Behaviour of interfering embedded footings laid in unreinforced and reinforced sand medium

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According to the literature, the current understanding of the interference effect on the performance of footings is with respect to surficial footings. In practice, however, the footings are laid below the ground surface. In this study, the interference behaviour of two identical strip and square footings embedded in a cohesionless, homogeneous soil medium was examined by performing 72 laboratory model tests. The sand bed was prepared using rainfall technique and reinforced with a single biaxial geogrid layer. Parameters such as footing shape, embedment depth and the spacing between the footings were altered. Using the observed data, multiple regression analysis established a relationship between interference variables related to load-carrying capacity/ settlement footing spacing and embedment depth for unreinforced and reinforced soil medium. The test results show that the embedment depth of ultimate bearing capacity and settlement affects interfering footings more than surficial footings. Strip footings are affected to a greater extent than square footings. The load-carrying capacity of two footings increases due to the enhancement of the zone of interference by 12.2% and 39.6% for the strip and square footings respectively.

Keywords: Embedded footings, interference, reinforced soil, settlement characteristics, ultimate bearing capacity.

THE foundation is an essential structural component that safely distributes the superstructural load to the soil medium underneath. Foundation designers must interpret foundation stresses. Numerous design theories for isolated footings have been published. Due to nearby footings, such designs may be inconsistent in many instances. Structures and substructures are closer due to infrastructure expansion, urbanization and building space issues. Such foundations have distinct bearing capacity, settling, failure mechanism and rotational properties compared to isolated foundations. Experimental and numerical/analytical studies have addressed this problem, such as the method of stress characteristics[1], upper-bound limit analysis[2,3], lower-bound limit analysis[4], finite difference method[5,6], finite element method[7–10], and some laboratory, small-scale experimental procedures[11–18]. Ghazavi and Dehkordi[19] carried out an extensive state-of-the-art study on the influence of interference on the behaviour of shallow footings. The interference effect varies with embedment depth, footing width, shape, spacing and differential load intensity. In a series of 1g model tests on parallel strip footings on saturated sand with new footing close to the previously loaded old footing, Salamatpoor *et al.*[14] found that settlement increased by five times compared to the isolated footing. Saha Roy and Deb[16] examined rectangular footings with two-layered soil deposits and different length to width ratio (L/B). Closely spaced footings on a single-layer sand substrate have the highest interference factor. Besides, the interference factor increases with the L/B ratio. The interference impact of two closely spaced strip footings subjected to a uniformly distributed load on the settlement response was examined by Ghosh *et al.*[20] using the Pasternak model and linear and nonlinear elastic analysis. Using the three-dimensional finite element program, ABAQUS, Fuentes *et al.*[21] studied the interference behaviour of closely spaced shallow square footings.

The literature shows that studies have been done on surface footing, but placing the foundation at ground level is impractical. Most constructions have foundations below the earth, increasing bearing capacity and decreasing settlement due to their better shearing zone. The present experimental study emphasizes the bearing capacity and settling of embedded shallow foundations on an unreinforced and reinforced soil medium. The main objective of the study is to determine interference under an embedment condition, under regardless of the stress level with reference to full scale foundation.

Problem statement

Two identical strip and square footings of width B were embedded at a depth D_f, below the soil surface, and arranged close to and parallel to each other at a clear spacing S. The footings were rigid and rough, subjected to a vertical load P, until the soil medium failed. The footings were embedded in a uniform, dry cohesionless soil prepared using grade-II Ennore sand (from Chennai, Tamil Nadu, India) with and

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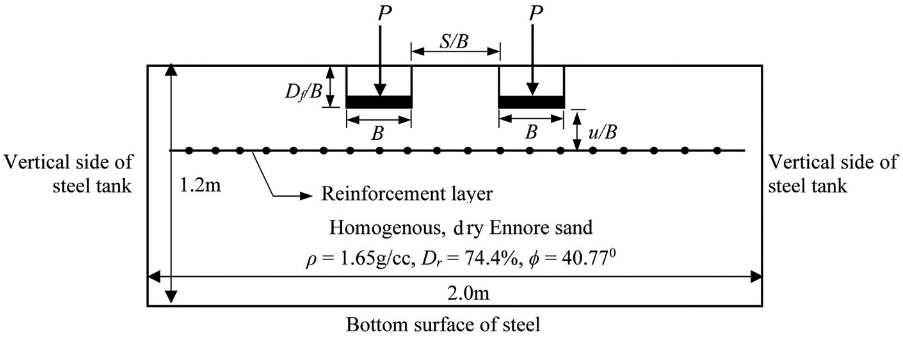

Figure 1. Schematic outline of the experimental analysis.

Table 1. Schedule and range of parameters altered in the study

		Interfering footing		Isolated footing
	Soil medium	D_f/B	S/B	D_f/B
Footing		0.0 (Surface)	0.25, 0.50, 1.0, 2.0 3.0	0.0 (Surface)
	Unreinforced	0.5	0.25, 0.50, 1.0, 2.0 3.0	0.5
		1.0	0.25, 0.50, 1.0, 2.0 3.0	1.0
Strip		0.0 (Surface)	0.25, 0.50, 1.0, 2.0 3.0	0.0 (Surface)
	Reinforced	0.5	0.25, 0.50, 1.0, 2.0 3.0	0.5
		1.0	0.25, 0.50, 1.0, 2.0 3.0	1.0
		0.0 (Surface)	0.25, 0.50, 1.0, 2.0 3.0	0.0 (Surface)
	Unreinforced	0.5	0.25, 0.50, 1.0, 2.0 3.0	0.5
Square		1.0	0.25, 0.50, 1.0, 2.0 3.0	1.0
		0.0 (Surface)	0.25, 0.50, 1.0, 2.0 3.0	0.0 (Surface)
	Reinforced	0.5	0.25, 0.50, 1.0, 2.0 3.0	0.5
		1.0	0.25, 0.50, 1.0, 2.0 3.0	1.0

without reinforcement. Figure 1 depicts the problem statement. The foundation soil medium was reinforced with a single layer of biaxial geogrid at u/B (u is the depth of the first layer of reinforcement below the footing base and B is the width of the footing; u/B is the ratio) below the base of the footings. The objective was to study the interference effect on the performance of two closely spaced strip and square footings embedded in the unreinforced and reinforced sand medium by conducting small-scale laboratory model tests. The load-settlement response, ultimate bearing capacity (UBC) and settlement were studied by varying the shape of the footings, embedment depth (D_f/B), and clear spacing (S/B) between them.

Experimental analysis

A total of 72 tests (60 interfering footings and 12 isolated footings) were conducted for the range of parameters shown in Table 1.

Experimental set-up

A 6 mm-thick steel tank measuring 2.0 m × 1.2 m × 1.2 m was used for testing. Figure 2 *a* is a schematic representation of the experimental model tank. The 15 mm steel plate, strip (150 mm width × 750 mm length) and square (150 mm width) were considered as footings. Sandpaper-glued footing bases mimic rough footing characteristics. Figure 2 *b* shows the photograph of the footings. A hand-operated hydraulic jack at the centre applies the vertical load on the interfering footings. The centre load cell and hydraulic jack gradually load the footings to attain shear failure. A linearly varying differential transducer (LVDT) monitors the settlement of the footings. The load is progressively applied to monitor the settlements until shear failure to generate the load–settlement plot. The rigid footings settled equally owing to simultaneous load application on the interfering footings.

Foundation soil medium and reinforcement

The standard sand obtained from Ennore, confirming IS:650 (ref. 22; grade-II), was used as the soil bed; it was found to be uniformly graded. The coefficient of uniformity (C_u), coefficient of curvature (C_c) and effective size (D_{10}) obtained were 1.71, 0.84 and 0.445 mm respectively. The specific gravity of the sand was 2.65. The maximum and minimum densities were 1.70 and 1.52 g/cm^3 respectively. The foundation bed was prepared at a density of 1.65 g/cm^3, having a relative density (D_r) of 74.40%. The corresponding angle of internal friction was obtained as 40.77°

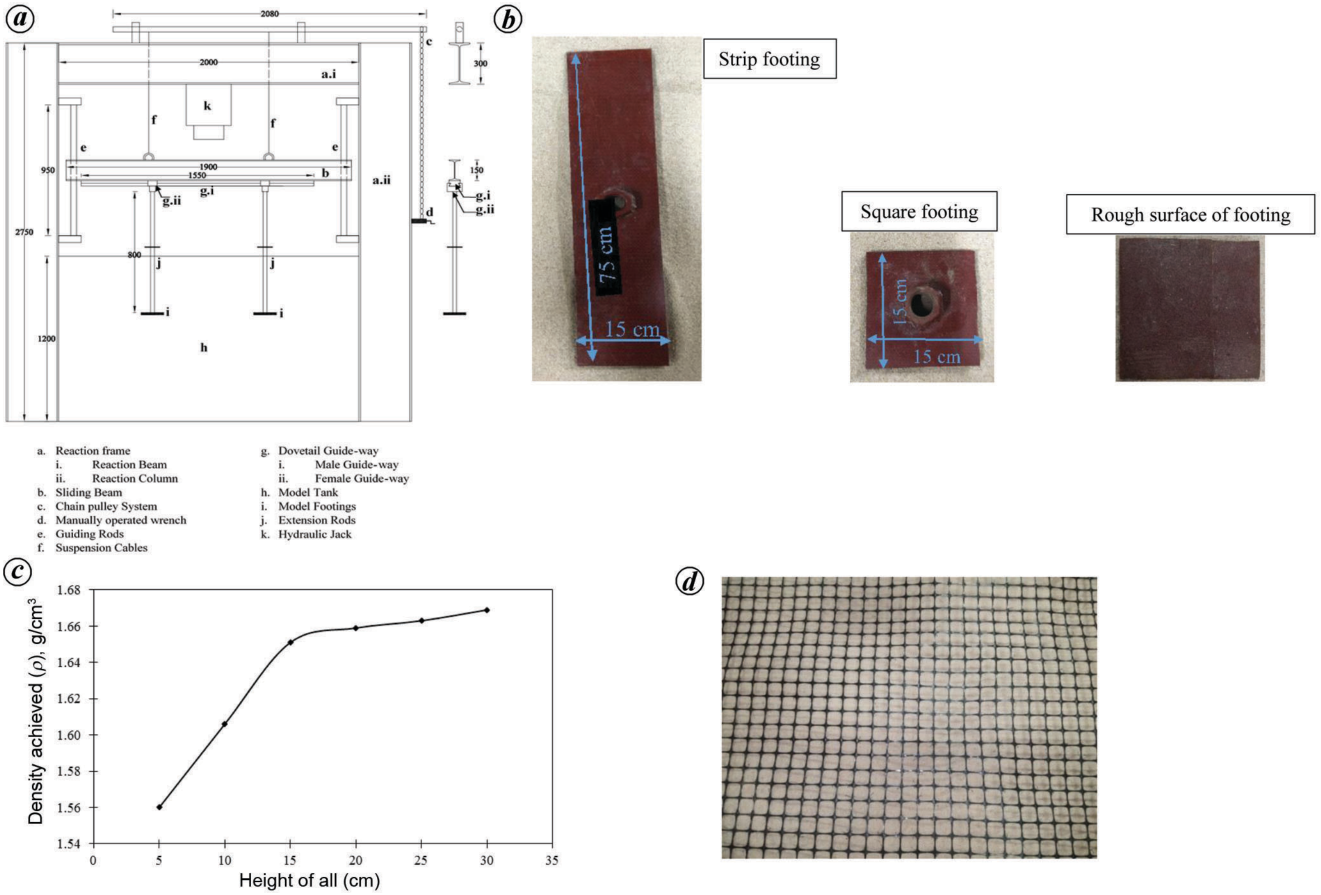

Figure 2. Experimental set-up. ***a***, Schematic representation of the experimental model tank (all dimensions are in mm). ***b***, Photograph of model test footings. ***c***, Variation of placement density with the height of fall of sand. ***d***, Biaxial geogrid.

using a direct shear test. It is noteworthy that the tests followed Indian Standard codes. According to the fixed volume method, placement density affects fall height (Figure 2 *c*). The biaxial geogrid having a square aperture size of 40 mm, was used for reinforcing soil medium at a depth of $u/B = 0.35$ (Figure 2 *d*; ref. 23).

Results and discussion

To ensure accuracy, each test was conducted twice and the average was considered.

Isolated footings embedded in unreinforced and reinforced cohesionless soil

The Meyerhof[24] analytical equation was compared to the load at ultimate shear failure from model testing for isolated strip and square footing embedded in unreinforced soil. Equation (1) was used for calculating bearing capacity.

$$\frac{q_{\mathrm{u}}}{A} = qN_qS_qd_q + 0.5B\gamma N_\gamma S_\gamma d_y, \tag{1}$$

considering bearing capacity factors

$$N_q = e^{\pi \tan\phi} \tan^2\left(45 + \frac{\phi}{2}\right),$$

$$N_\gamma = (N_q - 1)\tan(1.4\phi),$$

and shape and depth factors

$$S_q = S_\gamma = 1 + 0.1K_p \frac{B}{L},$$

$$d_q = d_\gamma = 1 + 0.1\sqrt{K_p}\,\frac{D_{\mathrm{f}}}{B},$$

where B is the width (m) of the footing, L the length (m), γ the unit weight of the soil (kN/m^3), q the overburden at a level of the footing ($\gamma \times D_{\mathrm{f}}$) (kN/m^2), ϕ the soil friction angle, A the plan area (m^2) of the footing and $K_p = \tan^2(45 + \phi/2)$.

Strip footing values for $D_{\mathrm{f}}/B = 0.0$, 0.5 and 1.0 were 14.96, 21.39 and 32.2 kN deviating 8.27%, 1.35% and 2.09% respectively from the analytical equation. For square footing, the analytical equation deviated 3.3%, 12.6% and 9.2% from 4.25, 9.24 and 11.26 kN for $D_f/B = 0.0$, 0.5 and 1.0 respectively. Comparisons were made between the ultimate failure load (UFL) of isolated footings embedded in reinforced and unreinforced soil beds, and the effect of reinforcement was quantified using the bearing capacity ratio (BCR) and the settlement ratio (SR_f and SR) as defined below

$$\mathrm{BCR} = \frac{\left(\begin{array}{c}\text{Ultimate failure load of an isolated footing}\\ \text{embedded in reinforced soil medium}\end{array}\right)}{\left(\begin{array}{c}\text{Ultimate failure load of an isolated footing}\\ \text{embedded in an unreinforced soil medium}\end{array}\right)}, \quad (2)$$

$$\mathrm{SR_f} = \frac{\left(\begin{array}{c}\text{Settlement at failure of an isolated footing}\\ \text{embedded in reinforced soil medium}\end{array}\right)}{\left(\begin{array}{c}\text{Settlement at failure of an isolated footing}\\ \text{embedded in an unreinforced soil medium}\end{array}\right)}, \quad (3)$$

$$\mathrm{SR} = \frac{\left(\begin{array}{c}\text{Settlement of an isolated footing embedded}\\ \text{in reinforced soil medium corresponding}\\ \text{to failure load of an isolated footing embedded}\\ \text{in an unreinforced soil medium}\end{array}\right)}{\left(\begin{array}{c}\text{Settlement at failure of an isolated}\\ \text{footing embedded in an unreinforced}\\ \text{soil medium}\end{array}\right)}, \quad (4)$$

BCR estimated for $D_f/B = 0.0$, 0.5 and 1.0 for strip footing were 1.43, 1.42, and 1.34 representing 43%, 42% and 34% increase in load capacity for reinforced soil respectively. For square footing, it was 1.63, 1.34 and 1.56 respectively. The settlement ratio (SR_f) for strip footing assessed for $D_f/B = 0.0$, 0.5, and 1.0 was 1.23, 1.15 and 1.13, whereas, for square footing, it was 1.44, 1.05 and 1.08 respectively. The SR for strip and square footings derived using eq. (4) was less than one. For $D_f/B = 0.0$, 0.5 and 1.0, strip footing SR = 0.77, 0.67 and 0.72 respectively. This suggests that reinforced case settlement, corresponding to UFL of an unreinforced soil, has decreased. Percentage improvement for $D_f/B = 0.0$, 0.5 and 1.0 was 23, 33 and 28 respectively. Likewise, the respective percentage improvement for square footing was 35, 44 and 52.

Interfering strip footings embedded in unreinforced and reinforced cohesionless soil

UFL and settlement were evaluated from the load–settlement plots. The results are presented in terms of the non-dimensional interference factor for failure load (ξ_{UR}), defined as in eq. (5), and the interference factor for settlement (ζ_{UR} and ζ'_{UR}), defined as in eqs (6) and (7).

$$\xi_{UR} = \frac{\left(\begin{array}{c}\text{Ultimate failure load of interfering}\\ \text{footing embedded in unreinforced soil}\end{array}\right)}{\left(\begin{array}{c}\text{Ultimate failure load of isolated}\\ \text{footings embedded in unreinforced soil}\end{array}\right)}, \quad (5)$$

$$\zeta_{UR} = \frac{\left(\begin{array}{c}\text{Settlement at failure of interfering footing}\\ \text{embedded in unreinforced soil}\end{array}\right)}{\left(\begin{array}{c}\text{Settlement at failure of isolated footings}\\ \text{embedded in unreinforced soil}\end{array}\right)}, \quad (6)$$

$$\zeta'_{UR} = \frac{\left(\begin{array}{c}\text{Settlement of interfering footing}\\ \text{corresponding to failure load of isolated}\\ \text{footing embedded in unreinforced soil}\end{array}\right)}{\left(\begin{array}{c}\text{Settlement at failure of isolated}\\ \text{footing embedded in unreinforced soil}\end{array}\right)}. \quad (7)$$

Figure 3 *a* and *b* shows load–settlement plots for unreinforced and reinforced soil for footings at varied spacings and isolated footing for $D_f/B = 1.0$. $D_f/B = 0.0$ and 0.5 show a similar pattern. Figure 3 shows that interfering footings have a greater load-carrying capacity, and it further increases with increase in embedment depth. The load observed at the failure point for interference is greater than the single footing and increases with spacing and D_f/B ratio. The load–settlement curves show an apparent kink, indicating the failure point. The load–settlement plot for $S/B = 0.5$ is found at the top of all D_f/B ratios considered. Therefore, it can be concluded that the interference effect is significant at this spacing ($S/B = 0.5$). The percentage increase in UFL between $S/B = 0.25$ and 0.50 for $D_f/B = 0.0$, 0.5 and 1.0 was 3.4, 1.7 and 2.6 respectively. The footings act as a unit until $S/B = 0.5$; thereafter, the interference effect diminishes.

The interference factors associated with failure load (ξ_{UR}) were evaluated using eq. (5). Figure 4 shows the variation of ξ_{UR} with S/B ratio for various D_f/B ratios. It can be seen that at the minimum spacing considered ($S/B = 0.25$), $\xi_{UR} > 1.0$, revealing that footings have a larger failure load due to the merging of their passive zones. With increased spacing, ξ_{UR} increases to attain peak ($\xi_{UR}^{\max}$) magnitude at $S/B = 0.50$ (due to arching effect). Its ξ_{UR} decreases continuously with a further increase in S/B to reach unit magnitude at far spacing (footings act individually). Moreover, it can be noted that in a specified S/B ratio (say $S/B = 1.0$), ξ_{UR} decreases with an increase in D_f/B ratios. Notably, the influence of interference is considerably significant for embedded footings, as the shear zone is higher than surface footings. ξ_{UR} is defined with respect to the isolated footing, and the failure load of isolated footing increases with an increase in footing embedment depth; correspondingly, ξ_{UR} decreases. The percentage increase in failure load between $D_f/B = 0.0$ and 0.5 is 22.3, measured for $S/B = 0.5$, while for $D_f/B = 0.0$ and 1.0, it is 55.3.

The non-dimensional settlement interference factors for the entire range of parameters varied were evaluated using

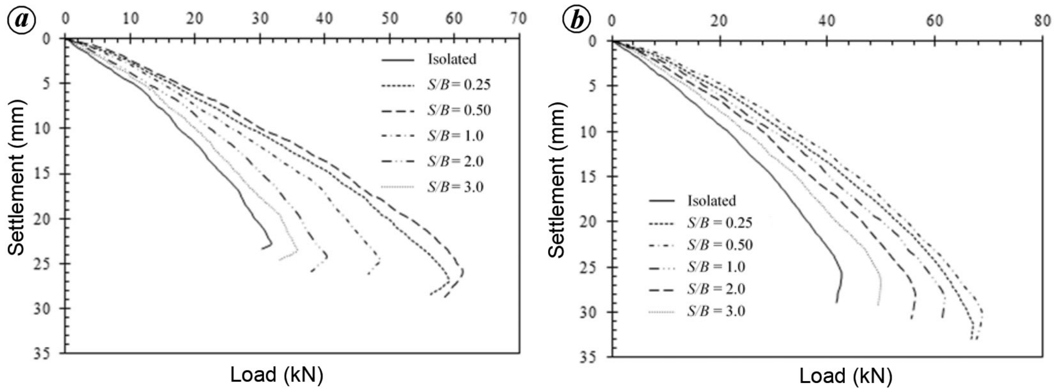

Figure 3. Load–settlement curves for different spacings of interfering strip footings in (***a***) unreinforced and (***b***) reinforced soil at $D_f/B = 1.0$.

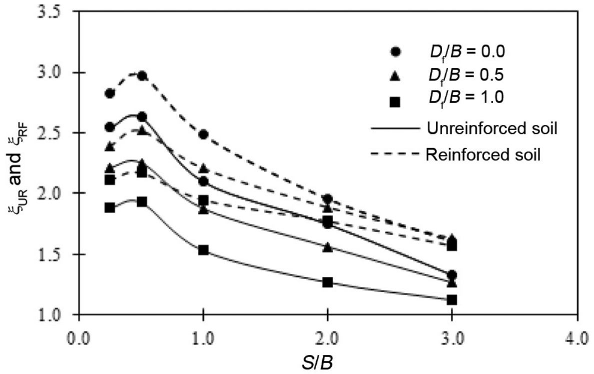

Figure 4. Variation of ξ_{UR} and ξ_{RF} with *S*/*B* ratio of interfering strip footings placed on unreinforced and reinforced soil for different D_f/B ratios.

eqs (6) and (7) respectively, for settlement corresponding to UFL (ζ_{UR}) and UFL of an isolated footing (ζ'_{UR}). The variation with *S*/*B* and for D_f/B is presented in Figure 5 *a* and *b* for ζ_{UR} and ζ'_{UR} respectively. It can be seen from Figure 5 *a* that $\zeta_{\mathrm{UR}} > 1$ (settlement of interfering footing is higher than that of an isolated footing) and decreases continuously with an increase in *S*/*B* ratio to reach unit value at far spacing. The trend was similar for all D_f/B ratios considered. Further, at a given *S*/*B* ratio, ζ_{UR} decreases with an increase in the D_f/B ratio. In contrast, the variation of ζ'_{UR} observed in Figure 5 *b* is dissimilar compared to Figure 5 *a*. The magnitude of $\zeta'_{\mathrm{UR}} < 1$ at $S/B = 0.25$. The settlement of interfering footings is smaller (due to confining effect) than that at the failure of an isolated footing. The non-dimensional interference factor for UFL (ξ_{RF}), defined in eq. (8) below, and the interference factor for settlement (ζ_{RF} and ζ'_{RF}), defined in eqs (9) and (10) were used for the analysis of reinforced soil.

$$\xi_{\mathrm{RF}} = \frac{\left(\begin{array}{c}\text{Ultimate failure load of interfering}\\ \text{footings embedded in reinforced soil}\end{array}\right)}{\left(\begin{array}{c}\text{Ultimate failure load of isolated}\\ \text{footing embedded in unreinforced soil}\end{array}\right)}, \tag{8}$$

$$\zeta_{\mathrm{RF}} = \frac{\left(\begin{array}{c}\text{Settlement at failure of interfering}\\ \text{footings embedded in reinforced soil}\end{array}\right)}{\left(\begin{array}{c}\text{Settlement at failure of isolated}\\ \text{footing embedded in unreinforced soil}\end{array}\right)}, \tag{9}$$

$$\zeta'_{\mathrm{RF}} = \frac{\left(\begin{array}{c}\text{Settlement of interfering footings embedded}\\ \text{in reinforced soil corresponding to failure load}\\ \text{of isolated footing embedded in unreinforced soil}\end{array}\right)}{\left(\begin{array}{c}\text{Settlement at failure of isolated footing}\\ \text{embedded in unreinforced soil}\end{array}\right)}. \tag{10}$$

Figure 4 presents the variations of ξ_{RF} for different *S*/*B* and D_f/B ratios. The trend observed is similar to ξ_{UR}; however, the magnitudes are higher for the reinforced case. Reinforced soil has 12.9%, 11.8% and 12.2% higher UFL than unreinforced soil for $S/B = 0.5$. The *S*/*B* ratio 0.5 for footings embedded at $D_f/B = 1.0$ increases UFL by 54.4%. Figure 5 *a* shows the variation of ζ_{RF} with spacing and different D_f/B ratios. ζ_{RF}, which is greater than one, decreases continuously with an increase in *S/B* ratio. In contrast, ζ'_{RF} shows an increasing trend with increase in footing *S/B* ratio (Figure 5 *b*). Furthermore, decrement in the settlement is also observed by reinforcing the soil bed, which is reflected by a decrease in the magnitude of ζ'_{RF} from ζ'_{UR}. The percentage decrease between ζ'_{RF} and ζ'_{UR} for $S/B = 0.25$, 0.50, 1.0, 2.0 and 3.0 for footings placed at an embedment depth of $D_f/B = 1.0$ was 14, 15, 17, 29.6 and 35% respectively.

Interfering square footings embedded in unreinforced and reinforced cohesionless soil

Figure 6 *a* and *b* show unreinforced and reinforced soil load–settlement plots for square footings at different *S*/*B* ratios and $D_f/B = 1.0$. Minimum spacing ($S/B = 0.25$) had a significant interference effect. For all D_f/B ratios, decreasing *S*/*B* ratio enhanced settlement at UFL.

Figure 7 presents the variation of ξ_{UR} with *S*/*B* ratio for square footings embedded in unreinforced sand at $D_f/B = 0.0$,

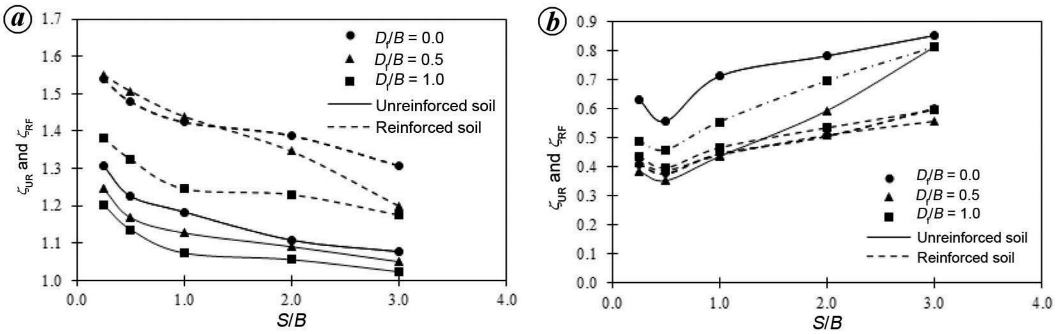

Figure 5. Variation of settlement interference factors (***a***) ζ_{UR} and ζ_{RF} (***b***) ζ'_{UR} and ζ'_{RF} with the *S/B* ratio of interfering strip footings placed on unreinforced and reinforced soil for different D_f/B ratios.

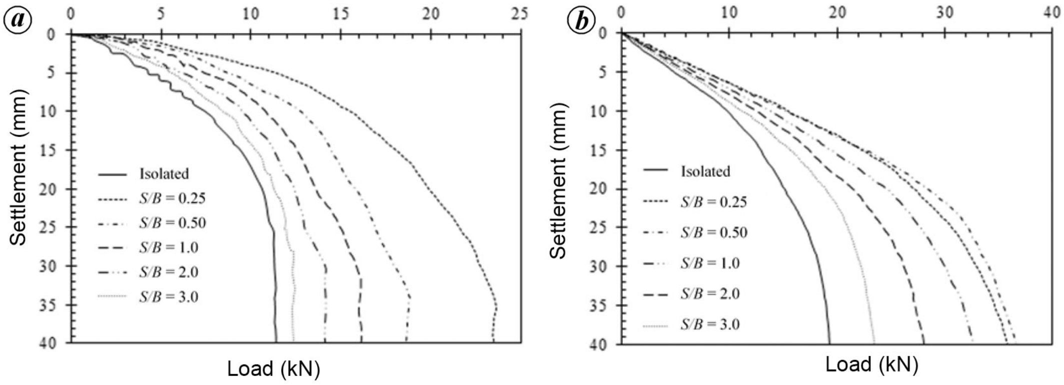

Figure 6. Load–settlement curves for different spacings of interfering square footings placed in (***a***) unreinforced and (***b***) reinforced soil for different D_f/B and *S/B* ratios.

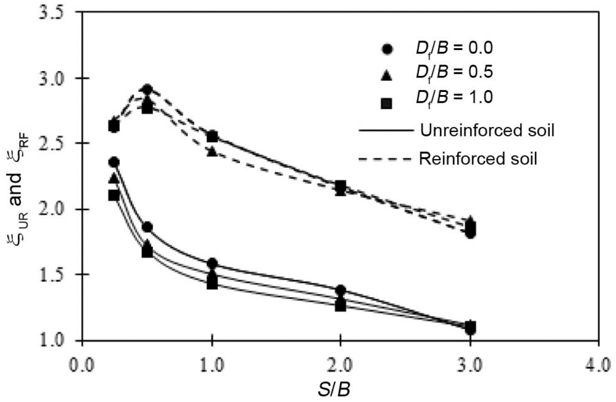

Figure 7. Variation of ξ_{UR} and ξ_{RF} with the *S/B* ratio of interfering square footings placed on unreinforced and reinforced soil for different D_f/B ratios.

0.5 and 1.0. The magnitude of ξ_{UR} noted at $S/B = 0.25$ is significant. The variation trend of the magnitudes of ξ_{UR} with D_f/B ratio is observed to be similar to that of strip footing; the footing shape affects peak values and *S/B* ratio. The percentage increase in UBL when D_f/B is increased from 0.0 to 0.5 is 50.5 measured for $S/B = 0.5$, and the same between $D_f/B = 0.0$ and 1.0 is 58.1. The variation of ζ_{UR} and ζ'_{UR} with *S/B* ratio for different D_f/B ratios is presented in Figure 8*a* and *b* respectively. ζ_{UR} decreases with an increase in spacing between the footings, which is valid for all the D_f/B ratios, with a change in magnitude. In contrast, ζ'_{UR} increases with an increase in *S/B* ratio for all D_f/B ratios considered. The maximum effect for UFL and settlement of reinforced soil occurs at $S/B = 0.5$ for all D_f/B ratios, unlike the maximum impact at 0.25 for unreinforced soil.

The observed pattern for ξ_{RF} is close to that of an unreinforced soil medium. However, the magnitudes for the case of reinforced soil medium are observed to be higher. For $D_f/B = 0.0$, 0.50 and 1.0, the reinforced soil has 36.1%, 39.0% and 39.6% higher failure loads respectively, than unreinforced soil at $S/B = 0.5$. The settlement of interfering square footings was compared to the failure of an isolated footing on unreinforced soil. Figure 8 shows the interference factors (ζ_{RF} and ζ'_{RF}). The percentage decrease between ζ'_{UR} and ζ'_{RF} for S/B = 0.25, 0.50, 1.0, 2.0 and 3.0 for footings placed at an embedment depth of $D_f/B = 1.0$ is 6.67, 6.45, 27.3, 40.7 and 48.1% respectively.

Comparison of results

The results of the present study were compared with those reported in the literature[11,13,18,25–27]. The variation of

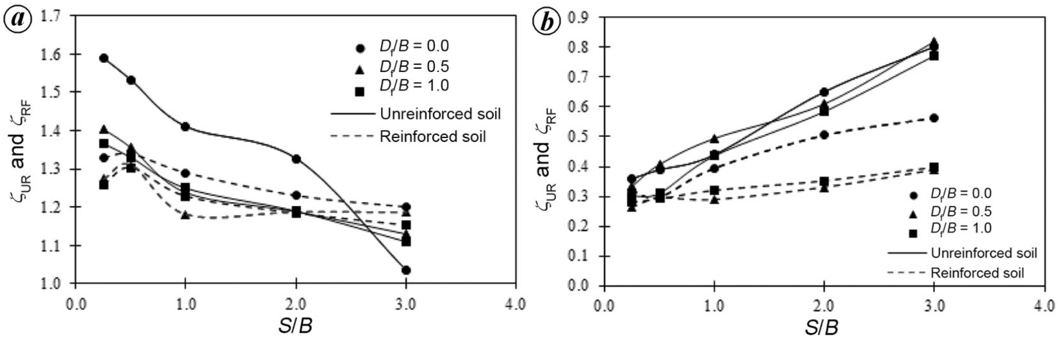

Figure 8. Variation of settlement interference factors (***a***) ζ_{UR} and ζ_{RF}, and (***b***) ζ'_{UR} and ζ'_{RF} with the S/B ratio of interfering square footings placed on unreinforced and reinforced soil for different D_f/B ratios.

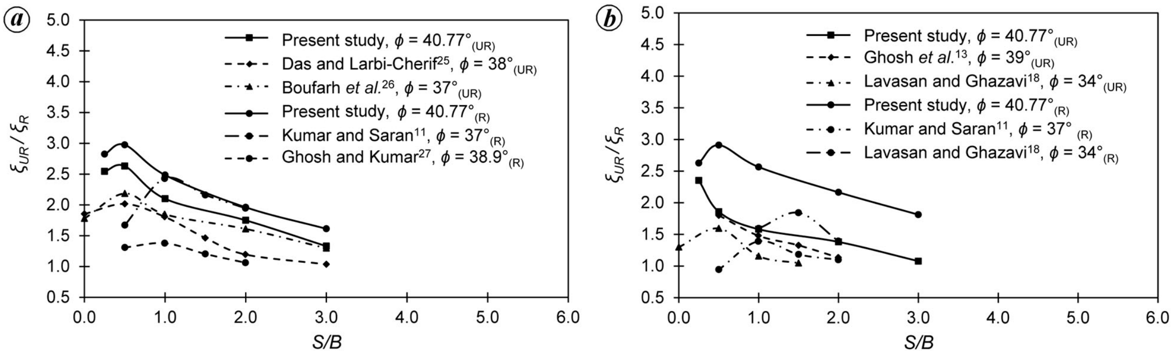

Figure 9. Comparison of a present experimental study with the literature for surface (***a***) strip footings and (***b***) square placed on unreinforced and reinforced soil beds.

ξ_{UR}/ξ_{RF} for strip and square footings is shown in Figure 9 *a* and *b* respectively. It can be observed from Figure 9 *a* that the variation of ξ_{UR} is in line with that of the reported data[13,18]. The values reported here are higher owing to the soil friction angle ($\phi = 40.7°$), but the variation in trend matches well. For $S/B = 0.5$, the blocking effect occurs at 0.5B, and the footings act as a larger unit. The variation of ξ_{RF} with S/B is similar; however, the results of Kumar and Saran[11] are higher, whereas those of Ghosh and Kumar[27] are lower. Such differences in findings are related to differences in reinforcing properties and soil friction angle. The variation trend agrees well that with Ghosh *et al.*[13], which is a continuous decline as the spacing between the footings increases. However, according to Lavasan and Ghazavi[18], ξ_{RF} increases and then decreases.

It should be noted that Kumar and Saran[11] estimated the interference factor for the settlement of interfering footings on reinforced soil compared to the settlement of an isolated footing on the same reinforced soil. In the present study and that of Lavasan and Ghazavi[18], the comparison is made with an isolated footing on unreinforced soil.

Regression analysis

Regression analysis was used to assess experimental interference factors resulting from the measured ultimate load of the interfering strip and square footings embedded at varied depths. Based on the results, interference factors as a function of embedment depth and footing spacing are provided. The interference factors for the case of unreinforced and reinforced soil medium for strip footings are presented in eqs (11) and (12) respectively. Subsequently, the equations for square footings are presented in eqs (13) and (14) respectively.

$$\xi_{UR} = \left(0.1682\left(\frac{D_f}{B}\right) - 0.4614\right)\left(\frac{S}{B}\right) + \left(-0.7479\left(\frac{D_f}{B}\right) + 2.7014\right), \quad (11)$$

$$\xi_{RF} = \left(0.2831\left(\frac{D_f}{B}\right) - 0.4818\right)\left(\frac{S}{B}\right) + \left(-0.837\left(\frac{D_f}{B}\right) + 3.0167\right), \quad (12)$$

$$\xi_{UR} = \left(-0.1136\left(\frac{D_f}{B}\right) + 1.57\right)\left(\frac{S}{B}\right)^{\left[-0.032\left(\frac{D_f}{B}\right)^2 + 0.074\left(\frac{D_f}{B}\right) - 0.289\right]} \quad (13)$$

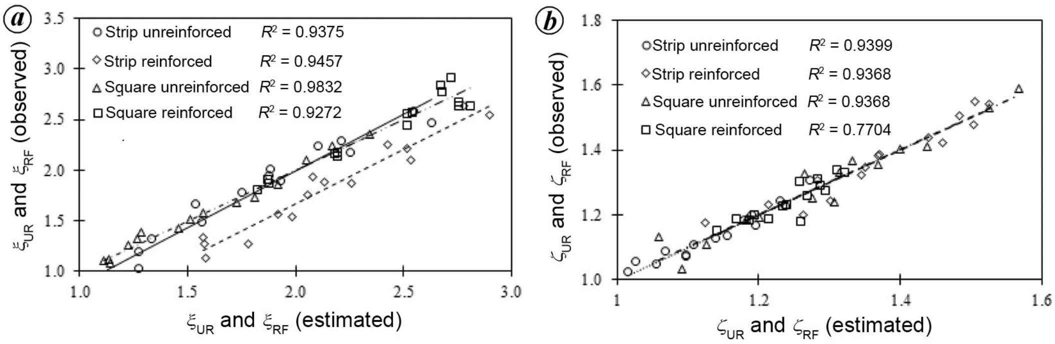

Figure 10. Comparison between estimated and observed plots of interference factors for strip and square footings on unreinforced and reinforced soil. (***a***) Ultimate failure load and (***b***) settlement.

$$\xi_{\mathrm{RF}}=\left(-0.0698\left(\frac{D_{\mathrm{f}}}{B}\right)^2+0.1095\left(\frac{D_{\mathrm{f}}}{B}\right)-0.3589\right)\left(\frac{S}{B}\right)$$

$$+\left(0.131\left(\frac{D_{\mathrm{f}}}{B}\right)^2-0.1981\left(\frac{D_{\mathrm{f}}}{B}\right)+2.9005\right),\qquad(14)$$

Comparing the predicted and observed data, we can determine the model prediction accuracy. Figure 10 *a* shows unreinforced and reinforced interference factor plots for strip and square footings with UFL. R^2 is 92–98%. Equations (15) and (16) for strip footings and eqs (17) and (18) for square footings are regression equations for settlement at failure. Figure 10 *b* shows the corresponding comparison plots for strip and square footings.

$$\zeta_{\mathrm{UR}}=1.309-0.0822\left(\frac{D_{\mathrm{f}}}{B}\right)-0.1595\left(\frac{S}{B}\right)$$

$$+0.0295\left(\frac{S}{B}\right)^2,\qquad(15)$$

$$\zeta_{\mathrm{RF}}=1.5468+0.0795\left(\frac{D_{\mathrm{f}}}{B}\right)-0.08816\left(\frac{S}{B}\right)$$

$$-0.2367\left(\frac{D_{\mathrm{f}}}{B}\right)^2,\qquad(16)$$

$$\zeta_{\mathrm{UR}}=1.6105-0.462\left(\frac{D_{\mathrm{f}}}{B}\right)-0.1727\left(\frac{S}{B}\right)$$

$$+0.202\left(\frac{D_{\mathrm{f}}}{B}\right)^2+0.0977\left(\frac{D_{\mathrm{f}}}{B}\right)\left(\frac{S}{B}\right),\qquad(17)$$

$$\zeta_{\mathrm{UR}}=1.3325-0.0529\left(\frac{D_{\mathrm{f}}}{B}\right)-0.04623\left(\frac{S}{B}\right).\qquad(18)$$

Remarks

In comparison to the full-size model, the scale effect becomes critical owing to variations in the stress level. Due to the differences in stress, no assessment can be performed; this is the limitation of the present study. The present footing scale is 1: 10 in contrast to the full-scale model, which is consistent with other researchers. The UBC of isolated footing assessed using Meyerhof's[24] theory decreases by a factor of 3, 4 and 5 for embedment depths 0.0, 0.5 and 1.0 respectively, for both strip and square footings. The factor increases by one for every 0.5 cm of embedment.

Conclusion

- Footings spaced closely increase load-bearing capability, and reinforced soil improves this further. Due to overburden, embedment depth also influences the load–carrying ability.
- *S/B* = 0.25 and 0.50 respectively, are the principal interference zones for square and strip footings. However, the main interference zone for reinforced soil is located at *S/B* = 0.50 (both square and strip footings).
- For reinforced soil, the magnitudes of ξ_{RF} for square footings are relatively greater than strip footings for $D_{\mathrm{f}}/B = 1.0$. The percentage difference in ξ_{RF} between square and strip footings placed at a spacing of *S*/*B* = 0.50 is 2.06 and 21.6 for D_{f}/B = 0.0 and 1.0 respectively.
- If two footings are placed close together and designed for load and settlement well within the failure point, the interference phenomenon improves bearing capacity and settlement criteria.
- Strip footings are more significantly affected by interference phenomenon compared to square footings.

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