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IMPROVEMENT OF BEARING CAPACITY OF PILE SKIRTED FOOTINGS IN SAND DUE TO VARYING SIZE & LENGTH OF SKIRT

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Abstract: Improvement of bearing capacity of sand by skirt piles is a one of the recognised method. An experimental laboratory work has been worked out to observe the effect of pile length and skirt size on the bearing capacity improvement of model footing. To perform the laboratory work, steel model footing and steel piles were used as a skirt for confinement of sand. Influence of various pile configurations with different skirt sizes was observed by comparing the load settlement curve of confined footing to unconfined footing. Based on the comparing analysis of confined model footing to unconfined model footing for various configurations of skirt sizes & pile length, the bearing capacity of model footing can be maximum for smaller skirt size and longer pile length. The results show that bearing capacity of sand increased two times by use of skirt piles.

Key words: Sandy soil, Model test, Footing, Bearing capacity, Confinement, Settlement.

I. INTRODUCTION

Granular soil poses a challenge as a small lateral movement leads to its failure. However, if the lateral movement of sand can be restricted then it becomes suitable material for foundation. So if, the soil is confined, as in the case of footings/rafts surrounded by skirt-piles, the bearing capacity is increases.

Skirt is an enclosure which can withstand considerable hoop stress and confine the soil within it. Skirts forms closed space in which soil is restrained laterally and works as a unit with the skirt to transfer superstructure loads to the soil. In this method a rigid reinforced concrete or Ferro-cement wall called "skirt" is constructed around a footing in order to confine the soil below the footing. Or in simple words the skirts are vertical walls around the footing at distance from the edge of footing. The skirt may be of any shape but generally the shape of the skirt is kept same as that of the footing. The provision of such skirt is found to increase the bearing capacity and reduce the settlement. Several investigators have reported that confining the soil by using vertical soil reinforcement increases the bearing capacity of supporting soils. The use of vertical reinforcement along with horizontal reinforcement was investigated as well (Dash et al. 2001). Significantly (Nirmala Devi et al., 1997, Purohit and Ameta, et al., 1999). Sawwaf and Nazeer (et al., 2005) studied the significant effects of confinement on soil by using confining cylinders made of un-plasticised polyvinyl chloride (UPVC). Extensive laboratory tests were also carried out utilizing a square foundation model confined by rigid steel walls resting on sand that was also vertically confined (Eid et al. 2009). Kumar, Prasad and Singh (et al., 2011) studied behaviour of confined square and rectangular footings on confined granular soil of square and rectangular skirts. However this skirted foundation technique has the inherent disadvantage of being not easy to install. This is because (i) provision of skirt box requires excavation of an area larger than that of the footing (ii) excavation in loose sand may require side support to prevent collapse of sides. The application of a number of small diameter skirt piles in the form of a skirt is thought to be an alternative solution for providing confinement. Small diameter piles of steel can be used as skirt piles. These piles can be easily driven beside and around the footing to impart confinement to the soil, which helps in the improvement of bearing capacity of the soil.

This technique of providing skirt piles overcomes the disadvantages of skirted footing mentioned above.

II. EXPERIMENTAL INVESTIGATION

For conducting this research work used the model footing of size 100mm x 100mm with the ratio of 1:10 to the actual footing. Sand bed was prepared in a closed tank. The size of tank was confirmed from Boussinesq's stress theory and isobar diagram for a concentrated point load. The material is also considered weightless and unstressed. Also from the IS 1888-1982 the size of the tank should be five times the test plate size. And effective depth should be two times the footing width. For the required project analysis depth should be more than three times. The required tank size was 500mm x 500mm x 500mm. The sand used in the present study is poorly graded with proportion of size of particles between 300 μ to 75 μ is dominant. The minimum and maximum density are $\gamma_{min} = 14.20$ kN/m³ and $\gamma_{max} = 17.0$ kN/m³. The relative densities on which the investigation was conducted are 50 % and corresponding density was 15.48 kN/m³. The used skirt piles were HYSD plain bars of 10mm diameter. On the base tip of pile conical necking of 10mm length was done for

easy to penetration in sand. For experimental work different length of piles 150mm, 200mm, 250mm were required. The required no. of piles for different skirt sizes was calculated as:

$$G \times S = D$$

Where, G = no. of gap present in one edge, No. Of piles = G+1; S = Spacing between two consecutive piles; D = width of piles skirt.

Spacing was kept as a constant and width of skirts was taken as 2B, 3B and 4B, where B = width of model footing that was known parameter for the above equation. So there was only two variable G and s. From the method of hit and trial got the approximate value of G as a whole number for an assumed spacing.

At the spacing 28.00mm the approximate values of G for different values of were given below

For $D1 = 2B = 2 \times 100 \text{ mm}; G1 = 7.14$

$D2 = 3B = 3 \times 100 \text{ mm}; G2 = 10.71$

$D3 = 4B = 4 \times 100 \text{ mm}; G3 = 14.28$

These were the minimum variation between whole No. and calculated values as compared to other values of G1, G2, and G3 for spacing like 27mm, 29mm, and 30mm. So consider the obtained values of G1, G2, and G3 as whole no. G1=7; G2=11; G3=14

Hence for above consider values of G1, G2, and G3. Required No. of piles for different skirt sizes were shown in the following table

Table 01 piles requirement for different sizes of skirts

Skirt size in mm	No. of piles required
200 x 200	8
300 x 300	12
400 x 400	15

For comparing the bearing capacity of sand in confined condition to unconfined condition , three tests without skirt (unconfined case) and 27 tests with skirt (confined case) were conducted. Reaction loading is used to apply the load by hydraulic jack. The load increment is applied till the total settlement reached 25 mm i.e. 25% of the size of model footing. Analysis is done by drawing load-settlement curve of skirted foundation and comparing with un-skirted case.

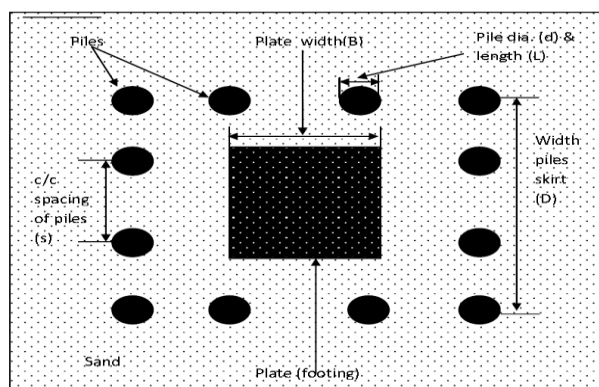


FIG.01 Schematic Diagram for Geometrical Parameters of Skirted Model footing

III. RESULT AND DISCUSSIONS

To know the bearing capacity of sand, the load settlement behaviour of model footing under unconfined condition was tested. Then improvement in the bearing capacity of sand by inserting skirt piles was tested. The behaviour of skirted footing for different skirt sizes and different length of skirt piles was observed to see the effect of skirt on the bearing capacity of sand. To check the consistency of test result, three no. of test were performed for each case and variation was observed maximum.

The ultimate load is to be taken for dense sand at the stage of continued settlement. To compare different load settlement curves of unconfined & confined case, least ultimate load settlement curve is taken out of three trials on same case. Draw the super imposed curve in a single graph and see the effect of skirt. The graphs are drawn for different skirt sizes with different lengths of piles and the improvement in bearing capacity was recorded.

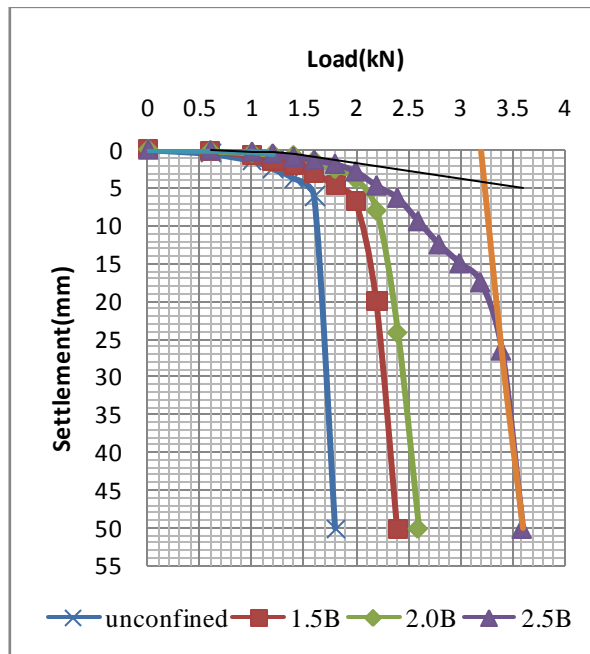


Fig.2 Load-settlement curves of model footing for diff. pile length for (D/B) = 2

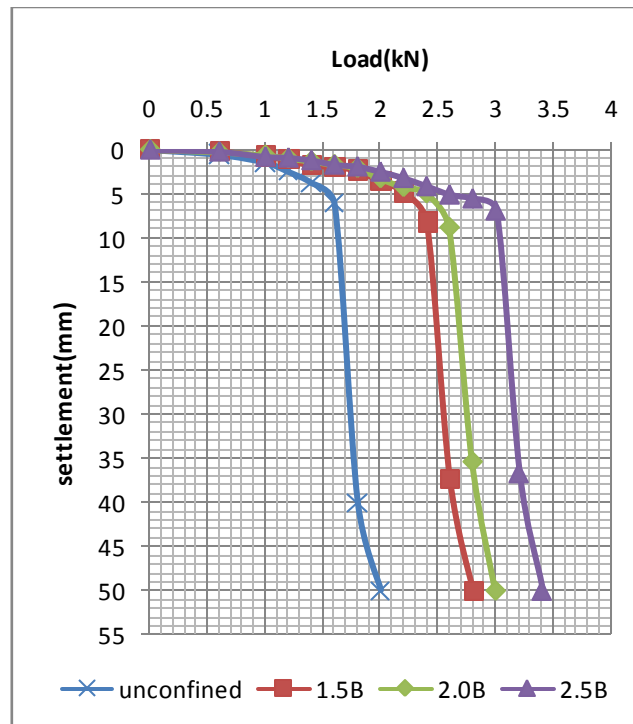


Fig.3 Load-settlement curves of model footing for diff. pile length for (D/B) = 3

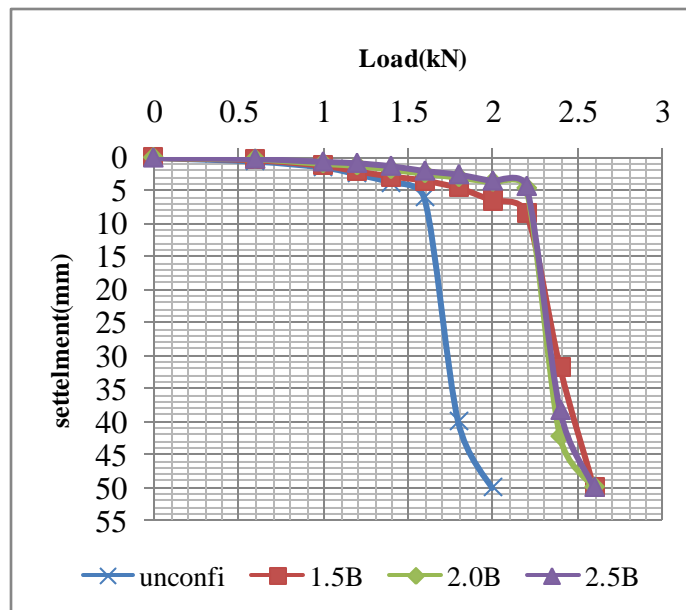


Fig.4 Load-settlement curves of model footing for diff. pile length for (D/B) = 4

From the figures 2, 3 & 4 the ultimate loads for model footing in confined & unconfined case are different for different pile lengths. From fig. 2 piles skirt size (D/B = 2), ultimate loads for unconfined & confined case with different pile lengths (L/B = 1.5, 2.0 & 2.5) are 1.6kN, 2.0kN, 2.2kN & 3.2kN respectively. Similarly from fig.3 piles skirt size (D/B = 3), ultimate loads for unconfined & confined case with different pile lengths (L/B = 1.5, 2.0 & 2.5) are 1.6kN, 2.4kN, 2.6kN & 3.0kN respectively. Similarly from fig.4 piles skirt size (D/B = 4), ultimate loads for unconfined & confined case with different pile lengths (L/B = 1.5, 2.0 & 2.5) are 1.6kN, 2.2kN, 2.2kN & 2.2kN respectively.

For skirt size (D/B) = 2.0 the maximum improvement in bearing capacity is 100% with the pile length (L/B) = 2.5. Similarly For skirt size (D/B) = 3.0 the maximum improvement in bearing capacity is 87.5% with the pile length (L/B) = 2.0. and For skirt size (D/B) = 4.0 the maximum improvement in bearing capacity is 37.5% with all pile lengths.

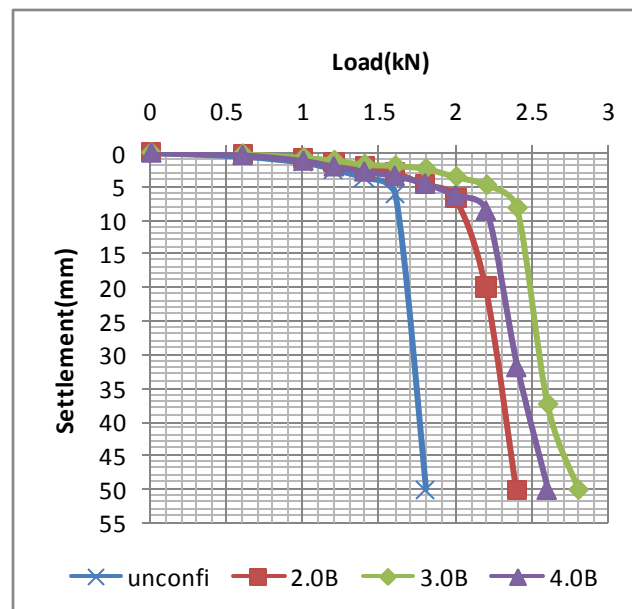


Fig. 5 load settlement curve of model footing for pile length (L/B) = 1.5 at various skirt sizes

From the above results for different graphs show that for small skirt size & longer pile length has a maximum load bearing capacity up-to two times the unconfined case of model footing i.e. 3.2kN with respect to 1.6kN. and mode of failure is also changing as the pile length increases.

But if the skirt size increases then the tendency of failure is also changing. For $(D/B) = 3.0$ maximum load is found at $(L/B) = 2.0$. However it is less than the maximum load for $(D/B) = 2.0$. (i.e. 2.6kN with respect to 3.2kN). Hence from this skirt size, it can be inferred that as the length of pile increases load bearing capacity is improved up-to certain point. Again if the skirt size is increased up-to $(D/B) = 4.0$ improvement in load bearing capacity is constant. There is no improvement in bearing capacity for different length of skirt piles.

The above discussion is based on the skirt size for different pile lengths. The result on the basis of pile length for different skirt sizes.

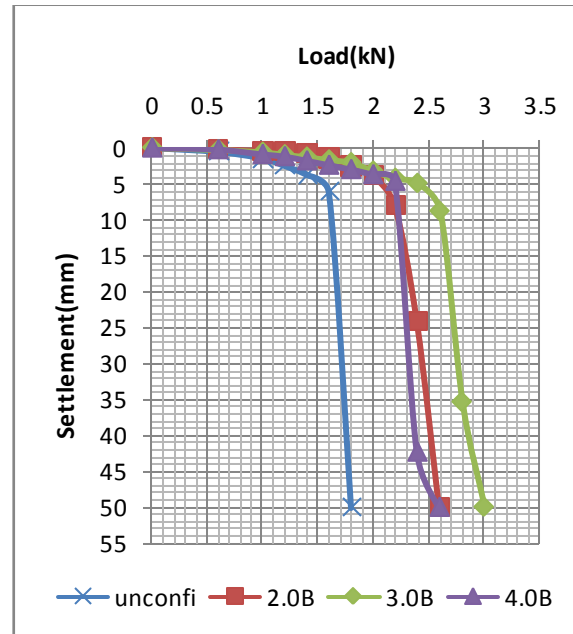


Fig. 6 load settlement curve of model footing for pile length $(L/B) = 2.0$ at various skirt sizes

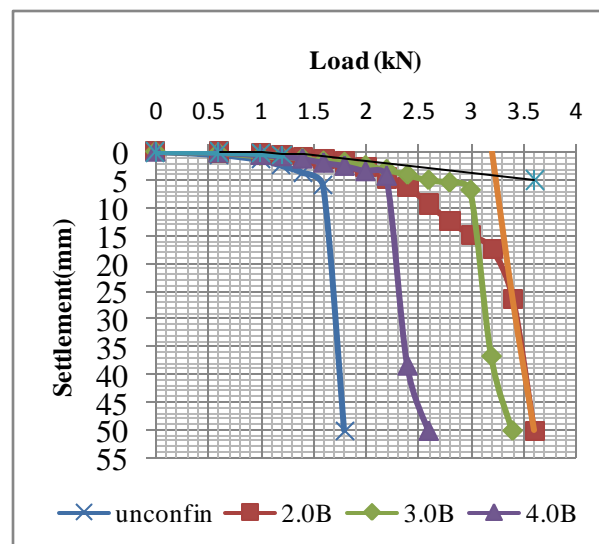


Fig. 7 load settlement curve of model footing for pile length $(L/B) = 2.5$ at various skirt sizes

From fig. 5 & 6, it is observed that for pile length $(L/B) = 1.5$ & 2.0 . The load bearing capacity is increased up-to skirt size $(D/B) = 3.0$ then it is decreased and for pile length $(L/B) = 2.5$ as the skirt size is increases the bearing capacity is decreases. Hence maximum load bearing capacity is 3.2kN for the pile length $(L/B) = 2.5$ and skirt size $(D/B) = 2.0$. and also for pile length $(L/B) = 2.5$ the failure plane is changed as the size of skirt is varying.

General statement to be included for all figure 2 to7 shows that variation of bearing capacity of confined footing with respect to unconfined footing is maximum for small skirt size & longer pile length.

IV. CONCLUSION

Based on the results of the laboratory test on model footing following conclusion can be drawn:

Higher load carrying capacity for footings on sand deposits can be obtained with closer spacing of skirt piles. Improvement of bearing capacity up to 2.0 times that of unconfined footing was observed with close spacing of piles ($S/B=2.85$) and pile length ($L/B=2.5$), where S =piles spacing, B =plate width, L =length of pile .

Load settlement relation showed well defined failure with closer spacing of piles up to $L/B=2.0$. Length of skirt piles defines the depth up to which confining has to be provided. Increasing the pile length (L) beyond certain optimum value did not significantly improve the ultimate load bearing capacity. Though the optimum pile length was found to be dependent on the pile spacing, an optimum L/B ratio of 2.0 can be generally recommended.

At smaller skirt size ($D/B=2$), as the pile length increases failure plane changes from well defined shear failure to local shear failure. For skirt sizes greater than $2B$, as the pile length increases the bearing capacity of sand increases up to certain limit than decreases. And the maximum bearing capacity was reached at $L/B=2.0$. For skirt size greater than $2.0B$, for particular pile length as the skirt size increases the bearing capacity of sand is increased up to certain limit then decreases.

For skirt size greater than $2B$, for particular pile length maximum bearing capacity observed at skirt size to plate size ratio was 3.0. For skirt size to plate size ratio is more than 3.0, pile length isn't effect on bearing capacity improvement. It has constant effect. Maximum stress from loading on plate load test reached only up to the depth of $2B$ then it is decreasing at the distance of $1.0B$ from the edge of footing. And for the distance of $0.5B$ the depth of stress will be more than $2.0B$.

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