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Settlement Studies of Single Skirt Isolated Square Footing for different Skirt Parameters

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Abstract: Isolated square footing are most common and preferred type of footing in building construction. The function of a footing is to support the loads acting on it and to distribute them in a satisfactory manner over the contact area of the soil. In poor soils, modern method of footing function improvement is providing a skirt below the footing. Skirt is a plate or wall provided in vertical plane, below the footing and is usually provided with shallow foundation. The dimensions of the plate/wall perpendicular to the plane of footing is known as depth of the skirt and the dimension of plate/wall parallel to the side or edge of footing is known as length of the skirt. In the present study, numerical models of single skirted Isolated square footing have been studied with Net Upward Soil Pressure being restricted to 80 KN/m^2 and 150 KN/m^2, for two skirt depths as 250mm and 1500mm. The study is being carried out to see the effect of different locations and length of single skirt on the settlement of footing. For this purpose, 09 observation points on the different locations of the footing area have been considered. Numerical model footing is analysed by using finite element based software SAP2000 Vs18. The encouraging results obtained from this study shows that the effectiveness of skirt foundation be very significant when skirt is provided symmetrically or co-axial to the footing side. At the same time 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.

Keywords: Single skirt, skirt location, skirt length, Depth of Skirt, Net upward soil pressure, SAP2000Vs18.

I. INTRODUCTION

The clayey soil often possess design, construction and maintenance problems to Civil Engineering structures founded on them. For unfavourable ground conditions i.e. the soil having low or poor bearing capacity, or even the footing is abutting a property line; it becomes essential for design engineer to make use of some special type of foundation improvement technique. Skirted footings are one of the best option available to overcome such problems. The skirted foundation is one in which vertical or inclined wall surrounds one or more sides of the soil mass beneath the footing. The skirts confine the soil mass and works as a unit which results reduction in settlement of the footing. The Single skirted isolated square footing has been studied with Net Upward Soil Pressure being restricted to 80 KN/m^2 and 150 KN/m^2. Skirt is a plate or wall provided below the footing. The dimension of plate/wall perpendicular to the plane of footing is known as depth of the skirt and dimension of the plate/wall parallel to the side or edge of the footing is known as length of skirt. The study is being carried out to see the effect of length of single skirt on the settlement of footing and location of the skirt when length of the skirt is less than side of the footing. For this the skirts of different lengths i.e. 1.0L, 0.5L & 0.25L have been considered. The different locations of the skirts have been considered along the edge of the footing. L is the dimension of the side of footing on which skirt has been provided. The side of the footing on which skirt has been provided is being designated as Near Side and opposite side of the footing is designated as Far Side. The other two sides of the footing are designated as sides. The side on the right side of the skirt shall be designated as Right Side and the side on the left side of the skirt is designated as Left Side. For the two net upward soil pressure cases, settlement of the Single Skirted Isolated Square footing at various points are observed. In this study Net Upward Soil Pressure, length of the skirt and the depth of skirt has also been varied. When length of the skirt is less than the side of the footing than what will be the effect of location of the skirt on settlement at various points of footing has also been studied. For this purpose, 09 points on the different locations of footing area have been considered. The point of junction of left side and near end has been designated as Left Near End (LNE). Similarly, junction of right side and near side shall be designated as Right Near End (RNE). The junction of left side and far side shall be designated as Left Far End (LFE) and junction of right side and far side shall be designated as Right Far End (RFE), respectively. The centre points of all the four edges of the footing, i.e. near side, far side, left side and right side shall be designated as Near Mid-Point (NMP), Far Mid-Point (FMP), Left Mid-point (LMP) and Right Mid-point (RMP), respectively.

The diagonal joining Left near End with Right Far End shall be designated as Near End Diagonal (NED) and diagonal joining Right Near End with Left Far End as Far End Diagonal (FED). Centroid of the footing area has been designated as Centre Point (CP).

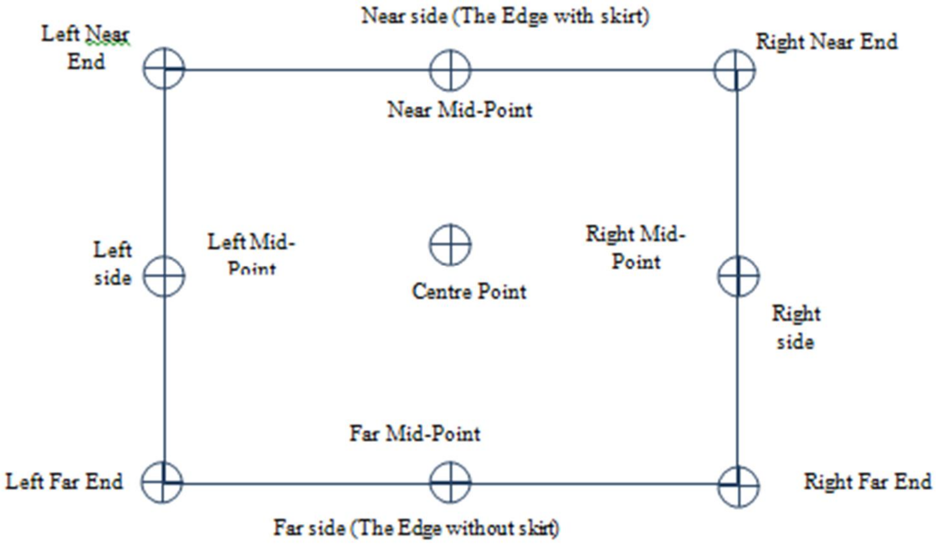

Fig.1 General Arrangement of Footing

In order to understand the effect of skirt, the differential settlement along the sides, along the two diagonals, and amongst the opposite mid points are studied. Similarly, average settlement along the sides and average settlement of the footing considering all the 09 points shall be studied. Numerical model footings are analysed by finite element-based software SAP 2000 Vs.18.

II. LITERATURE REVIEW

The objective of literature review is to identify the contribution established by previous researchers on skirted foundations in terms of behaviour, performance, analysis approaches by numerical and analytical study and to identify the gap in research for the present study.

Tammineni Gnanandarao Et al(2020) conducted an investigation on the model unskirted/skirted footing (plus and double box) on sand. Skirt depth, sand relatively density, footing interface conditions and skirted footing type were varied parameters. Skirt depth (Ds) varied in this investigation was from 0.25B to 1.5B (B footing width). Finally for the settlement reduction factor an empirical equation was developed. C. Goutham et. al (2019) conducted 3D finite element analysis using Abaqus Vs6.12 to evaluate performance of skirt foundations influence by vertical load, soil medium, aspect ratios and area ratios of skirted foundation. The increase in the aspect ratio (d/D) of skirted foundation will increase the vertical load carrying capacity significantly. Keivan Esmaelli Et al (2018) studied semi-deep skirted foundations and numerical solution to evaluate bearing capacity where the soil beneath the foundation is loose to a great depth and there is no possible way to use any way of soil improvement and applying piles would not be a logical way considering their cost and time of enforcing. In addition the bearing capacity of a skirted foundation under combined loading loading V-H space has been analysed by this approach and two dimensional failure envelope has been presented. Chandani Seth et. al (2017) carried out dynamic analysis of pile block foundation model using SAP:2000Vs18 of dynamic response of foundation was analysed.

Results are compared and validated with mode shapes and frequencies. For block foundation resting on soil, piles and soil can be modelled by spring elements, the dynamic behaviour can be represented accurately. It is recommended for block foundation to include the whole structure and replaced the soil/ piles by spring elements. 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%. Location of skirt with respect to load direction has significant effect on horizontal load carrying capacity of footing. Dr. S. PUSADKAR et.al (2016) a series of various numerical model were analyzed using finite element software PLAXIS 2D to evaluate the bearing capacity of strip footing with and without structural skirts resting on sand slopes.

III. NUMERICAL MODELLING

In present study two footing sizes (F_1) = 2x2x0.5 m and (F_2) =3.6x3.6x0.85 m are considered with skirt depths (Ds) 250 mm and 1500 mm. The thickness of skirt is 200 mm. Total 36 nos. Numerical model footings of single skirted Isolated Square footing subjected to concentric load from column are analyzed using SAP 2000Vs18. These two footing sizes F1 and F2 are analyzed for four different locations of single skirt i.e. A, B, C, & D Considering four length of skirt (1.0L, 0.5L, 0.25L, 0.5CL). Spring stiffness based on two values of Net Upward Soil Pressure 80 KN/m^2 and 150 KN/m^2 are used to apply soil properties on model footings.

A. *Different Locations are As*

1) *Location A:* Skirt provided along the full length of footing side (1.0L) connecting Left Near End (LNE), Near Middle Point (NMP) and Right Near End (RME) designated as Near End.
2) *Location B:* Skirt provided along the half length of footing side (0.5L) connecting Left Near End (LNE) and Near Middle Point (NMP) at Near End.
3) *Location C:* Skirt provided along the quarter length of footing side (0.25L) starting from Left Near End (LNE) to quarter length of footing side at Near End.
4) *Location D:* Skirt provided along the half central length (0.5CL) of footing side in which the centre of skirt length coincides with the centre of the footing side at Near Middle Point (NMP).

Details of various geometrical parameters, load, skirt length and skirt depth are given in figures and tables below.

Table 1: material properties for model footings

S.No.	Parameter	Value
1.	Material Name	M20
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

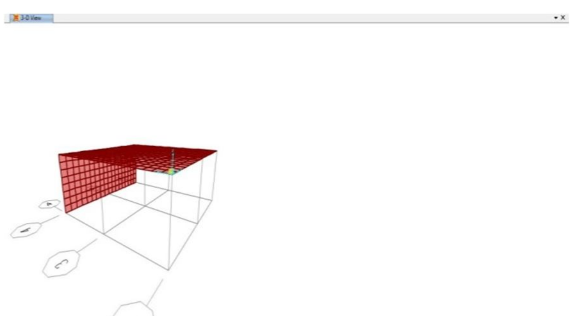

Fig. 2 SSISF with Skirt Location A

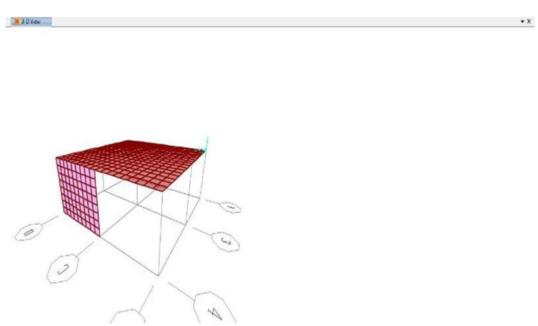

Fig. 3 SSISF with Skirt Location B

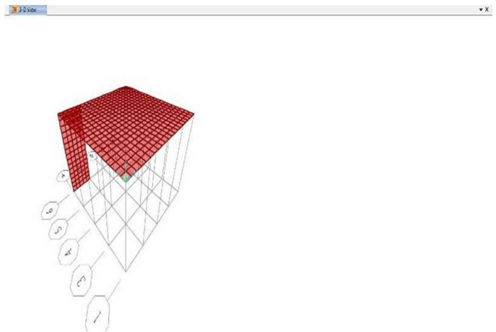

Fig. 4 SSISF with Skirt Location C

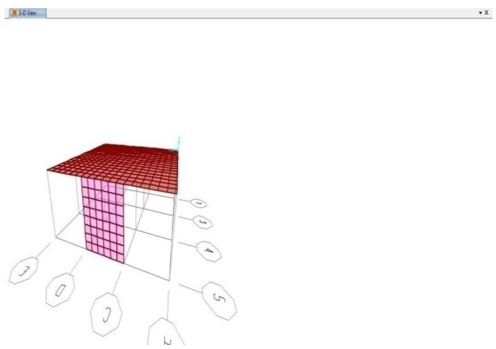

Fig. 5SSISF with Skirt Location D

Table No.2 Numerical Model Footing Data

S.No.	Size of Footing (in m)	Load in (KN)	Net Upward Soil Pressure(KN/m^2)	Depth of skirt(Ds)(mm)	Length of Skirt
1	F1	265	80	250	1.0L
2	F1	265	80	250	0.5L
3	F1	265	80	250	0.25L
4	F1	265	80	1500	0.5CL
5	F1	265	80	1500	1.0L
6	F1	265	80	1500	0.5L
7	F1	265	80	1500	0.25L
8	F1	265	80	1500	0.5CL
9	F1	265	80	0	without skirt

Table No.3 Numerical Model Footing Data

S.No.	Size of Footing (in m)	Load in (KN)	Net Upward Soil Pressure (KN/m^2)	Depth of Skirt(Ds)(mm)	Length of Skirt
1	F_1	540	150	250	1.0L
2	F_1	540	150	250	0.5L
3	F_1	540	150	250	0.25L
4	F_1	540	150	1500	0.5CL
5	F_1	540	150	1500	1.0L
6	F_1	540	150	1500	0.5L
7	F_1	540	150	1500	0.25L
8	F_1	540	150	1500	0.5CL
9	F_1	540	150	0	without skirt

Table No.4 Numerical Model Footing Data

S.No.	Size of Footing (in m)	Load in (KN)	Net Upward Soil Pressure (KN/m^2)	Depth of Skirt(Ds)(mm)	Length of skirt
1	F_2	745	80	250	1.0L
2	F_2	745	80	250	0.5L
3	F_2	745	80	250	0.25L
4	F_2	745	80	1500	0.5CL
5	F_2	745	80	1500	1.0L
6	F_2	745	80	1500	0.5L
7	F_2	745	80	1500	0.25L
8	F_2	745	80	1500	0.5CL
9	F_2	745	80	0	without skirt

Table No.5 Numerical Model Footing Data

S.No.	Size of Footing (in m)	load in (KN)	Net Upward Soil pressure (KN/m^2)	Depth of Skirt(Ds)(mm)	Length of skirt
1	F_2	1640	150	250	1.0L
2	F_2	1640	150	250	0.5L
3	F_2	1640	150	250	0.25L
4	F_2	1640	150	1500	0.5CL
5	F_2	1640	150	1500	1.0L
6	F_2	1640	150	1500	0.5L
7	F_2	1640	150	1500	0.25L
8	F_2	1640	150	1500	0.5CL
9	F_2	1640	150	0	without skirt

IV. RESULTS AND DISCUSSION

On the basis of numerical modelling of SSISF for different locations of skirt and skirt depth Ds due to Concentric load from column, the various interpretation regarding settlement of footing have been computed using SAP 2000 Vs18. Average settlement of footing at all the nine points, Differential settlement amongst opposite mid points i.e. (NMP & FMP) & (LMP & RMP), Differential settlements along sides (Left Side & Right Side), and Differential settlement along two diagonals (NED) & (FED) had been observed. Results obtained from the comparative analysis are represented by various bar charts as shown below.

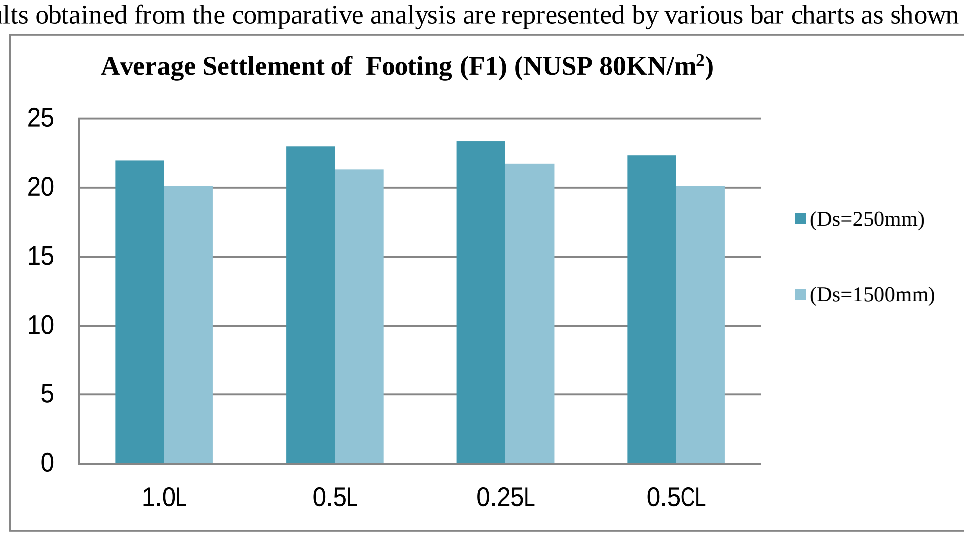

Fig.6 Average Settlement of All Nine Points of Model Footing with Skirt Depth (250mmm & 1500mm)

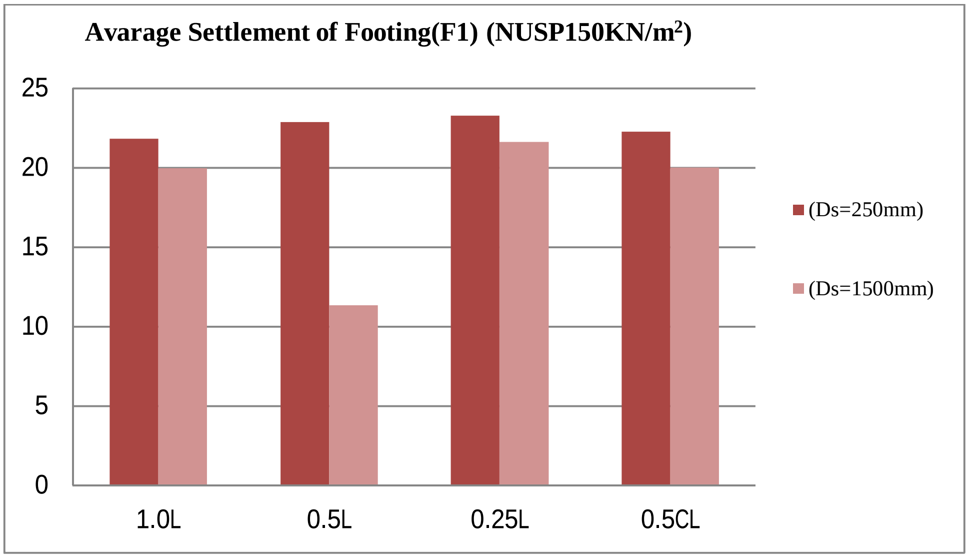

Fig.7 Average Settlement of All Nine Points of Model Footing with Skirt Depth (250mm &1500mm)

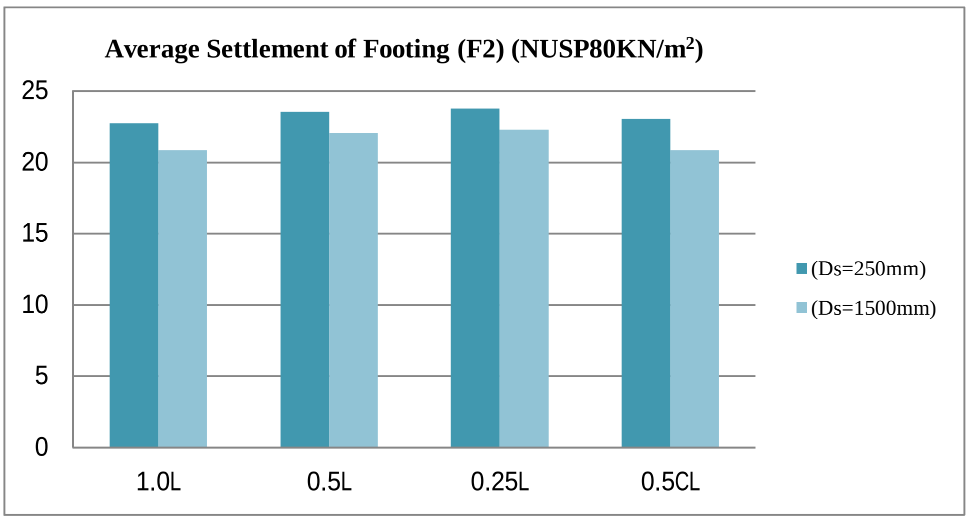

Fig.8 Average Settlement of All Nine Points of Model Footing with Skirt Depth (250mm & 1500mm)

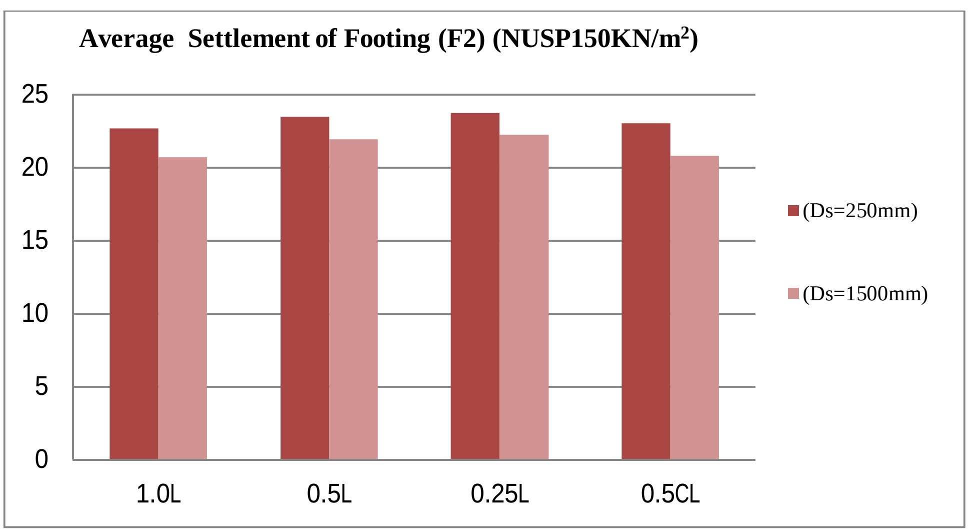

Fig.9 Average Settlement of All Nine Points of Model Footing with Skirt Depth (250 mm &1500mm)

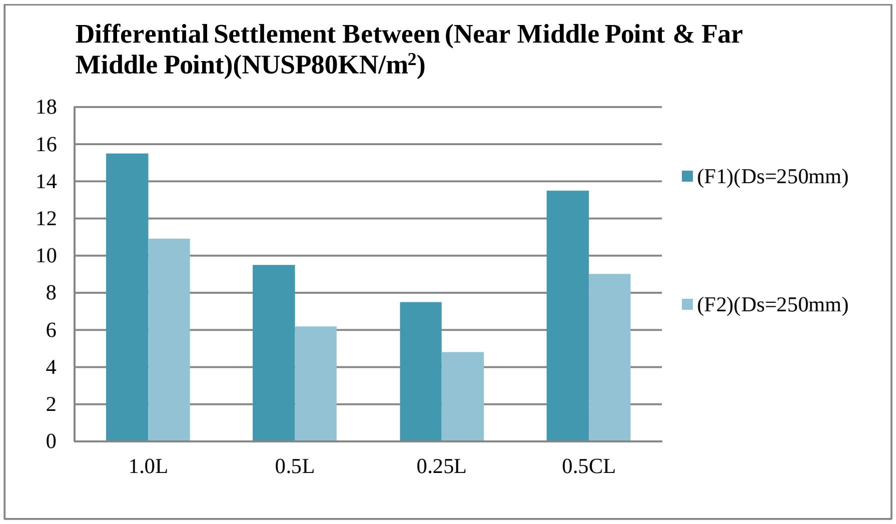

Fig.10 Differential Settlement Between (Near Middle Point & Far Middle Point)

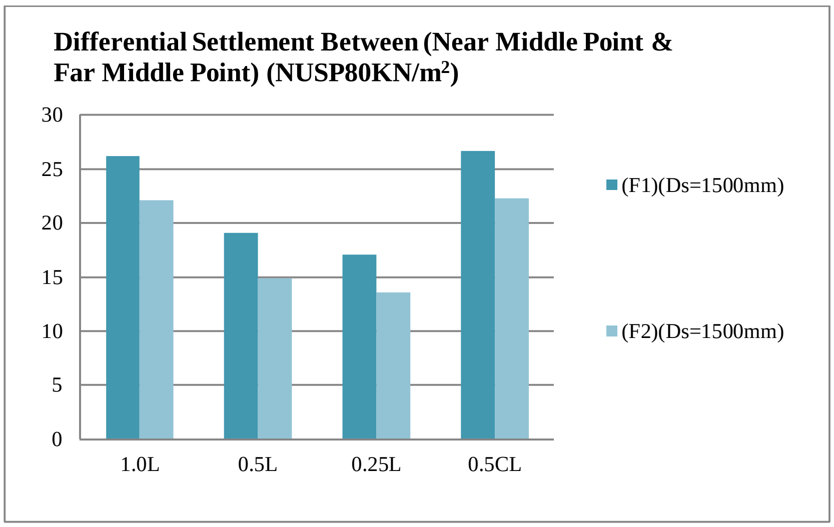

Fig.11 Differential Settlement Between (Near Middle Point & Far Middle Point)

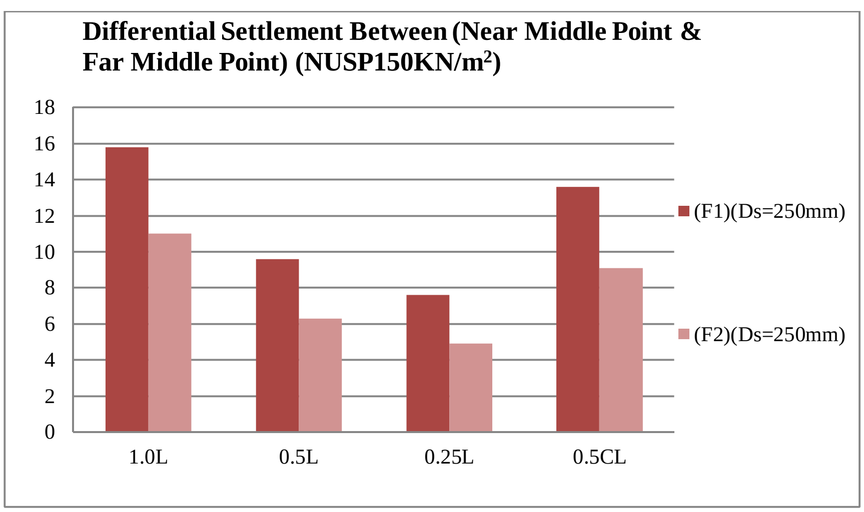

Fig.12 Differential Settlement Between (Near Middle Point & Far Middle Point)

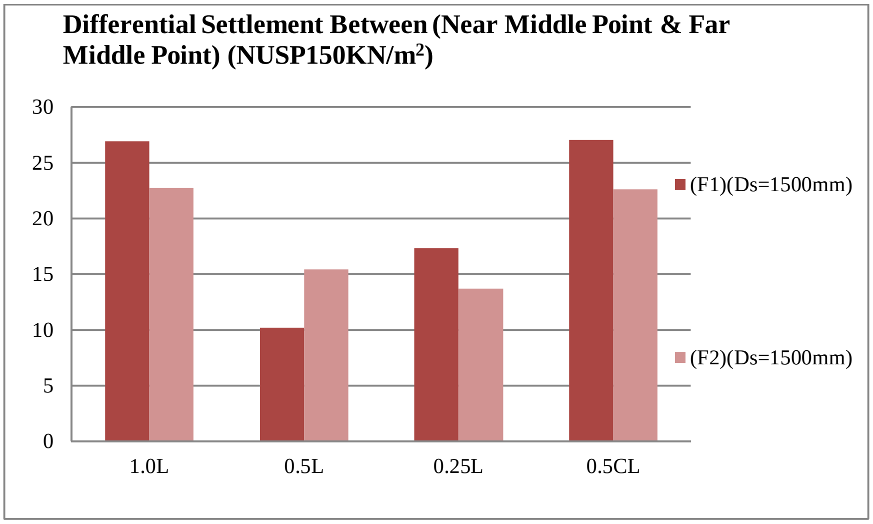

Fig.13Differential Settlement Between (Near Middle Point & Far Middle Point)

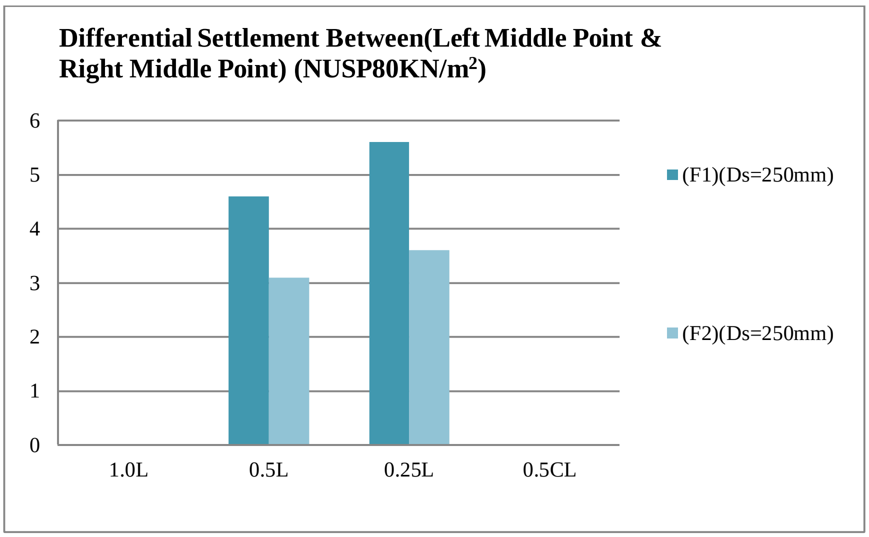

Fig.14 Differential Settlement Between (Left Middle Point & Right Middle Point)

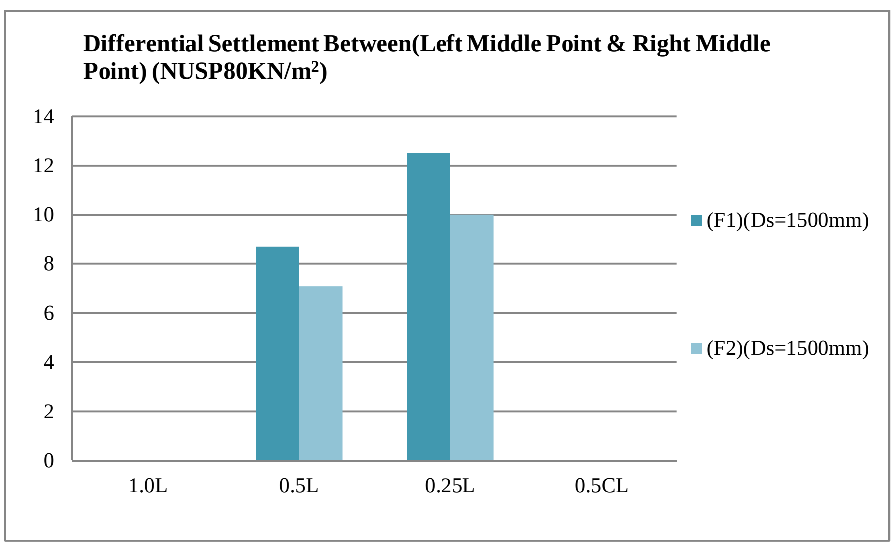

Fig.15 Differential Settlement Between (Left Middle Point & Right Middle Point)

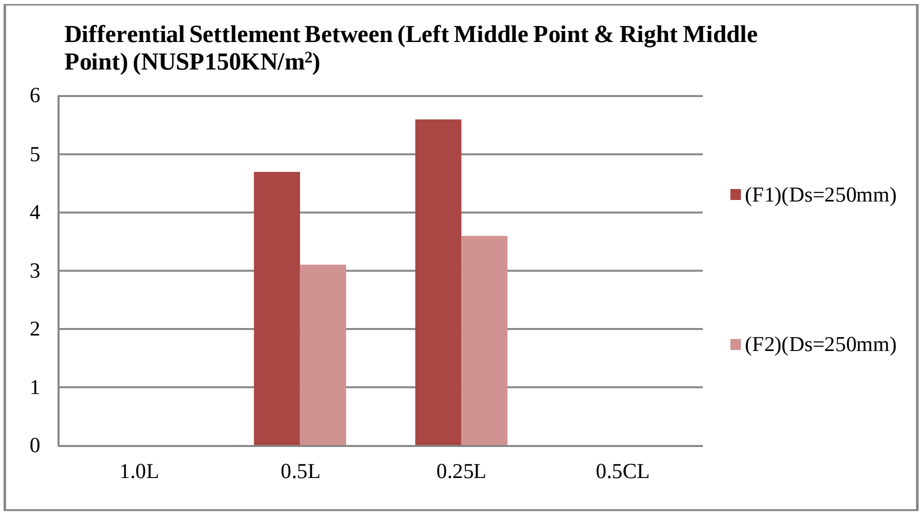

Fig.16 Differential Settlement Between (Left Middle Point & Right Middle Point)

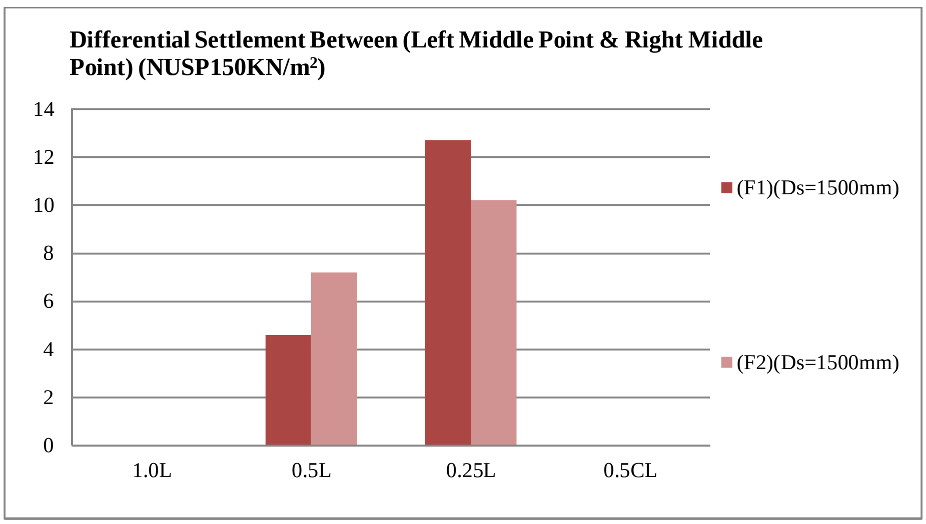

Fig.17 Differential Settlement Between (Left Middle Point &Right Middle Point)

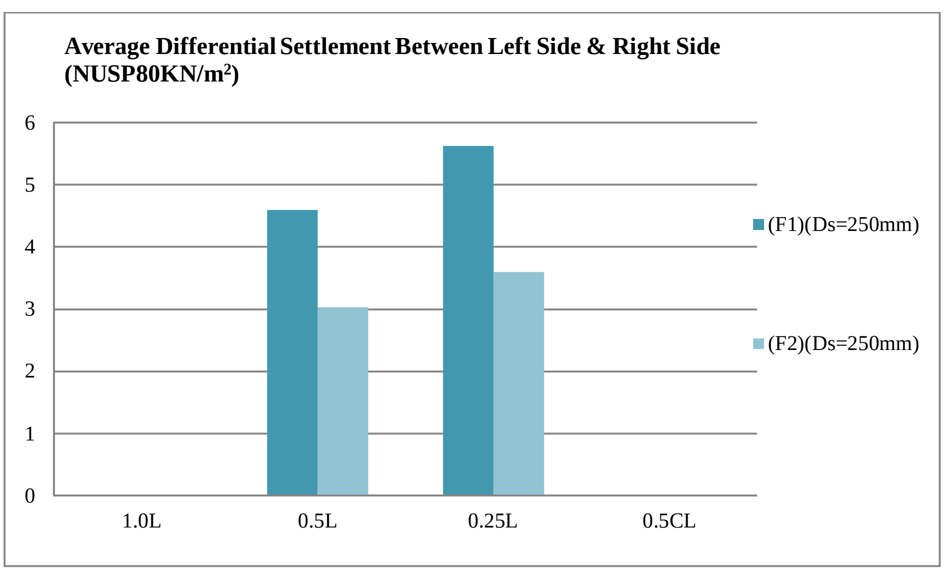

Fig.18 Average Differential Settlement Between Left Side & Right Side

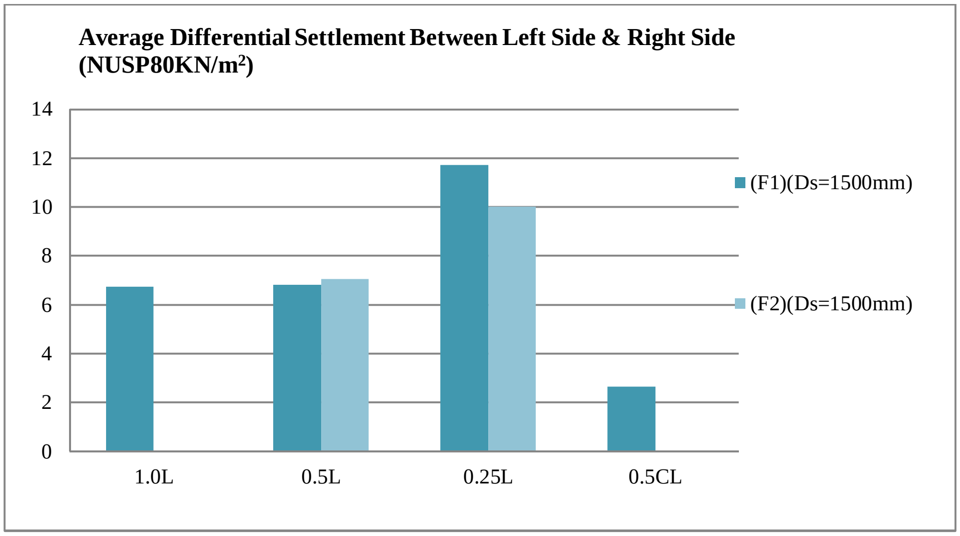

Fig.19 Average Differential Settlement Between Left Side & Right Side

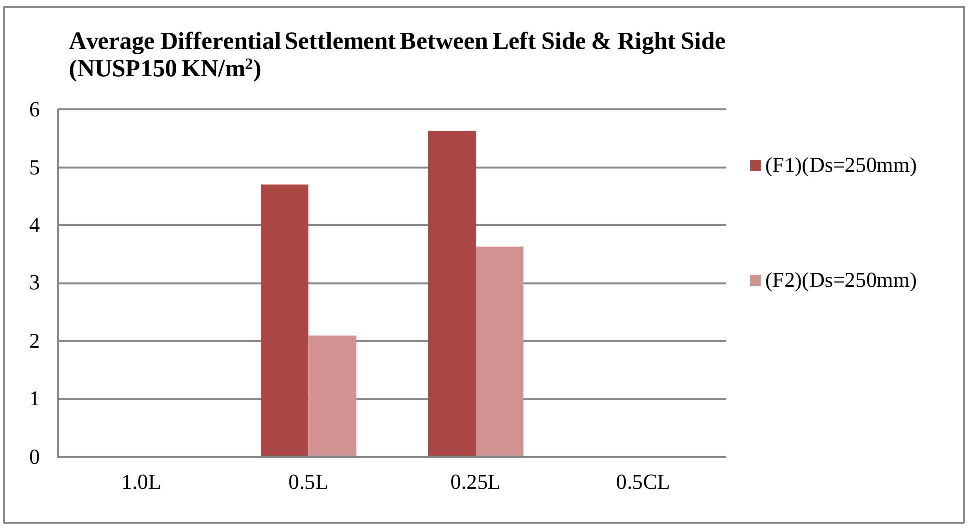

Fig.20 Average Differential Settlement Between Left Side & Right Side

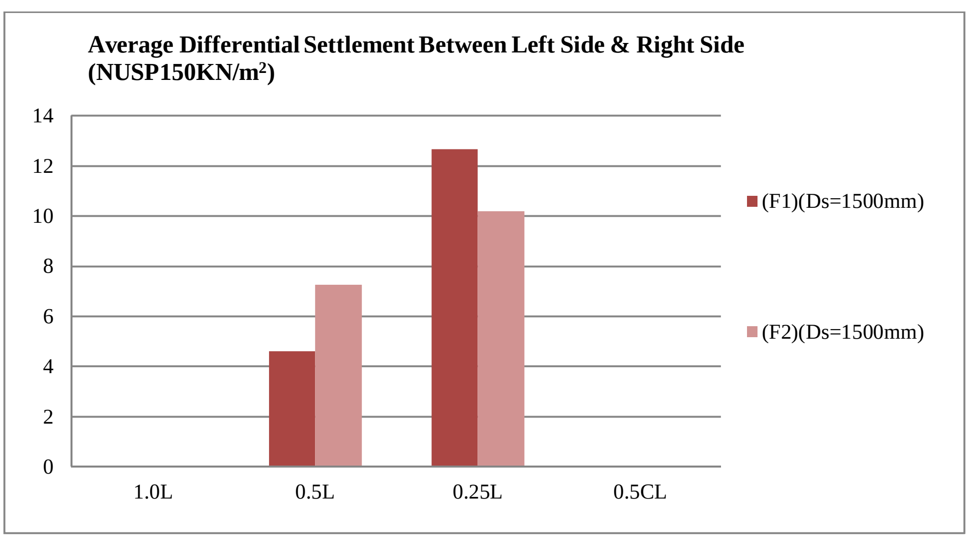

Fig.21 Average Differential Settlement Between Left Side & Right Side

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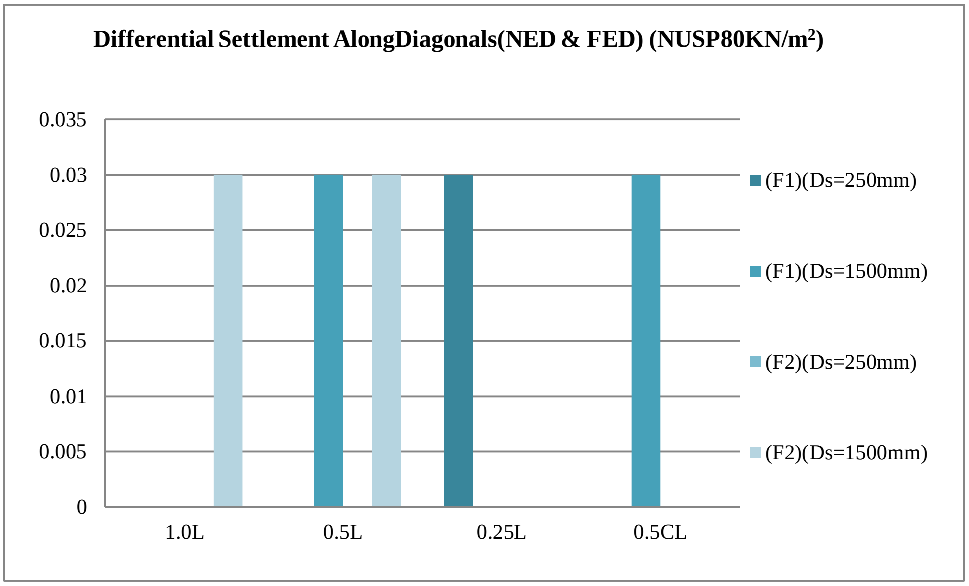

Fig.22 Differential Settlement Along Diagonals (NED & FED)

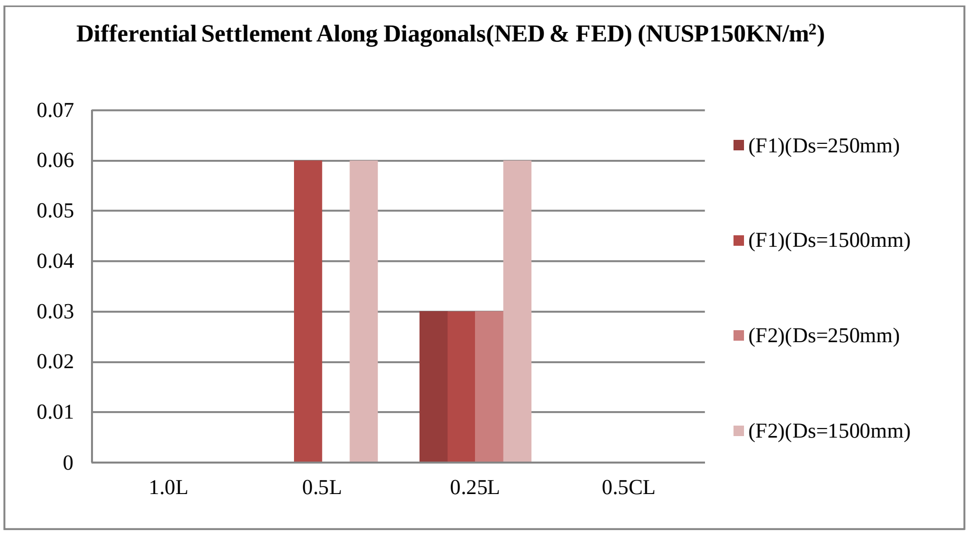

Fig.23 Differential Settlement Along Diagonals (NED & FED)

V. CONCLUSIONS

From the graph & tables following conclusions are drawn

A. When skirt is provided at full length (1.0L) and half central length (0.5CL) of footing ; the average settlements of footings are found to be almost same for both the values of net upward soil pressures ($80KN/m^2$ &$150KN/m^2$) and depth of skirt D_S (250mm & 1500mm). Refer fig.6, fig.7, fig.8 & fig.9.

B. If symmetrically placed half skirt length (0.5CL) is provided then the average settlement of footing is same as that of full length (1.0L) skirted footing.

C. If it is not possible to provide full length skirt (1.0L) then the symmetrically placed partial length skirt should be provided according to size of footing.

D. Length of skirt to be provided is the parameter which is independent of depth of footing.

E. The average settlement of footing with full length skirt (1.0L) reduces to about 40%, where as footing with half length skirt (0.5L) reduces the average settlement by 35% and footing having quarter length of skirt (0.25L) shows 32% reduction in average settlement of footing, as compare to average settlement of footing without skirt which is 24.6 mm.. Thus it is not necessary to provide skirt for full length of footing; reduction in skirt length to 05L & 0.25L may be a better option. Refer fig.6, fig.7, fig.8 & fig.9.

F. In all the cases of footings studied here and for both the values of net upward soil pressures, the average settlement values belongs to all 09 observation points of a footing are found to be less than 25 mm, i.e. maximum allowable settlement of Isolated footing.

G. Differential settlement amongst opposite mid points (NMP), (FMP) & (LMP), (RMP) of footings are found to be independent of net upward soil pressure as well as size of footing. Refer fig.10, fig. 11, fig.12 & fig.13.

H. For skirt length (1.0L) & (0.5CL); the differential settlement of left and right sides of footing i.e. (LMP) & (RMP) are found almost zero. Showing equal or uniform settlement of both sides. Whereas in case of skirt length (0.5L) & (0.25L) the differential settlements are having some values but showing a uniform pattern of footing settlement with respect to both sides. This shows that the differential settlements of sides of footing is also independent of net upward soil pressure and size of footing. Refer fig.14,fig.15, fig.16 & fig.17.

I. Average differential settlement of both the sides i.e. left side and right side of footing is also independent of net upward soil pressure and size of footing. Refer fig.18, fig.19, fig.20 & fig.21.

J. All footing sizes with depth of skirt 250 mm and 1500 mm shows **zero** values for differential settlement along both the diagonals of footing i.e. Near End Diagonal (NED) & Far End Diagonal (FED), and thus ensures equal settlement along the diagonals. It is also found to be independent of net upward soil pressure and size of footing. Refer fig.22 , fig.23.

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