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Research Article

Prediction of Highway Embankment Settlement on Clays by the Application of Preloading and Prefabricated Vertical Drains

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Keywords

Consolidation,
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Abstract

Construction of dual carriageway embankments on smooth clay soils is severely essential problem for the serviceability of subgrade projects. It is a exquisite situation to expect the agreement of the embankment on smooth soil. Generally, Geotechnical trouble is located wherein the soils are composed of smooth clay. In this case, it's miles had to expect the Consolidation agreement of clay. The prefabricated band drains are used for accelerating the consolidation of smooth soils. During the Construction of high-manner troubles on smooth soil, it's miles required to investigate balance associated with the discount of consolidation agreement. In this work, empirical strategies of Prefabricated Vertical Drains (PVDs) & Preloading are used to investigate the agreement comprehensively. By the method of preloading, consolidation of soil may be executed to an extensive quantity earlier than making use of real creation load. The end result of the agreement evaluation of the Highway Embankment withinside the studies vicinity is 248 mm, which takes nearly 21 years for number one consolidations to obtain a 95% degree of consolidation. To lessen the period of consolidation agreement Prefabricated Vertical Drains(PVDs)and Preloading are applied. The Kjellman formulation is used for the estimation of the consolidation time. A triangular sample is followed withinside the intensity of nineteen m with a spacing of 1m and the decreased time for number one consolidation agreement is nearly a hundred and twenty days.

1. Introduction

Consolidation is one among an appropriate method wherein for the occasion of geotechnical residences of soil for the occasion of structures; avenue hill Construction in tender soil is one among them. Predicting the conduct of embankments created on tender soil strong with vertical drains remained a complicated issue, aleven though high-quality development has been created thru rigorous numerical fashions during the last few years. As soon as very compressible, usually consolidated clayey soil layers lie at limited/big depths, large consolidation settlements region unit anticipated because of the outcomes of the numerous large buildings, avenue embankments, earth dams, etc.

Pre-compression and provision of vertical drains in tender soil are also familiar with minimizing post-creation settlement. This approach has resulted in a number of techniques involving:

- Pre-compression or Pre-loading
- Sand drains
- Pre-fabricated Vertical Drains
- Vacuum consolidation
- High Vacuum Densification Method (HVDM)

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2. Objectives

The purpose of this research work is to estimate and predict the consolidation settlement of soft soil & consolidation time for the construction of high-way embankments on soft clay soil.

3. Method

3.1. Data

Based on the results of observations on the drill knowledge and laboratory analysis, the drill purpose knowledge wont to describe the soil layer at the study website were three locations. The results of the interpretation administered by considering the outline of the soil and also the results of drilling and also the N-SPT price may be delineated because the soil conditions within the PVD space.

Soil parameters are obtained from N-SPT and Laboratory tests. The N-SPT test was carried out to Understand the soil engineering properties, which will then be used to analyze soil degradation and vertical drainage.

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Table 1. Parameters and necessary data for settlement calculation

Parameters	Data	Unit
Initial Void ratio, e_0	1.01	
Unit Weight of Soil	18	kN/m^3
Unit Weight of Water	10	kN/m^3
Compression Index, C_c	0.173	
Coefficient of consolidation, c_v	4.69	m^2/year
Time Factor for Consolidation, T_v	1.129	for 95% Consolidation
Road Height	3.8	m
Road Width	34.4	m
Area	157.49	m^2
Surcharge Load from Height	2834.8	kN
Surcharge Load/m from Height	57.35	kN/m

3.2. Ground Improvement Methods

The ground can be improved by preloading with a vertical drain method as the soil is mainly soft clayey soil, and preloading alone will not permit a time period to improve the ground in the assigned road construction period.

The following two methods can be applied as a vertical drain:

(a) Sand Drain
(b) Prefabricated Vertical Drain (PVD)

The main advantage of PVDs over sand drains

- PVDs do not require drilling and, thus, installation is much faster. Installation of PVDs is typically 6,000 linear meters per day with a machine.
- PVDs have high discharge capacities than sand drains.
- Smear effects are much smaller for PVDs than for the large diameter sand drains.
- During soil settlement of the ground, there is no risk of shear failure of PVD, but the sand drain is vulnerable to shear failure during soil settlement.
- There is no risk of the breaking of PVD during installation, but sand drain can be discontinued if Mandril is withdrawn very fast.

Considering the above-mentioned advantages of the PVDs, PVDs are recommended for ground improvement in this project.
PVDs can be inserted in the ground in 2 patterns – Triangular pattern and square pattern, as depicted in the following figure.

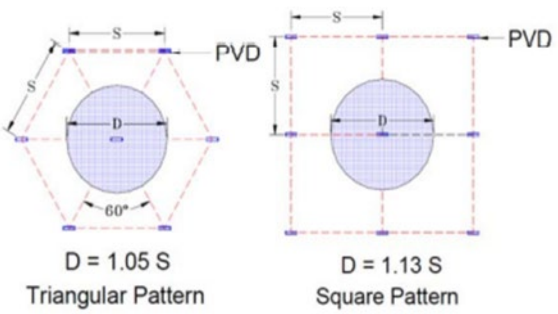

Figure 1. Patterns of PVDs

3.3. Prefabricated Vertical Drain (PVD)

The design of vertical drainage assuming ideal conditions do not take into account the effects of disruption and drainage resistance and only take into account the distance factor between vertical drainage, with distance variations 1 m, 1.5 m and 2 m.

$$F(n)=\ln(n)-0.75 \quad (1)$$

Where F(n) is drain distance factor

$$n = D/d_w = r_e/r_w \quad (2)$$

$$d_w = (2(w+h))/\pi \quad (3)$$

The above typical equation [3] can be used to detemine the equivalent drain diameter

Where $r_e = D/2$ is cylinder radius effects vertical drainage

$r_w=d_w/2$ =vertical drainage radius

4. Design Table – PVD Spacing, Depth, Surcharge, and Settlement and consolidation Time

4.1. Calculation Procedure for PVD Spacing, Depth, Surcharge

In this research work, the Kjellman formula is used for the estimation of the consolidation time. The equation is given below.

$$t=\frac{D^2}{8c_h}\left[\ln\left(\frac{D}{d}\right)-\frac{3}{4}\right]\ln\frac{1}{1-U_h} \quad (4)$$

Where,

t = consolation period (years)

D = diameter of drained soil cylinder (m)

d = equivalent diameter of drain (m)

ch = coefficient of horizontal consolidation (m2 /year)

Uh = average horizontal degree of consolidation

Usually, the triangular pattern of PVDs is more efficient than that of the square pattern. In this project, a triangular pattern is recommended to implement in the field. For triangular pattern, the diameter of the drained soil cylinder, D =1.05s, here, s is the distance between successive PVDs. In the calculation, the equivalent diameter of PVD, d, is calculated with the following equation, which is proposed by Hansbo (1979),

$$d=\text{circumference}/\pi$$

or, (5)

$$d= (2(\text{width} + \text{thickness}))/\pi$$

Equation (4) shows only one soil parameter is required to obtain consolidation time, which is ch, coefficient of horizontal consolidation. The coefficient of horizontal consolidation is usually one to four times the coefficient of vertical consolidation, cv. Here, the same value, ch = cv, is used considering safety factors. The coefficient of vertical consolidation is obtained from the Oedomoter Test report.

Table 2. Summary of PVD spacing and Depth for Triangular Arrangement near Patiya Bridge

Number of Layer	Depth Of Layer (m)	Depth at Mid layer (m)	Surcharge load (Δp)	Mean Effective Stress (P_0)	Settlement (mm)
1	2	1	57.35	8	156.71
2	2	3	19.12	24	43.71
3	2	5	11.47	40	18.81
4	2	7	8.19	56	10.19
5	2	9	6.37	72	6.33
6	2	11	5.21	88	4.29
7	2	13	4.41	104	3.10
8	2	15	3.82	120	2.34
9	2	18	3.19	144	2.45

4.2. Calculation Procedure for Estimated Consolidation Settlement and Consolidation Time

Consolidation settlement is calculated considering soft clay as a normally consolidated soil. The equation used is depicted below

$$S_c = H.\left[\frac{c_c}{1+e_0}\log\frac{\sigma_0^{/}+\Delta\sigma}{\sigma_0^{/}}\right]$$

(6)

Where,

H = thickness of the clay layer for untreated soil, it is the spacing of the PVDs for the treated soil e_0 = initial void ratio
c_c = compression index
Sc = consolidation settlement
σ'_0 = initial effective stress of the ground
$\Delta\sigma$ = stress increment due to the surcharge load

Initial void ratio and compression index are obtained from the consolidation (Oedometer) Test report.

Table 3. Estimated Settlement Calculation and Time

Bore hole No.	Chainage (Km)	PVD Spacing (m)	PVD Depth (m)	Estimated Settlement (mm)	Waiting Period (day)
BH-1	0+109	1	19	248	120
BH-2	0+230	1	19	163	120
BH-3	0+341	1	19	222	120
BH-4	0+463	1	19	402	120
BH-5	0+616	1	19	338	120
BH-6	0+745	1	19	371	120

5. Result and Discussion

- Total Estimated Maximum settlement =248mm [Table-3]
- Depth of layer = 19 m [Table-3]
- Estimated time for settlement = 120 days [Table-3]
- The total settlement in the table-3 represents the primary consolidation settlement after the complete dissipation of excess pore water pressure. The time is the time required for 95% consolidation.
- Excess Pore water pressures due to rapid embankment construction can be reduced by introducing PVDs

6. Conclusion

- Analysis of Settlement by using PVD to achieve a consolidation time of 95% shows that the variation in distance of 1 m PVD, results in a shorter consolidation time compared to variations in the distance of 1.5 m and 2 m.
- The percentage effect of fixing settlement of soil by using PVD and not using PVD on time and the consolidation process reduces the time 21 years to 120 days.

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Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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