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Performance Study for No-Tilt Condition of Bi-Angle Shape Skirted Footing in Clayey Soil Subjected to Eccentric Load

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Abstract—In selected part of clayey soil region of Malwa (M.P.),where Black cotton (B.C.) soil is available up to a large extent of depth, normally footing rest on B.C. soil strata having low bearing capacity or on naturally compacted yellow soil strata having considerable bearing capacity. Environmental changes have great impact on the behavior and strength parameter of the clayey soil like B.C. soil or Yellow soil. Skirted footing in which vertical walls surrounds sides of the soil mass beneath the footing is one of the recognized bearing capacity improvement technique. Construction of vertical skirts at the base of the footing, confining the underlying soil, generates a soil resistance on skirt sides that helps the footing to resist sliding. Bi-angle shaped skirt in which vertical walls surrounds two adjacent sides of the footing is a special case of skirted footing. A model study has been performed to investigate the behavior of Bi-angle shape skirted footing resting on B.C. soil and Yellow soil, subjected to two way eccentric load resulting in Bi-axial bending of the footing. The study helps in evaluating performance of skirted footing. The difference between the settlement of near end and far end is known as tilt of diagonally opposite corners of the footing. The tilt of diagonally opposite corners of the footing is affected considerably due to presence of skirts. Skirts have been found to be helpful in reducing tilt due to eccentric loading.

Index Terms—Bi-angle shape skirted footing model, eccentric load, bearing capacity, no tilt condition, Black cotton soil, Yellow soil.

I. INTRODUCTION

Industrial machines foundations, footing of retaining walls, abutments, and portal framed buildings are not only subjected to vertical or inclined loads but also to moments. Moments on the foundation base are mainly caused by horizontal forces acting on the structure. Horizontal forces are the resultant of earth pressure, wind pressure, seismic force, and water hydrostatic pressure etc. These forces and moments can be replaced by two way eccentric load on the footing. The general objective of this work is to study the behavior of Bi-angle shape skirted footing under the effect of eccentric loads. The work comprises of an experimental investigation for footing model in B.C. soil and Yellow soil . The experimental work has been directed to study the effect of variation of load , load eccentricity, and skirt lengths.

Experimental study on the Performance of skirted strip footing subjected to eccentric inclined load was performed by Nasser M. saleh et.al (2008). Al-Aghbari and Zein (2004, 2006) was performed tests on strip and circular footing models resting on sand.

Mahiyar and Patel (2000), Martin(2001), EL Sawwaf and Nazer (2005), have noticed a significant improvement in the footing response due to the ring beam resistance to lateral displacement of soil underneath the footing. Boushehrian and Hataf (2003), Laman and Yildiz (2003) experimentally investigated the ultimate bearing capacity of ring foundations supported by a sand bed. Gourvenec (2002, 2003) applied two and three dimensional finite element analysis to assess the behavior of strip and circular skirted foundations subjected to combined vertical, moment, and horizontal loading. Yun and Bransby (2003) carried out a series of centrifuge model tests to investigate the response of skirted foundation on loose sand under combined vertical, horizontal, and flexural loading. Ortiz (2001) inserted a discontinuous vertical skirt dowels around existing foundation. A marked increase 20 % in the bearing capacity and a reduction of settlement were observed. Nighojkar S. and Mahiyar H.K. (2006) had studied experimentally Bi-angle shaped skirted footing subjected to two way eccentric load under mixed soil condition.

Part – I For B.C. Soil

Table I. PROPERTIES OF THE BLACK COTTON (B.C.) SOIL BEING USED IN EXPERIMENT

Properties	Values
Specify Gravity	02.60
Liquid Limit	65.00 %
Plastic Limit	33.00 %
Shrinkage Limit	15.00 %
Angle of internal friction	13^0
Cohesion	1.05 Kg/cm^2
Free Swell	50.00 %
Gravel Portion	03.50 %
Sand Portion	08.00 %
Silt + Clay portion	88.00 %
Classification as per IS 1498-1970	**CH**

In present study behavior of an isolated footing with Bi-angle shaped skirt subjected to eccentricity (e) along a diagonal running through junction of skirts has been carried out. A square footing has been considered with side B. Skirts of the different depth, D (skirt depth) have been taken. The study is based on the experimental results obtained during the experiment conducted on B.C. soil with sand beneath the footing. The ratio of eccentricity to width of footing is known as e/B ratio. The ratio of skirt depth to width of footing is known as D/B ratio. Load V/S settlement curve for different e/B, D/B ratios and loads are plotted to find no tilt condition of footing and effect of e/B & D/B, on it.

II. EXPERIMENTAL WORK

A. Test Apparatus and Material Used

Model loading tests of the Bi-angle shape skirted footing (Figure.1) consists of; test tank, loading frame, footing model and the measuring devices. The test tank is a properly stiffened steel fabricated tank having dimensions of 1.21mx0.77mx0.45m. The footing model used is 150mm steel plates with rough base. Eight screw holes at equal spacing along the two adjacent edges of the footing were made to connect the vertical skirts to the footing by means of steel bolts. A loading frame and a loading jack of 10KN capacity (Figure. 2) is being used to apply load. Two sensitive dial gauges were applied to measure the vertical displacement of footing.

Two way eccentricity of load is generated by applying the load along one of the diagonal of footing in a straight line. From the C.G. of the footing, the e/B ratio increases towards the junction of both the vertical skirts with footing, termed as near end. The diagonally straight opposite end of near end (N.E.)is known as Far end of the footing. For achieving the object one steel plate of 150mm X 150mm X 8mm has been taken. Drills of 2mm dia. at an equal interval of 7.5mm from center of footing along the diagonal, in a straight line on footing plate were made. These holes show e/B values equal to 0.0, 0.05, 0.10, 0.15, 0.20, 0.25, and 0.30. Ten steel plates of 150mm width and 8mm thickness and having different lengths were taken. The length of first plate was 37.5mm (i.e. D/B=0.25), second plate had length of 75mm (i.e. D/B=0.50) third, fourth, fifth plates respectively have length equal to 112.5mm (i.e. D/B=0.75), 150mm (i.e. D/B= 1.00) and 187.5mm (i.e. D/B= 1.25).

First of all in the central pit (obtained after compacting soil in rectangular tank and keeping a hollow steel box of size 158mm X 150mm X 195mm) was made. On one wall of pit the steel plate of 187.5mm was kept vertically and then sand was filled in the pit at a density of 1.7gm/cm3 to occupy a volume equal to 150mm X 150mm X 187.5mm. At the top level of sand steel plate (used as footing) was kept at leveled with the help of a spirit level. The footing plate and projection plates (D/B= 1.25) were joined by inserting bolt in the holes provided at the top of projection plates and edge of footing plate.

Black cotton soil: - Locally available B.C. soil (swelling type) was used for the experiment. It was dried in the atmosphere and then it was broken to smaller particle size by compacting through hammer. The soil passing through 2.36mm IS sieve was used for experimental work.

The properties of the B.C. soil being used have been tabulated in TableI.

Sand: - The sand was purchased from local market, clean dry sand passing through 2.36mm IS sieve is used. Properties of the sand being used is given in TableII.

TABLE II . PROPERTIES OF THE SAND

Properties	Values
Dry Density of sand	1.70 gm/cm^3
γ_{max} (Maximum dry density)	1.72 gm/cm^3
γ_{min} (Minimum dry density)	1.62 gm/cm^3
Relative density (ID)	80.88 %
Angle of internal friction	30^0
Cohesion	0.20 Kg/cm^3

III. SKIRTED FOOTING BEHAVIOR

Series of experiments on Bi-angle shape skirted footing has been made and test results for load–settlement and eccentricity–tilt have been obtained. The footing without skirt (D/B=0.0) is shown on their corresponding figures and used as the basic case of comparison for the same loading conditions. All test results

Figure. 2 Experimental setup

indicated the same trend as the ultimate bearing capacity increases with the increase of skirt depth. The failure load can be found at the point of rapid progressive settlement or when the footing starts to slide horizontally. Results indicated that the footing tilt increases with the progress of loading. Embedment of Bi-angle shape skirt under the footing provided a resistance to sliding against lateral loads. With increasing the skirt length to D/B = 0.75, sliding failure was prevented. This due to the resultant of the horizontal soil reaction on the skirt side is a function of the skirt depth and horizontal displacement. Differential settlement (tilt) of diagonally opposite corners of the footing has been worked out and plotted against D/B ratio. For e/B=0.2 the graph is shown in Figure.3. The study has been carried out for e/B=0.0,0.05,0.1,0.15,0.2,0.25 and 0.3. The same trend has been observed for all e/B ratios as shown in Figure.3. Differential settlement (tilt) for different load intensities have been plotted and is shown in Figure.4. For D/B ratio 0.75 to 1.0, differential settlement (tilt), is almost independent of load intensity. The Figure.4 has been shown for e/B=0.2. The same has been obtained for different e/B ratios.

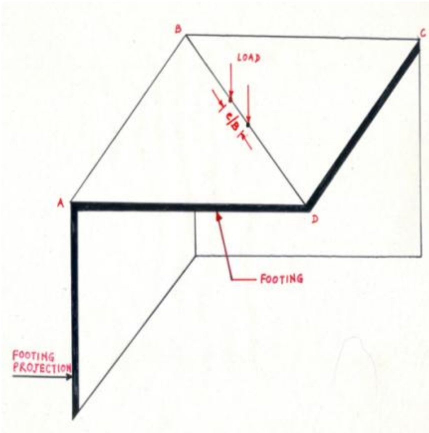

Figure. 1 Bi-angle shape skirted footing

Figure.2 Experimental setup

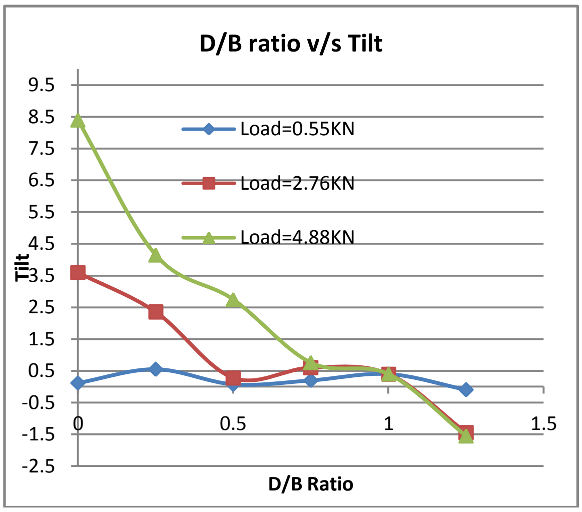

Figure. 3 Variation of Tilt with D/B ratio for e/B=0.2

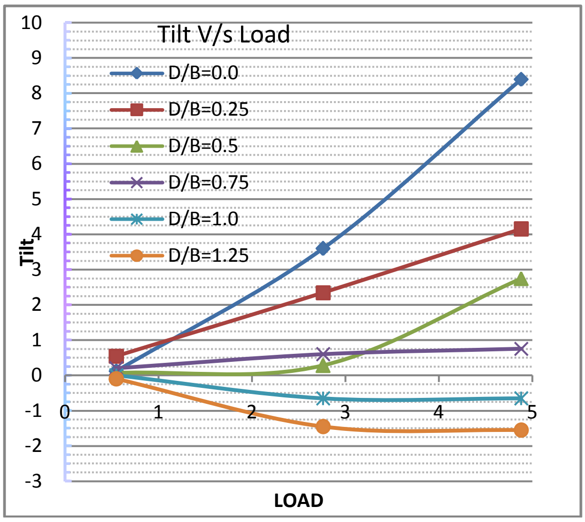

Figure. 4 Variation of Tilt with Load for e/B=0.2

IV. CONCLUSIONS

I) From the Figure.3 for D/B=0.75, and e/B=0.2,the Tilt of diagonally opposite corners of the footing is almost zero which indicate no tilt condition or in other words there will be uniform pressure distribution at various load intensities for D/B=0.75 & e/B=0.2.

Thus Biangle shaped skirted footing helps in resisting eccentricity thereby helps in resisting moments acting on the footing. Hence Biangle shaped skirted footing can be used to resist lateral loads on footing and ensure uniform pressure distribution under footing.

II) On the basis of study carried, it can be concluded that tilt is almost linear and hence it is independent of load intensities. The tilt being linear as the footing is more stiff as compared to soil.

Part- II For Yellow Soil

TABLEI. PROPERTIES OF THE YELLOW SOIL BEING USED IN EXPERIMENT

Properties	**Values**
Specify Gravity	02.70
Liquid Limit	40.00 %
Plastic Limit	25.00 %
Shrinkage Limit	24.00 %
Angle of internal friction	07.00 %
Cohesion	0.63 Kg/cm2
Free Swell	04.33 %
Gravel Portion	03.46 %
Sand Portion	02.78 %
Silt + Clay portion	93.76 %
Classification as per IS 1498-1970	CH

V. EXPERIMENTAL WORK

A. Test Apparatus and Material Used

Model loading tests of the Bi-angle shape skirted footing (Figure.1) consists of; test tank, loading frame, footing model and the measuring devices. The test tank is a properly stiffened steel fabricated tank having dimensions of 1.2mx1.2mx1.2m. The footing model used is 150mm steel plates with rough base. Eight screw holes at equal spacing along the two adjacent edges of the footing were made to connect the vertical skirts to the footing by means of steel bolts. A loading frame and a hydraulic jack of 50KN capacity (Figure. 2) is being used to apply load. Two sensitive dial gauges were applied to measure the vertical displacement of footing.

For achieving the object one steel plate of 150mm X 150mm X 150mm has being taken. Drills of 2mm dia. at an equal interval of 7.5mm from center of footing along the diagonal, in a straight line on footing plate were made. These holes show e/B values equal to 0.0, 0.05, 0.10, 0.15, 0.20, 0.25, and 0.30. Ten steel plates of 150mm width and 8mm thickness and having different lengths were taken. The length of first plate was 37.5mm (i.e. D/B=0.25), second plate had length of 75mm (i.e. D/B=0.50) third, fourth, fifth plates respectively have length equal to 112.5mm (i.e. D/B=0.75), 150mm (i.e. D/B= 1.00) and 187.5mm (i.e. D/B= 1.25).

First of all in the central pit (obtained after compacting soil in rectangular tank and keeping a hollow steel box of size 158mm X 150mm X 195mm) was made. On one wall of pit the steel plate of 187.5mm was kept vertically and then sand was filled in the pit at a density of 1.7gm/cm3 to occupy a volume equal to 150mm X 150mm X 187.5mm. At the top level of sand steel plate (used as footing) was kept at leveled with the help of a spirit level. The footing plate and projection plates (D/B= 1.25) were joined by inserting bolt in the holes provided at the top of projection plates and edge of footing plate.

Yellow Soil: - The non swelling type cohesive soil yellow in color locally called as yellow soil was also obtained from the institute campus. It was also broken by hammer and passed through an IS sieve of 2.36mm size. The properties of the yellow soil being used have been tabulated in Table1.

Sand: - The sand was purchased from local market, clean dry sand passing through 2.36mm IS sieve is used. Properties of the sand being used is given in Table2.

TABLE II. PROPERTIES OF THE SAND

Properties	**Values**
Dry Density of sand	1.70 gm/cm^3
γ max (Maximum dry density)	1.72 gm/cm^3
γ min (Minimum dry density)	1.62 gm/cm^3
Relative density (ID)	80.88 %
Angle of internal friction	300
Cohesion	0.20 Kg/cm^3

VI. SKIRTED FOOTING BEHAVIOR

Series of experiments on Bi-angle shape skirted footing has been made and test results for load–settlement and eccentricity–tilt have been obtained. The footing without skirt(D/B=0.0) is shown on their corresponding figures and used as the basic case of comparison for the same loading conditions. All test results indicated the same trend as the ultimate bearing capacity increases with the increase of skirt depth. The failure load can be found at the point of rapid progressive settlement or when the footing starts to slide horizontally. Results indicated that the footing tilt increases with the progress of loading. Embedment of Bi-angle shape skirt under the footing provided a resistance to sliding against lateral loads. With increasing the skirt length to D/B = 0.50, sliding failure was prevented. This due to the resultant of the horizontal soil reaction on the skirt side is a function of the skirt length and horizontal displacement. A Differential settlement of footing defined as difference of settlement of near end and far end of footing has been worked out and plotted against D/B ratio. For e/B=0.2 the graph is shown in Figure.3. The study has been carried out for e/B=0.0,0.05,0.1,0.15,0.2,0.25 and 0.3. The same trend has been observed for all e/B ratios as shown in Figure.3. Differential settlement for different load intensities have been plotted and is shown in Figure.4. For D/B ratio 0.25 to 1.0, differential settlement is almost independent of load intensity. The Figure.4 has been shown for e/B=0.2. The same has been obtained for different e/B ratios.

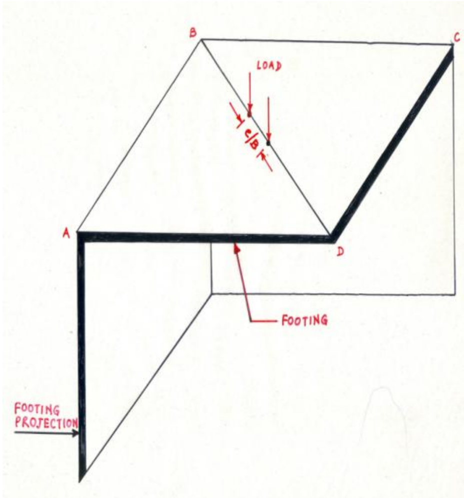

Figure 1 Bi-angle skirted footing

Figure. 2 Experimental setup

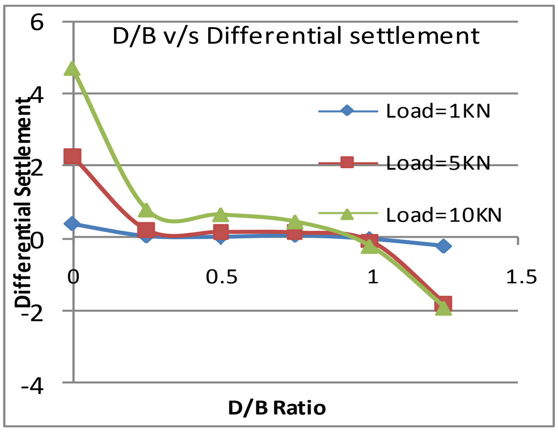

Figure. 3 Variation of Differential settlement with D/B ratio for e/B=0.2

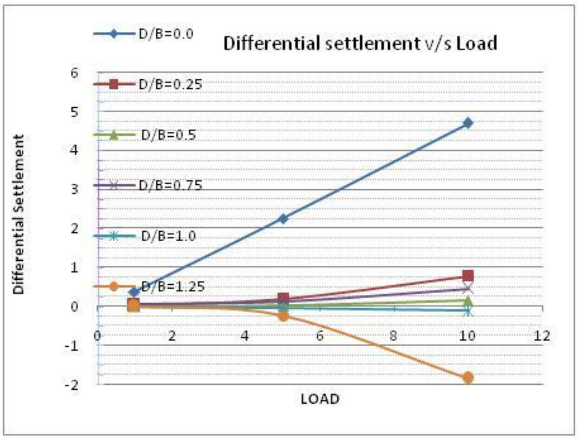

Figure. 4 Variation of Differential settlement with Load for e/B= 0.2

VII. CONCLUSIONS

I) From the Figure.3 for D/B=1.0, and e/B=0.2,the differential settlement is almost zero which indicate no tilt condition or in other words there will be uniform pressure distribution at various load intensities for D/B=1.0 & e/B=0.2.

Thus Biangle shaped skirted footing helps in resisting eccentricity thereby helps in resisting moments acting on the footing. Hence Biangle shaped skirted footing can be used to resist lateral loads on footing and ensure uniform pressure distribution under footing.

II) On the basis of study carried, it can be concluded that differential settlement is almost linear and hence it is independent of load intensities.

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