Improving Engineering Properties of Soft Soil Using Preloading and Prefabricated Vertical Drains

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ABSTRACT

Preloading and Prefabricated Vertical Drains (PVD) is a ground improvement technique used to increase the consolidation process of clayey soils by means of shortening the drainage path. This paper discusses a case study of a road construction where a part of road alignment goes through a low laying water logged area. Primary consolidation of soft clay will continue for longer period of time after the road pavement is constructed which results in cracking and uneven settlement of the pavement to avoid such a problem ground improvement in the form of prefabricated vertical drains was recommended. Recent improvement in the finite element method analysis has enabled modeling of PVD in finite element software for calculating the settlement magnitude and time rate of consolidation. This paper gives the finite element modeling (FEM) of the proposed layer of road where ground improvement is done by prefabricated vertical drains. Field Settlement values of road at different time intervals are compared with the settlement magnitudes obtained from the FEM model. Field Settlement values with and without placement of vertical drains is also compared. The ultimate strength of soil was found to be increased due the preloading by the action of PVD.

Keywords: Alignment, Consolidation, Finite element method (FEM), Preloading, Prefabricated vertical drains (PVD).

1. INTRODUCTION

Soft soils having poor engineering properties such as bearing capacity and exhibit large settlement. In recent years an increasing need of construction has made it necessitate on different sites which is underlying by soft cohesive soil. In such cases the soil improvement techniques such as preloading can be adopted to provide adequate bearing capacity and to minimize total and differential settlements. [1]

Preloading is the application of surcharge load on the site prior to the construction of permanent structure until most of the primary settlement has occurred. Preloading is the most widely used techniques to pre consolidate and strengthen weak compressible soils. T.Stapelfeldt (2001) paper deals with the soil improvement by preloading technique and utilization of the vertical drains. It introduces installation methods of drains and possible influences of the drain efficiency. Methods for assessing the effectiveness of soil improvement are described [2]

Preloading with prefabricated vertical drains is generally adopted to accelerate the rate of consolidation and to minimize settlement of treated area under future dead and live loads. Preloading increases the bearing capacity of soil and also reduces compressibility of weak ground by making the soil to consolidate. The drainage path is reduced by using PVD i.e. the shortest path is taken by the pore water to dissipate. HOLTZ (2000) explained the influence of drain characteristics on the vertical drain design. Cost, specifications, installations, and particular
problems associated with drains are discussed. The procedure for design of drain is explained for a particular site.[3]

Advancement in Finite element analysis is used to find the settlement magnitude and rate of consolidation. Plaxis (2D) v8 software which works on the principle of Finite element method is used in this project. Indraratna (2005) described ground improvement technique of a port area and the settlement values are compared with the settlement values obtained by back analysis using Asakoa method. [4]

This paper discusses the case study of a low laying water logged area near Kakkanad, Thankalam new road, India where the ground improvement techniques are suggested with prefabricated vertical drains. The soil was soft and there was a need in soil improvement. Since the normal consolidation takes longer period hence preloading with prefabricated vertical drains was adopted. Considering the time factor and practical problems, numerical analysis is done using FEM and compared with the field monitored values. The depth of soil was considered as 15m. Soil properties for the underlying soft soil and fill material used for preloading are given in table 1.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>Γsat Kn/m3</th>
<th>Γunsat Kn/m3</th>
<th>C</th>
<th>Φ</th>
<th>Kx(m/s)</th>
<th>Ky(m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOFT SOIL</td>
<td>16</td>
<td>15</td>
<td>1</td>
<td>28</td>
<td>7.3*105</td>
<td>1</td>
</tr>
<tr>
<td>FILL</td>
<td>17</td>
<td>18</td>
<td>0</td>
<td>30</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

2. FINITE ELEMENT MODELLING

A FEM software Plaxis v8 which works on the principle of Finite element analysis is used. In order to study the stress strain distribution in the in-situ soil a model was created which was subject to a load intensity of 50kN/m2. The deformation field is shown in fig.1 the maximum settlement was observed to be 2.38m. The effective stress and shear stress distribution is shown in Fig.2 & Fig.3 respectively. The maximum value of effective stress was found to be -98.00 Kn/m2 whereas maximum shear stress was -330.06*10^-3 Kn/m2.
In order to check the acceleration on consolidation of in-situ soil a model was created by introducing drains. The prefabricated vertical drains were suggested at the site to reduce the consolidation time and the spacing was taken as 1.3m suggested from preliminary calculations and the vertical drains are installed up to a depth of 10m. A geotextile layer is kept above the soft soil layer for the passage of pore water. A porous layer (sand) was also placed on the top of geotextile for passage of pore water and a uniformly distributed preload of 50KN/m² was applied over a plate which is kept on the top the porous (sand) soil. The study was conducted in four stages initial stage, installation stage, consolidation stage, loading stage. The settlement after consolidation stage is shown in Fig. 5

The settlement obtained was 0.17m, which is completely settled by the use vertical drains here the consolidation time is reduced these vertical drains helps for the dissipation of pore water at a faster rate. Hence the bearing capacity and ultimate strength are also increased. Flow field after the installation of drains is shown in Fig. 6 as shown in Fig. 6 as the preload is applied the pore water gets dissipated and by the installation of vertical drains the pore water takes the shortest path which is along the vertical drains and goes through the porous layer. The flow time is reduced as compared to the soil without drains.

Strength of the soil is increased when the soil is preloaded with prefabricated vertical drains. In order to check the possibility of improvement in strengths, the treated (preloaded) soil was loaded in the same manner in the final stage and the displacement of soil is shown in Fig. 5. The total displacement is reduced from 2.39m to 3.39mm which clearly indicates that strength of preloaded soil with drains is increased. Settlement for the same load intensity was reduced to 3.39mm and % reduction was observed as 95%.
3. COMPARISON WITH FIELD DATA

A portion of new road at Kakkanad, Thankalam new road, India where ground improvement may be required has been identified as about 1000m and road width is expected to be 1.2m. Part of the road alignment goes through low lying water logged area. The primary consolidation of soil will continue for a longer period of time it was about 2.36 years from preliminary calculations which results in uneven settlement and severe cracking of the pavement surface apart from this frequent maintenance is required. To avoid such problem ground improvement in the form of prefabricated vertical drains is recommended.

Geotechnical instrumentation consisting of settlement gauges are installed within the ground improvement area and ground settlement shall be monitored until at least 90% of expected soil consolidation is completed. Only after attaining this consolidation the road pavement is constructed. 15 settlement gauges were used at this site and the settlement values were collected which was carried for 4 months. The photo of vertical drain stitcher through which pre-fabricated vertical drains are installed is shown in Fig 8.

These prefabricated vertical drains are placed at a distance of 1.3m spacing the period required for ground improvement using PVD was 1 month for mobilization, 3 months for PVD installation, clay consolidation period was about 3 months. Fig 10 shows the ground improvement area after installation of drains.

These drains are installed up to a depth of 10m generally PVD are band shaped (triangular in cross section) products consisting of geotextile filter material surrounding a plastic core, size of the prefabricated vertical drain is 10cm wide and 3 to 4mm in thickness this material consists of plastic core formed to create channels which are wrapped in a geotextile filter. Function of the filter of the vertical drain ensures that fine particles do not pass and clog the drainage channels in the core. The cross section of vertical drain is shown in Fig. 9.

Fig. 8 Installation of Vertical Drain

Fig. 9 Cross Section Of Vertical Drain

Fig. 10 After Installation of Drains
The settlement from field observations was up to 0.03mm and from FEM it is 0.06mm. The settlement vs. time graph is drawn for field conditions which is shown in Fig.11. As the loading is removed after the consolidation stage and the same load of 50KN/m$^2$ is applied the swelling occurs in case of FEM analysis and the stress strain distribution was observed.

Fig. 11 Settlement Versus Time Curve

4. CONCLUSION

The preloading with prefabricated vertical drains of soft soil is discussed and a field study was done, FEM analysis for the field conditions is done using PLAXIS. Using the FEM the flow of the pore water is seen. After preloading the consolidation time was reduced and the % reduction in time after preloading was up to 30%. As the settlement of soil is observed by preloading hence the bearing capacity of the soil was improved.

REFERENCES


