GROUND IMPROVEMENT OF DEEP SOFT CLAY LAYERS USING VIBRO REPLACEMENT FOR CONSTRUCTION OF A PORT AND CONNECTING HIGHWAY AT KOCHI, INDIA

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ABSTRACT: Kochi is underlain by deep soft marine clay deposit. These clay layers are highly compressive and of very low shear strength. In order to develop infrastructure like Ports, Transshipments terminals, highways in such type of soil, it is necessary to provide suitable foundation technique. Ground improvement using vibro replacement is one of the suited technique to increase the shear strength of soils and to reduce the compressibility. This paper presents case history of application of vibro replacement columns to support Jetty facilities at ICTT (International Container Transshipment Terminal) at Vallarapadam port and to support the connecting 4 lane highway to ICTT. The various aspects of sub soil conditions, design, construction methodology, quality control and test results are discussed in this paper.

INTRODUCTION

As the Indian economy integrates with the global economy, maritime infrastructure will play an ever growing role. This rapid growth in trade can be sustained only if the port infrastructure keeps pace with the increasing volumes of cargo. Road and rail connectivity forms an integral part of the port infrastructure to have an end to end solution. With this in view perspective plans have been prepared by Government of India for developing major ports along with a consolidated National Development Plan.

The subsoil’s along the coastal belt are generally very weak. These soils pose challenges to the designers with their variable thickness, low shear strength and high compressibility for designing a robust foundation design keeping life span of the facility in mind. This paper gives details of application of the ground improvement using vibro replacement technique to create suitable platform to support the port infrastructure.

PROJECT DETAILS

Dubai Ports (DP World) is developing an International Trans-shipment terminal (ICTT) at Vallarpadam, Kochi, India. This all-weather port is strategically located on the east west trade route on the south west coast of India. The project involves construction of 600m of deep water quay (-16.5m CD Dredge depth) with associated container storage yards, rail container terminal and container freight station facilities. National Highways Authority of India (NHAI) is developing a dedicated new four lane road connecting ICTT at Vallarpadam and NH-47 at Kalamassery. The total route length of the proposed road is approximately 17.2km. Figure 1 shows the location of the proposed terminal and connecting highway. The work includes construction of several culverts, bridges, flyover, underpasses and a toll plaza.

Fig. 1 Layout showing ICTT and alignment of connecting highway.

SUB SOIL PROFILE

The sub soil at the proposed terminal and the connecting highway indicates the presence of an upper compressible layer which is a mixture of sandy, silty and clayey deposits. These are underlain by medium to dense silty sand layer. Firm to stiff silty clay layer was observed below silty sand layer. The thickness of the upper compressible strata is varying in thickness. The thickness of this layer was observed as 22m at the terminal and along the connecting highway it is varying from 7m to 25m. Typical borelogs with the subsoil strata are presented below in Figure 2.

The SPT, N values in the upper compressible strata are ranging from 2 to 8 and C_u is in the range of 10 to 40 kPa. The presence of weak subsoil resulted in the requirement of ground improvement prior to development of infrastructure facilities at the port.

GROUND IMPROVEMENT SCHEME

Vibro replacement is proposed as the ground improvement scheme to support the structures proposed at the facility.
Ground improvement using Vibro Replacement (Vibro Stone Columns) technique has a long proven track record. The technique is widely used to support, industrial and commercial developments on poor ground. It has been used extensively beneath road/rail embankments, bridges, projects requiring protection against potential liquefaction caused by earthquakes, slope stability and coastal reclamation works (Raju V.R. et al., 2004a and Raju V.R. et al. 2004b).

In this method, the soil is stabilized by displacing horizontally with the help of depth vibrator, refilling the resulting space with granular material and compacting the same with the vibro-float. The resulting matrix of compacted soil and stone columns will have improved load bearing and settlement characteristics.

Vibro Replacement is employed for the following purposes at ICTT and along the connecting highway:

- To improve soil strength along the dredged slope area below the quay
- To improve the soil strength and bearing capacity immediately landward of the sheet pile wall
- To improve the soil strength throughout the active zone of the sheet pile wall and the active and passive zone of anchor wall.
- To support the embankments, reinforced cantilever wall (RC Wall) and under passages with adequate bearing capacity and without excess settlement.

To achieve the performance criteria and design requirements following vibro replacement design scheme is used:

At ICTT, Vallarpadam

- Diameter of columns : 1100mm
- Spacing of columns : 2.1 to 2.5m Triangular grid pattern
- Average Depth of columns : 22.5m
- Area replacement ratio : 17 to 25%

Along NH Connectivity Road
- Diameter of columns : 1000mm
- Spacing of columns : 1.65 to 2.0m Triangular grid pattern
- Depth of column : 7m to 25m
- Area replacement ratio : 22% to 33%

Figure 3 and 4 shows a typical sketch showing the application of vibro replacement technique at ICTT and connecting highway, respectively.
Fig. 5: Picture showing the vibro replacement works at ICTT for the quay wall.

Fig. 6: Picture showing the installation vibro replacement columns along the connecting highway for RC Wall foundation.

A total of about 600,000 linear meters of vibro stone columns were installed in phased manner starting from August 2008 to June 2010.

QUALITY CONTROL

Quality management of the vibro replacement works was carried during the construction process and after the construction by means of load tests. Monitoring of the installation process was carried out using an “M4” computer, which measures the depth of penetration, time and amperage. The M4 Display unit was mounted inside the crane with a visual display to aid the operator in constructing the column. The data was printed out real time in the crane cabin for the review of the engineer and for daily report for the site. A typical printout of the vibro stone column of 25m deep is presented in figure.7.

Fig. 7: Typical quality control output (M4 Graph) during installation of Vibro Replacement column.

LOAD TEST

As part of the quality control process single column and three column group load tests were conducted over the improved ground intervals to assess effectiveness of ground improvement. The results of some of the tests are summarized in the table.1.

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<th>SNo</th>
<th>Location/Chainage</th>
<th>Type of Test</th>
<th>Design Load (tons)</th>
<th>Settlement at Design load (mm)</th>
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<tbody>
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<td>9</td>
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<td>ICTT</td>
<td>3 column group</td>
<td>123</td>
<td>22</td>
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<td>8</td>
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<td>4</td>
<td>9 +010 m</td>
<td>3 column group</td>
<td>54.5</td>
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</tbody>
</table>
Typical arrangement of the vibro stone columns layout for a three column group and single column load test is presented below in the figure.8. Load settlement graph for the single column and three column group load test is presented in figure 9 and 10, respectively.

**CONCLUSIONS**

Subsoil in Kochi consists of deep soft upper compressible layer having very low shear strength. Construction of foundations in these soils has been always challenging to foundation designers keeping the in view the time and cost of the project. Vibro Replacement has been successfully used to increase shear strength along dredge soil below quay wall and in turn stabilizes the slope below quay wall. It is also used successfully as reinforced cantilever wall foundation. Vibro Replacement has proven to be a good solution for both ICTT and its connecting highway both technically and commercially. It also reduces the construction time of the project significantly.

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**REFERENCES**