

Subdue of Severe Soil Collapsibility Potential Via Rigid Foundation System in Normal Structural Buildings

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ABSTRACT: Existence of collapsible soils has been reported in all of the world continents. In Egypt dealing with such soil becomes one of the major challenges facing geotechnical and structural engineers due to horizontal expansion in constructing new urbans heading to the desert where collapsible soil are abundant, the most foundation systems used in this region are isolated and strip footing connected with concrete tie beams. Therefore studying the behavior of isolated footing connected with tie beam and resting on partially saturated collapsible soil is very crucial.

The objectives of this study are to investigate the effect of different parameters on the behavior of isolated footing connected with tie beams by numerical analysis and to evaluate the relative significance of these investigated parameters. Parametric study was performed by Finite Element program PLAXIS 3-D utilizing the conventional Mohr-Coulomb model for soil behavior.

The parameters to be analysed in this stage of analysis are: tie beams dimension, spacing between columns, collapsible soil thickness, contact stress, use of sand cushion, location of water leakage, and changing foundation system to inverted T-section strip footing. The study shows that the most important soil parameters in the problem are the use of sand cushion as well as width of tie beams, inverted T-section strip footing is more convenient than isolated footing.

KEYWORDS: collapsible soils, rigid tie beam, PLAXIS3-D.

I. INTRODUCTION

Since late seventies, urban development plans have been widely extended to cover many desert areas in Egypt where new communities are being constructed. In these areas collapsible soil formations are abundant, it is always very confusing whether these soil are collapsible or not, and how much danger would be expected if soil is exposed to foundation loads and seeping water. The fundamental mechanism of collapsing soils has been early recognized and identified in a wide variety of soils and the phenomenon leads to serious engineering problems in many regions all over the world. This research aims to investigate the effect of different parameters on the behavior of foundation rigidity of tied isolated and inverted T-section strip footing, and to evaluate the relative significance of these investigated parameters. These parameters are tie beams dimensions, contact stress, use of compacted sand cushion, and location of water leakage.

II. MODEL DESCRIPTION

A hypothetical case of an isolated grid footing for a small building connected with tie beams resting on collapsible soil is obtained. The case is generally flat with subsoil consisted of collapsible silty sand and loose to medium dense sand. The case is numerically modelled in a Finite element program PLAXIS 3-D, the numerical analysis for this case study was performed using Mohr-coulomb model. Results of numerical modelling is presented in terms of bending moment, settlement, and differential settlement

Base model generation

The 3-D model considers the effect of different collapsible soil thickness (2, 3 and 4m) from 9 m thickness of soil; the dimensions of the model are 25m x 25m and the vertical dimension defined to be 9m. The model subsoil is divided into

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

- A. Soil S1 for collapsible soil with 10% degree of saturation
 - B. B-Soil S2 for collapsible soil with 25% degree of saturation
 - C. C-Soil S3 for collapsible soil with 50% degree of saturation
 - D. D-Soil S4 for collapsible soil with 60-100% degree of saturation
2. Deep sand layer which is not affected by wetting

Footing and tie beams simulation:

In the modelling of footing and tie beams, it was assumed as floor elastic material. This assumption was made to study the effect of change in tie beam width and tie beam thickness separately.

Different tie thicknesses and different tie width have been implemented in the finite element model to evaluate the effect of tie beam's stiffness on damping differential settlement resulting from differential saturation of collapsible soil. Density of footing is taken equal to 24 KN/m^3 , Poisson's ratio = 0.20 and young's modulus = $2\text{E}+07 \text{ KN/m}^2$.

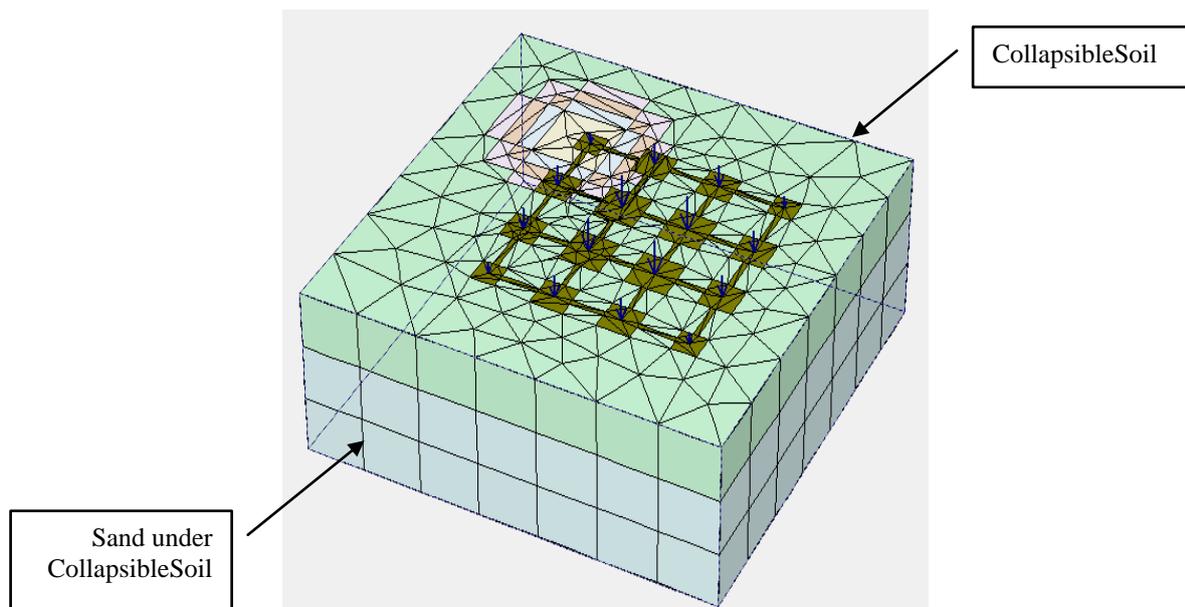


Figure 2: Generation of 3-D model

Calculation steps

After the procedure described in the previous section has been accomplished, the analysis procedure is ready to commence. The analysis of this 3-D model was done in three step-wise calculation phases as listed below:

The first phase (the initial phase), is automatically generated by the program to calculate stresses and settlement of the problem before inundation occur. In this phase foundation soil are defined as collapsible soil before wetting, footing and loads are also defined. In the second phase (phase 1) foundation soil have been removed and footing have been inactivated to separate between soil before wetting and soil after wetting, then in the third phase (phase 2) soil have been redefined with reduced stiffness as described in pervious sections. Footing, ties and loads have been activated in this phase, Phase 1 was considered to start from the initial phase and phase2 commenced from phase 1.

III. RESULTS AND ANALYSIS OF INCREASING FOOTING RIGIDITY

Effect of tie beam thickness

Figure 3, 4, and 5 shows the effect of tie thickness on the maximum total settlement, differential settlement, and bending moment generated for collapsible soil of thickness (d) equal to 3.0 m and tie width (B) equal to 30cm for different spacing between columns(S).It can be certainlycomprehended that the maximum settlement and differential settlement decreases as the tie thickness increases. This is could be endorsed to the increase in tie beam stiffness, it is

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

also envisaged that the maximum settlement decreases as the spacing between columns increases, in addition, the total settlement and differential settlement have a small decrease for column spacing from 5m to 4m and a considerable decrease for column spacing equal to 3m, this is attributed to the concentration of the problem in the area of wetting while the footings distant from this corner are not affected by the soil collapse. Moreover, figure 5 shows that the maximum moment increases as the tie thickness increases, this is apparently interrelated to the increase in tie stiffness. Secondly, the maximum moment decreases as the spacing between column decreases that is deemed rational due to the highly statically effect of span on the moment value.

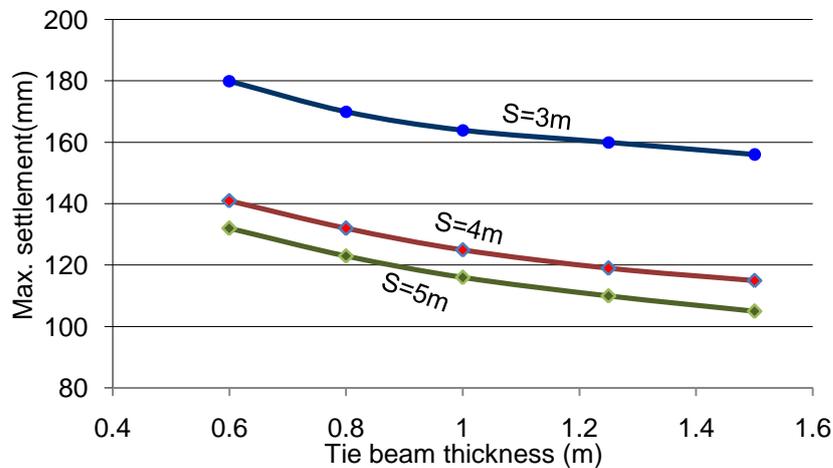


Figure 3: Effect of tie beam thickness on total settlement for different columns' spacing "S"

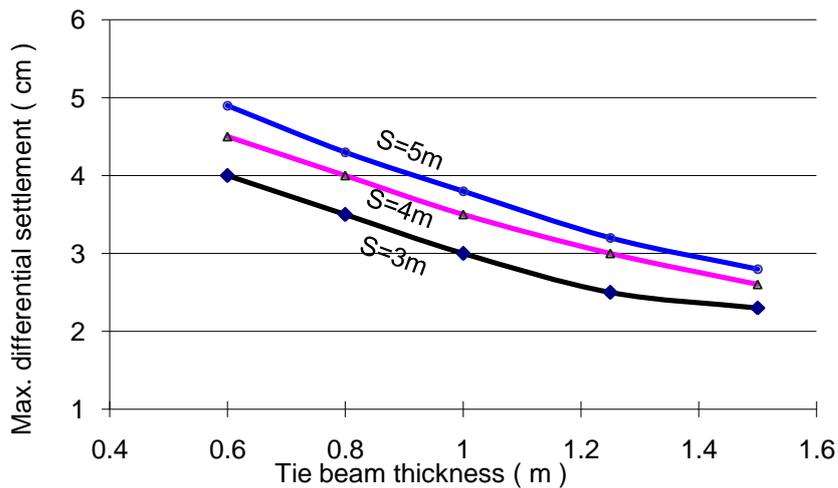


Figure 4: Effect of tie beam thickness on differential settlement for different columns' spacing "S"

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

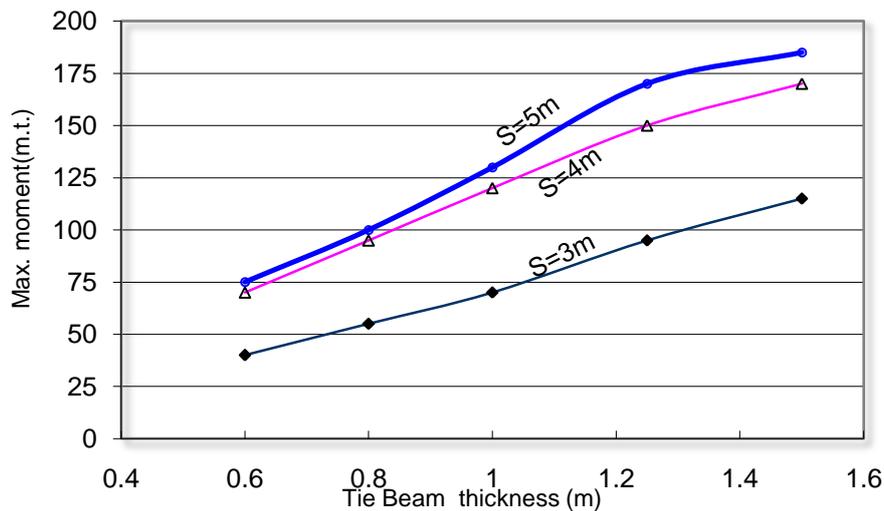


Figure 5: Effect of tie beam thickness on maximum moment for different columns' spacing "S"

Effect of tie beam width

Figure 6 shows that the effect of increasing tie beams width on the maximum settlement is the same as increasing tie beams thickness, From Figure 6, and 7 it can be seen that: the maximum settlement and differential settlement decreases as the tie width increase. This is could be related to the increase in tie stiffness, moreover, it can be perceived as well that the decrease in maximum settlement largely affected by tie beams as well as tie thickness, this is clearly seen in ties 30x100 and 40x80 however tie beam 30x100 have large inertia than tie beam 40x80, Figure 8 shows that the maximum moment decreases as the tie width increase

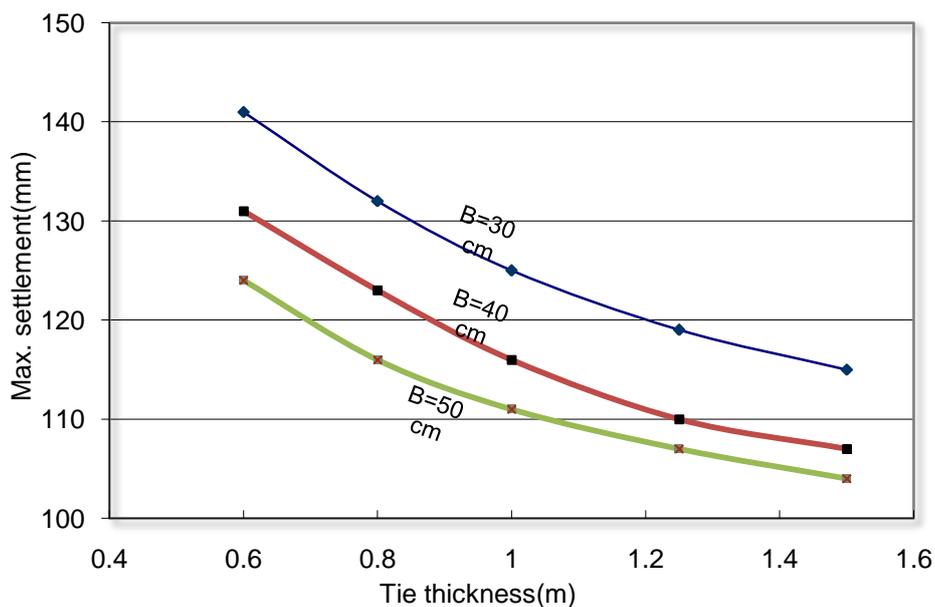


Figure 6: Effect of tie beam width on total settlement for different tie beams' thickness

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

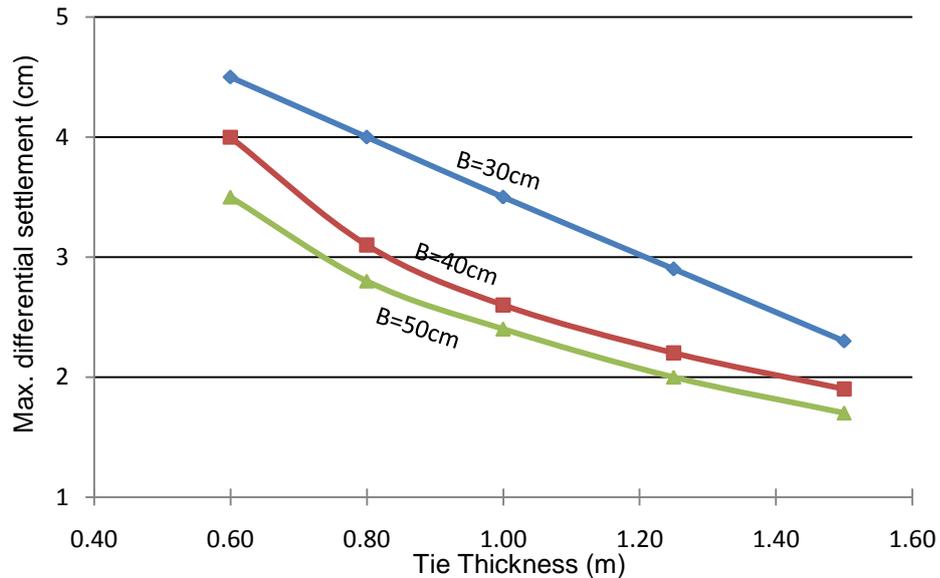


Figure 7: Effect of tie beam width on differential settlement for different tie beams thickness

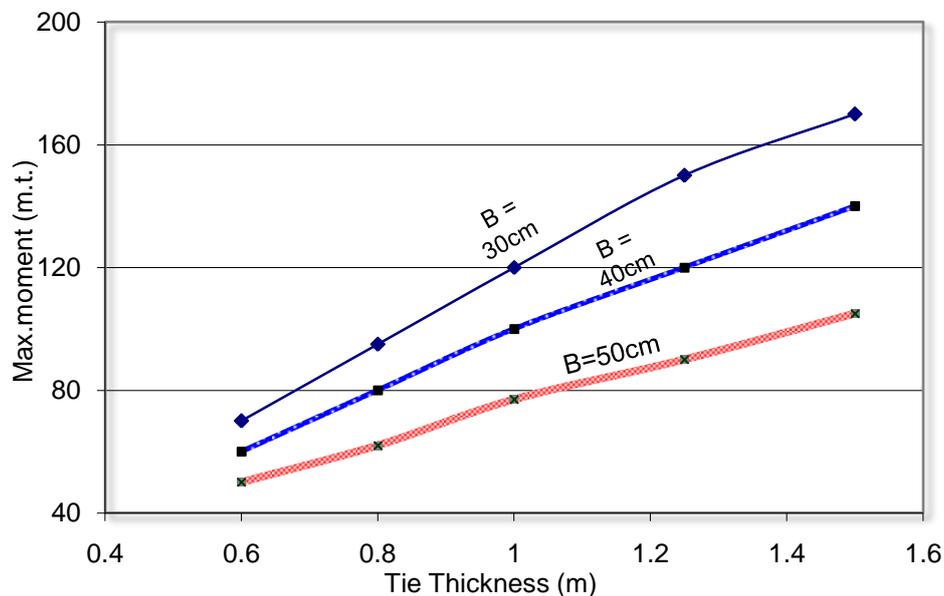


Figure 8: Effect of tie beam width on maximum moment for different tie beams thickness

IV. RESULTS AND ANALYSIS OF SOIL IMPROVEMENT

Effect of soil replacement using sand cushion

The effect of soil replacement on the behavior of footings rested on partial saturated collapsible soil layer was studied by using sand cushion compacted to yield a constrained modulus not less than 750 kg/cm² (75 MPa). These cushions

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

were studied at three thicknesses; h/H ratio equal to $1/6$, $1/3$, and $1/2$ (where h is the cushion thickness equal to 50, 100, and 150 cm, and H is the original layer thickness equal to 300 cm). All of these cases were run under different contact stresses; 8, 10, and 15 t/m^2 .

Figure 9, 10, and 11 show that; the use of sand cushion has drastic effect on decreasing the total settlement, differential settlement, and moment. For example, the total settlement at contact stress equal to 10 t/m^2 , has values of 100, 81, and 61 mm for h/H equal to $1/6$, $1/3$ and $1/2$; respectively. This could be explained as thicker cushion experience smaller settlement. It also shows that settlement resulting from using cushion 1 m ($h/H=1/3$) is smaller than increasing tie beam thickness by 90 cm (using tie beam 30 x 150) for the same contact stress.

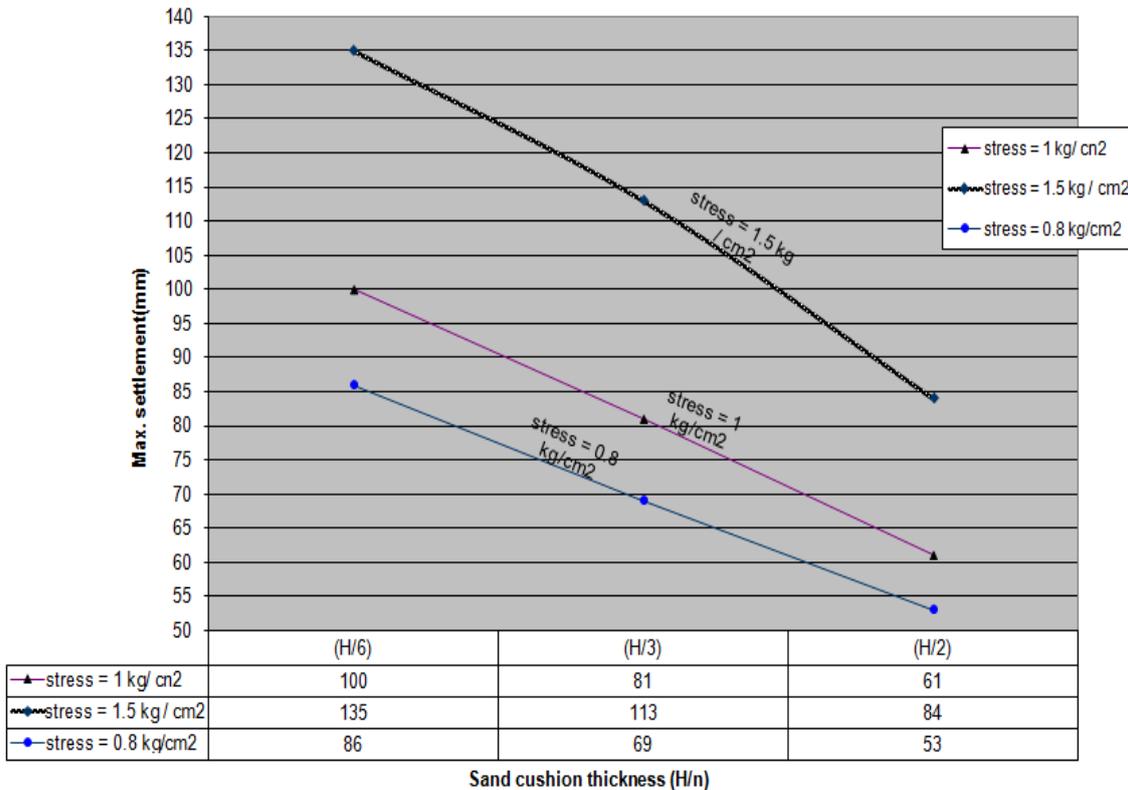


Figure 9: Effect of sand cushion thickness on maximum settlement for different contact stresses

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

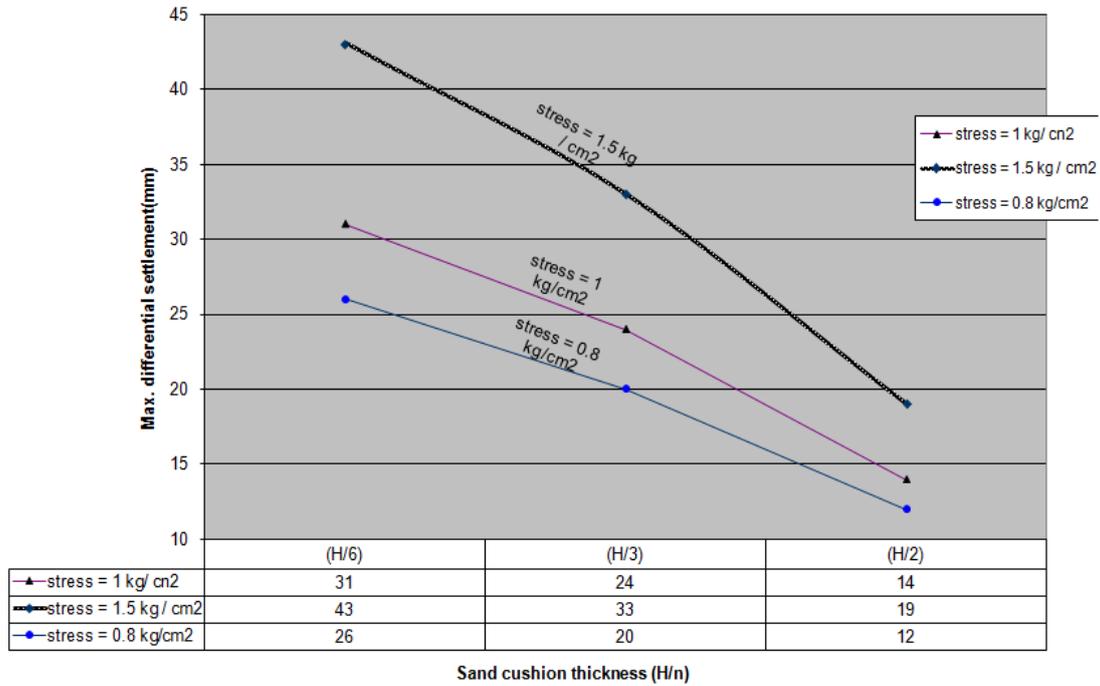


Figure 10: Effect of sand cushion thickness on maximum differential settlement for different contact stresses

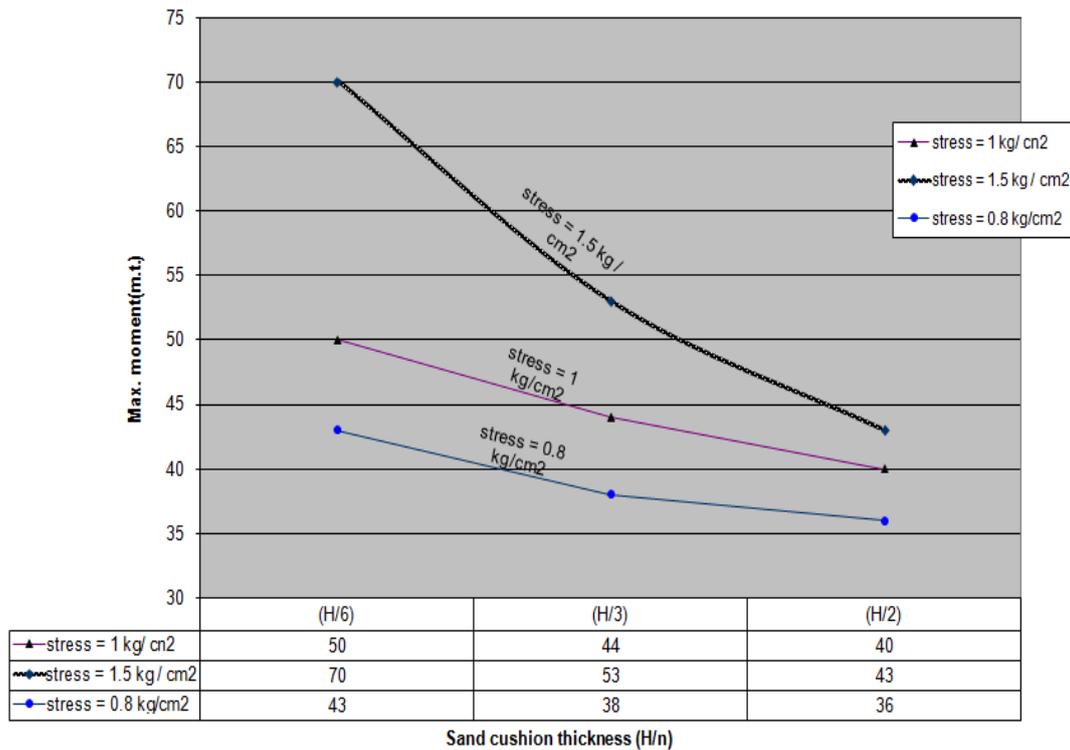


Figure 11: Effect of sand cushion thickness on maximum moment for different contact stresses

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

Using a combination of sand cushion and inverted T-section strip footing

The model was extended to provide a combination of inverted T-section strip footing having an inertia equivalent to tie beam 30x80 over a sand cushion; this model yields the best results on reducing the total settlement and differential settlement as shown in Charts 12 and 13. From these results it can be seen that the maximum total settlement reduced by 8 % when a sand cushion with thickness = $H/6$ was used, and the maximum differential settlement reduced by 10%. When a sand cushion with thickness = $H/3$ was used the maximum total settlement reduced by 20 %, and the maximum differential settlement reduced by 24%, when a sand cushion with thickness = $H/2$ was used the maximum total settlement reduced by 36%, and the maximum differential settlement reduced by 44%.

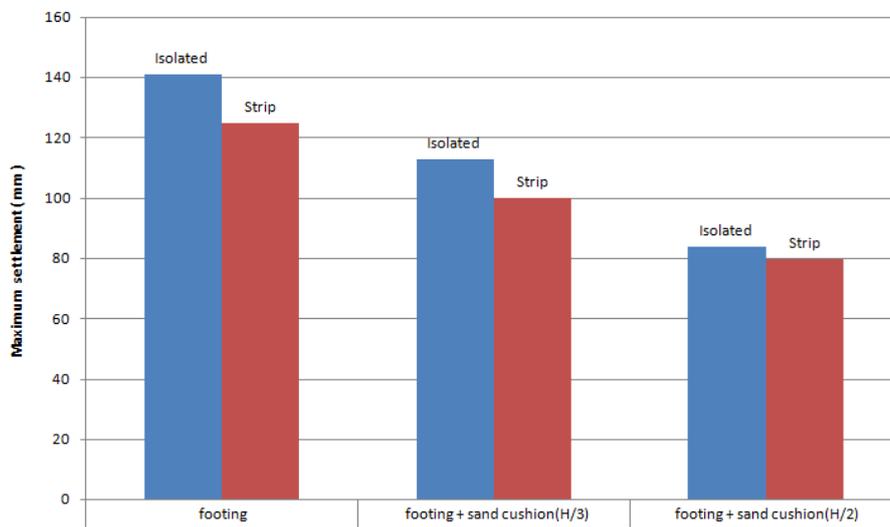


Figure 12: Effect of footing type with or without sand cushion (soil replacement of different thickness) on maximum settlement

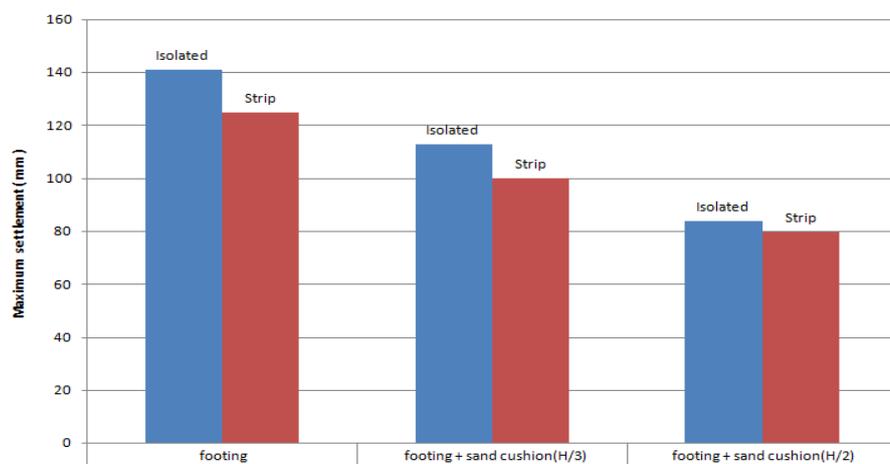


Figure 13: Effect of footing type with or without sand cushion (soil replacement of different thickness) on maximum differential settlement

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2015

V. CONCLUSIONS

The main conclusions that can be derived from the results obtained in this research are summarized as follow;

1. The use of sand cushion is the major parameter affecting the total settlement, differential settlement, and moment. Using sand cushion of thickness = $H/3$ reduces total settlement by 20%, differential settlement by 27%, and moment by 25%, and increasing sand cushion thickness to $H/2$ reduces total settlement by 41%, differential settlement by 58%, and moment by 40% (where H = thickness of collapsible layer).
2. Increasing tie beams thickness or width by 33% reduces total settlement by 7%, differential settlement by 11%. Increasing tie beams thickness or width by 66% reduces total settlement by 12%, differential settlement by 22%.
3. Using inverted T-section strip footing (with low contact stress) over a sand cushion gives the best results on reducing the total settlement and differential settlement.
4. The use of sand cushion with thickness equal to $H/3$ is more efficient than increasing tie beams dimension with 100%
5. Using inverted T-section strip footing reduces settlement by 12%, and differential settlement by 33% than using isolated footing
6. Reducing contact stress from 1.5kg/cm^2 to 1.0 kg/cm^2 reduces settlement by 35% , differential settlement by 29%, and moment by 29%
7. Using sand cushion with great thickness reduces the effect of the other parameters

Recommendations for Future Study

The following are some of research points that have not been studied in this research and worth conducting more research to enhance the geotechnical practice:

1. Studying the effect of saturation distribution in the vertical direction.
2. Comparison study between results obtained at site of collapsibility potential and results obtained by finite element.
3. Using other solution for soil collapse such as chemical stabilization to have a less cost more efficiency.

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