_B/s_{u0}$ – effect of shape of footing.

Table 3. (BCR)$_{ncb}$ values for different $\rho_B/s_{u0}$ and type of footing.

| Footing            | Circle | Square | Rectangle ($B/L = 0.6$) | Strip |
|--------------------|--------|--------|-------------------------|-------|
| $\rho_B/s_{u0} = 0$| 2.93   | 2.86   | 2.53                    | 1.96  |
| 4                  | 2.61   | 2.51   | 2.25                    | 1.78  |
| 12                 | 2.41   | 2.29   | 2.07                    | 1.66  |
| 24                 | 2.25   | 2.11   | 1.93                    | 1.56  |

Table 4. (BCR)$_{ncbr}$ values for different $\rho_B/s_{u0}$ and type of footing.

| Footing            | Circle | Square | Rectangle ($B/L = 0.6$) | Strip |
|--------------------|--------|--------|-------------------------|-------|
| $\rho_B/s_{u0} = 0$| 11.59  | 7.19   | 5.65                    | 3.13  |
| 4                  | 9.03   | 5.72   | 4.59                    | 2.67  |
| 12                 | 7.33   | 4.75   | 3.88                    | 2.35  |
| 24                 | 6.07   | 4.02   | 3.34                    | 2.11  |

Table 5. (BCR)$_{ncbr}$* values for different $\rho_B/s_{u0}$ and type of footing.

| Footing            | Circle | Square | Rectangle ($B/L = 0.6$) | Strip |
|--------------------|--------|--------|-------------------------|-------|
| $\rho_B/s_{u0} = 0$| 3.95   | 2.52   | 2.24                    | 1.60  |
| 4                  | 3.45   | 2.28   | 2.04                    | 1.50  |
| 12                 | 3.05   | 2.08   | 1.87                    | 1.42  |
| 24                 | 2.70   | 1.90   | 1.73                    | 1.35  |

Fig. 10. Comparison of present study with experimental results of Meyerhof (1974).

Figure 10 compares the present method for estimation of bearing capacity of footings embedded in a granular bed over soft non-homogeneous ground, with experimental results for strip and circular footings performed by Meyerhof (1974), for $\phi = 47^\circ$, $D_y/B$ of 0.5, $\rho_B/s_{u0}$ of 0 and $\gamma_B/s_{u0}$ of 0.04. Predicted normalized bearing capacities compare well with those obtained by Meyerhof (1974).

4 CONCLUSIONS

A study on effect of shape on bearing capacity of embedded footings on reinforced foundation beds over soft non-homogeneous ground is presented. Consideration of in-situ non-homogeneity of soft ground yields relatively higher bearing capacity of footing over a homogeneous case. BCR of footing in a two-layered system of reinforced granular fill over soft non-homogeneous ground is enhanced due to contribution from axial resistance of reinforcement when compared to an unreinforced one. Square and circular footings exhibit relatively higher bearing capacity and BCR over rectangular and strip footings.

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