International Journal of Civil Engineering (IJCE)
ISSN (P): 2278–9987; ISSN (E): 2278–9995
Vol. 9, Issue 5, Jul–Dec 2020; 1–12

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

PERFORMANCE STUDY OF BI-ANGLE SKIRTS; A SPECIAL CASE OF MULTI SKIRTED FOOTING FOR ISOLATED SQUARE FOOTING

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ABSTRACT

Numbers of foundation performance improvement techniques are used to overcome settlement problems for the footings. Skirted footing is one of the techniques commonly being used for offshore structures. Now it has attracted the attention in using it for clayey soils. It has been reported that the skirts can be effectively used as one of the foundation performance improvement techniques for clayey soils. In this study, performance of Bi-angle skirts, a special case of multi skirted footing has been focused upon. In this study two types of soils, three locations of skirts, and three different sizes of footings have been considered. The study shows that provision of semi Bi-angle skirt on two diagonally opposite corners of the footing is the most efficient technique to control settlement as well as rotation (differential settlement) of footing. Analysis is carried out using finite element based software SAP2000 Vs.18.

KEYWORDS: *Differential Settlement, Location of Skirt, Multi Skirted Footing, SAP2000 Vs.18, Semi Bi-Angle Skirt*

Article History

Received: ***12 Aug 2020*** **|** ***Revised:*** ***17 Aug 2020*** **|** ***Accepted:*** ***28 Aug 2020***

INTRODUCTION

Differential settlement of footing resting on clayey soil is a common but important problem. To overcome this problem a foundation performance improvement technique is needed. Skirted footing is one of the innovative techniques to improve performance of footing. The skirts help in improving the performance by confining the soil under the footing. Thus, helping in reducing and restricting the settlement and rotation of footing within permissible limit. Skirt is an arrangement of vertical wall projected below the footing plane. In this paper, three models of Isolated square footings F1, F2 & F3 along with seven different depths of skirts at three different locations have been resting on two types of soils having bearing capacities 80 KN/m^2 and 150 KN/m^2. Earlier studies have shown that skirts effectively help in reducing the settlement at some points but may not be able to restrict settlement all along the footing. It results in rotation (Differential settlement) of the footing. Uneven settlement under the footing also results in uneven pressure distribution. In some cases, the pressure distribution may exceed the safe bearing capacity of the soil, which is not desirable. Or even if the pressure distribution is within the limit but rotation exceed the permissible values for angular rotation of the footing. If the rotation is within the permissible limit with the settlement all along the footing it ensures that pressure under the footing shall be within permissible limits of Safe Bearing capacity of the soil.

In this study analysis of Isolated square footing with vertical skirt at various locations with different depth of skirts has been modelled using finite element-based software SAP2000 Vs18. For the analysis three footing sizes (F1=2x2x0.5)m, (F2= 2.8x2.8x0.65)m and (F3= 3.6x3.6x0.85)m with seven different depths of skirt ranging from 0 to 1500mm i.e.(0,250,500,750,1000,1250&1500) have been considered. For analysis three different locations of skirts considered are,

- Single skirt is provided along full length of one side of Isolated square footing.
- Two half length skirts are provided along the adjacent sides of Isolated square footing with their junction at corner termed as semi Bi-angle skirt.
- Two semi Bi-angle skirts are provided at two opposite corners of a diagonal of an Isolated square footing.

Following three cases have been considered based on three locations of skirt:

- **Case-I** - Footings (F1, F2 & F3) with location (i).
- **Case-II**- Footings (F1, F2 & F3) with location (ii).
- **Case-III**- Footings (F1, F2 & F3) with location (iii).

The side of footing with skirt is designated as skirt side and other sides are designated as non-skirt sides. These footings (F1, F2 & F3) are subjected to axial loads (comprises of DL & LL) from columns. The footing and skirt have been considered to be of the same material. Thickness of skirt is kept 200mm. The study has been carried out considering different parameters such as loads, bearing capacity of soil, depth of skirt and location of skirt to evaluate behaviour of footing on the basis of settlement and soil pressure below the footing using SAP 2000 Vs.18.

LITERATURE REVIEW

The research that conducted by Ortiz (2001) inserted discontinuous vertical skirt dowels around existing foundation. A marked increase 20 % in the bearing capacity and a reduction of settlement were observed. Mohammed Y. Gourvenec (2002, 2003) applied two and three dimensional finite element analysis to assess the behaviour of strip and circular skirted foundations subjected to combined vertical, moment, and horizontal loading. Al-Aghbari and Zein (2004, 2006) performed tests on strip and circular footing models resting on sand. 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. Experimental study on the Performance of skirted strip footing subjected to eccentric inclined load was performed by Nasser M. saleh et.al (2008). EI WAKIL (2013) using 18 laboratory test of skirted circular footing that machined from steel, with the sand as the media of testing and concluded that the use of skirted footing is very effective on increasing the value of footing bearing capacity.

Thakare Et al (2016) studied the performance of rectangular skirted footing resting on sand bed subjected to lateral loads and concluded that as the D/B ratio increases from 0.5 to 2.0, the ability of skirted footing for resisting lateral load increases up to 300%.

Performance of vertical skirted strip footing on slope using finite element software PLAXIS 2D by Dr. S. PUSADKAR et.al (2016). A series of various numerical model were analyzed using PLAXIS 2D to evaluate the bearing capacity of strip footing with and without structural skirts resting on sand slopes

Al-Aghbari and A. Mohamedzeim (2018) investigate the use of skirts to improve the bearing capacity and to reduce the settlement of circular footing resting dune sand. The improvement in bearing capacity is up to about 470% for a surface footing with skirt of depth 1.25Band settlement reduces by 17%.

B. Nail et al (2020) studied the settlement of single skirt Isolated square footing for different skirt parameters and found that the effectiveness of skirted foundation be very significant when skirt is provided symmetrically or coaxial to the footing side. Whereas the effect of size of footing and value of net upward soil pressure does not affect the settlement of single skirted footing much as compared to the depth of skirt.

S. Nighojkar et.al (2020) have conducted the performance study of skirt depth on settlement and net upward pressure characteristics of single skirted Isolated square footing and concluded that at near side on which skirt is provided, the average settlement is reduces by 40 to 60% of skirt depth 250 mm and by almost 60 to 70% for skirt depth of 1500 mm.

S. Nighojkar et.al (2020) on finite element modelling of Bi-angle shape skirted footing resting on clayey soil using SAP2000 Vs.18 and concluded that skirted footing resting on clayey soil having low bearing capacity of 80 KN/m^2 is taking load which belongs to 1.87 times higher upward pressure of soil. Also for various skirt depths, settlement of footing comes within the assumed permissible limit of 25 mm. Though the initial settlement of the footings was already within the permissible limit for higher bearing capacity of 200 KN/m^2.

In this paper; the comparative study has been performed on isolated square footing provided with single skirt at full length and semi Bi-angle skirt half length along two adjacent sides. The model footings (F1, F2 & F3) axially loaded has been analyzed for different locations and depth of skirts to investigate the utility of skirt in reducing the average settlement and soil pressure using finite element software SAP 2000 vs.18.

MODELLING

Present research study based on finite element modeling and analysis of three different sizes of footing (F1 = 2 x 2 x 0.5) m, (F2 = 2.8 x 2.8 x 0.65) m & (F3 = 3.6 x 3.6 x 0.85) m have been considered. The seven depths of skirt (0, 250, 500, 750, 1000, 1250, 1500) have been used for model footings (F1, F2, F3). Skirts are provided at three different locations of model footing F1, F2 & F3. Location –I the skirt provided on full length of model footings at single edge. Location-II semi Bi-angle skirt at one corner of model footings. Location-III two semi Bi-angle skirts provided at diagonally opposite corners of model footings. Location-II and location- III both are considered as special case of Bi-angle shape skirted footing. The location-I of skirt on footings (F1, F2, F3) may be considered as case-I. Similarly Location-II and location-III of skirt may be considered as case-II and case-III respectively. The two extreme values of bearing capacities i.e. 80KN/m^2 and 150KN/m^2 have been considered for case-I, case-II, case-III of model footings (F1, F2, F3).The material properties mentioned in Table 2 are applicable to model footings (F1, F2, & F3) as well as skirts. The linear static analysis of model footings (F1, F2, F3) along with skirt thick shell element have been considered.

Allowable maximum permissible settlement of model footing analysis in SAP2000 vs.18 is restricted to 25mm. The modulus of sub grade reaction is a conceptual relationship between soil pressure and deflection i.e. widely used in structural analysis of foundation members. It is used for continuous footing, Mat and various types of piling, this ratio is defined as Ks=q /δ.

Table 1: Material Properties for Footings (F1, F2 & F3) and Skirt

S. No.	Parameter	Value
1.	Material Name	M_{20}
2.	Material type	Concrete
3.	Weight per unit volume	24.9926
4.	Mass per volume	2.5485
5.	Modulus of elasticity	22360680
6.	Poisson ratio	0.2
7.	Coefficient of thermal expansion A	5.500E-6
8.	Shear modulus G	9316950
9.	FCK	20000

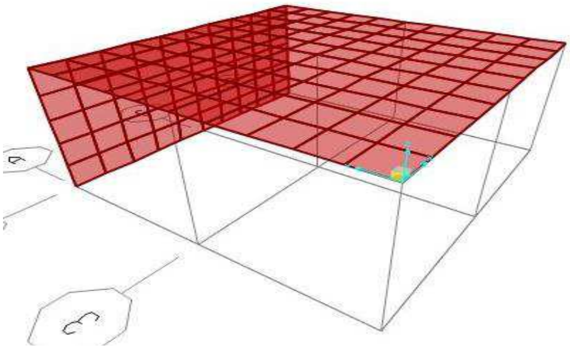

Figure 1: Single Skirted Isolated Square Footing (Case-I).

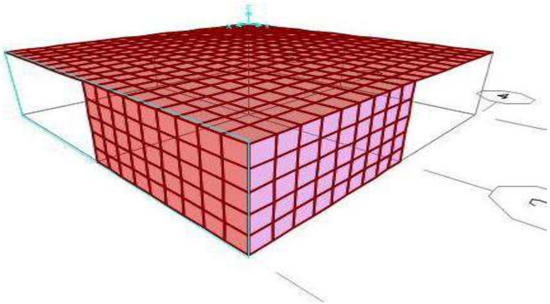

Figure 2: Semi Bi-Angle Skirt Single Side of Isolated Square Footing (Case-II).

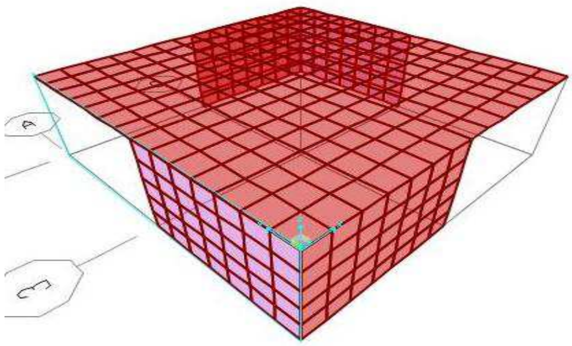

Figure 3: Two Semi Bi-Angle Skirts at Opposite Diagonals of Isolated Square Footing (Case-III).

RESULT & DISCUSSION

On the basis of modelling and analysis of isolated square footings (F1, F2 & F3) with and without skirt subjected to concentric load from column considering three different cases based on location and depth of skirts, following interpretation are drawn.

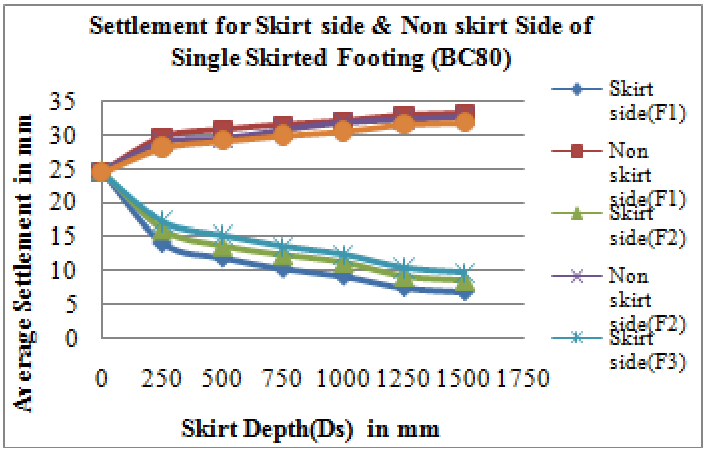

Figure 4: Variation of Settlement for Footings (F1, F2 & F3)(Case-I).

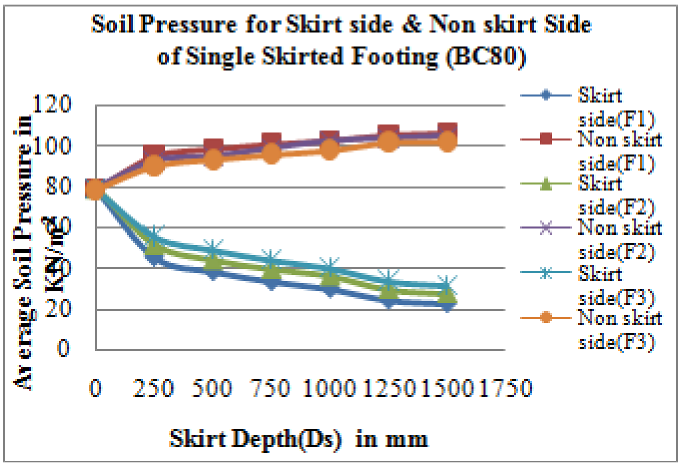

Figure 5: Variation of Soil Pressure for Footings (F1, F2 & F3) (Case-I).

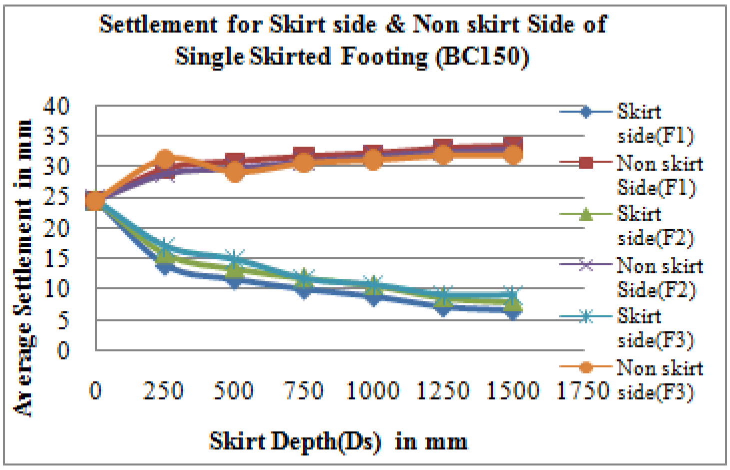

Figure 6: Variation of Settlement for Footings (F1, F2 & F3) (Case-I).

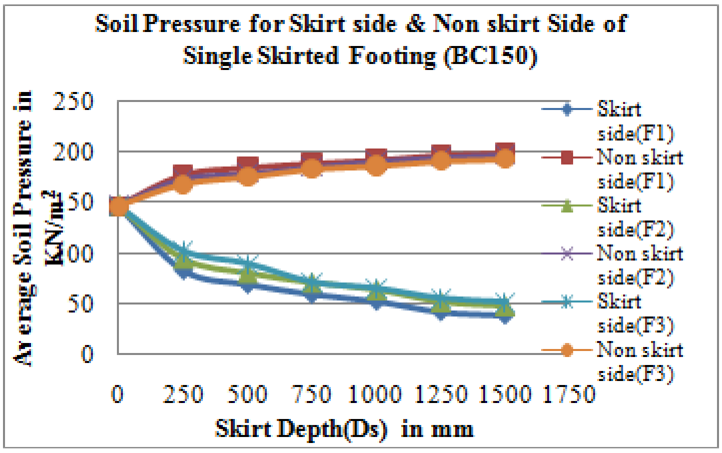

Figure 7: Variation of Soil Pressure for Footings (F1, F2 & F3) (Case-I).

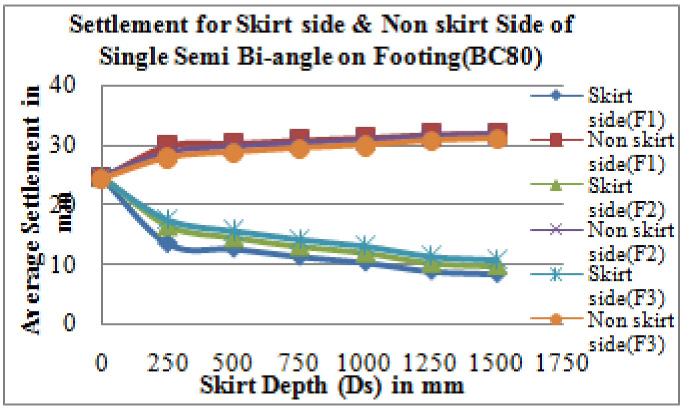

Figure 8: Variation of Settlement for Footings (F1, F2 & F3) (Case-II).

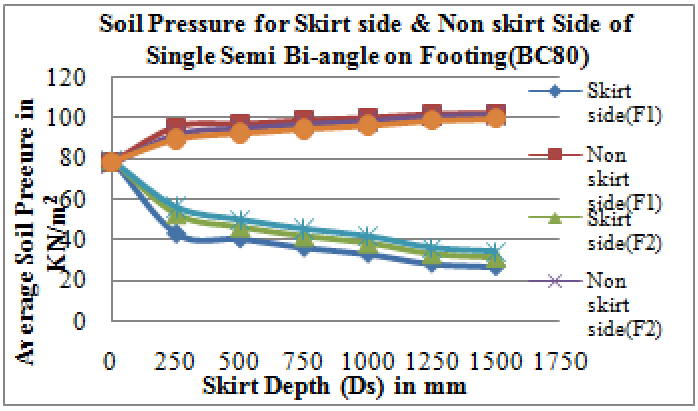

Figure 9: Variation of Soil Pressure for Footings (F1, F2 & F3) (Case-II).

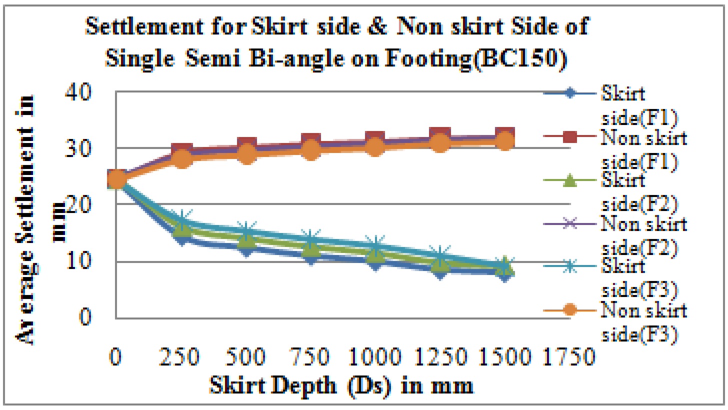

Figure 10: Variation of Settlement for Footings (F1, F2 & F3) (Case-II).

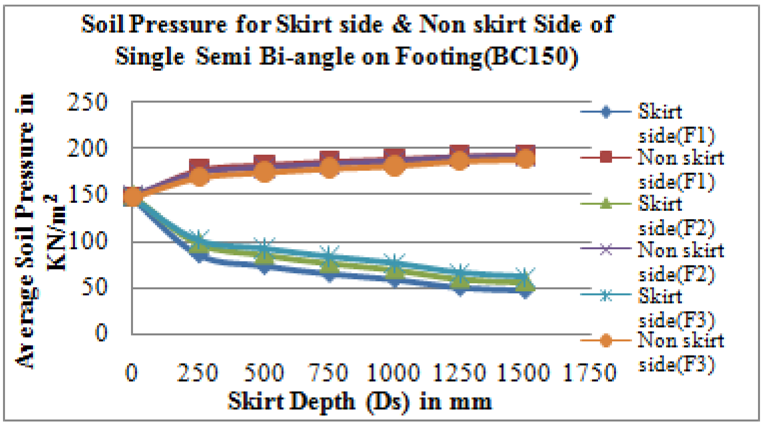

Figure 11: Variation of Soil Pressure for Footings (F1, F2 & F3) (Case-II).

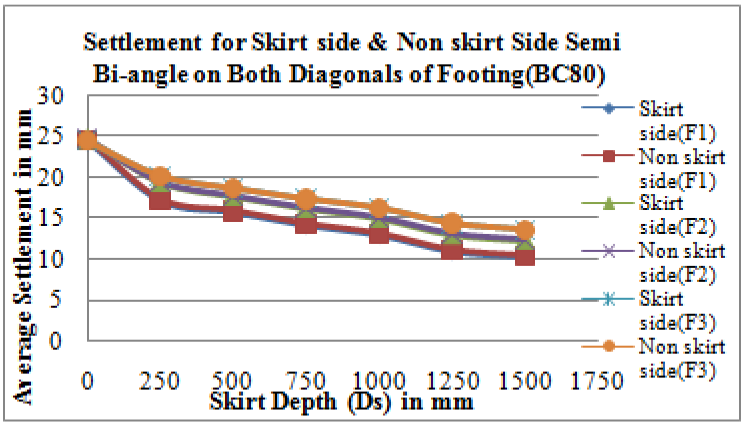

Figure 12: Variation of Settlement for Footings (F1, F2 & F3) (Case-III).

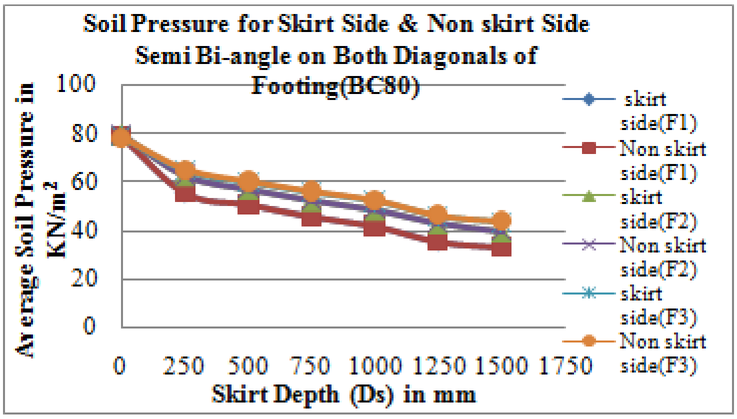

Figure 13: Variation of Soil /Pressure for Footings (F1, F2 & F3) (Case-III).

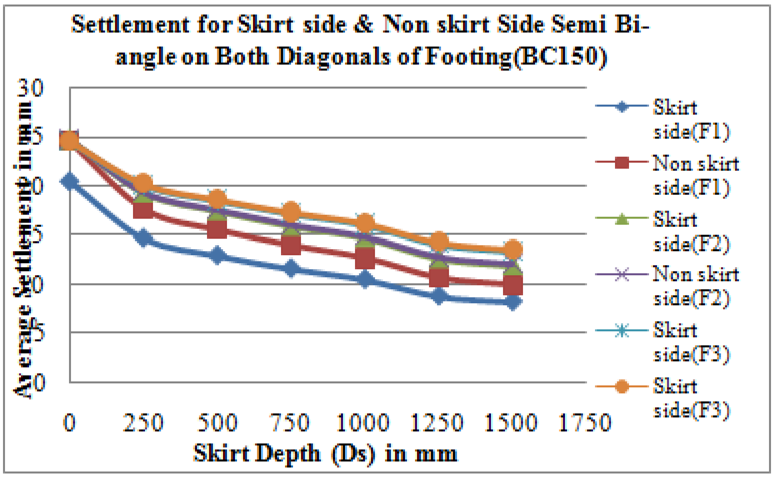

Figure 14: Variation of Settlement for Footings (F1, F2 & F3) (Case-III).

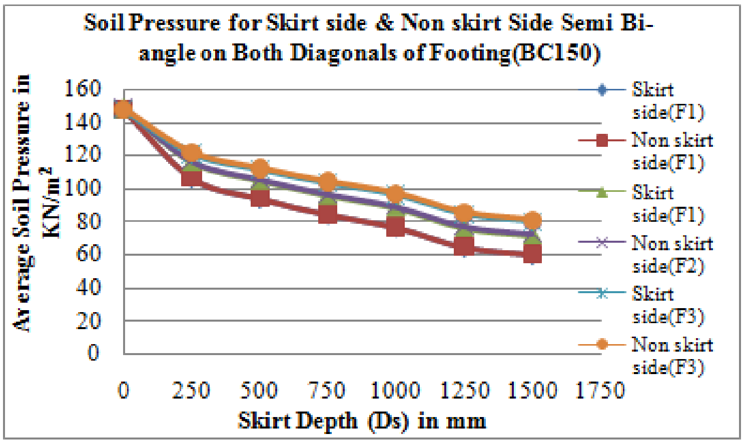

Figure 15: Variation of Soil Pressure for Footings (F1, F2 & F3) (Case-III).

- For case-I, referring figure 4 & 6– showing settlement skirt side and non skirt side, it is found that pattern of all footings (F1, F2, F3) at different skirt depth are almost same for both types of soil. This shows that the settlement pattern is independent of the values of bearing capacity of soil.

Referring figures 5 & 7 for the variation of soil pressure below the footings (F1, F2 & F3), clearly indicates that pattern for variation of soil pressure is almost following the pattern of settlement curves as obtained in figure 4 & 6. In this case although the footings are subjected to differential settlements but within standard permissible limit.

- For case-II referring figure 8, figure 10 for settlement and figure 9 figure 11 for soil pressure, it is indicated that curve pattern showing the variation of settlement and soil pressure below the footings (F1, F2 & F3) are almost same. When single semi Bi-angle skirt is provided, the footings are subjected to differential settlement but obviously within the permissible limit.
- For case-III referring figure 12 and figure 14 for settlement, and figure 13 and figure 15 for soil pressure. When footings (F1, F2, & F3) are provided with two semi Bi-angle skirts at diagonally opposite corners does not subjected to any differential settlement of the footing. In this case settlement curves at skirt side and non skirt side are coinciding on each other, which show the uniform settlement of footings within permissible limit.

The same is true for variation of soil pressure below the footings (F1, F2 & F3). Curves of soil pressure at skirt side and non skirt side are coinciding each other. This shows uniform soil pressure below the footings.

Thus provision of two semi Bi-angle skirts at diagonally opposite corner of footing is found to be very effective technique to control the problem of differential settlement of footing.

CONCLUSIONS

The following points have been concluded form the study of various cases of footing F1, F2 & F3 resting on bearing capacity of soil 80KN/m^2 and 150KN/m^2.

- From the study and analysis of all the three cases it is concluded that provision of skirts results a considerable percentage reduction ranging from 20% to 40% in average settlement and soil pressure below the footing.
- From figure it is clearly indicated that behavior of footing is almost same and found to be independent of bearing capacity of soil.
- In case I and case II, the provision of skirts results in reduction of settlement at skirt side but at the same time results in increase of settlement at non skirt side. Though the differential settlement increases, it is within permissible limit mentioned in codal provision. The settlement at skirt side reduces with the increase in depth of skirt for all cases; six times increase in depth of skirts reduces the settlement by about 33%.
- With increase in depth of skirt from 250 mm to 1500 mm, the settlement at non skirt side reduces; though reduction in settlement is very less.
- As in case III, the provision of two semi Bi-angle skirts at diagonally opposite corners reduces differential settlement of footing by almost 100%.Hence it seems to be an effective and efficient option where the problem of differential settlement of footing is significant.

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