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Parametric Study of Behavior of Sub-Soil of Chitwan District

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Abstract

The “Parametric Study of Behavior of Subsoil of Chitwan District” investigates the geotechnical characteristics of two locations, Mangalpur and Ratnanagar having clayey and sandy soil respectively. This study explores the influence of varying soil parameters, specifically cohesion, water table depth, internal angle of friction and Poisson ratio, on the behavior of foundations in these regions. The investigated data is taken for the analysis which is considered as secondary data. The findings reveal substantial disparities in soil parameters between two location, leading to notable differences in foundation performance. Additionally, the study highlights the significance of foundation width as a critical factor in ensuring stability and minimizing settlement under varying subsoil conditions. A numerical model is developed using PLAXIS 2D. Finite element analysis is carried out using Mohr-coulomb failure criteria to represent two-dimensional soil model. Foundation is modelled and load of 2250 kN/m2 is applied till the soil model fails. Results were presented in charts to visually compare the different parameters between Mangalpur and Ratnanagar using PLAXIS. In 2D finite element analyses, the footing for various widths was modeled and the deformation at cross-section of -1 m depth is discussed. Greater subsoil strength in clay soil is indicated by a higher cohesion value. A lower Poisson’s ratio provides suitable strength for both soils, and the results showed that changing the depth of the water table for both soils suggested that a greater depth enhances subsoil strength in the case of clay, while a smaller depth is advantageous in the case of sand.

Keywords: *Effective stress, foundation width, finite element method, plaxis 2D, soil parameters, total displacement, water table depth.*

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Introduction

Soil is a complex mix of organic matter, minerals, water, air, and living organisms, playing a critical role in the stability and foundation of buildings and structures. Understanding soil behavior and its interaction with structural foundations is essential for the successful design and construction of civil engineering projects like buildings and bridges. This comparative study aims to investigate and analyze the behavior of subsoil in two distinct locations: Mangalpur and Ratnanagar, with a focus on varying soil parameters and foundation widths.

Chitwan district, particularly in Mangalpur and Ratnanagar, is experiencing a rise in construction due to an influx of people from hilly regions. This study examines how soil properties and foundation widths affect subsurface performance to ensure safe building foundations, which is crucial for both residential and commercial construction. Understanding subsurface behavior in Mangalpur and Ratnanagar is crucial for designing stable foundations. The study examines how factors like foundation width, groundwater table, and soil properties affect soil stability and load-bearing capacity, guiding engineers in ensuring safe and stable structures.

The reviewed literature highlights key factors influencing soil bearing capacity, crucial fofoundation design. (Dixit & Patil, February 2010), identified cohesion, soil unit weight, foundation depth, and internal friction angle as critical parameters, with circular and square footings having higher capacities under local shear failure. (Waheed, October 2018), found the hardening soil model in Plaxis-3D most accurate for simulations. (Majedi, Celik, & Akhbulut, September 2018), showed that increasing cohesion, friction angle, and foundation width enhances bearing capacity. (Ravichandra, Mahmoudabadi, & Shrestha, October 2017), used Monte Carlo simulations to better predict bearing capacity in unsaturated soils affected by rainfall and water table variations. (Varsha, DR.Jayamohan, & Anjel, February 2020), observed that deeper foundations and vertical loads reduce lateral deformation, with micropiles improving performance. (Vilas, June 2015), confirmed Plaxis's accuracy, noting that a higher D/B ratio increases capacity and reduces settlement. (Gabar, December 2017), and (Orininovaa & Nguyenb, 2015), stressed the need for precise geotechnical data to optimize foundation design and avoid overdesign. These studies underscore the importance of accurate soil parameters and advanced modeling techniques.

The central problem is the lack of comprehensive understanding of how variations in soil parameters and foundation widths affect subsoil behavior in Mangalpur and Ratnanagar. This study aims to fill this gap by analyzing load distribution, stress propagation, and overall foundation performance, contributing to safer and more efficient construction practices in these regions.

Plaxis Modeling

The present paper deals with studying the behavior of Sub-soil with variation of soil parameters, specifically soil cohesion, internal angle of friction, Poisson ratio and water table depth. PLAXIS-2D is finite element software which works on the basic principle of discretization of whole geometry into large number of small sized elements. Each element is solved separately and the results are superimposed at nodes of neighboring elements to obtain the global behavior of whole model. The software allows for automatic generation of 2D and 3D finite element meshes, enabling quick creation of accurate 3D models based on material properties.

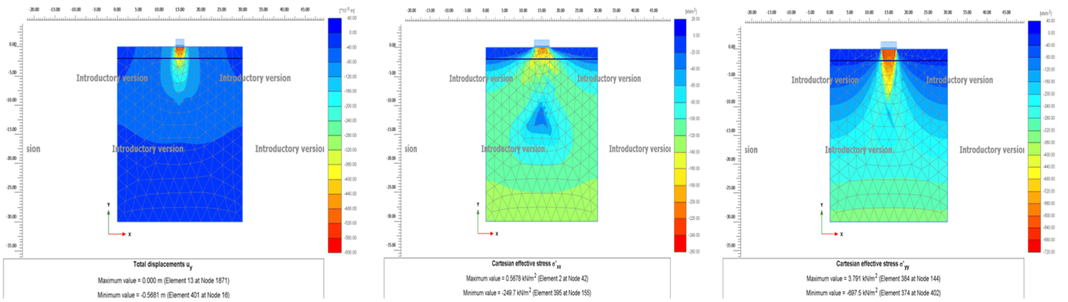

Figure 1 Geometry of footing model by Plaxis and the distribution of vertical displacement under load in the case study

Methodology

Study area

This study mainly focuses on understanding the subsoil behavior of chitwan district. Chitwan district is one of the 77 districts of Nepal which takes up the southwestern corner of Bagmati Province. The areas of our study are two locations of chitwan district which are about 30km apart from each other. The locations are Mangalpur and Ratnanagar. The study area of our project is shown in location map given below:

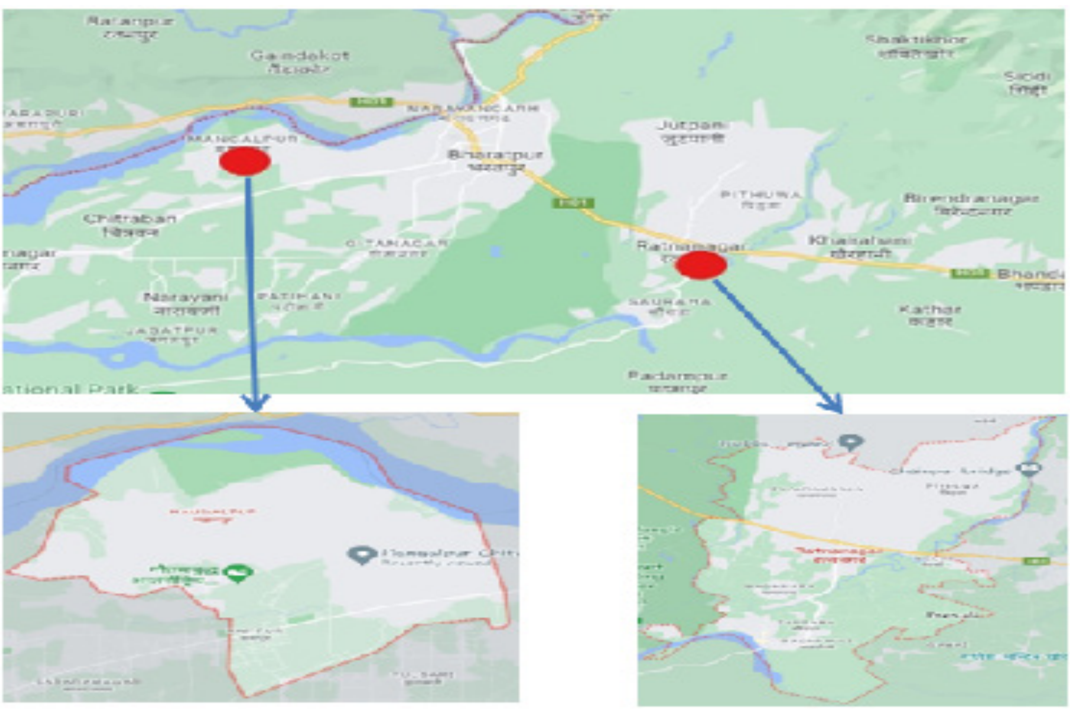

Figure 2 Location of Proposed Site

Data Collection

For our study the real field secondary data was collected from authorized data center for soil from Mangalpur and Ratnanagar site (i.e. From National Lab and Engineering Solution PVT. LTD. located at Bharatpur, Chitwan). The project data composed of investigation plan, geological reports, water table depth, and field borehole logs recorded during in-situ testing, laboratory testing programs issued by geotechnical engineers, results of laboratory tests and works. The load applied on the subsoil was calculated for a four story building which is shown in APPENDIX C.

Parametric Study

In parametric study a rectangular shape of foundation is considered. The parameters considered in this study can be summarized in Table 3.1, where the effect of these parameters on the behavior of raft foundation subjected to a uniform pressure was studied. A constant value is selected for each parameter when investigating the effect of other parameters.

Table 1 Parameters considered in this study

Parameters	Range of Values	
	For Mangalpur (Clay)	**For Ratnanagar (Sand)**
Foundation Width	2m, 4m*,6m	2m, 4m*,6m
Poisson ratio	0.25. 0.30*,0.35	0.25. 0.30*,0.36
Soil Cohesion (kPa)	17.38, 16.5*, 15.62	0
Internal Angle of Friction	35.73, 36.71*, 37.70	28.22, 34.97*, 35.54
Water Table	1 m and 2 m* below G.L	1 m and 2 m* below G.L
Surcharge Load (kN/m2)	2250*	2250*
Modulus of Elasticity of soil (kPa)	15015*	15015*

* Constant value of this parameter when study other parameters.

Numerical Modeling

In our study the soil data obtained from secondary sources for both soil was molded by using PLAXIS 2D software to understand how soils behave under various conditions and loads. And the sub-soil was simulated for each case of varying soil parameters and foundation width. The following procedure was followed during numerical modeling in each case of parameter variation:

a. The geometry of the model, boundary conditions and any other relevant geometric details was defined.

b. Materials properties such as soil type, unit weight, cohesion, internal angle of friction and Poisson's ratio was defined.

c. Head of Ground water level was also defined.

d. For loading condition, uniformly distributed vertical load on the foundation i.e. 2250KN/m/m was applied for each conditions.

e. Medium mesh was generated for the element distributions.

f. Then load was activated at staged condition to run model.

g. At last, following outputs were obtained from Plaxis modeling for each case of variation of foundation width, soil parameters and ground water level:

i. Total displacement along Y-axis.

ii. Cartesian Effective stress along X-axis

iii. Cartesian Effective stress along Y-axis.

Result and discussion

This chapter presents a numerical simulation of footing using PLAXIS software, examining how variations in soil parameters and foundation width affect subsoil performance. The soil parameters i.e. cohesion, internal angle of friction, Poisson's ratio, water table and foundation width were varied for soil of each locations. The obtained results were compared for each variation of parameters of soil of each location. Here, the results obtained from varying width of footing and soil parameters are discussed and interpreted.

Parametric Study of Behavior of Subsoil

Here, a symmetrical plain strain model was simulated considering 15-noded triangular elements with desired width and depth. The load on the foundation was considered as 2250 kN/m/m. The value of unit weight for clay was taken 16kN/m2 and 18kN/m2 for unsaturated and saturated conditions respectively. The value of unit weight for sand was taken 18kN/m2 and 20kN/m2 for unsaturated and saturated conditions respectively. The analysis considered variation of soil parameters and foundation width for each soil and the results obtained were discussed within different values of each soil.

Variation of Foundation Width

Here, Influence of variation of subsoil were analyzed with the variation of foundation width i.e. 2m, 4m, 6m respectively for both Mangalpur and Ratnanagar soil keeping other properties of subsoil constant the obtained results were discussed and interpreted.

Table 2 Data obtained while varying Foundation width

Location	Width of Foundation	Max Displacement (Y)	Min Displacement (Y)	Max Cartesian Effective Stress (X)	Min Cartesian Effective Stress (X)	Max Cartesian Effective Stress (Y)	Min Cartesian Effective Stress (Y)
Mangalpur	2 m	0.000 m	-0.568 m	-11.82 kN/m²	-273.9 kN/m²	5.04 kN/m²	-1022 kN/m²
	4 m	0.000 m	-0.434 m	0.57 kN/m²	-249.7 kN/m²	3.79 kN/m²	-697.5 kN/m²
	6 m	0.000 m	-0.204 m	3.77 kN/m²	-230.7 kN/m²	2.65 kN/m²	-316.8 kN/m²
Ratnanagar	2 m	0.000 m	-0.043 m	5.25 kN/m²	-137.7 kN/m²	1.76 kN/m²	-322.6 kN/m²
	4 m	0.000 m	-0.063 m	4.57 kN/m²	-141.4 kN/m²	2.47 kN/m²	-331.1 kN/m²
	6 m	0.000 m	-0.109 m	7.06 kN/m²	-147.7 kN/m²	2.25 kN/m²	-345.9 kN/m²

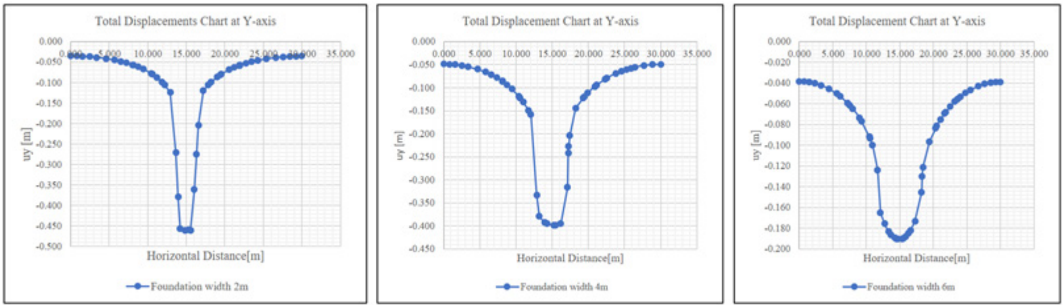

Figure 3 Total Displacement chart for varying Foundation width of Mangalpur

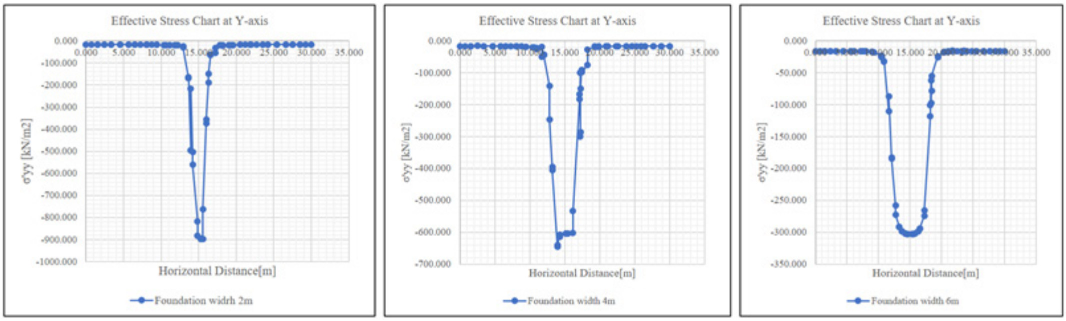

Figure 4 Effective Stress Chart at Y-axis for varying Foundation width of Mangalpur

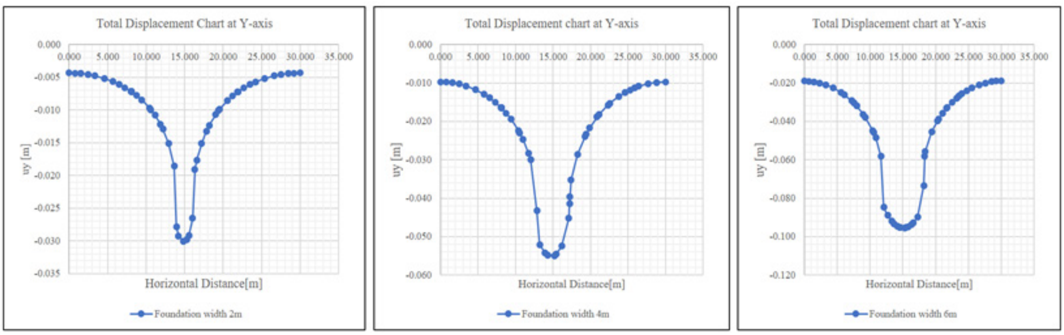

Figure 5 Total Displacement chart for varying Foundation width of Ratnanagar

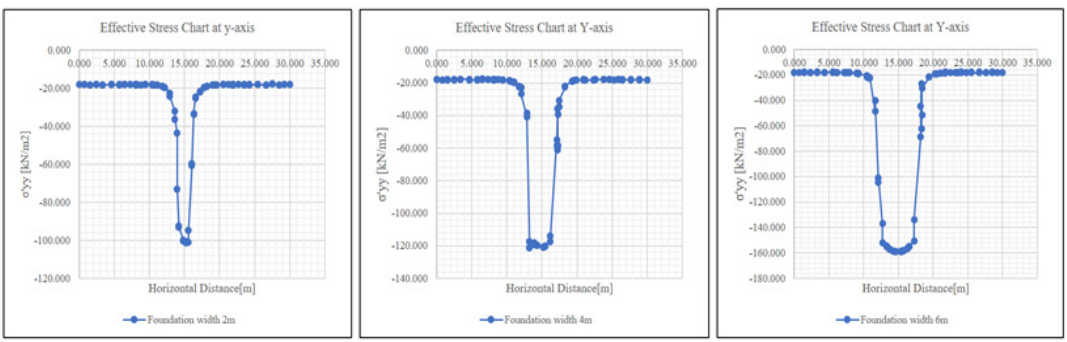

Figure 6 Effective Stress Chart at Y-axis for varying Foundation width of Ratnanagar

Variation of Soil Parameters

Here, the results obtained from variation of soil parameters i.e. cohesion, internal angle of friction and Poisson's Ratio keeping Modulus of elasticity as constant was discussed and interpreted as given below Table 3, 4 & 5.

Variation of Soil Cohesion

Here, Influence of variation of subsoil were analyzed with the variation of soil cohesion i.e. 15.62 kN/m² and 17.38 kN/m² for Mangalpur soil and 0 kN/m² for Ratnanagar soil keeping other properties of subsoil constant the obtained results were discussed and interpreted.

Table 3 Data obtained while varying Soil cohesion

Location	Cohesion	Max Displacement (Y)	Min Displacement (Y)	Max Cartesian Effective Stress (X)	Min Cartesian Effective Stress (X)	Max Cartesian Effective Stress (Y)	Min Cartesian Effective Stress (Y)
Mangalpur	15.62 kN/m²	0.000 m	-0.6043 m	-0.3414 kN/m²	-334.1 kN/m²	4.870 kN/m²	-847.8 kN/m²
	17.38 kN/m²	0.000 m	-0.5321 m	0.0669 kN/m²	-352.5 kN/m²	4.778 kN/m²	-813.2 kN/m²
Ratnanagar	0 kN/m²	0.000 m	-0.06280 m	4.569 kN/m²	-141.4 kN/m²	2.465 kN/m²	-331.1 kN/m²

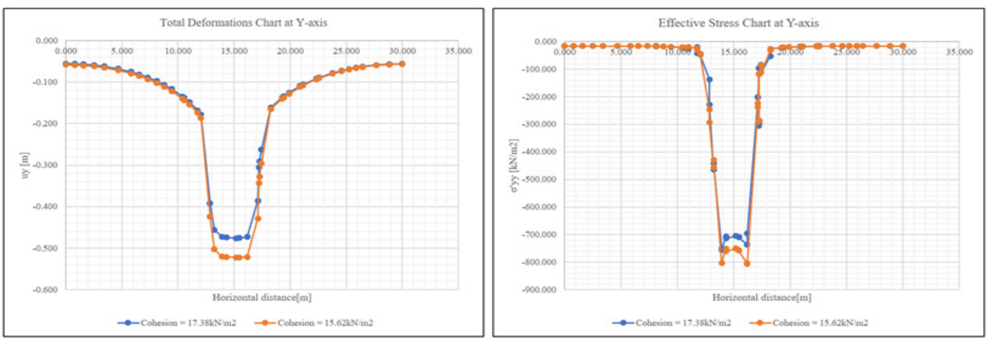

Figure 7 Chart for varying Soil cohesion of Mangalpur

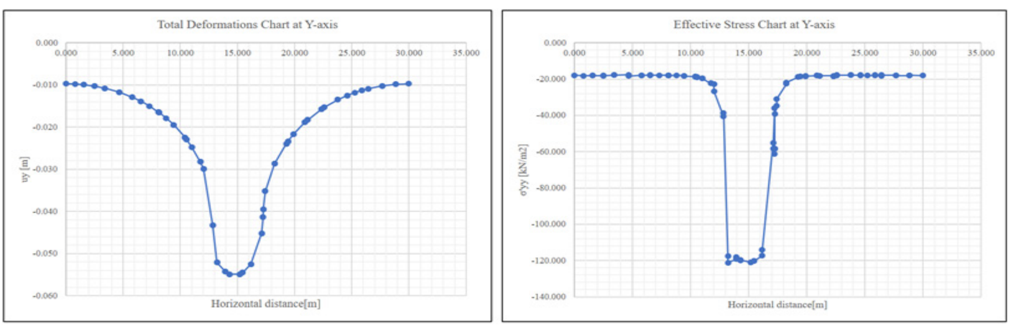

Figure 8 Chart for varying Soil cohesion of Ratnanagar

Variation of internal angle of friction

Here, Influence of variation of subsoil were analyzed with the variation of internal angle of friction i.e. 35.73° and 37.69° for Mangalpur soil and 28.22°, 34.97° & 35.54° for Ratnanagar soil keeping other properties of subsoil constant the obtained results were discussed and interpreted.

Table 4 Data obtained while varying internal angle of friction

Location	Internal Angle of Friction	Max Displacement (Y)	Min Displacement (Y)	Max Cartesian Effective Stress (X)	Min Cartesian Effective Stress (X)	Max Cartesian Effective Stress (Y)	Min Cartesian Effective Stress (Y)
Mangalpur	35.73°	0.000 m	-0.5179 m	1.782 kN/m²	-330.8 kN/m²	5.768 kN/m²	-775.6 kN/m²
	37.69°	0.000 m	-0.9193 m	-7.365 kN/m²	-343.5 kN/m²	5.315 kN/m²	-1172 kN/m²
Ratnanagar	28.22°	0.000 m	-0.02802 m	3.405 kN/m²	-169.8 kN/m²	1.579 kN/m²	-323.5 kN/m²
	34.97°	0.000 m	-0.06280 m	4.569 kN/m²	-141.4 kN/m²	2.465 kN/m²	-331.1 kN/m²
	35.54°	0.000 m	-0.06442 m	4.340 kN/m²	-139.1 kN/m²	1.980 kN/m²	-331.9 kN/m²

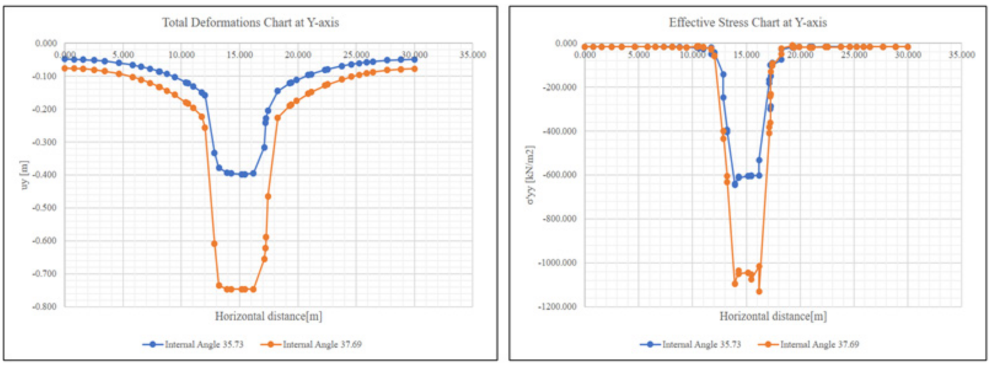

Figure 9 Chart for varying internal angle of friction of Mangalpur

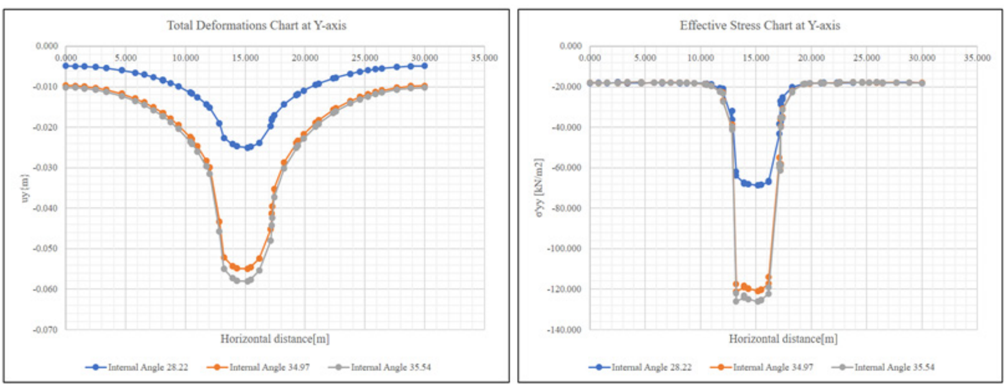

Figure 10 Chart for varying internal angle of friction of Ratnanagar

Variation of Poisson's Ratio

Here, Influence of variation of subsoil were analyzed with the variation of Poisson's Ratio i.e. 0.25, 0.30 & 0.35 respectively for both Mangalpur and Ratnanagar soil keeping other properties of subsoil constant the obtained results were discussed and interpreted.

Table 5 Data obtained while varying Poisson's Ratio

Location	Poisson's Ratio	Max Displacement (Y)	Min Displacement (Y)	Max Cartesian Effective Stress (X)	Min Cartesian Effective Stress (X)	Max Cartesian Effective Stress (Y)	Min Cartesian Effective Stress (Y)
Mangalpur	0.25	0.000 m	-0.1329 m	6.467 kN/m²	-240.2 kN/m²	2.67 kN/m²	-288.3 kN/m²
	0.3	0.000 m	-0.4342 m	0.5678 kN/m²	-249.7 kN/m²	3.79 kN/m²	-697.5 kN/m²
	0.35	0.000 m	-0.7502 m	-5.956 kN/m²	-330.2 kN/m²	11.31 kN/m²	-1111 kN/m²
Ratnanagar	0.25	0.000 m	-0.06789 m	4.716 kN/m²	-140.3 kN/m²	1.78 kN/m²	-329.8 kN/m²
	0.3	0.000 m	-0.0628 m	4.569 kN/m²	-141.4 kN/m²	2.47 kN/m²	-331.1 kN/m²
	0.35	0.000 m	-0.06290 m	4.782 kN/m²	-143.9 kN/m²	2.73 kN/m²	-332.8 kN/m²

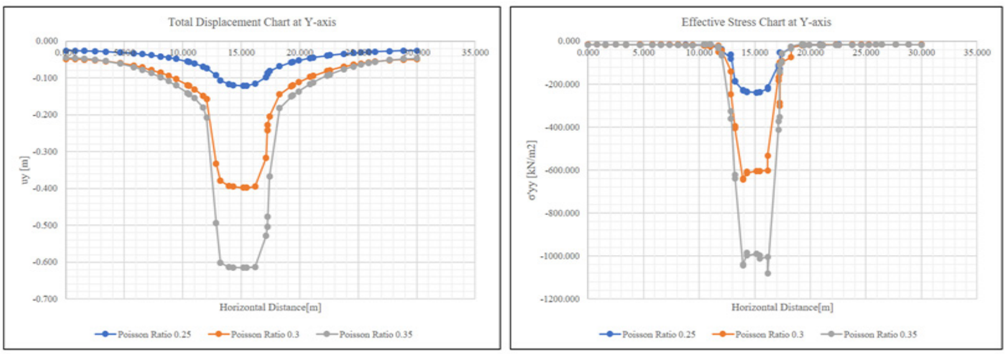

Figure 11 Chart for varying Poisson's Ratio of Mangalpur

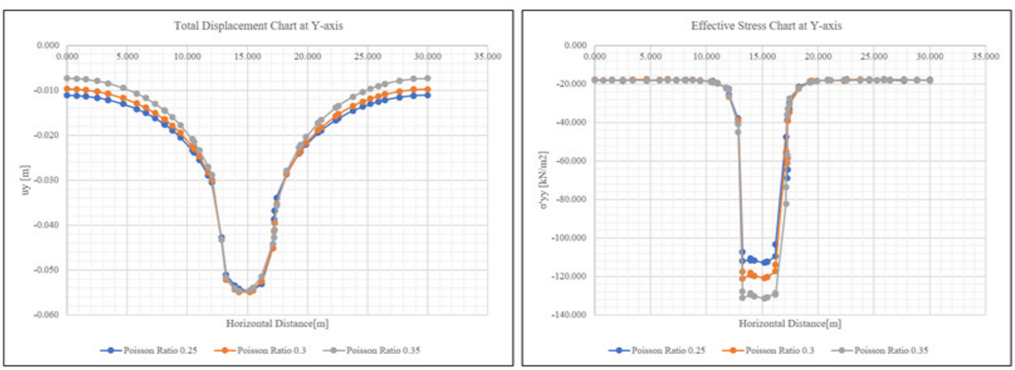

Figure 12 Chart for varying Poisson's Ratio of Ratnanagar

Variation of Water Table

We varied the depth of water table for clay i.e. soil of Mangalpur and for sand i.e. soil of Ratnanagar. The constant value of depth of water table was 2m below the ground level for both clay and sand respectively. We studied the effect of varying depth of water table i.e. WT=1m and 2m below the ground level for both locations.

Table 6 Data obtained while varying Water table depth

Location	Water Table Depth	Max Displacement (Y)	Min Displacement (Y)	Max Cartesian Effective Stress (X)	Min Cartesian Effective Stress (X)	Max Cartesian Effective Stress (Y)	Min Cartesian Effective Stress (Y)
Mangalpur	1 m	0.000 m	-0.5654 m	-3.03 kN/m²	-338.6 kN/m²	4.245 kN/m²	-809.4 kN/m²
	2 m	0.000 m	-0.4342 m	0.57 kN/m²	-249.7 kN/m²	3.791 kN/m²	-697.5 kN/m²
Ratnanagar	1 m	0.000 m	-0.06498 m	4.61 kN/m²	-137.5 kN/m²	2.124 kN/m²	-322.1 kN/m²
	2 m	0.000 m	-0.06280 m	4.57 kN/m²	-141.4 kN/m²	2.465 kN/m²	-331.1 kN/m²

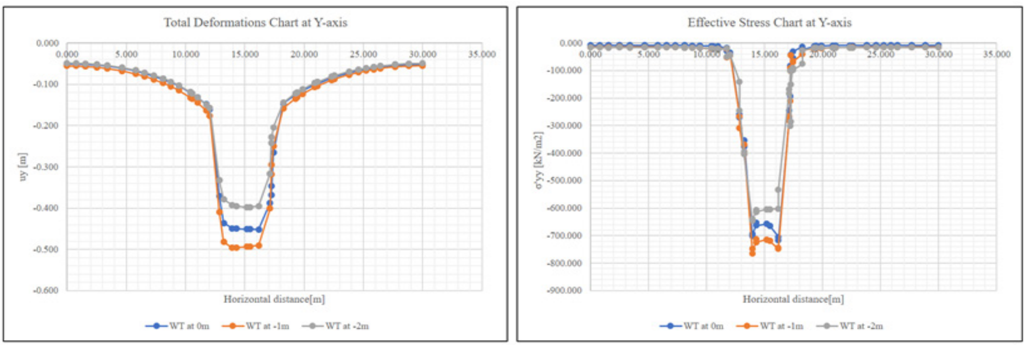

Figure 13 Chart for varying Water table depth of Mangalpur

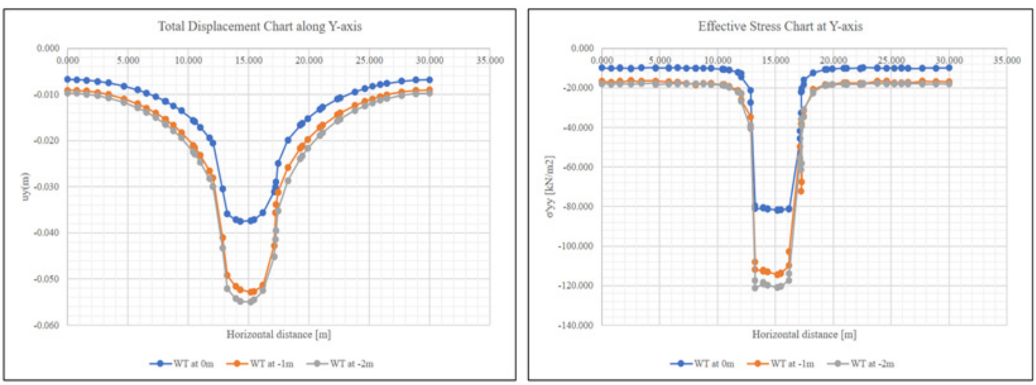

Figure 14 Chart for varying Water table depth of Ratnanagar

Comparison of varying parameters in clay

The effect of varying soil parameters on the behavior of clay was studied. The parameters were varied within certain range for clay and the obtained results were discussed and interpreted. The value of deformation and effective stresses were taken for cross section at 1m depth.

Table 7 Comparison table of varying parameters in clay soil

Case	Parameter	Range	Effect on Total Displacement (Y-axis)	Effect on Effective Stress (X-axis)	Effect on Effective Stress (Y-axis)
Poisson's Ratio	μ	0.25, 0.3, 0.35	Increase	Increase	Increase
Cohesion	c	15.62 kN/m², 17.38 kN/m²	Decrease	Decrease	Decrease
Internal Angle of Friction	Ø	35.73°, 37.69°	Increase	Increase	Increase
Water Table Depth	WT	1 m, 2 m below ground level	Decrease	Decrease	Decrease

Comparison of varying parameters in sand

The effect of varying soil parameters on the behavior of sand was studied. The parameters were varied within certain range for sand and the obtained results were discussed and interpreted. The value of deformation and effective stresses were taken for cross section at 1m depth.

Table 8 Comparison table of varying parameters in Sand

Case	Parameter	Range	Effect on Total Displacement (Y-axis)	Effect on Effective Stress (X-axis)	Effect on Effective Stress (Y-axis)
Poisson's Ratio	μ	0.25, 0.3, 0.35	Increase	Increase	Increase
Cohesion	c	0 kN/m²	No effect	No effect	No effect
Internal Angle of Friction	Ø	28.22°, 34.97°, 35.54°	Increase	Increase	Increase
Water Table Depth	WT	1 m, 2 m below ground level	Increase	Increase	Increase

Conclusion and Recommendation

Conclusion

The following conclusions were derived from our parametric study and analysis:

a. By varying the foundation, we came to know that, increase in foundation width results in decrease in deformation and stresses in clay soil and results in increase in deformation and stresses in sandy soil. So, greater width of foundations suitable for clay soil and smaller width foundation is suitable for sandy soil for the stability of the foundation.

b. We discovered that a higher cohesion value results in less deformation and stress by altering the cohesion for clay. Greater subsoil strength is therefore indicated by a higher cohesion value.

c. Findings by altering the internal angle of friction suggest that an increase in the value of the internal angle of friction results in an increase in deformation and stresses in both sand and clay. The subsoil is therefore more stable in both situations when the internal angle of friction is less.

d. Results show that by adjusting the Poisson ratio, the soil in Mangalpur and Ratnanagar experiences more deformation and stresses due to an increase in the value of the poisons ratio. As a result, a reduced Poisson ratio encourages the subsoil's increased strength.

e. The results showed that changing the depth of the water table for both clay and sand suggested that a greater depth of water table enhances the subsoil strength in case of clay and a smaller depth is advantageous in the case of sand.

Recommendations

The following recommendations were made for further studies:

sa. For our study we did not consider variation of load on foundation, unit weight and elastic modules of soil. So, further study can be done by considering effect of various loading conditions in subsoil behavior and variation of unit weight and elastic modules of soil.

b. The different loading conditions like, uniformly varying load, eccentric loading, etc. should be considered to study the behavior of subsoil under different loading conditions.

c. For our study we only consider two locations soil, so further study can be done by considering many different locations of different places.

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