Finite Element Analysis of Vane-Shaped Footing of Varying Projection Location using ANSYS

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Abstract— The load transferred to the soil strata has a tendency to move soil in vertical and horizontal directions and as a result settlements of foundation take place. Also when the footing is subjected to eccentric loading, it undergoes tilt. In the past researches, Angle Shaped Footings had been introduced to reduce the tilt up to zero. In Angle Shaped Footing, the footing is confined by providing vertical or inclined downward projection which remains embedded in soil. The concept of Angle Shaped Footing, which is found to be very useful in case of eccentric loading, was extended to Vane-Shaped footing. In Angle Shaped Footings, the vertical projection is provided at the edge while in Vane-Shaped footing, the vertical projection is provided at the centre and in both perpendicular directions. The vertical downward projection at centre is provided to improve the bearing capacity of soil against the application of central vertical loading which also provides considerable resistance against both overturning and sliding. Hence in the present work, different models of Vane-Shaped Footing have been analyzed with the change in the depth and location of vertical footing projection under the application of eccentric loading. The position of vertical projection is obtained for which tilt of footing becomes zero or brought within permissible limits of tilt as per Indian Standard Code. The deformations and stresses are also determined in both horizontal and vertical directions for different depths of projection under different eccentricities. The whole analysis has been performed over the ANSYS version 18.2.

Keywords: Vane Shaped Footing, Tilt, Projection, Eccentricity, Depth Width Ratio, Position of Footing Projection

I. INTRODUCTION

In design of footing it is an important aspect to understand the behaviour of footing due to loads applied on it. The method of footing design requires sufficient safety against tilt and settlement. It is generally considered that the settlement criterion is more critical than the bearing capacity in design of shallow foundation. By limiting the total settlement, differential settlements and any subsequent distress the structure are ensure to be safe. At the property line where it is not permissible to provide spread foundation when the centre of gravity of foundation and column doesn't matches, eccentricity formed and due to this the footing. Therefore it is desired to give combined or strap foundation where as it is highly uneconomical and hence cannot be recommended. Therefore it is the duty of the engineer to perform the task within the nominal cost as the load will be distributed near to surface. For designing foundation subjected to lateral forces such as earthquake, wind forces and due to eccentricity loading can be conveniently evaluated. Due to eccentric loading the two edges settle by different amounts, causing the footing to tilt.

We introduced vertical projection which may be very helpful to reduce settlement and tilt of footing. We using Vane shaped projection in footing to counter eccentric loading effects.

A. Eccentric Loading

When loading is applied on footing in such a manner, the resultant of load doesn't pass through the centre of footing then the loading is considered as the eccentric loading.
A footing may be subjected to eccentric loading due to any of the following reasons:

1) The centre of gravity doesn't coincide with the centre of gravity of column load.
2) The footing may be subjected to axial load along with some moments.
3) Footing is close to property line.

In addition with the vertical axial loads, the foundations in the case of portal- framed structures are often subjected to eccentric load which is caused due to wind and earthquake forces. The corner column sometimes located very close to the property line and gets subjected to the eccentric loading. Movement of the soil particles takes place in the horizontal and vertical directions when the structure is subjected to axial forces in addition with the moments. To reduce these movements of soil particles or to increase the bearing capacity of the soil, the footings are provided with the unequal offsets such that the centre of gravity of the footing area coincides with the centre of gravity of the column loads.

B. Vane-Shaped Footing

There are two wall projections which are perpendicular to each other mounted at the bottom of flat footing. Here we only move one of the walls for study of tilt along the direction of eccentricity of loading.

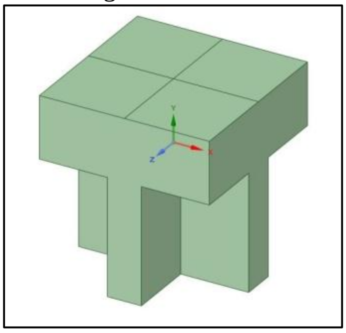

Fig. 1: Vane Shaped Footing

C. Terminologies Used

Parameter	Symbol
Eccentricity along X-axis	e_x
Width of footing	B

Depth of footing	D
Eccentricity-width ratio	e_x/B
Position of footing projection	C

Table 1: Symbols used in the study

II. LITERATURE REVIEW

A. *Mahiyar H.K. (2000)*

Footings are often subjected to eccentric loading due to (1) moments with or without axial forces; (2) the oblique loading; and (3) their location near the property line. Due to eccentric loading, the footing tilts and the pressure below the footing does not remain uniform. The tilt of footing increases with an increase in the eccentricity and the bearing capacity reduces considerably. Therefore, footing sizes increase and make the design uneconomical. The finite-element analysis of an angle shaped footing under eccentric loading has been carried out in the present study. One side vertical projection of footing confines the soil and prevents its lateral movement. It was concluded that footing subjected to uniaxial eccentric loads can be designed for no or negligible tilt by giving the footing an angle shape. The depth of footing projection will depend upon the eccentricity width ratio.

B. *Kanungo A. (2000)*

Studied the angle shaped footing in which (e/B) and (D/B) were in accordance with the equation proposed by Mahiyar H.K. (2000) :

$$D/B = 85.77\{e/B\}^3 - 8.95\{e/B\}^2 + 3.42\{e/B\} - 0.0012$$

And found that the tilt is zero. The various sizes of footings were considered. It was concluded that bearing capacity increase with increase in size of footing, the bearing capacity also increase with increase in (D/B) value

C. *Joshi D. (2000)*

Studied angle shaped footing subjected to eccentric inclined loading. The inclination on either side of vertical axis was provided and the angle of footing projection was also varied. The footings were found to be useful in resisting eccentric inclined load, although the load carrying capacity was less.

D. *Gupta D. (2000)*

Studied angle shaped footing with rectangular shaped in which eccentricity was provided on longer and shorter side. It was concluded that eccentricity along shorter side and footing projection on longer side is more effective.

E. *Mahiyar H.K. (2003)*

Studied the effect of shear parameters on load carrying capacity on angle shaped footing and concluded that load carrying capacity increase with increase in angle of internal friction and tilt is zero at all value.

III. METHODOLOGY

A. *General*

Finite element analysis is carried out for calculation of deflection and stresses in the Vane Shaped footing by ANSYS 18.2 software for various models with changed geometry and loading conditions.

B. *Material Property and Dimension*

1) Soil (sandy soil)

1) Density (ρ) = 1834.864 kg/m^3
2) Poison's Ratio (μ) = 0.333
3) Young's Modulus of Elasticity (E) = 16.864 MPa
4) Internal Friction Angle =30^0
5) Initial Cohesion = 0

2) Dimensions of soil

1) Length = 5000 mm
2) Width = 5000 mm
3) Height = 3000 mm
4) There is a cut out in soil for footing projection.

3) Concrete

1) Density (ρ) = 2300 kg/m^3
2) Poison's Ratio (μ) = 0.18
3) Young's Modulus of Elasticity (E) = 3000 MPa
4) Tensile ultimate stress = 5 Mpa
5) Compressive ultimate stress = 41 Mpa

4) Dimensions of footing (Vane Shaped)

1) Length = 1000 mm
2) Width = 1000 mm
3) Thickness = 400 mm
4) Thickness of projections = 200 mm
5) Depth of projection is varies in models.

C. *Processing*

Our analytic study is done in two parts as follows:

1) The effect of eccentricity of load:-
   a) Increasing gradually eccentricity value.
   b) Increasing gradually depth of projection.
   c) Calculating values i.e. deflection in x, y directions, normal stress in x, y directions.
2) The effect of positions the projection:-
   a) Shifting projection from centre gradually toward left edge.
   b) Increasing gradually depth of projection.
   c) Calculating values i.e. deflection in y directions, tilt of footing.

To determine the displacements and stress for a number of models of footing readymade software (ANSYS version 18.2) which is based upon the finite element method. Following models were prepared & studying.

1) The Eccentricity (e_x) to width (B) ratio i.e. e_x/B is kept as = 0.00, 0.05, 0.1 & 0.15. Fig.2
2) Depth of downward footing projection (D) is varied as D/B = 0, 0.25, 0.5, 0.75 & 1.0. Keeping the location of projection at the centre (C/B = 0). Fig.3
3) For models for C/B varies from 0 to 0.4 of 0.5 interval and Depth of downward footing projection (D) is varied as D/B = 0, 0.25, 0.5, 0.75 & 1.0. for e_x/B = 0.15. In all case a constant load of 250kN is applied. Fig.4

D/B Ratio	No. of models (for different values of C)
0	1
0.25	9
0.5	9
0.75	9
1	9
Total	37

Table 2: Number of models used for the analysis

As Table-2 describes number of models which are used in ANSYS version 18.2 for solution are pre processed in SpaceClaim software which is used to draw geometry of model. Some of the basic geometry is captured form computer model. In Fig.2 shows constant load i.e. 250 kN at different eccentricity, in Fig.3 shows varying projection depth and Fig.4 shows shifting of projection along X-direction.

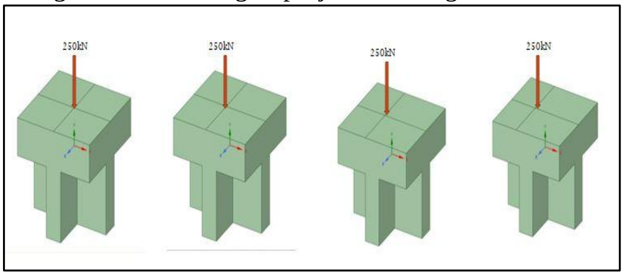

Fig. 2: Footing with varying e_x/B ratio (0.0, 0.05, 0.1, 0.15)

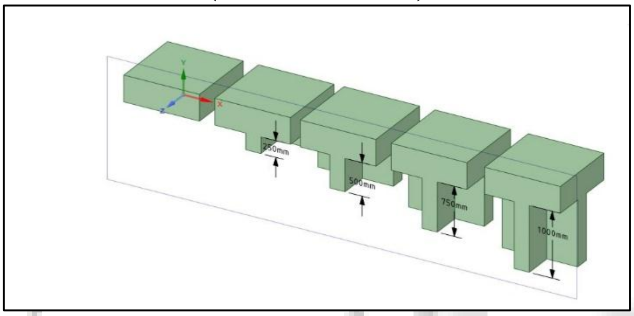

Fig. 3: Footing with varying e_x/B ratio (0.0, 0.05, 0.1, 0.15)

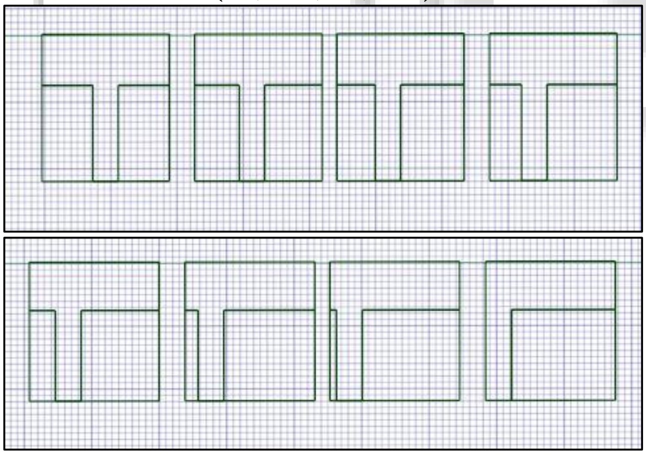

Fig. 4: Footing with varying C/B) ratio (0.05, 0.1,0.15,0.2,0.25,0.3,0.35,0.4)

IV. RESULT AND DISCUSSION

A. General

In this chapter the observation of the displacements Δ_x and Δ_y , normal stresses σ_x and σ_y for various cases of Vane- Shaped footing and its variation have been presented in contour diagram.

B. Results

Solutions are obtained from the analysis through ANSYS and the curves are plotted for the different cases of D/B ratio and e_x/B ratio for the following results:

1) Displacement in Y-direction
2) Displacement in X-direction
3) Normal Stresses in Y-direction
4) Normal Stresses in X-direction

After finding displacement along y direction the tilt has been calculated for various cases using the following equation;

$$\text{Tilt} = \frac{(\text{vertical displacement at node e}) - (\text{vertical displacement at node f})}{\text{width of footing}}$$

Following location of nodes are considered for the observations:

Using the readymade software i.e. ANSYS version 18.2 the results for displacements and stresses were determined at various nodes. However we have noted the results of displacements Δ_x and Δ_y , normal stresses σ_x and σ_y at some prominent points as marked and shown in Fig. 5

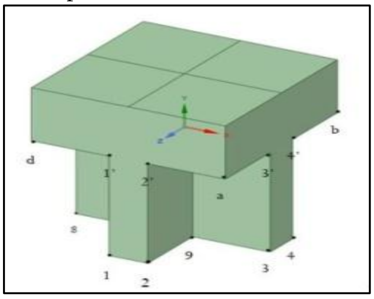

Fig. 5: Footing with all nodes for analysis

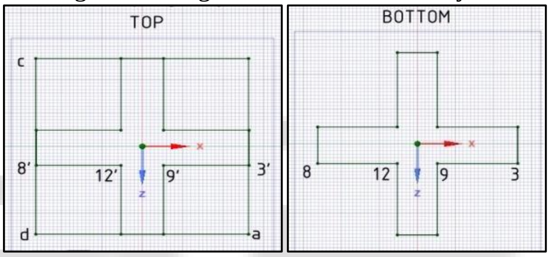

Fig. 6: Vane Shaped Footing with points

C. Discussion

From the analysis by ANSYS Software over Vane-Shaped Footing of size 1.0 m x 1.0 m x 0.4 m with different depths of projection and varying locations of projection, following points have been observed.

Displacements in Y-direction

a) On increasing the eccentricity of load, the value of vertical displacement (or displacement in Y-direction) increases.
b) As the depth of the footing projection increases, the value of vertical displacement (or displacement in Y-direction) decreases.

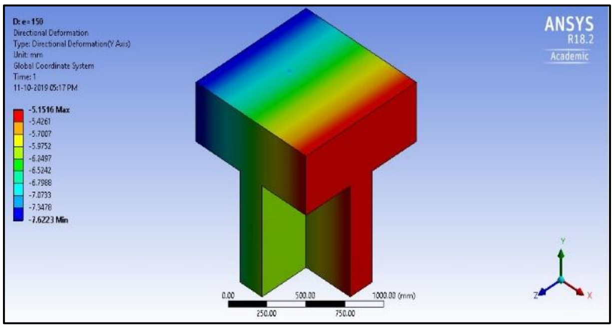

Fig. 7: Displacement contour along Y-axis for D/B = 0.75

Displacements in X-direction:

a) There is no horizontal displacement occurs when load is applied at centre of footing.
b) On increasing the eccentricity of load, the value of horizontal displacement increases.
c) As the depth of the footing projection increases, the value of horizontal displacement decreases.

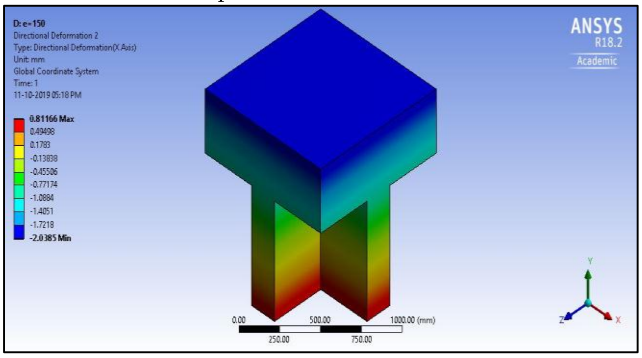

Fig. 8: Displacement contour along X-axis for D/B = 0.75

Normal stress in Y- direction:

There is no definite pattern obtained from the curves of stresses in Y-direction.

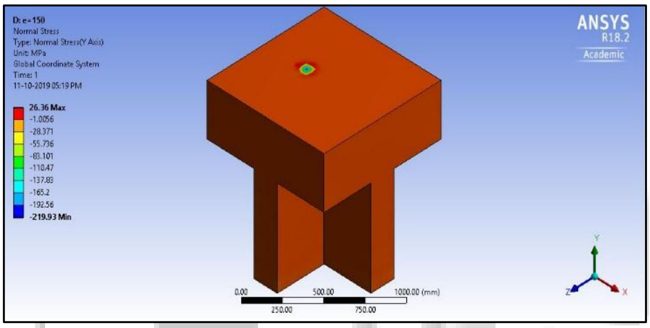

Fig. 9: Stress contour along Y-axis for D / B = 0.75

Normal stress in X- direction:

There is no definite pattern obtained from the curves of stresses in X-direction.

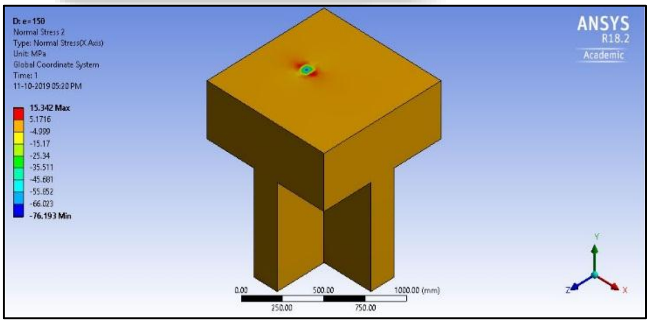

Fig. 10: Stress contour along X-axis for D / B = 0.75

Tilt of Footing:

a) As the depth of the footing projection increases, the value of tilt decreases when the eccentricity of load is kept constant (i.e. $e_x/B = 0.15$).
b) The value of tilt decreases when the position of footing projection is shifted towards the eccentricity of load up to a certain value.
c) At $e_x/B = 0.15$, the values of tilt are within permissible limit when D/B ratio is 0.75 and 1.0 for all projection cases.
d) At $e_x/B = 0.15$, when D/B ratio is 0.5. , the values of tilt are within permissible limit for all cases except location of projection at centre. i.e. C/B = 0
e) At $e_x/B = 0.15$, when D/B ratio is 0.25. , the value of tilt is within permissible limit for case when location of projection at the edge. i.e. C/B = 0.4

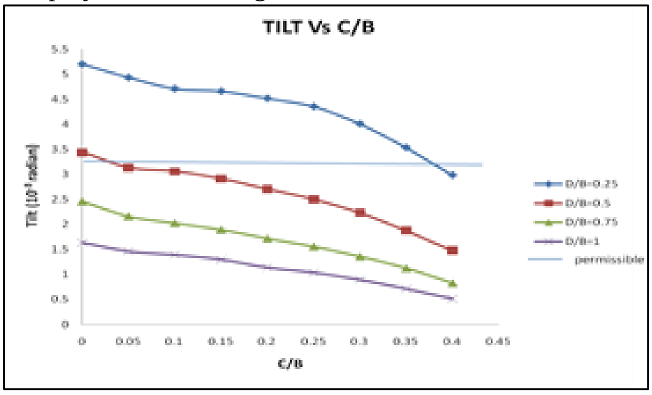

Chart 1: Value of tilt at $e_x/B = 0.15$ for various D/B and C/B values

V. CONCLUSIONS

The results obtained from the analysis using readymade software ANSYS version 18.2 were studied and following conclusions can be drawn:

– The vertical displacement decreases with increase in depth of projection (D) keeping the value of load and eccentricity width ratio (e_x/B ratio) constant.
– The vertical displacement increases with increase in eccentricity width ratio (e_x/B ratio) when the depth of projection and the value of load are kept constant.
– The value of tilt decreases with increase in depth of projection (D) for a fixed value of eccentricity width ratio (e_x/B ratio).
– When the footing projection is at edge i.e. C/B is equal to 0.4 and eccentricity width ratio (e_x/B ratio) = 0.15, the value of tilt comes under permissible limits when D/B ratio = 0.25 (fig.6)
– For eccentricity width ratio (e_x/B ratio) =0.15, at D/B ratio equal to 0.5,0.75&1.0, the value of tilt lies within permissible range when location of footing projection C/B is kept within between 0.05 to 0.4
– The slightly different values of tilt are observed when calculated from different nodes at same horizontal line at a particular section of footing which shows that there is a slight bending in the footing.
– The right angle between the footing and the projection before loading does not remain right angle when subjected to eccentric loading. There is a gradual reduction in this value and the reduction continues with the increase in either D/B ratio or e_x/B value.

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