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Finite Element Analysis of Bi Angle Shaped Square Footing Under Two Way Eccentric Loading

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Abstract

Footing subjected to eccentric loading along two mutually perpendicular axes is quite a common field problem. Due to this bearing capacity is reduced considerably as the effective size is drastically reduced. A footing may be subjected to two-way eccentricity due to many reasons. In the case of footing subjected to one-way eccentricity the common practice is to match the centre of gravity of column loads to centre of gravity of footing area. Strap footings are also commonly used when the footing is subjected to two-way eccentric load. These footings not only resist the eccentric loading without (negligible) tilt but increase the bearing capacity also. Using the idea of angle-shaped footings, which was a result from the study of partial confinement, another new idea, has been developed. These footings have shape in the form of two vertically downward projections towards the eccentric side of two adjacent edges. In the present paper Bi-Angle shaped footings have been analyzed by the Finite Element Technique using ANSYS Software. Square footings under a point load at some eccentricity along diagonal with two vertically downward footing projections of equal length along two adjacent sides towards the eccentricity have been analyzed. It has been observed that footings subjected to two-way eccentricity could be designed for no tilt by using Bi-Angle shaped footings. The depths of two footing projection of equal length will depend upon the eccentricity along the diagonal.

Keywords: *Footing, one-way eccentricity, two-way eccentricity, angle-shaped footings, bi-angle shaped footings*

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INTRODUCTION

The purpose of the foundation is to resist the column load by spreading it over a larger area in such a way that the pressure developed beneath the footing is less than bearing capacity of the soils and at the same time the settlement should be less than the allowable value. The pressure developed beneath the rigid footing is assumed to be uniform if the footing carries an axial load and the uniform pressure causes the footing to settle by same amount without any tilt. If a foundation were subjected to lateral loads and moments in addition to vertical loads, eccentricity in loading would result. The point of application of the resultant of all the loads would lie outside the geometric centre of the foundation, resulting thereby eccentricity in loading. The eccentricity 'e' is measured from the centre of the foundation to the point of application normal to the axis of the foundation. The maximum eccentricity normally allowed is B/6 (B = width of footing). The basic problem is to determine the effect of the eccentricity on the ultimate bearing capacity of foundation. When a foundation is subjected to an eccentric vertical load it tits towards the side of eccentricity and contact pressure increases on the side of tilt and decreases on the opposite side. When a footing with two vertical projections is subjected to two ways eccentric loading and such that the projections are an integral part of footing it is called Bi-Angle Shaped Footing. The footing projections prevent the tilt in the direction in which the footing has the tendency to tilt reducing the tilt to zero. Construction of vertical projections at the base of the footing, confining the underlying soil, generates a soil resistance on projection sides that helps the footing to resist sliding. Mahiyar and Patel developed a new concept of angle-shaped footings, in which the relationship between e_x/B and D/B values were developed such that the tilt is almost zero.

The equation for no tilt condition developed by Mahiyar is of following type:

$$\frac{D}{B} = 68.32\,(e/R)^2 - 0.172(e/R) + 0.00036$$

Where,
D=depth of the projections
B=breadth of the footing
e=diagonal eccentricity
R=diagonal length

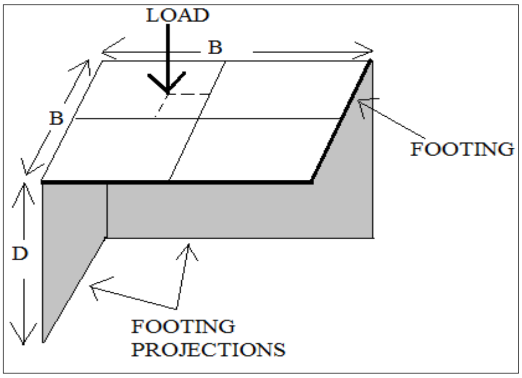

Fig.1: *3d Diagram of Bi-Angle Shaped Footing Subjected to Two Way Eccentric Vertical Loading.*

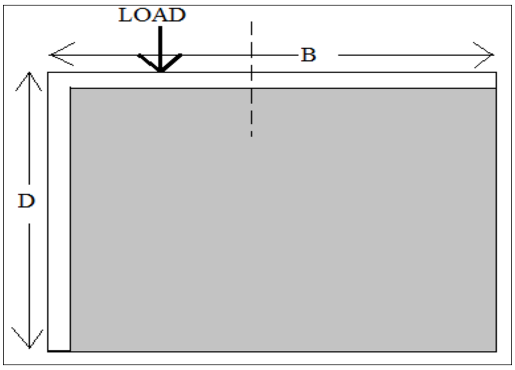

Fig. 2: *Cross Section X-X of Bi-Angle Shaped Footing Subjected to Two Ways Eccentric Loading.*

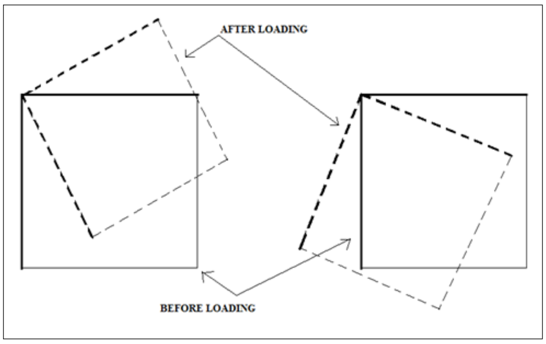

Fig. 3: *Behaviour of the Bi-Angle Footing After Loading.*

METHODOLOGY

General

The Bi-Angle shaped footing is a modern concept to optimize the geometry of structural element i.e. foundation, so that it becomes more useful and economical than its orthodox geometry. The capability of Bi-Angle shaped footing to support the structure depends upon various factors. These factors are intensity load, depth of projection and size of footing. The use of Bi-Angle shaped footing for the structures can be the solution for many of the civil engineering problems. But to make it safe for using it in the structure, it is necessary to know about the various forces developed in it.

The software ANSYS which is based on finite element technique is used for the purpose of analysis. The graphic user interface of any software makes good use of the features available for the development of the computerized model of the actual problem. The three dimensional model of angle shaped footing and two dimensional model gives the same results because the forces in the Z direction is negligible, and the problem can be considered as the plane stress problem.

Case Study

A square footing plate of mild steel of size 100 × 100 mm was taken. It was given the innovative shape by joining two another mild steel plates called as footing projection along two adjacent sides of the footing. Both the footing projections were at right angles to the footing. The widths of footing projections were kept equal to width of footing plates. The point load was applied at equal eccentricities along the axes towards the footing projection.

Keeping the depth of projection

D/B = 0.2, 0.4, 0.6, 0.8 Also, by changing the size of footing as follows;

B = 1.0 × 1.0 m, 1.5 × 1.5 m, 2 × 1.5 m, 2.5 × 2.5 m, 3.0 × 3.0 m & 4 × 4.0 m

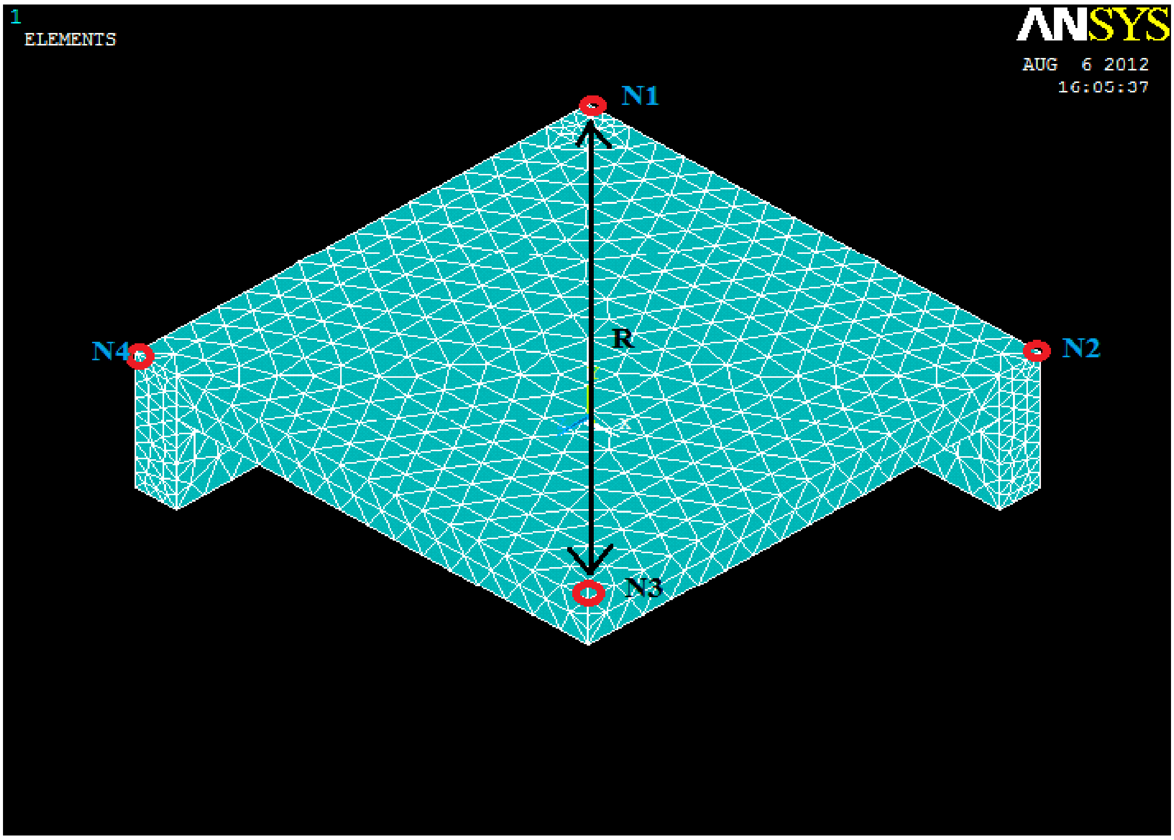

Fig. 4: *ANSYS Computer Model of Meshed Bi-Angle Shaped Square Footing Showing Isometric View for the N1, N2, N3, and N4.*

RESULTS

From the load settlement, the tilt was calculated when the settlement is 5% of footing width either at near end or far end, whichever occurs first. The tilt is calculated as the difference in settlement at near and far end divided by diagonal length of footing. The tilt is positive when the near end settles more and negative when far settles more. From the results, it is clear that settlement for D/B ratio of 0.8 of footing size of 2.0 × 2.0 m is varying drastically compared to other cases.

Table 1: *Vertically Downward Settlements of Bi-Angle Shaped Square Footing of Size 1.0 × 1.0 m for Load Intensity 250 kN/m^2.*

D/B	**Node number**				**Average settlement in mm**
	1	**2**	**3**	**4**	
0.2	9.1050	9.0165	9.0031	9.0072	9.03295
0.4	8.0808	7.5135	7.6133	7.5074	7.67875
0.6	7.9804	7.3458	7.1456	7.3279	7.44993
0.8	7.5876	7.3373	6.9842	7.2914	7.30013

Table 2: *Vertically Downward Settlements of Bi-Angle Shaped Square Footing of Size 1.5 × 1.5 m for Load Intensity 250 kN/m^2.*

D/B	**Node number**				**Average settlement in mm**
	1	**2**	**3**	**4**	
0.2	11.635	11.975	11.221	12.059	11.7225
0.4	12.068	11.459	11.911	11.481	11.7298
0.6	10.815	11.462	9.905	11.435	10.9043
0.8	10.691	10.963	9.867	10.963	10.621

Table 3: *Vertically Downward Settlements of Bi-Angle Shaped Square Footing of Size 2.0 × 2.0 m for Load Intensity 250 kN/m^2.*

D/B	**Node number**				**Average settlement in mm**
	1	**2**	**3**	**4**	
0.2	15.724	15.707	15.075	15.732	15.5595
0.4	15.945	15.222	15.986	15.275	15.607
0.6	14.793	14.892	13.977	14.870	14.633
0.8	14.534	14.669	13.863	14.631	7.15725

Table 4: *Vertically Downward Settlements of Bi-Angle Shaped Square Footing of Size 2.5 × 2.5 m for Load Intensity 250 kN/m^2.*

D/B	**Node number**				**Average settlement in mm**
	1	**2**	**3**	**4**	
0.2	19.975	19.377	20.403	19.374	19.7823
0.4	19.026	19.419	18.780	19.382	19.1518
0.6	19.486	19.005	19.796	19.037	19.331
0.8	19.558	18.355	19.012	18.333	18.8145

Table 5: *Vertically Downward Settlements of Bi-Angle Shaped Square Footing of Size 3.0 × 3.0 m for Load Intensity 250 kN/m²*.

D/B	Node number				Average settlement in mm
	1	2	3	4	
0.2	22.600	22.893	22.673	22.747	22.7283
0.4	23.838	23.164	23.106	23.064	23.293
0.6	22.630	22.820	22.102	22.852	22.601
0.8	22.388	21.933	21.947	21.927	22.0488

Table 6: *Vertically Downward Settlements of Bi-Angle Shaped Square Footing of Size 4.0 ×4.0 m For Load Intensity 250 kN/m².*

D/B	Node number				Average settlement in mm
	1	2	3	4	
0.2	31.585	30.985	31.828	31.252	31.4125
0.4	31.648	30.790	30.812	30.931	31.0453
0.6	30.484	29.973	29.904	29.958	30.0798
0.8	30.306	29.347	29.417	29.267	29.5843

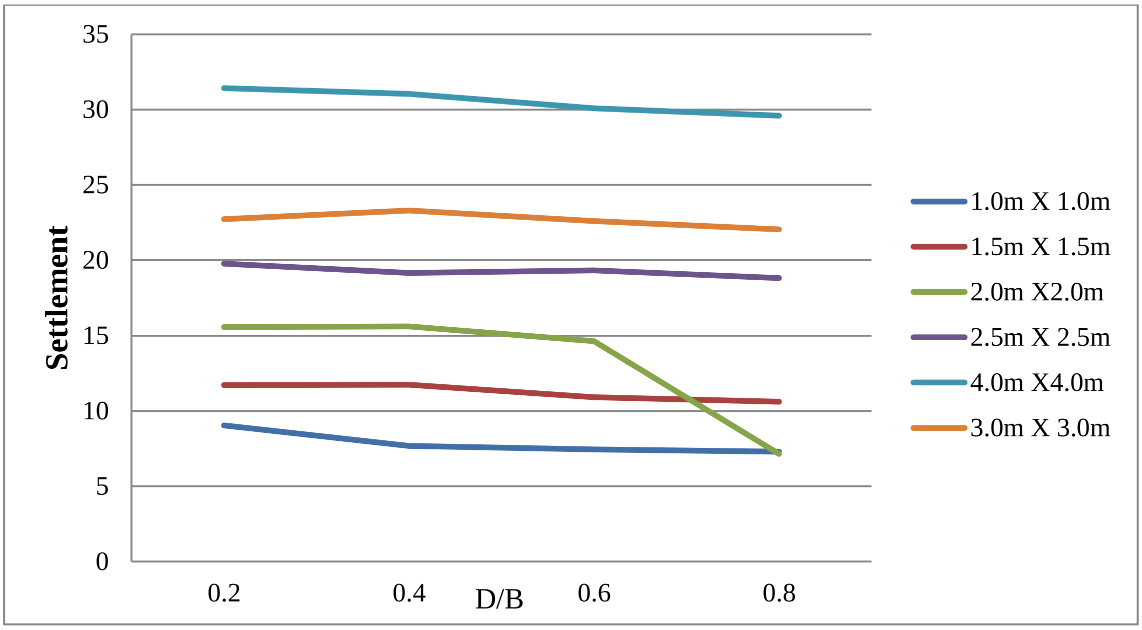

Fig. 5*: Settlement Vs D/B ratio graph for different size of footing.*

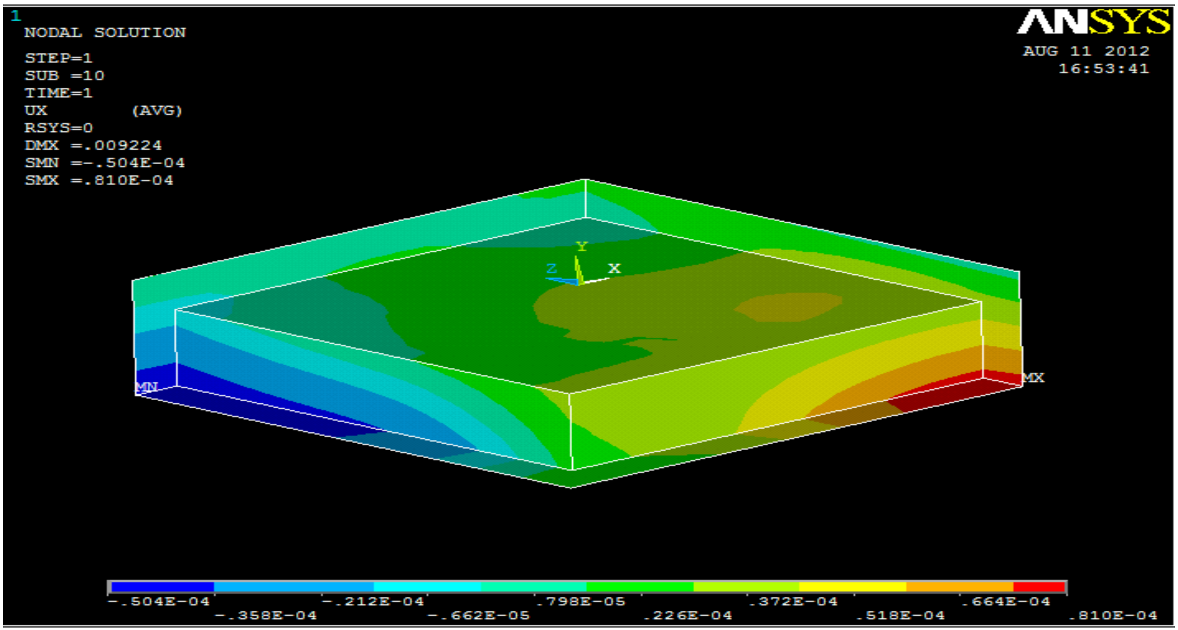

Fig. 6: *ANSYS model of Bi-Angle shaped square footing of size 1.0 × 1.0 m D/B=0.2 showing displacement in X with the maximum and minimum displacement.*

From the figure, it is clear that Maximum displacement (red colour) is occurring at the other end of the loading.

CONCLUSION

The equation derived earlier for zero tilt condition for Bi-Angle shaped square footing was verified using the simulation software ANSYS, so that the research can be utilized on field for the benefit of the common people. It has been observed that the zero tilt condition prevails as per the equation derived earlier. By varying the size of square footing the equation doesn't changes and the settlement at constant load intensity of 250 kN/m^2 increases linearly at a constant D/B.

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