GEOTECHNICAL INVESTIGATIONS AND DESIGN OF REMEDIAL MEASURES FOR ROADS AT VISAKHAPATNAM PORT AREA, VISAKHAPATNAM

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ABSTRACT: The Visakhapatnam Port Trust (VPT) situated in eastern coastal region of India, is among one of the busiest Ports in India. From VPT goods and other commodities are imported and exported from one place to another in India as well as Abroad. In order to cater the needs of operational requirements, a good road network always constitutes the basic necessity of port area. Presently the existing roads are used by heavily loaded trucks plying to and fro from the berth area. These trucks are carrying variety of commodities especially, the coal and iron ores. With the increase in the economic activities, new roads are constructed to cater the needs of additional handling capacity of the port. These roads lead to frequent failures, due to various problems viz., poor sub-soil conditions, inadequate pavement thickness and poor drainage conditions etc. Detailed investigations and settlement analysis was carried out for understanding the causes of failure of existing roads and recommendations for pavement designs for new as well as existing roads were provided to VPT. In the present paper, study of geotechnical characteristics of soft sub soil along the alignment of existing and new proposed roads and suggested methodology for ground improvement using stone columns have been explained.

INTRODUCTION
Visakhapatnam Port is very famous port from the ancient times, which had trade relations with the Middle East and Rome. Ships were anchored at open roads and were loaded with cargo transported from Visakhapatnam shore by means of small Masula boats. Now, the Visakhapatnam Port is one of the leading and busiest port in India which is situated at a latitude of 17°04' North and longitude of 83°17' East and the time zone is GMT + 5:30 on the eastern coast of India. The Port has three harbours viz., outer harbour, inner harbour and the fishing harbour. The outer harbour with a water spread of 200 hectares has 6 berths and the inner harbour with a water spread of 100 hectares has 18 berths. VPT is one of the busiest and famous Ports in India, where the goods and commodities are imported and exported from one place to another within India, as well as Abroad. With the increase in the economic activities and loading pattern on roads due to the trucks carrying variety of commodities especially the coal and iron ores from the sea berth to stockpile area of the port, the existing roads lead to frequent failures, due to various problems viz., poor sub-soil conditions, inadequate pavement thickness and poor drainage conditions. The Chief Engineer Visakhapatnam Port Trust selected the four major roads and referred these critical roads to CRRI for investigations of causes of failures, suggestion of remedial measures as well as to provide the design of existing and new proposed roads (1) The work of investigation of four roads viz. Existing B.T Road along east side of NALCO boundary road, (2) New road from 3rd tippler approach of H2 drive House in OHC along East side of S1 conveyor (3) New road from H6 to SBC Road including Box culverts at OHC (4) New road from NMDC screening plant gate to the front area of machine. In order to carry out the field investigations and to assess the causes of failure, team of scientists visited the site. During the course of field investigations, ten number of test pits were made in the existing as well as proposed new roads and their conditions were observed. The disturbed /undisturbed soil samples and material samples of the different pavement layers from the pits were also collected and brought to CRRI for detailed laboratory investigations. The plan of four roads for which the field investigations were carried out is shown in Fig. 1.

Fig. 1 Site Plan and Location of Test Pits

2 SURFACE CONDITION OF ROADS
Surface conditions of both the existing roads and the alignment of new proposed roads were evaluated by taking visual observations all along these roads through a walkover survey.
**Existing Roads**

The existing bituminous road was earlier a four lane road which was catering to the heavy traffic in the port area. However, in due course, the two lanes on the side of the berth area became un-trafficable due to continued and uneven settlements (Fig. 2).

![Fig. 2 Un-Even Settlement in the Existing Pavement](image)

It was observed that the settlement was slow, however it was still continuing at different locations. To make the road traffic worthy, VPT authorities have provided concrete block pavement over the entire two lane of distressed pavement. It was informed that whenever the settlement took place, the block pavement was removed and replaced after proper sand filling in the settled area. During the course of investigations it was found that apart from vertical settlement, lateral movement of soft sub soil caused by vibrations/waves created in the water due to movement of heavily loaded ships was also adding to the amount of settlement. The lateral movement was also confirmed by the failed newly constructed berth (Fig.3) which experienced movements towards the sea side.

![Fig. 3 Failed Newly Constructed Berth](image)

It was also observed that about 50-100m length of bituminous road along the in-use two lane road by the side of failed berth has also settled thereby affecting the smooth movement of traffic. The road has been repaired by concrete blocks (40cm x 20cm x 20cm) as shown in Fig 4.

![Fig. 4 Existing Road Repaired by Using Concrete Block](image)

**Drainage of existing road**

It was observed that heavily loaded trucks carrying coal and iron ores ply on the existing roads which creates dust nuisance, thereby, affecting the port environment. In order to keep the dust under control, VPT authorities sprinkle water regularly using the water tankers.

![Drainage of existing road](image)

Though the drains were built in the area all along the existing road for carrying the surface water, however these were found to be choked at the time of investigations. During the field investigations, it was also observed that, the percolated water mixed with the dust, generally of fine silt size, was pumped to jet out from the cracks of bituminous road under the load of moving trucks. There was continuous accumulation of water on the bituminous surface resulting in various forms of distress such as development of cracks, settlements, striping and rutting etc. Since the heavily loaded trucks were plying on these existing roads, rutting of the bituminous surface was predominant in the area as shown in Fig.5. The accumulated water would eventually percolate into the pavement, thereby, affecting the sub surface drainage. The pumping out phenomenon also resulted in differential settlement of the concrete blocks, which were provided over the bituminous road sections. These loosened joints were regularly monitored and filled up with cement/sand to make the road section trafficable.

**Proposed New Roads**

There were three new proposed roads namely; Road from 3rd tippler approach of H2 drive House in OHC along East side of S1 conveyor, Road from H6 to SBC Road including...
Box culverts at OHC, and Road from NMDC screening plant gate to in front of machine. The proposed roads to be constructed by the side of iron ore handling yard area would be used by loaded trucks moving in and out of the ore handling area.

It was observed that the alignment of the new roads had already been fixed by filling with approximately 0.5-1m thick iron ore material/construction and demolition wastes. The top surface along the alignments were observed to be uneven either because of improper filling or due to settlements of soft sub soil. Typical photographs of new proposed roads are shown in Fig 6. These roads were also investigated with a view to propose the renewed pavement crust on the road sections.

**SUB-SOIL INVESTIGATIONS**

**Existing road**
Sub soil investigations were carried out by making three test pits at different locations along the existing road. Each test pit was located considering the road surface condition viz. good, moderate and poor condition. The locations of these test pits are shown in Fig.1. The un-disturbed soil samples were collected using sampling tube made of PVC pipes. The disturbed soil samples were also collected directly from the test pits. These soil samples were properly sealed to preserve moisture, labeled and brought to CRRI for further laboratory testing. The typical pit observations are summarized in Table 1. It was observed that the pavement thickness at various test location was varying from 0.65m to 2.25m. It appears that the road has been brought to the present formation level by dumping sand, moorum bolder soling and iron ore etc. in various thickness. The test pit observations further reveal that no fixed composition of pavement was chosen for the existing road sections.

**Table-1 Pit observation (Bituminous pavement)**
(Dock Yard/ NALCO boundary)

<table>
<thead>
<tr>
<th>S.No</th>
<th>Depth(m)</th>
<th>Soil Profile</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 -0.10</td>
<td>Bituminous surface</td>
<td>Water table @ 1.45 m</td>
</tr>
<tr>
<td>2</td>
<td>0.10 – 0.30</td>
<td>WBM</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.30 – 1.30</td>
<td>Murrum</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.30 – 1.55</td>
<td>Boulder</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.55 – 2.45</td>
<td>Murrum</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2.45 – 3.45</td>
<td>Sandy clay</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Below 3.45</td>
<td>Soft soil</td>
<td></td>
</tr>
</tbody>
</table>

**LABORATORY INVESTIGATIONS**
As mentioned earlier, the disturbed/undisturbed soil samples were collected from the pits. The soil samples were evaluated for their index and engineering properties. The laboratory tests were carried out which included; Grain size analysis, Atterberg limit tests, Un-drained shear strength and Consolidation tests, characteristics of soft sub soil. The laboratory results are summarized in Table 2.

**Table 2 Summary of geotechnical characteristics of soft sub soil**

<table>
<thead>
<tr>
<th>Wl(%)</th>
<th>PI(%)</th>
<th>qU(kPa)</th>
<th>Cc</th>
</tr>
</thead>
<tbody>
<tr>
<td>73-93</td>
<td>54-62</td>
<td>7-16</td>
<td>0.61</td>
</tr>
</tbody>
</table>

**Need of ground improvement**
Based on the consolidation characteristics of soft subsoil, the estimated total consolidation settlement was expected to be of the order of 202-281mm, which cannot be completed during the construction period. Based on field and laboratory investigations, it was found that the consolidation settlement may continue for next 3-4 years under the given loading. In order to minimize the time of consolidation, some ground improvement methods like Stone Column/Band drains and Stage construction would be required. If the ground improvement by stone column technique is not feasible due to budget constraints, the following alternative method may be adopted.
Alternative method for ground improvement - Stage construction

Following steps may be followed for stage construction:

✓ Excavate the soil up to the subgrade level and level it with sand or any non-plastic soil to such a depth that the proposed pavement can be accommodated within this depth. The filled-up sand/any other suitable material shall be adequately compacted (95% of MDD). This level will form the top of subgrade soil.
✓ Lay a geotextile on the top of subgrade supporting the pavement. The layer of geotextile would prevent the intermixing of pavement layers.
✓ Provide a layer of GSB (150 mm, Gr-I close gared) on top of geotextile layer followed by two layers of WBM (One layer of WBM Gr-II and one layer of WBM Gr-III).
✓ Provide the wearing course with either premix carpet with seal coat or mix seal surface (MSS)
✓ Allow the traffic on this road and record the pavement settlement for 2 years. When the pavement seized to settle, provide a layer of DLC (20 cm thick) and PQC (26 cm thick).

Remedial measure for Existing two lane bituminous roads

During the course of investigations it was found that a stretch of 50m along the NALCO boundary was badly affected because of failure of berth which is very close to the existing road and continuous sprinkling of water was done to avoid the dust nuisance. This resulted in the continuous seepage of water into the pavement crust thereby, causing intermittent rutting. It was, therefore, recommended to provide concrete overlay above the existing bituminous surface. A 26 cm thick Pavement Quality concrete (PQC) was recommended over 10 cm thick Dry Lean Concrete (DLC) leveling course provided over the existing bituminous surface. The cross section of the overlay is shown in Fig 8. It is expected that the new roads would also be used by coal and iron ore loaded trucks. Since, the sprinkling of water to avoid dust nuisance would continue and hence providing bituminous surface may not be feasible. It was suggested to provide concrete pavement surface in stages. As the expected settlement in these new roads varies from 20.2 cm to 25.1 cm, provision of concrete pavement directly over the existing surface would result in cracking and failure.

CONCLUSIONS

The sub soil is very soft and it needs ground improvement. The ground improvement with stone column is very costly when compared with stage construction. Finally ground improvement with stage construction was suggested. The existing bituminous roads should be reconstructed with concrete roads due to waterlogged problems

REFERENCES

1 CRRI (2010), Report on “Investigation of four roads in VPT area, Visakhapatnam” Central Road Research Institute, New Delhi.

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