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Performance of Strip Footing on Slope Stabilized with Piles

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***Abstract**: The present paper is the study of the performance of strip footing placed on sandy slope stabilized with a number of rows of piles at various locations. The parameters such as a number of pile rows and location of pile rows are varied. The length of piles, the diameter of piles, and spacing between two adjacent piles in a row and setback distance of strip footing were kept constant. The study revealed that provision of rows of piles along the slope improves the bearing capacity of strip footing. The bearing capacity increases as the number of rows of piles increases.*

***Keywords**: Slope stabilization, Piles, Pile Row Locations, Bearing Capacity, BCR.*

I. INTRODUCTION

In many situations, engineers are forced to construct footings on sloping surfaces like hills, such as footings for bridge abutments. This results in a decrease in bearing capacity of footing, depending on the location of the footing with respect to the slope crest. Therefore, shallow foundations are avoided, and provision of piles or caissons to stabilize the slope remains the only feasible choice.

Stability of slope can be increased by using various solutions such as injection of bacterial solutions in the soil, soil reinforcement, or installation of continuous or discrete walls or piles. These type of solution not only increases the bearing capacity of footing but also affects the settlement of footing. In the case of stabilizing piles, these goals are achieved by the lateral resistance provided by piles against the movement of the soil mass.

Most of the previous studies were concentrated on the analysis of slope stability, very few considered the performance of footing and its bearing capacity. Therefore, this study aims to study the changes in bearing capacity of strip footing placed on slope stabilized with a number of rows of piles. The main objective is to determine the optimum location of rows of piles along the slope. So, a number of tests were carried out for different combinations of varying parameters and the results obtained are presented and discussed below.

II.LITERATURE REVIEW

A. Mostafa *et al.* (2005) studied the behavior of strip footing on pile and sheet pile stabilized the sand slope. The parameters studied were pile diameter, pile length, the ratio of c/c spacing and footing width, pile diameter footing width, the height of sheet pile, the location of sheet pile, the ratio of length to width of the pile. It was observed that the bearing capacity was found maximum when pile spacing was minimum and pile length was maximum. The pile spacing had greater significance than pile length or diameter. The optimal location of the pile for maximum bearing capacity ratio was at slope crest. However, sheet pile stabilized slope shows better results as compared to pile stabilized slope.

P. Induja *et al.* (2015) studied the effectiveness of providing micropile as foundation support to resist dynamic loads. The parameters varied were footing edge distance from the crest, micropile depth, and slope inclination. The coefficient of elastic uniform compression (C_u) was determined from cyclic load test conducted and it was found that the value of C_u for reinforced case shows an increase by about 2.5 times that of the value obtained for unreinforced case indicating an increase in stiffness of soil. They also concluded that it is safe to place the footing at a setback distance of two times the width of the footing for safe behaviour.

H. Gullu *et al.* (2013) studied the effect of the pile on slope stability by PLAXIS 2D by changing the location of the pile at the toe of the slope, at the middle, at the top, two rows of pile at toe and middle of slope & at middle and top of slope. He concluded that factor of safety of slope-pile system increases with the increased row of pile. In the single row of pile application, it was found that the factor of safety decreases as the slope was reinforced towards the top of the slope. The study suggests using either the single row pile at the toe or two-row piles at the toe and middle of slope in practice.

I. Hsuan *et al.* (2014) presented the results of numerical study of slope stabilizing piles in undrained clayey slopes with a weak thin layer by varying parameters such as ratio of undrained shear strength of weak layer to that of remaining soil mass (0.2-1), ratio of width of slope to that of height of slope (0-12), ratio of distance of pile from toe to that of slope length (0-1), spacing to diameter ratio (0-12) and pile head conditions as free and fixed. He concluded that the pile should be extended half way below the weak layer. The use of fixed head piles increases the effectiveness of stabilizing piles compared with free head piles. He also stated that the middle portion of the slope is the optimal pile position for pile stabilized slope.

T. Ito *et al.* (1981) analysed the stabilizing piles against landslide using one row of piles with varying parameters as ratio of clear distance between piles to the centre to centre distance between them (0.4-0.9), pile head as free, hinged, unrotated and fixed, diameter of pile (0.6- 1.0). It was concluded that safety factor of the pile stability decreases with increase in pile length while safety factor for slope stability increases. The improvement in the safety factor for pile and slope stability with multi-row to single row pile was observed.

M. Ghazavi *et al.* (2013) proposed an analytical approach to calculate the bearing capacity of a footing supported on one or two rows of piles stabilizing slope with the effects of fixity of pile head, crest distance, the ratio of the distance of pile from toe to that of slope length. They concluded that the maximum footing bearing capacity is achieved when non-fixed piles in the stable layer are installed at the middle of the slope and fixed piles in the stable layer are installed near the slope crest at various positions and the restrained pile head (hinged or fixed) was recommended for slopes.

III. EXPERIMENTAL SETUP

To study the load settlement characteristics of the footings for various parameters, the plate load tests were conducted. The laboratory set-up consisted of a tank, a reaction frame, a model footing, and screw jack, proving ring, dial gauges, and piles as reinforcement. These are described in following sections.

A. Test sand

For the model tests, cohesion-less, dry, clean and washed Kanhan sand was used as a filling material for slope. The particle size of sand used for the test was passing through 2 mm IS sieve and retaining on 1 mm IS sieve.

B. Model footing

The model footing used for model plate load test was made up of a rigid steel plate. The strip footing with dimension 80 mm x 580 mm and 10 mm thick was used. Footing had a little groove at the center to facilitate the application of load.

C. Model Piles

The model piles of the circular section were fabricated by using mild steel rods of diameter 6.0 mm and length 120 mm.

D. Tank

The test tank used for experimental investigation was made of 3 mm thick mild steel sheet having dimensions 1000mm x 600mm in plan and 650mm high. The minimum tank size required is 5 times the width or breadth of footing whichever is more. The bulging effect counteracts by providing sufficient horizontal and vertical bracings at sufficient intervals.

E. Screw Jack

The load was applied on the model footing with the help of a 25 Ton capacity screw jack. The screw jack was fixed at the center of the horizontal member of reaction frame.

F. Proving Ring

For laboratory plate load test, proving ring of 50 kN capacity was used. The proving ring was fixed to the bottom plunger of screw jack to transfer load from proving ring to footing.

G. Reaction frame

The reaction frame used for applying loads on the model footing consisted of a horizontal member and two vertical members made of IS channel section.

H. Slope Preparation and Pile Insertion

In the present experimental investigations, the relative density of sand slope was maintained by using sand rainfall technique. The height of fall to achieve the desired relative density was determined as a priory by performing a series of trials with different height of fall. In the present investigation, the height of fall was selected as 40 cm in rainfall technique and the corresponding relative density was maintained at 40% and corresponding density was 16.56 kN/m^3. The height of slope was maintained as 360 mm. The slope was prepared in layers of 5 cm and face of the slope was smoothened with a trowel to obtain the slope of 1:1.5 (V: H).

Once the setup of the sand slope was completed, a row of model piles was installed using an assembly of steel plates which held the piles vertical during the installation. The guide system was initially placed in the tank on the slope and then the piles were pushed vertically manually at the pre-decided location along the slope with required spacing. The spacing of piles was kept constant as 80 mm center to the center of piles. No visible movement in the sand slope was observed during the installation process. The difference in the relative density of the sand, which occurs during pile installation due to the difference in the pile lengths, was considered to be small and neglected.

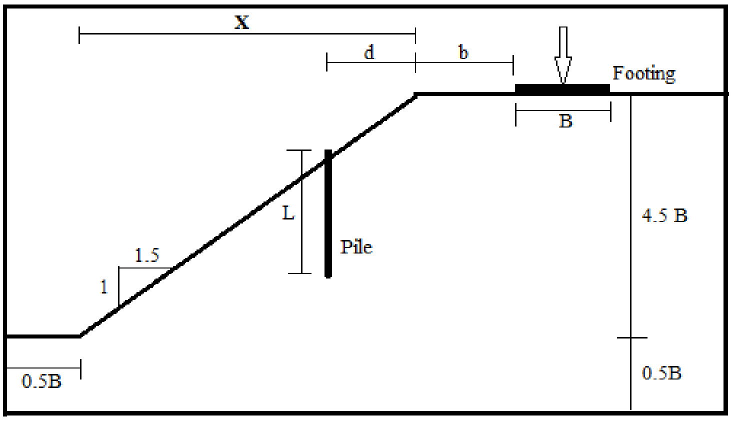

Fig. 1. Geometric parameters of pile -stabilized sand slope model

TABLE 1
MODEL TESTS PROGRAM

Sr. No.	No. of Rows of Piles	Location of Rows of Piles
1	For 1 Row	0X, 0.25X, 0.5X, 0.75X, 1X
2	For 2 Rows	0X&0.25X, 0.25X&0.5X, 0.5X&0.75X, 0.75X&1X
3	For 3 Rows	0X&0.25X&0.5X, 0.25X&0.5X&0.75X, 0.5X&0.75X&1X

I. Laboratory plate load test

For the experimental investigations, the model plate load tests were conducted in accordance with IS: 1888-1982 to evaluate the bearing capacity and settlement.

J. TEST PROCEDURE

The tests were performed on stabilized sand slope as per following procedure.

1. The test sand slope was prepared as discussed above. The footing was placed carefully without disturbing the sand slope at distance 2B from the crest.
2. The dial gauges were carefully placed on a model strip footing. The loading unit was then lowered through proving ring so that the bottom plunger attached to the proving ring just touches the center groove on the footing.
3. The load was then applied on a footing in increments. Each load increment was approximately equal to one-fifth of the ultimate bearing capacity of the strip footing. The final dial gauge readings were noted when the rate of settlement became less than 0.02 mm/hour.
4. After the failure occurred, the load on the footing was released. The footing and piles were removed and the test sand slope was again prepared and next tests were then performed.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A. Load Settlement Behavior of Strip Footing on Slope Stabilized with One Row of Vertical Piles

A single row of piles was placed at various distances viz., 0*X*, 0.25*X*, 0.5*X*, 0.75*X* and 1*X* along the slope to study the effect of location of vertical pile row on improvement in bearing capacity of strip footing on a slope. The load-settlement curves for strip footing corresponding to various locations of a single row of vertical piles are as shown in Fig.2.

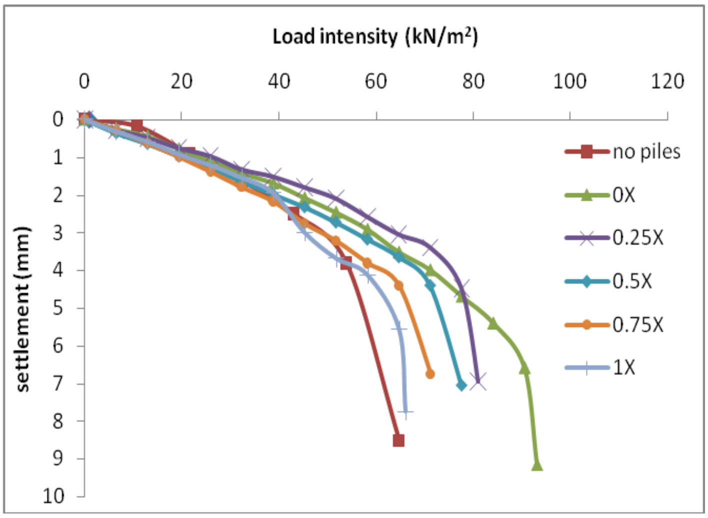

Fig. 2. Load Settlement Curves for Strip Footing Corresponding to Various Locations of Single Row of Vertical Piles
The variations of BCR for a single row of piles at various pile row location are shown in Fig.3.

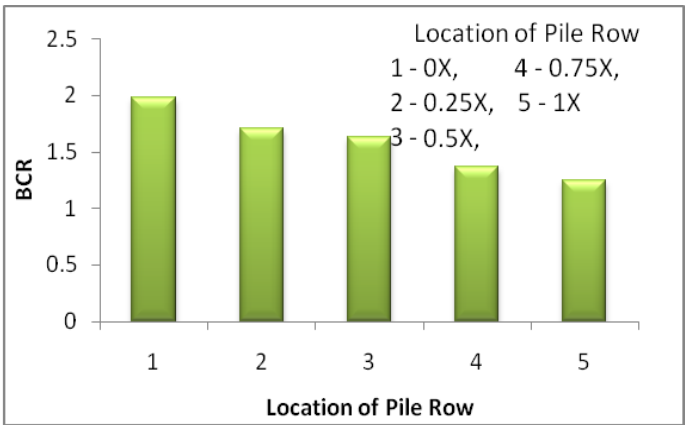

Fig. 3. Variations of BCR with Location of Pile Row for Single Row of Piles

From Fig.2, the ultimate bearing capacity of strip footing on the slope for different locations of a single row of piles was determined. The ultimate bearing capacity of strip footing on a slope and the values of bearing capacity ratio for the various location of the single row of piles are tabulated in Table 2.

TABLE 2

UBC OF STRIP FOOTING FOR DIFFERENT LOCATIONS OF SINGLE ROW OF PILES

Sr. No.	Crest Distance of Single Row of Piles	UBC (kN/m^2)	BCR
1	0*X*	93.5	1.98
2	0.25*X*	81	1.71
3	0.5*X*	76.5	1.63
4	0.75*X*	64.5	1.37
5	1*X*	58.5	1.25

It can be seen that the single pile row placed closer to the slope crest, gives higher bearing capacity. Maximum improvement in UBC is obtained when pile row is placed at the crest of the slope. Thus, the optimum location for a single row of vertical piles may be considered as at the slope crest.

B. Load Settlement Behavior of Strip Footing on Slope Stabilized with Two Rows of Vertical Piles

Two rows of piles were placed with the first row of piles at various horizontal crest distances viz., 0*X*, 0.25*X*, 0.5*X*, 0.75*X* and 1*X* along the slope and the second row of piles at a horizontal distance of 0.25*X* from the first row to study the effect of location of vertical pile rows on improvement in bearing capacity of strip footing on slope. The load-settlement curves for strip footing corresponding to various locations of two rows of vertical piles are as shown in Fig. 4.

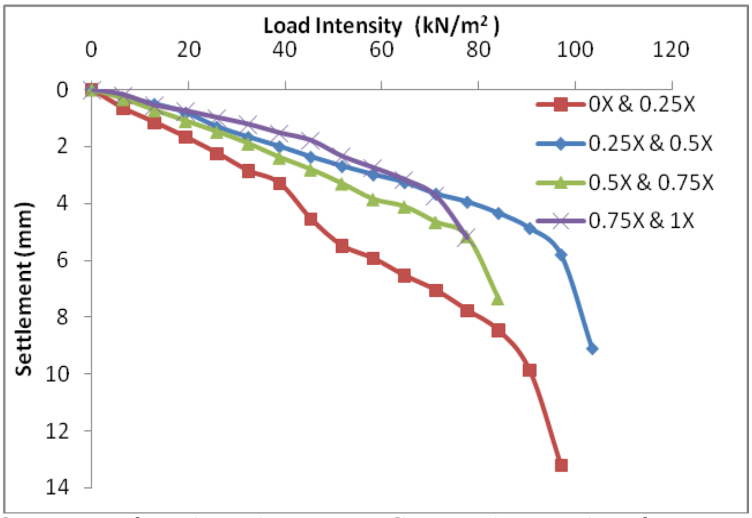

Fig. 4. Load Settlement Curve for Strip Footing Corresponding to Various Locations of Two Rows of Vertical Piles
The variations of BCR with the location of pile rows are shown in Fig. 5.

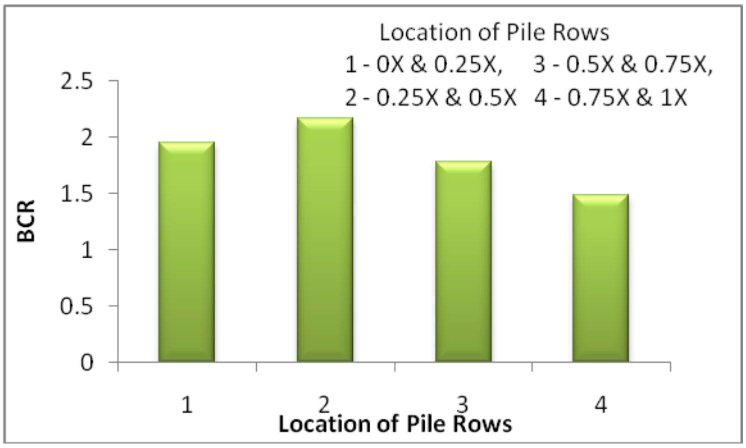

Fig. 5. Variations of BCR with location of Pile Rows for Two Rows of Piles

From Fig. 4., the ultimate bearing capacity of strip footing on the slope for different locations of two rows of piles were determined. The corresponding values of UBC and the values of bearing capacity ratio for various locations of two rows of piles are tabulated in Table 3.

TABLE 3
UBC OF STRIP FOOTING FOR DIFFERENT LOCATIONS OF TWO ROWS OF VERTICAL PILES

Sr. No.	Crest Distance of Two Rows of Piles	UBC (kN/m^2)	BCR
1	0*X* & 0.25*X*	91.5	1.95
2	0.25*X* & 0.5*X*	102	2.17
3	0.5*X* & 0.75*X*	84	1.78
4	0.75*X* & 1*X*	70	1.49

From the Fig. 5., it is observed that the optimum location for two rows of vertical piles is 0.25*X* from crest for the first row of piles and second row of piles at a spacing of 0.25*X* from the first row of piles. From Fig. 5., it is also seen that the performance of strip footing is better when rows of piles are provided in the upper half of the slope as compared to the lower half.

C. Load Settlement Behavior of Strip Footing on Slope Stabilized with Three Rows of Vertical Piles

Three rows of piles were provided with the first row of piles at a horizontal distance of 0*X*, 0.25*X*, 0.5*X*, 0.75*X* and 1*X* from the crest and second and third rows of piles at a horizontal distance of 0.25*X* and 0.5*X* from the first row respectively along the slope to study the effect of location of vertical pile rows on improvement in bearing capacity of strip footing on a slope. The load-settlement curves for strip footing corresponding to various locations of three rows of vertical piles are as shown in Fig. 6.

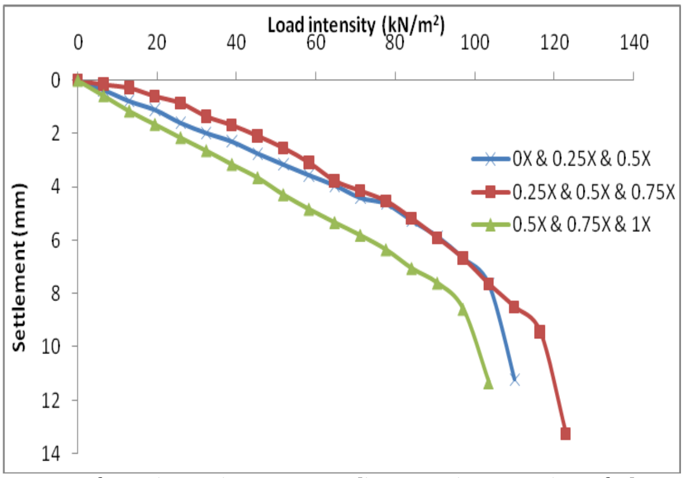

Fig. 6. Load Settlement Curves for Strip Footing Corresponding to Various Locations of Three Rows of Vertical Piles

The variations of BCR with the location of pile rows are shown in Fig. 7.

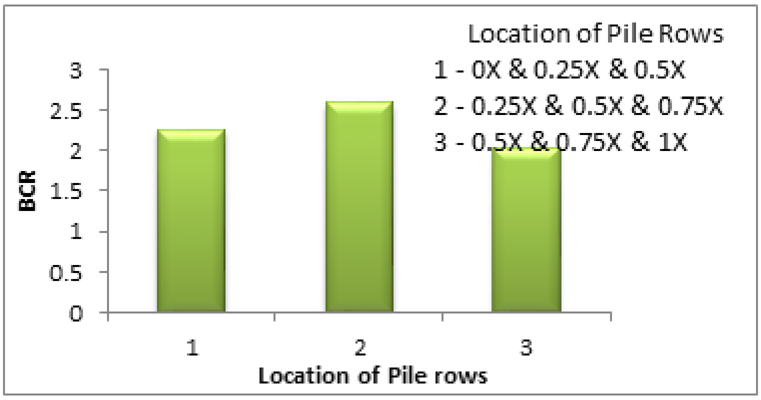

Fig. 7. Variations of BCR with Location of Piles for Three Rows of Piles

From Fig. 6., the ultimate bearing capacities of strip footing on slope for different locations of three rows of piles were determined. The corresponding values of UBC and the values of bearing capacity ratio for various locations of three rows of pile are tabulated in Table 4.

TABLE 4

UBC OF STRIP FOOTING FOR DIFFERENT LOCATIONS OF THREE ROWS OF PILES

Sr. No.	Crest Distance of Three Rows of Piles	UBC (kN/m²)	BCR
1	0*X* & 0.25*X* & 0.5*X*	106	2.26
2	0.25*X* & 0.5*X* & 0.75*X*	122	2.59
3	0.5*X* & 0.75*X* & 1*X*	95	2.02

From the Fig. 7, it is observed that the optimum location for three rows of vertical piles is 0.25*X* from crest for the first row of piles with second and third rows at a spacing of 0.25*X* and 0.5*X* respectively from the first row of piles.

CONCLUSIONS

Based on the experimental results, the following conclusions can be drawn.

- Pile reinforced slope shows the better performance as compared to natural slopes.
- Higher the number of pile rows, better is the performance of strip footing on slope.
- The optimum location of the single row of piles for reinforcing the slope is at the crest of slope.
- For two rows of piles provided for reinforcing the slope, the optimum location for the first row of piles is at distance of 0.25 times the horizontal projection of slope from the crest and for the second row of piles is at a spacing of 0.25 times the horizontal projection of slope from the first row of piles along the slope.
- For three rows of piles provided for reinforcing the slope, the optimum location for the first row of piles is at a distance of 0.25 times the horizontal projection of slope from crest and second and third rows of piles at spacing of 0.25 times the horizontal projection of slope and 0.5 times the horizontal projection of slope respectively from first row of piles along the slope.

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REFERENCES

[1] Gullu H. "A Numerical Study on Pile Application For Slope Stability", *2nd International Balkans Conference on Challenges of Civil Engineering, BCCCE, Epoka University, Tirana, Albania*, pp. 810-816, 2013.

[2] Haghbin M. and Ghazavi M., "Bearing Capacity of Footings on Pile-Stabilized Slopes", *IJST, Transactions of Civil Engineering*, Vol.37, pp. 257-269, 2013.

[3] I-Hsuan Ho. "Numerical Study of Slope-Stabilizing Piles in Undrained Clayey Slopes with A Weak Thin Layer", *Int. Journal of Geomechanics* (ASCE), 2014.

[4] Induja P. C. and Salinitha K., "Behaviour of Micropile Reinforced Strip Footing Near Slope", *50th Indian Geotechnical Conference*, 2015.

[5] Ito T., Matsui T. and Hong W.P., "Design Methods for Stabilizing Piles against Landslide-One Row of Piles", *Soils and Foundation*, Vol.21 No-1, pp. 21-37, 1981.

[6] Mostafa A. and Sawwaf E., "Strip Footing Behaviour on Pile and Sheet Pile- Stabilized Sand Slope", *J. Geotech. Geoenvirontal. Engg.* Vol.131, pp.705-715, 2005.

