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Varying Base Pressure and Groundwater Level Effect on Settlement of Clayey Soil Under Circular Loading

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Abstract – Settlement of clayey soil depends on various factors. Groundwater level and base pressures are main responsible ones. In this study, base pressure and groundwater level impact on soil settlement were investigated 11 different ground water level (0-10 m below the ground surface) and 18 different base pressures (0-900 kPa) were used for this purpose. 198 cases were analysed with Settle 3D software. Soil layers used were 10 m sand layer, following 10 m of clayey layer and 10 m sand layer again which was totally 30 m. Bousinessq method was selected for stress computations. Settlements were calculated for 10 to 18250 days (50 years). Graph between base pressure and settlement were drawn for maximum settlement of all cases. Base pressure values made settlement values exceeded 7.5 and 12.5 cm were also evaluated. Results showed that there can be created a relationship of 2^{nd} degree polynomial between base pressure and settlement. Settlements for all cases were below 7.5 cm when the base pressures were 100 kPa and lower. Settlement of Case 1 (groundwater level at the beginning of clay layer) were approximately 1.35 times of Case 11 (groundwater level at the end of clay layer). Change in groundwater level and level of base pressure must be taken into account while computing settlements of engineering structures.

Keywords – Base Pressure, Clayey Soil, Groundwater Level, Settle 3D, Settlement.

I. INTRODUCTION

Various engineering structures have been built in all around the world. Those buildings can be constructed for any purpose that human being demands. Structures having a different geometry have been increasing day by day. Population in the world is increasing day by day [1]. This make it obligatory to construct huge building. Those buildings may result high base pressures on foundations resting on soils. They also enhance the settlement due to soil profiles beneath the foundation. Especially, clayey soils are very complex materials to be totally understand. Structures built on high plasticity clayey soils reveal high swelling and settlement problems. Settlement should be in the allowable limits of regulations created by the countries. Therefore, numerous studies [2-13] about settlement were performed.

Comparison of measured values and computed values from the software is important. Embankment resting on soft clay for test fill was investigated and gave close values [5]. New methods to forecast the consolidation coefficient and settlement values were proposed and the derivative method were better to apply [7]. Settlement calculations can be performed by dividing layers 1 or more. Study on this indicated that 1.2-50 times of settlement difference was observed when comparing to single and infinite number of soil layer [9]. Settlement more than desired can be lowered by improving soil properties or applying improvement methods. Bored piles were applied to eliminate the possible settlement risk regarding to liquefaction since settlement value of 1.70 cm was found for the bridge [10]. Settlement analysis for section of rail stations were executed and prefabricated vertical drain were applied to lower the settlement [11]. Prediction of settlement is so important and it should be done for embankments also [12]. Traditional methods may have some disadvantageous since they need are time consuming. Back analysis for consolidation settlement for 1-D problems by emphasizing the disadvantages of classic observartional methods [13]. Method of back analysis gave reasonable values for in-situ conditions.

Parametric studies gain importance in today's world. Determining the lower and upper limit of values become significant to analyse any engineering problems. This make sense when taking into account the changes in field conditions. In this study, effect of change in groundwater level and base pressure were observed for this purpose and base pressure values that make the settlement 7.5 cm and 12.5 cm were evaluated.

II. MATERIALS AND METHOD

Settle 3D software were used for the settlement analyses. Bousinessq method were used since it is a well known and easy to apply for most of the problems. Soil profile seen in Fig. 1 was adopted for the model. First 10 m below the ground surface represents the dense sand layer, between 10 – 20 m clay layer exists and loose sand layer is located at the last 10 m.

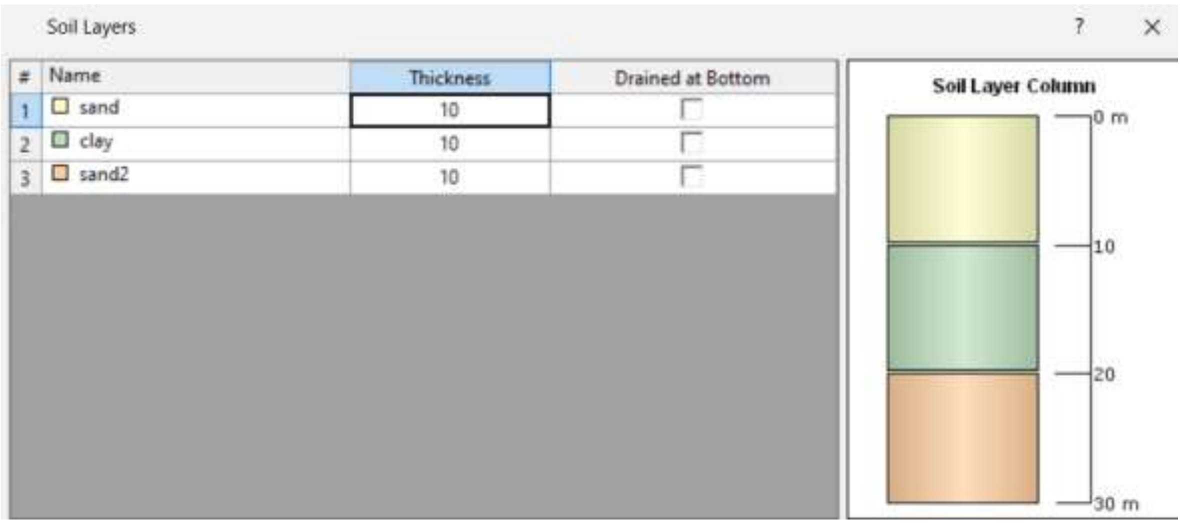


Figure 1. Soil layer used for the model

Soil properties were given in Table 1. Immediate settlements were not applied and primary consolidation stage was just selected for the clay layer. Therefore, there was no need to assign C_c, C_r, C_v and e_o values for sand layers as indicated in the table below.

Table 1. Soil properties

Soil	Unit weight (kN/m^3)	Saturated Unit Weight (kN/m^3)	Poisson's ratio	C_c	C_r	C_v (cm^2/s)	e_o
First sand layer	13.24	17.16	0.3				
Clay layer	15.69	18	0.35	0.35	0.03	$4.76*10^{-5}$	0.781
Second sand layer	18	20	0.2				

Various base pressures and groundwater level were applied for the analyses. Settlement time were selected as 18250 days. The main reason to choose 18250 days (approximately 50 years) was to take into account the service life of the structure. Base pressures used were 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800 and 900 kPa. Groundwater levels were initiated from the beginning of the clay layer until the end by 1 meter apart of each one. Details of the analyses were shown in Table 2. Analysis model that was created with Settle 3D software was shown in Fig 2.

Table 2. Problem details

Case	Base Pressure	Groundwater Level
1	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800, 900	At the beginning of the ground surface
2	Same with 1st case	1 m below the ground surface
3		2 m below the ground surface
4		3 m below the ground surface
5		4 m below the ground surface
6		5 m below the ground surface
7		6 m below the ground surface
8		7 m below the ground surface
9		8 m below the ground surface
10		9 m below the ground surface
11		10 m below the ground surface

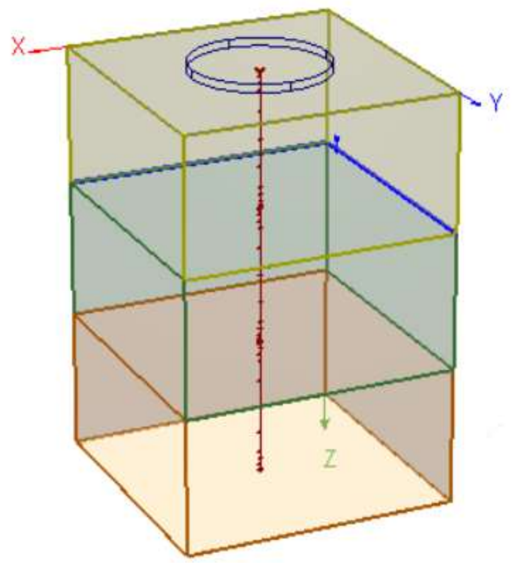
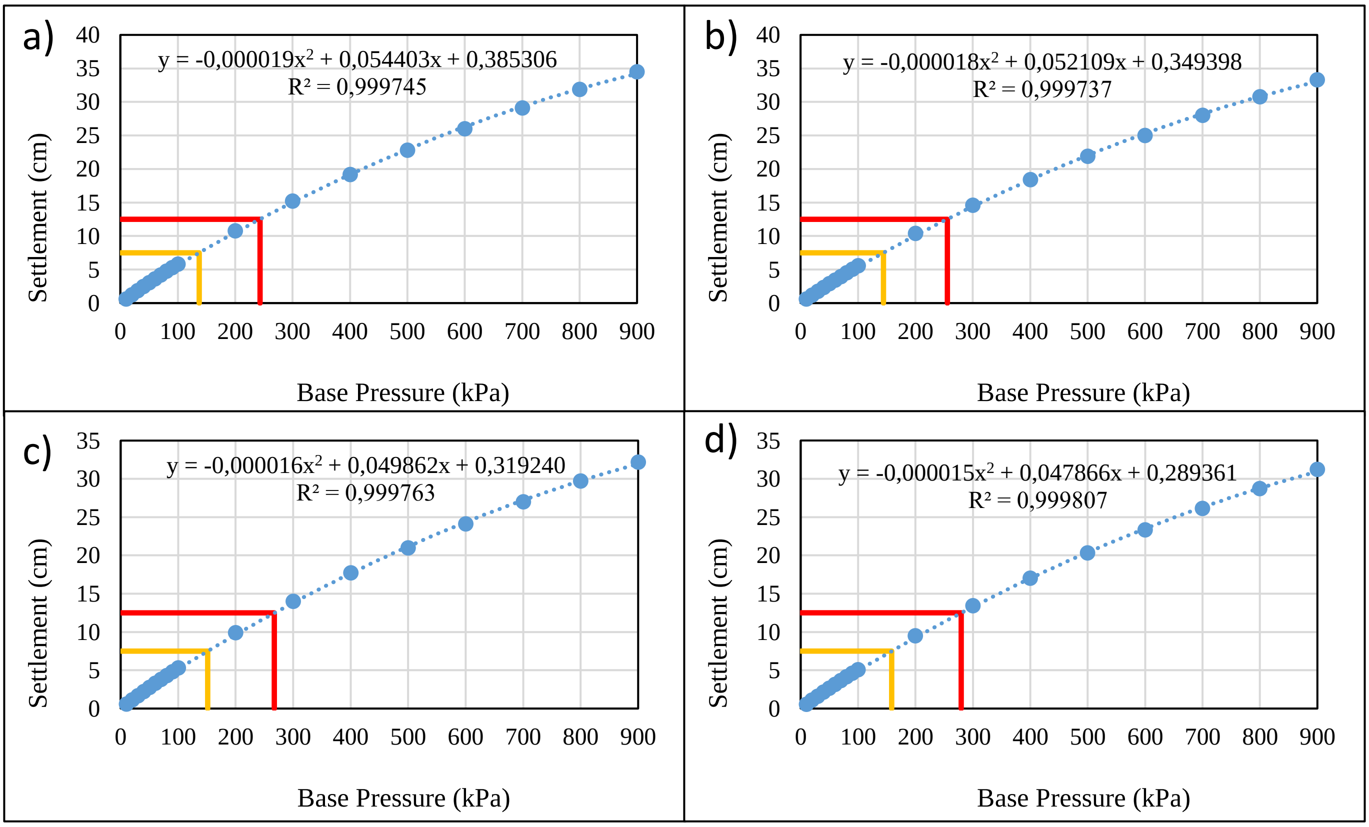


Figure 2. Model used in the analysis.

III. RESULTS

Results of the analyses were summarized in the graphs of base pressure – settlement shown in Fig 3. Red line indicated the base pressure corresponding to 12.5 cm of Settlement while other line showed the base pressure corresponding to 7.5 cm settlement. There are just 10 kPa interval for the first 10 base pressure values (10-100 kPa). After that interval became 100 kPa and the final pressure value is 900 kPa. Main reason for selecting this range is that more than 50% of structures face base pressure 100 kPa or lower. Settlement enhanced with an increase in base pressure. 2nd degree of polynomial equations between base pressure and settlement seems to be good since R^2 values for all cases are higher than 0.999. Settlement were not reached 7.5 cm for all cases except base pressure higher than 100 kPa. Maximum settlement value of all cases was 34.5 cm while the minimum one was 25.5 cm for 18250 days.



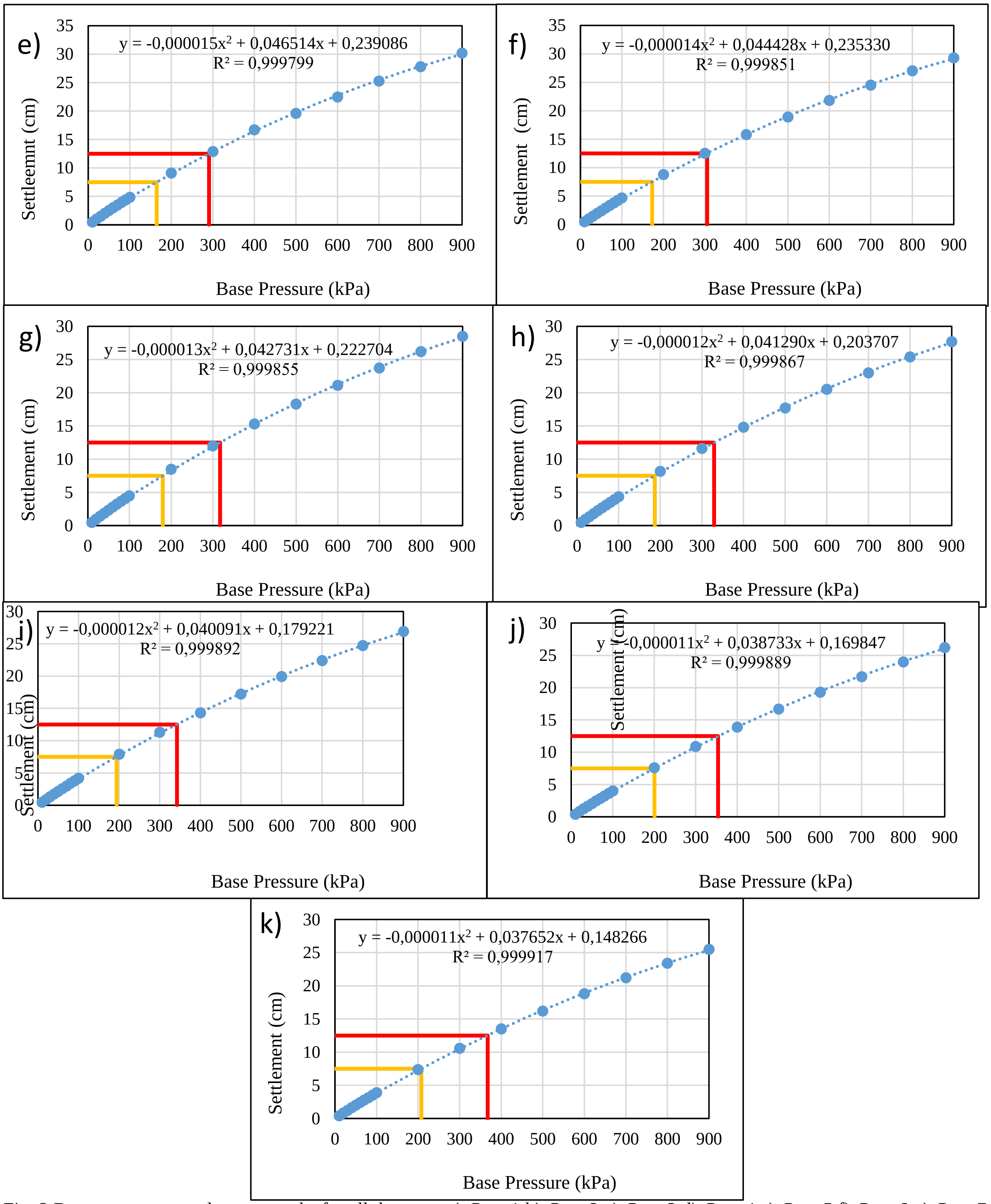


Fig. 3 Base pressure – settlement graphs for all the cases a) Case 1 b) Case 2 c) Case 3 d) Case 4 e) Case 5 f) Case 6 g) Case 7 h) Case 8 i) Case 9 j) Case 10 k) Case 11

IV. DISCUSSION

Change in groundwater level have vital importance on settlement values for all cases. Due to rainy weather conditions on desired areas of construction made this more important. Change in level of water affected the settlement significantly since settlement of Case 1 is approximately 1.35 times of Case 11. Settlement of 7.5 cm were calculated when the base pressure was 137.37 for Case 1 while it was obtained 207.88 kPa base pressure value for Case 11. Settlement of 12.5 cm were calculated when the base pressure was 243.37 kPa for Case 1 while it was obtained 367.51 kPa base pressure value for Case 11. First 8 cases have settlement values around 5 cm and less for base pressures of 100 kPa and lower. Acceleration in settlement gets slower when base pressure was increased for all cases. Trend of graph for all cases seem to be same.

V. CONCLUSION

In this study, total of various groundwater levels (11) and base pressure values (18) were taken into account to investigate their effect on the settlement of clay. Long period of time (50 years) was taken into account to analyse the settlement. Following result were obtained.

1) Groundwater level have strong effect on the settlement of clay and thus this analyse should be carefully performed for any engineering problems
2) Base pressures less than 200 kPa gave settlement values lower than 12.5 cm. Lower base pressures gave reasonable and allowable settlement value for this problem.
3) 2^{nd} degree of polynomial were very compatible for base pressure and settlement relationships and it can be used to estimate this kind of problem for the same soil profile and loading condition.
4) It is difficult to find the base pressure value that makes the settlement increase almost zero.

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