ANALYSIS OF CAVITIES ON PERFORMANCE OF SHALLOW FOOTING

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ABSTRACT : The stability of any structure depends on bearing capacity of foundation soil, which plays major role in geotechnical engineering. The bearing capacity will change with presence of minerals in soil, with level of water table and with presence of cavities or voids in soil. The objective is to study the effect of number of voids, shape of void, size of void, spacing between voids and depth of voids and arrangement of voids on the stability of foundation. The parameters considered for the present study includes load inclination (0, 10, 20, and 30). This parameter effect is studied using PLAXIS 2D.

Keywords: *Stability, cavities, Shallow footing, Bearing Capacity, PLAXIS 2D.*

1. INTRODUCTION:

The existence of underground void affects stability of rigid surface structures such as foundations, rigid pavements over tunnels and underground pipe lines and also the integral stability of structure. Due to the population growth and in response to existing needs, the demand of tunnels for urban transportation has rapidly increased. These tunnels usually excavated close to the soil surface and their effects will develop to the ground level and can significantly affect the performance of shallow foundations located above these voids. Results of prior researches in this field indicated that the interaction between shallow foundation and underground voids has significant effects on the performance of shallow foundations.

1.1 Necessity of Studying Effect of Cavities on the Performance of Footing:

It is not uncommon that structures are founded above underground voids. A majority of the engineers contacted feel that cavities occur under structures at greater frequency in the areas having limestone and dolomite formations, and also in the areas which have been involved in active mining operations. The presence of underground void can cause serious engineering problem leading to instability of the foundation, incurring, severe damage to the super structure. If the void is located just below the footing at shallow depth, the consequence can be very costly and dangerous.

1.2 Objectives:

The literature review shows that studies on footing over void had been carry out considering many factor such as footing width, eccentricity of void, vertical distance of void from base of footing, size of void, shape of void, spacing of voids, depth of void by analytically and experimentally. However it is observed that the study of effect of void needs for effect of multiple voids (more than two), interference of footing in presence of void etc. Keeping in view the literature following objectives is planned.

i. Effect of multiple voids on bearing capacity of footing
ii. Effect of void on interference of footing
iii. The factor influencing bearing capacity of footing in presence of void such as size, depth, shape, spacing and distance of void from footing
iv. Effect of type of loading in footing on voids.

2. METHODOLOGY

1. Defining the geometry and finite element model layout.
2. Specifying material parameters: appropriate selection of material strength and stiffness parameters from laboratory or in-situ tests.
3. Generating stresses.
4. Construction staging i.e. defining various stages of excavation using staged construction.
5. Engineering judgment.

2.1 Problem Definition

In many situations it necessitates that the placement of footings on the soil having cavities e.g. footings above the tunnels, conduits, sewer networks. The provision of footing on voids may results into failure and hence there is need to study the effect of void on interference of footing. Fig. 3.3.1 shows the strip footing of width B subjected to vertical load placed on soil model having circular void of area A and two footings subjected to vertical loading having circular void of diameter D beneath it. The soil model is rectangular in shape.

B = Width of footing

t = Thickness of footing

A= Area of void

Z = Depth of void from base of footing

S = Spacing between voids

θ = Angle of load inclination with vertical axis

D= Diameter of circular void

Y= Spacing between two footing

P = Applied load

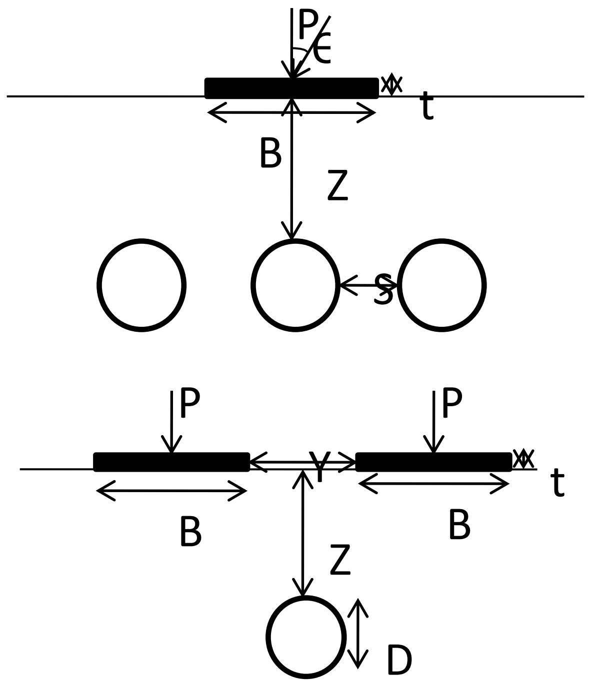


Figure 2.1: Problem Statement for Analysis

3. Computational Analysis with PLAXIS 2D

The effect of cavities on the performance strip footing behavior subjected to vertical/ inclined load had been studied using PLAXIS 2D software. Initially the analysis was carried out only for determining ultimate bearing capacity of natural soil model (20B×15B) with footing placed at the top of the soil model at its center for vertical and inclined load. There after the analysis were carried out for ultimate bearing capacity of soil model having multiple voids of different shapes as shown in Fig. 3.1 in it parallel to axis of footing with different load inclination. The various cases studied using PLAXIS 2D is presented in Table 1.

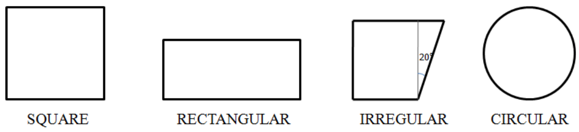


Figure 3.1 Geometry for Shapes of Cavities

Sr. No.	Cases	Shape	Eccentricity of Combination (X/B)	Combinations	Load Inclination	No of Footings	No. of Voids
1	Case I	Square, Rectangular, Irregular, Circular	0, 0.5, 1	All In One Row, All In One Column, Right Angle Placement, Skew Placement	0°	1	3
2	Case II	Square, Rectangular, Irregular	0, 0.5, 1	All In One Row, All In One Column, Right Angle Placement, Skew Placement	10°	1	3
3	Case III	Square, Rectangular, Irregular	0, 0.5, 1	All In One Row, All In One Column, Right Angle Placement, Skew Placement	20°	1	3

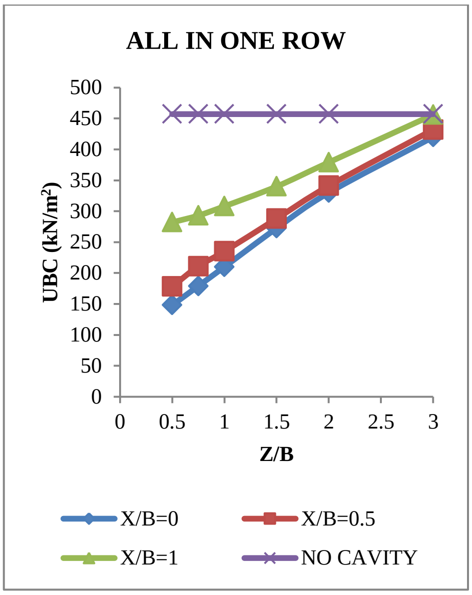
4	Case IV	Square, Rectangular, Irregular	0, 0.5, 1	All In One Row, All In One Column, Right Angle Placement, Skew Placement	30°	1	3
5	Case V	Circular	0	---	0°	2	1

Table 1 Cases for Complete Analysis Program

3.1 Case I: Analysis of Single Footing above Three Voids for Different Combinations and Shapes Subjected to Vertical Loading

3.1.1 Square Cavity:

Figure 3.1.1.1 (a-d) illustrates the results of computational analysis for single footing placed on three square cavities with varying depth *(Z/B)* for all in One Row combination and varying area *(A)* for all in One Column, right angle placement and Skew Placement for different eccentricities *(X/B)*. Here *(Z/B)* = 0.5, 0.75, 1, 1.5, 2, 3, *A* = 0.25, 1, 2.25, 4 m² and *(X/B)* = 0, 0.5, 1



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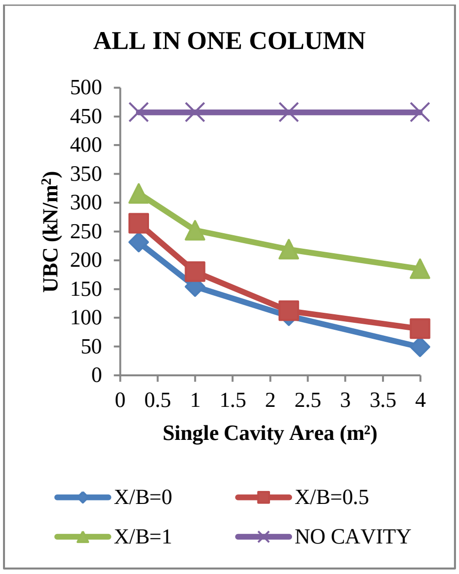

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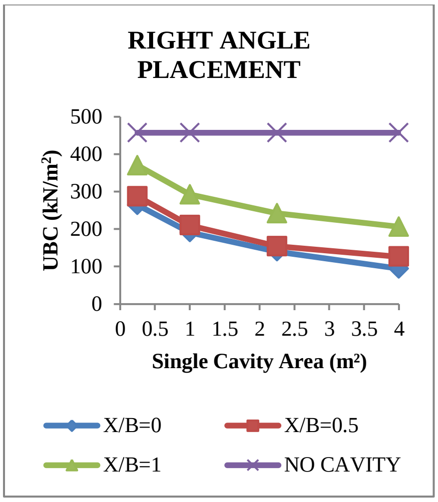

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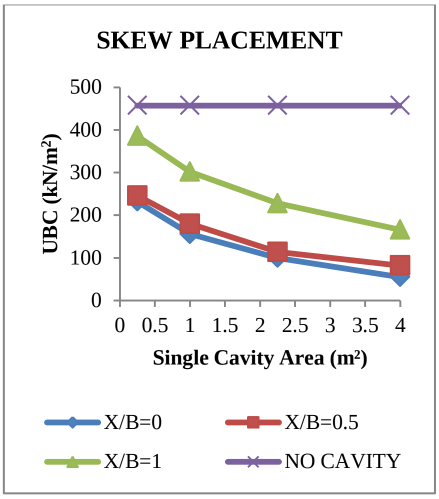

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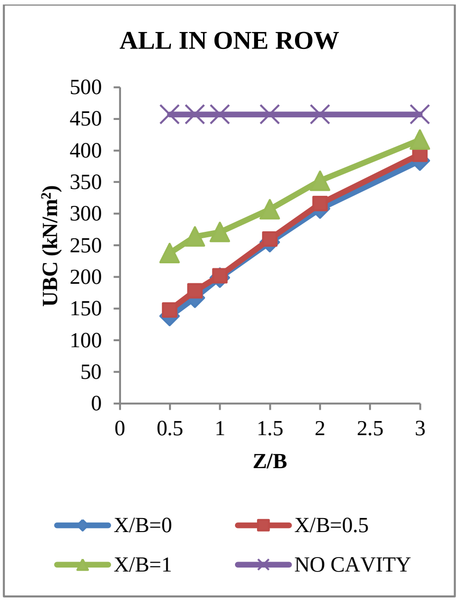
Figure 3.1.1.1 Variation of UBC for Different Eccentricities of Combination for Vertical Loading

3.1.2 Rectangular Cavity:

Figure 3.1.2.1 (a-d) illustrates the results of computational analysis for single footing placed on three rectangular cavities (aspect ratio 2:1) with varying depth *(Z/B)* for All In One Row combination and varying area *(A)* for All in One Column, right angle placement and Skew Placement for different eccentricities *(X/B)*. Here *(Z/B)* = 0.5, 0.75, 1, 1.5, 2, 3, *A* = 0.25, 1, 2.25, 4 m^2 and *(X/B)* = 0, 0.5, 1.



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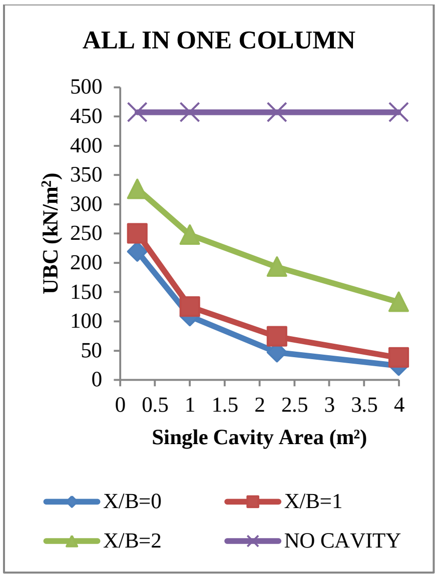

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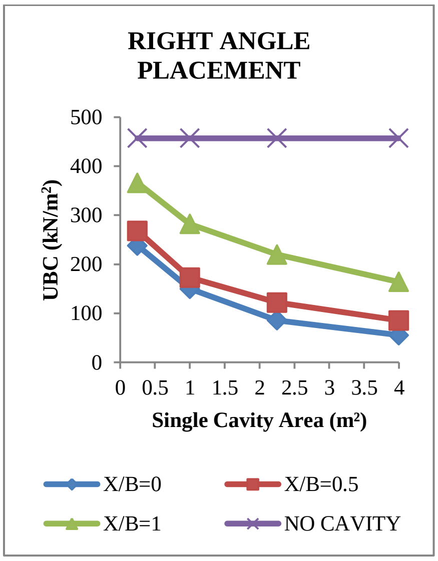

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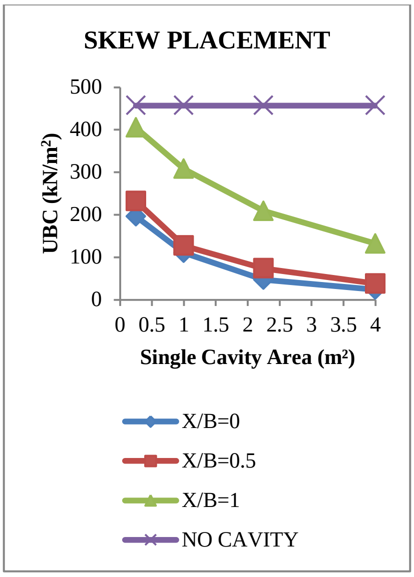

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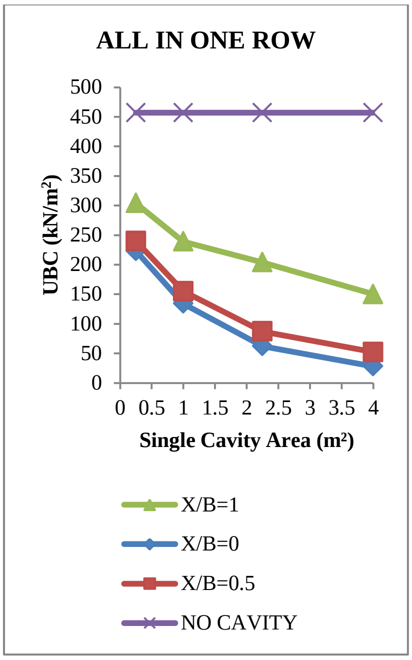
Figure 3.1.2.1 Variation of UBC for Different Eccentricities of Combination for Vertical Loading



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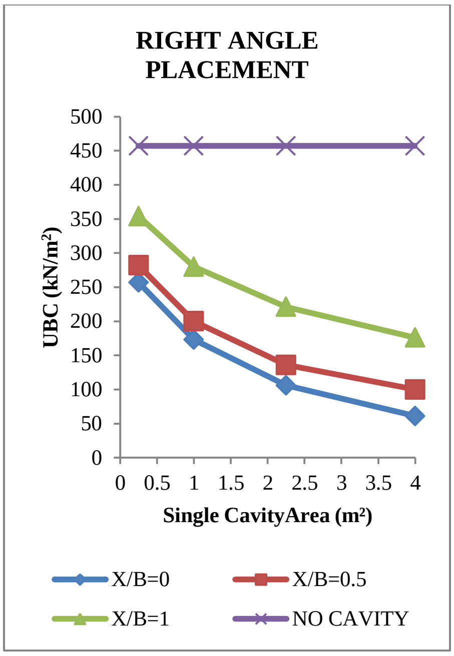
3.1.3 Irregular Cavity:

Figure 3.1.3.1 (a-d) illustrates the results of computational analysis for single footing placed on three irregular cavities with varying depth *(Z/B)* for all in One Row combination and varying area *(A)* for all in One Column, right angle placement and Skew Placement for different eccentricities *(X/B)*. Here *(Z/B)* = 0.5, 0.75, 1, 1.5, 2, 3, *A* = 0.25, 1, 2.25, 4 m² and *(X/B)* = 0, 0.5, 1.



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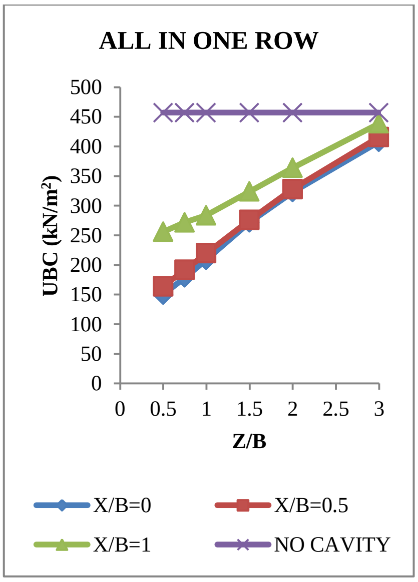

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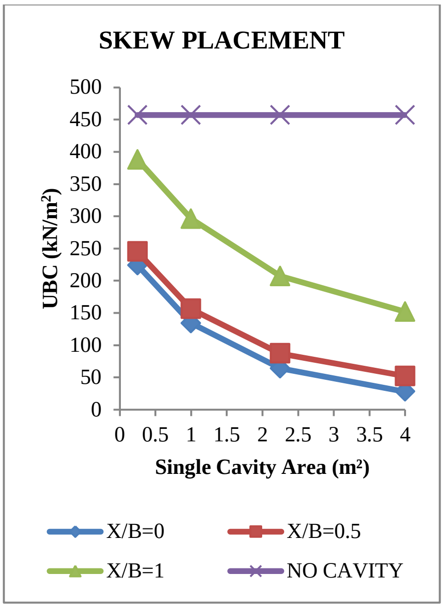

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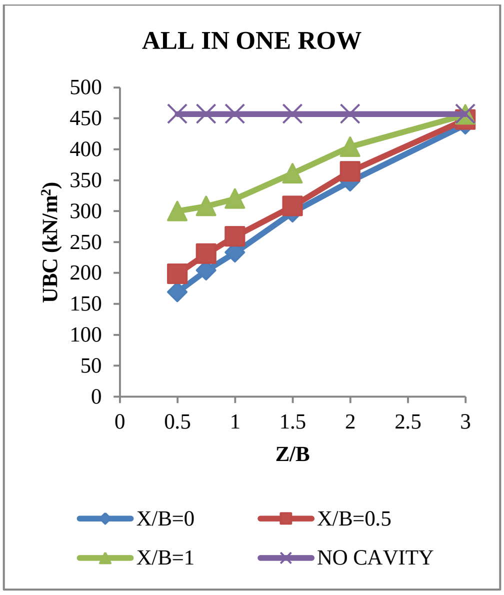
Figure 3.1.3.1 Variation of UBC for Different Eccentricities of Combination for Vertical Loading

3.1.4 Circular Cavity:

Figure 3.1.4.1 (a-d) illustrates the results of computational analysis for single footing placed on three circular cavities with varying depth *(Z/B)* for all in One Row combination and varying area *(A)* for all in One Column, right angle placement and Skew Placement for different eccentricities *(X/B)*. Here *(Z/B)* = 0.5, 0.75, 1, 1.5, 2, 3, *A*= 0.25, 1. 2.25, 4 m² and *(X/B)* = 0, 0.5, 1.



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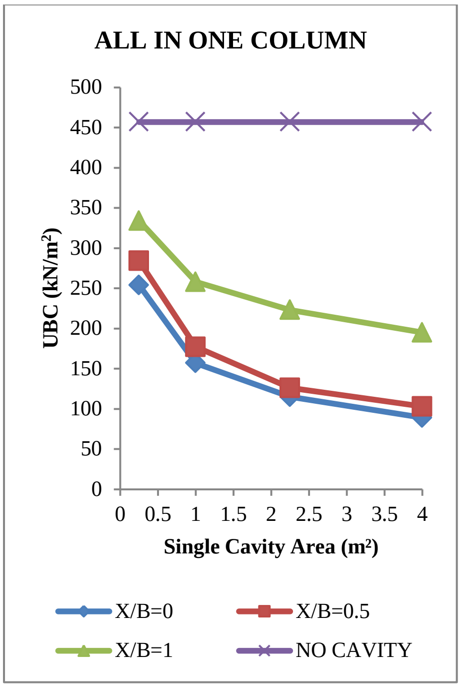

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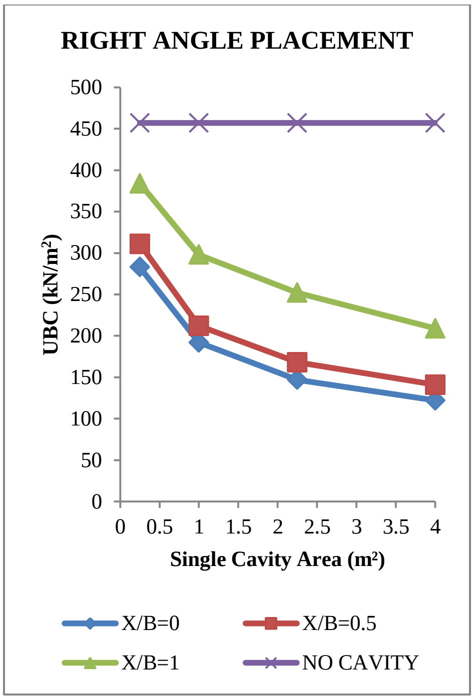

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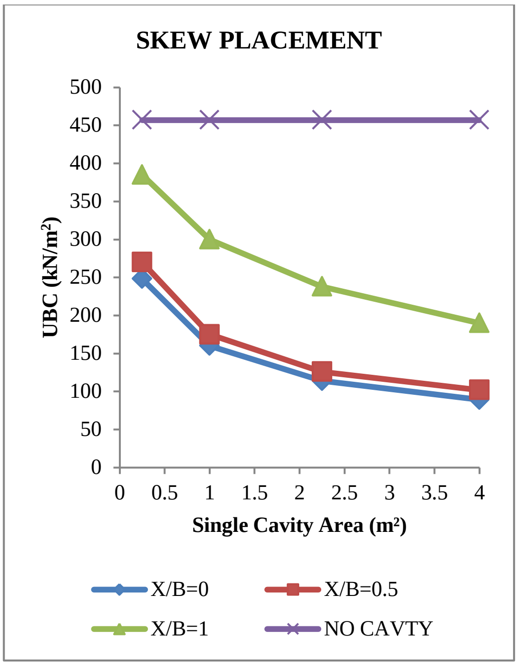

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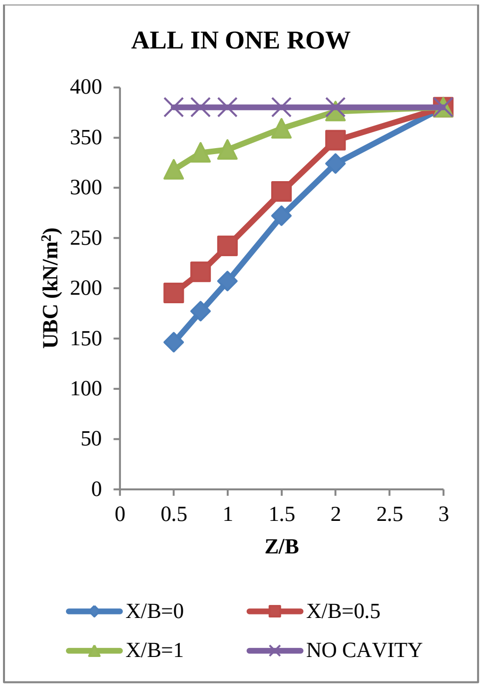
Figure 3.1.4.1 Variation of UBC for Different Eccentricities of Combination for Vertical Loading

4.1 Case II: Analysis of Single Footing above Three Voids for Different Combinations and Shapes Subjected to 10° Inclined Loading

4.1.1 Square Cavity:

Figure 4.1.1.1 (a-d) illustrates the results of computational analysis for single footing placed on three square cavities with varying depth *(Z/B)* for all in One Row combination and varying area *(A)* for all in One Column, right angle placement and Skew Placement for different eccentricities *(X/B).* Here *(Z/B)* = 0.5, 0.75, 1, 1.5, 2, 3, *A* = 0.25, 1, 2.25, 4 m^2 and *(X/B)* = 0, 0.5, 1



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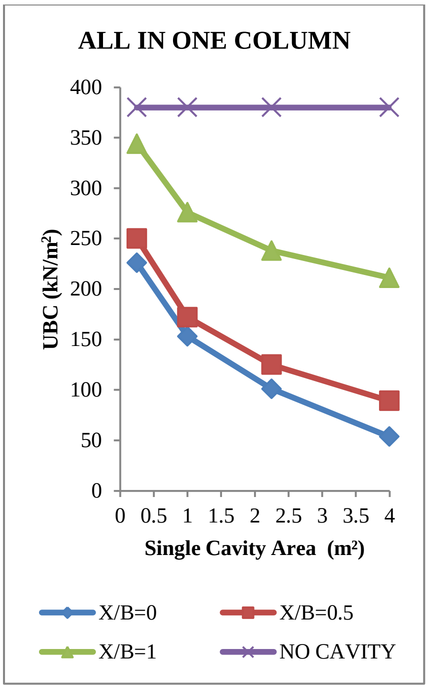

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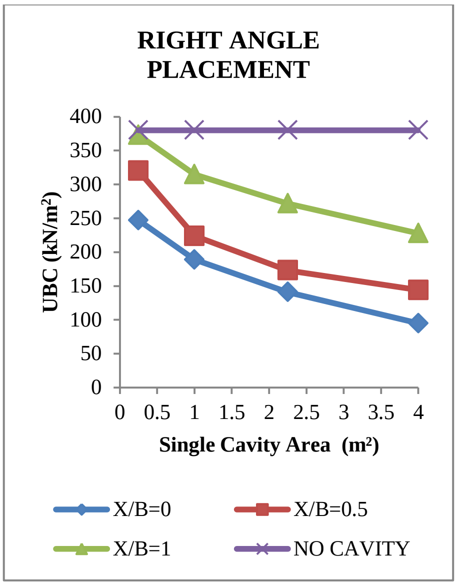

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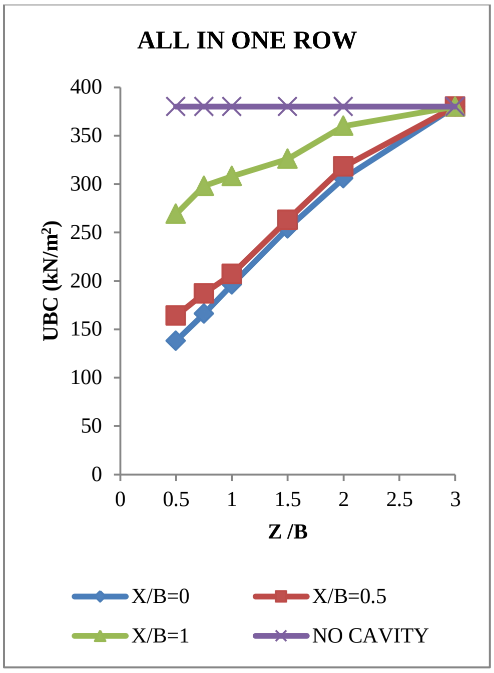

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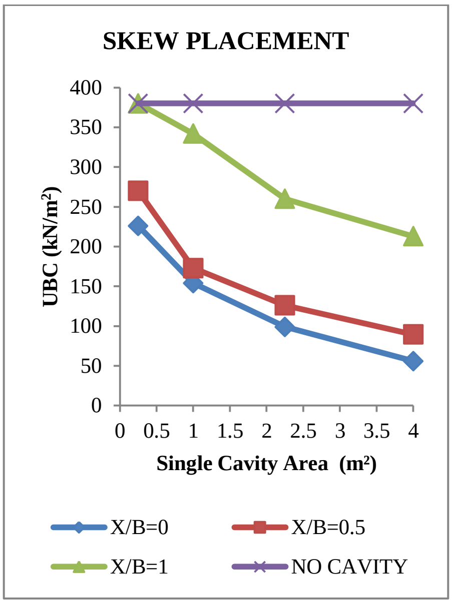

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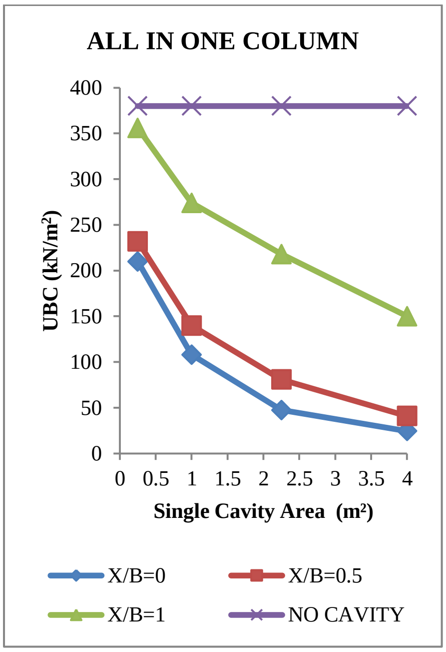

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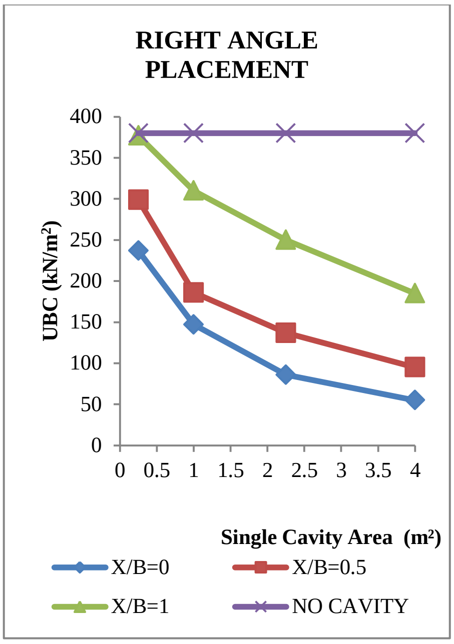
Figure 4.1.1.1 Variation of UBC for Different Eccentricities of Combination for Load Inclined at 10°

4.1.2 Rectangular Cavity:

Figure 4.1.2.1 (a-d) illustrates the results of computational analysis for single footing placed on three rectangular cavities (aspect ratio 2:1) with varying depth *(Z/B)* for All In One Row combination and varying area *(A)* for All In One Column, right angle placement and Skew Placement for different eccentricities *(X/B)* subjected to 10° inclined loading. Here *(Z/B)* = 0.5, 0.75, 1, 1.5, 2, 3, *A* = 0.25, 1, 2.25, 4 m² and *(X/B)* = 0, 0.5, 1



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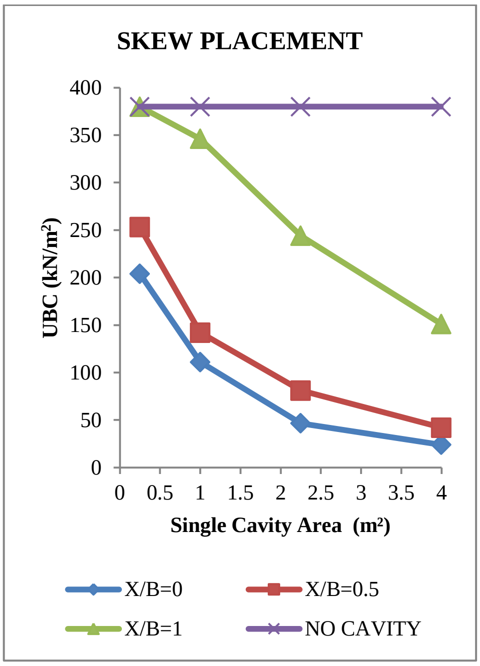

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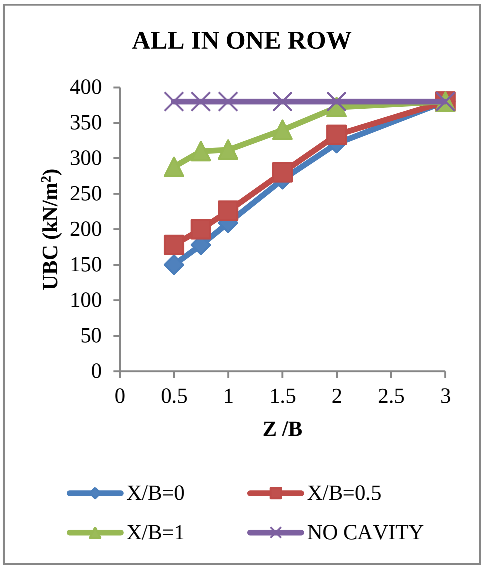
Figure 4.1.2.1 Variation of UBC for Different Eccentricities of Combination for Load Inclined at 10°

4.1.3 Irregular Shape:

Figure 4.1.3.1 (a-d) illustrates the results of computational analysis for single footing placed on three irregular shape cavities with varying depth *(Z/B)* for All In One Row combination and varying area *(A)* for All In One Column, right angle placement and Skew Placement for different eccentricities *(X/B)* subjected to 10° inclined loading. Here *(Z/B)* = 0.5, 0.75, 1, 1.5, 2, 3, *A* = 0.25, 1, 2.25, 4 m² and *(X/B)* = 0, 0.5, 1.



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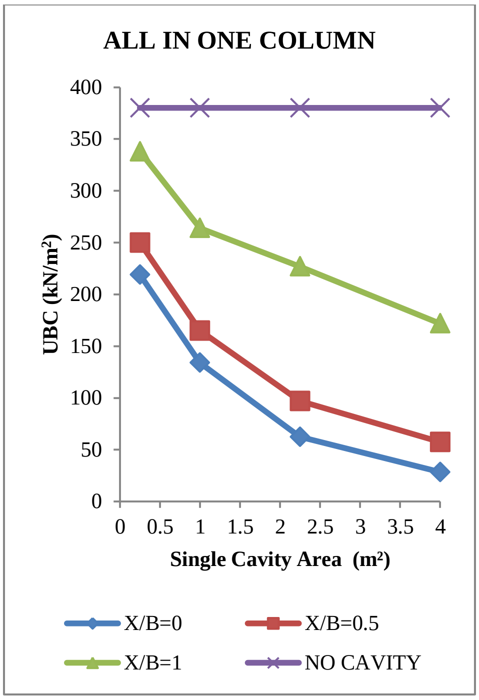

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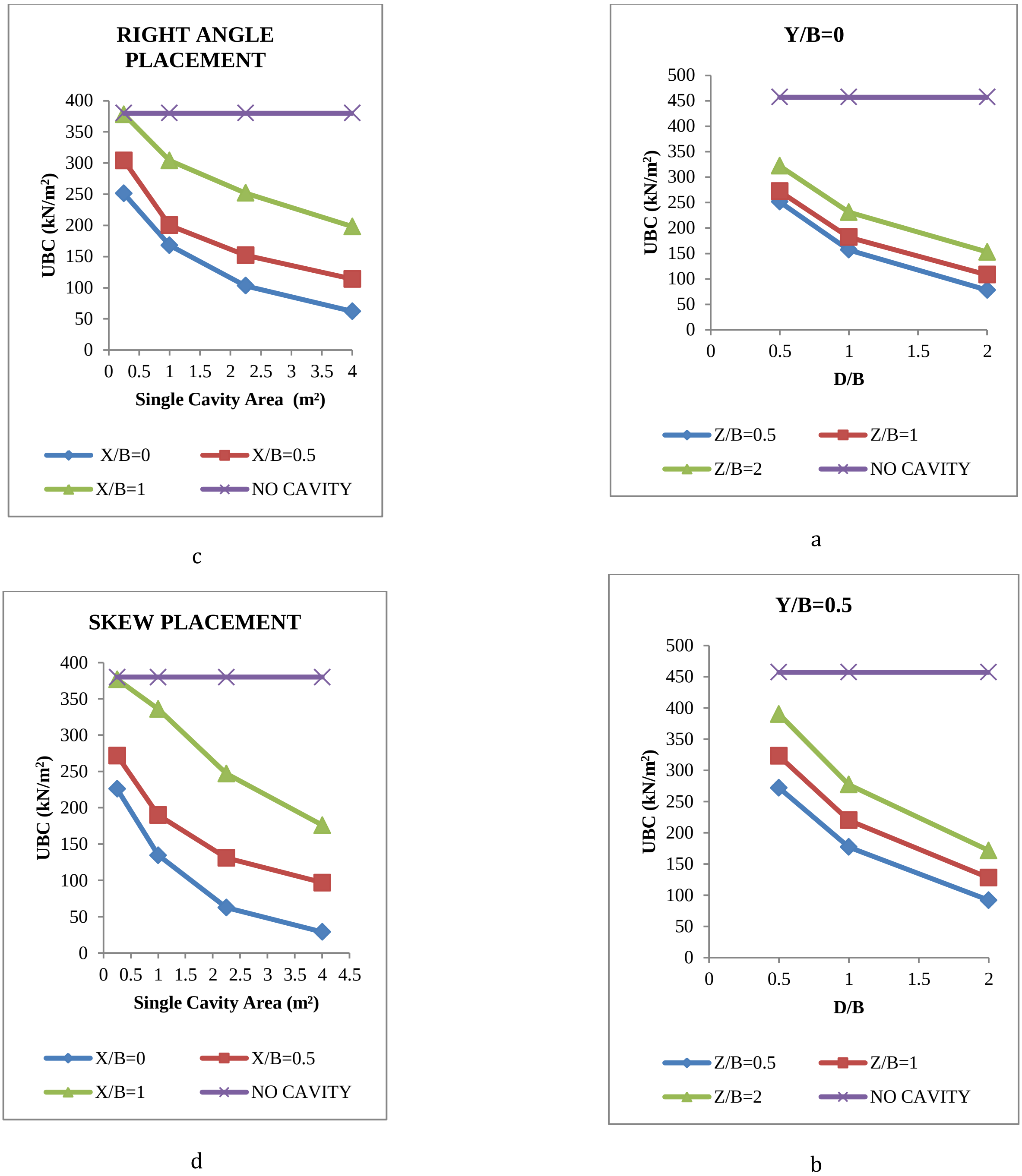
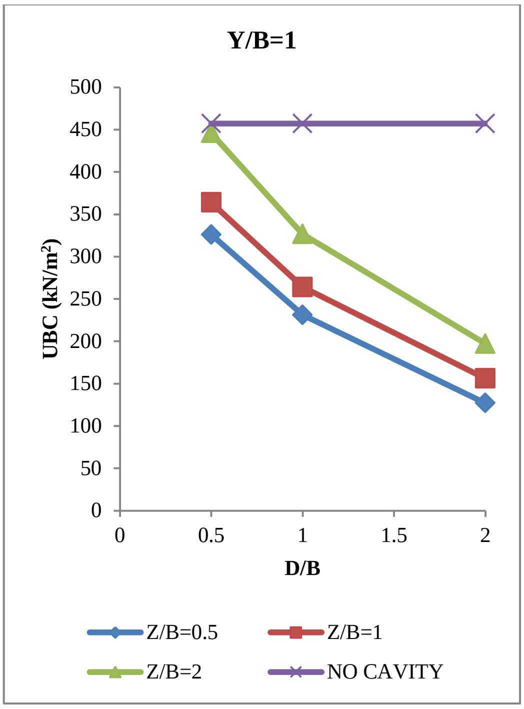


Figure 4.1.3.1 Variation of UBC for Different Eccentricities of Combination for Load Inclined at 10°

5.1 Case-III

Analysis of Two Footings above Single Circular Cavity Subjected to Vertical Loading

Figure 5.1.1 (a-d) illustrates the results of computational analysis for two footing placed on single circular cavity with varying depth *(Z/B)*, varying diameter *(D/B)* and varying spacing between footings *(Y/B)*. Here *(Z/B)* = 0.5, 1, 2, *D/B* = 0.5, 1, 2, and *(Y/B)* = 0, 0.5, 1, 2



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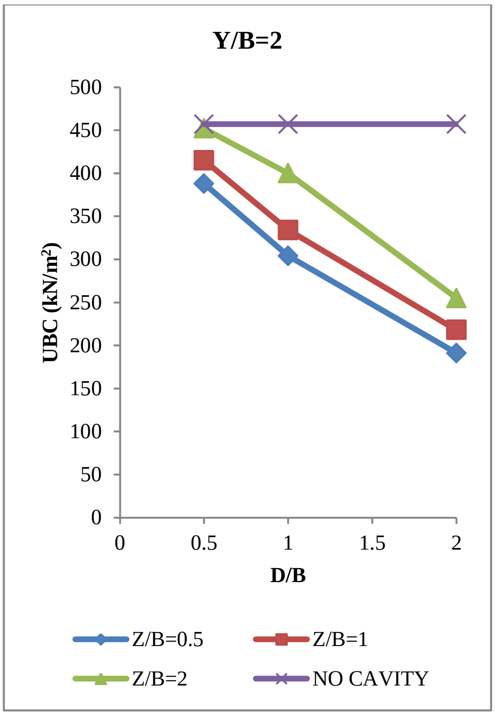

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Figure 5.1.1 Variation of UBC for Different Diameter and Crest Depth of Circular Void for Vertical Loading

6. CONCLUSIONS

i. Bearing Capacity Ratio (BCR) of shallow foundations in presence of underground cavities is less than in case of without cavities, depending on the geometry and configuration of cavities.

ii. Bearing Capacity Ratio (BCR) increases with increase in crest depth of cavities.

iii. Bearing Capacity Ratio (BCR) increases with increase in distance of the cavity from the center of footing.

iv. Bearing Capacity Ratio (BCR) decreases with increase in size of cavity.

v. Bearing Capacity Ratio (BCR) for circular cavity is more than that of other shapes such as rectangular cavity, irregular shaped cavity and square cavity.

vi. The inclination of load in presence of cavity on footing has negligible effect of on bearing capacity.

vii. Bearing Capacity Ratio (BCR) increases with increase in inclination of load on footing with vertical.

6.1 Two Footings above Single Circular Cavity:

i. Bearing Capacity Ratio (BCR) increases with increase in crest depth of circular cavity from bottom of footings.

ii. Bearing Capacity Ratio (BCR) increases with increase in spacing between two footings.

iii. Bearing Capacity Ratio (BCR) decreases with increase in diameter of circular cavity for constant crest depth and spacing between footings.

6.2 Future Scope:

The present knowledge of effect of cavities on performance of footing is limited. The present study may be extended further considering following aspects:

i. The effect of cavities on the performance of footing can be analyzed for multilayered soil.

ii. The effect of cavities on performance of footing can be analyzed for eccentric vertical and inclined loading.

iii. The effect of cavities on performance of footing can be analyzed for sand.

iv. The combinations studied for single footing can be studied for two footing.

v. Effect of dynamic forces can be also studies on footings above the cavities.

6.3 Applications:

Due to the population growth and in response to existing needs, the demand of tunnels for urban transportation has rapidly increased. These tunnels usually excavated close to the soil surface and their effects will develop to the ground level and can significantly affect the performance of shallow foundations located above these cavities. Results of prior researches in this field indicated that the interaction between shallow foundation and underground cavities has significant effects on the performance of shallow foundations. The knowledge acquired can help to select suitable position of underground structure such as tunnels, aqueducts, conduits etc. to minimize its effect on stability of existing foundations. Also the knowledge will be useful for design of foundation of soil bed with existing multiple cavities.

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