Geotechnical Engineering

Central Road Research Institute

Annual Report 2009-10
Project Team Members of Geotechnical Engineering Division
Engineering of Structures against Natural and Other Disasters

This project has been taken up as a network project coordinated by SERC, Chennai. In order to study natural disasters, three sites, one under the heavy flood and the other two large landslide affected areas were chosen. Under the heavy flood area, field visit was made to West Bengal to study impact of Cyclone Aila on road network Fig. 1(a & b). Discussions were held with officials from Ganga Flood Control Commission, WBIWD and DST, Govt of India. Various remedial measures being taken up were studied and recommendations for improving the same were provided.

Under the large landslide affected area, two landslides namely Patalganga and Kaliasaur landslides have been selected for detailed investigations. At Patalganga landslide on National Highway-58, Uttarakhand, sixty five numbers of specially designed steel pedestals have been installed in the landslide body for monitoring the dynamic behaviour of the landslide and their original position has been fixed by using DGPS (Differential global positioning System). Earlier, twenty five numbers of steel pedestals were surveyed to measure the shift in their position, if any, so that magnitude and direction of movement may be assessed. The movement of the pedestals is attributed to the movement of the blocks (formed by dilational and shear fractures in the main body) resting on the slip surfaces on which pedestals were installed. The sixty five numbers of additional pedestals which were installed in the year 2007 have been monitored for the movement and it was found that the shifting of position (Fig. 2 (a & b) of some of the pedestals ranges from 0.31 to 8.26m. Monitoring of Patalganga landslide depicts that it has shallow kind of movement. Current monitoring of the slide reveals that the movement ranges from 0.31 to 8.68 meters. Movement of lower magnitude has been observed in the upper parts of the landslide area whereas higher magnitude movement has been recorded in the lower parts of landslide

![Fig. 1 (a & b) A view of heavy flood in West Bengal](image)
area. It depicts the erosion in toe parts during rainy season. Most of the movement of the pedestals trend towards SW and WNW direction. Monitoring will be continued in the future as well. The project is currently under progress.

**Detailed Geological, Geotechnical Investigation, Instrumentation and Monitoring of Amparav Landslide**

As reported earlier (Annual Report 2008-09) the study on Amparav landslide has been sponsored by the Department of Science and Technology (DST). The Amparav slide is located on the Kathgodam – Nainital road, 4 km. before Jyolikot on NH-87 in Nainital District of Kumaun Division, Uttarakhand State. Detailed geological and geotechnical studies were carried out. For this purpose, large scale mapping done at 1:500 scales with 2 m contour interval. Large scale mapping include all topographical, manmade features and also the dimension of landslides. It was found that study area is highly venerable for slope instability. Mainly, three different types of failures namely, plane/block failure, talus failure on higher reaches and rotational failure at lower reaches are affecting the NH-87 (Fig. 3). Further, studies revealed that there were natural as well as anthropological factors playing important role, causing instabilities in the area. These factors are given in Table – I. Proposed remedial measures are given in Fig. 4. Project report has been submitted to DST.

**Table – I Causative Factors Identified at Amparav Landslide**

<table>
<thead>
<tr>
<th>Natural Causative Factors</th>
<th>Anthropological Causative Factors</th>
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<tbody>
<tr>
<td>Geology Weak Lithology</td>
<td>Deforestation</td>
</tr>
<tr>
<td>Structure Domination</td>
<td>Excessive Irrigation in Agriculture Fields</td>
</tr>
<tr>
<td>Steep Slope</td>
<td>Improper Drainage</td>
</tr>
<tr>
<td>Land Use and Land Cover</td>
<td>Inadequate Maintenance of Old Existing Remedial Measures</td>
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<tr>
<td>High Weathering</td>
<td>Construction of Concrete Bridge with Low Ground Clearance</td>
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<tr>
<td>Presence of Mud Stone Layers</td>
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<td>High Seismic Zone / Close to MBT</td>
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Fig. 3 Different modes of failure of Amparav landslide

Fig. 4 Proposed remedial measures in Amparav slide area
Investigation, Instrumentation and Monitoring of Kaliasaur Landslide on National Highway-58

As reported earlier, (Annual Report 2008-09), the project has been sponsored by Department of Science & Technology (DST) to suggest remedial measures for long term stability of Kaliasaur landslide on NH-58. The study was initiated four years ago. The final report along with suggestion of long term remedial measures for slope stability is submitted to DST. Important deliverables from the project work include topographic map of the area on a scale of 1:500 that served as the base map for many studies such as: large scale geomorphological, geological and structure map. It helped in creation of various data layers such as lithology, structure, rock mass and slope mass classes etc. and their geo-referencing with the base map and creation of digital terrain model from base map on a scale of 1:500. Draping the various data layers on the terrain model facilitated the virtual navigation, flight simulation and 3-D walk for understanding the terrain better, derivatives of terrain model (slope distribution map, aspect distribution map, water flow line analysis map). The geomorphic analysis and maps of the landslide area of different time frames by acquiring base maps from various sources, rock mass and slope mass characterization of the landslide area, rock mass and slope mass zonation maps of the landslide area based on the analysis of rock mass and slope mass characterization, stability analysis of main slide have been integrated for design of suitable remedial measures. The upward extension of the slide boundary has been shown in Fig. 5, indicates 20m extension from 1984 to 2009.

Experimental Test track with Cement Stabilization

This research project has been undertaken as an in-house research programme. In this study, design of road pavement is carried out using the cement stabilized materials in comparison with other available methods viz. South Africa method, Tanzanian method etc. to reduce the pavement crust thickness (saving of aggregates) and modify the present construction methodology of cement stabilization. Construction of experimental test track section of 60 m length (2 lanes) using cement stabilization is carried out on Amritsar-Wagha border road near Amritsar. In this construction, subgrade and GSB layers are stabilized with 2.5 per cent cement. Quality
check is carried out during the construction viz. quantity of cement, water content, mixing of cement, density etc. After construction of each stabilized layer, 7 days curing is carried out by covering the layers using next upcoming layer material. After 7 days of curing, sample of stabilized subgrade materials were taken out from the site and compressive strength of the sample is determined in the laboratory. Fig. 6 shows some of the construction steps such as laying of cement, mixing of subgrade and cement, density determination after compaction.

Pilot Project on Use of Jute Geotextiles in PMGSY Roads

As reported earlier, this project is being supported by Jute Manufactures Development Council (JMDC) as a sponsored research project with the objective to study efficacy of Jute Geotextile (JGT) for drainage, erosion control, capillary cut-off and subgrade improvement and hence performance monitoring forms an important component of this project. Under this project, construction of five PMGSY roads using different types of jute geotextiles has been completed in four states. Each of these PMGSY roads, comprises of several sub-sections in which JGT of different varieties (woven, non woven and open weave), of different strengths and rot treated as well as non treated varieties have been laid to study their relative performance. Control sections without JGT have also been constructed. A distinguishing feature of these test roads is the construction of reduced pavement thickness sections where in JGT as drainage improvement layer has been laid above subgrade. Presently the performance monitoring of these roads is under progress. The performance indicators which have been recognised for monitoring include – Benkelman Beam deflection studies, DCP tests at subgrade level, retrieval of JGT samples below pavement and tests on retrieved JGT samples and visual pavement surface condition evaluation for recording distress (Fig. 7 & 8). Performance
monitoring will be carried out for a period of 18 months.

revised guidelines encompass the review of soil stabilization which is the process whereby soils and related materials are made stronger and more durable by mixing with a stabilizing agent. Although many stabilizing agents can be used, cement and lime are by far the most important and the guidelines mainly concentrate on use of Lime, Cement, Lime-fly ash/Lime-cement fly ash as stabiliser. The guidelines include, general features of stabilization, guidelines for soil/granular material stabilization, specifications and test requirements for stabilised materials, construction procedure, quality control and limitations on the use of stabilised materials. These guidelines have been made considering prevailing Indian and International practices. The guidelines have been approved by IRC Council.

Consultancy Assignments

Soil Nailing Technique for Facilitating Construction of RUB by Box Pushing Technique at Western Approach of Old Yamuna Bridge

Delhi PWD is constructing a bypass ring road from Salimgarh Fort to Velodrome Road as part of Commonwealth Games works. This road is proposed to pass under west end approach of old Yamuna Bridge (Railway cum Road Bridge) and a Road Under Bridge (RUB) was proposed to be constructed below the existing railway line. The approach to the railway bridge has been constructed by providing rubble stone masonry retaining walls and backfilling Yamuna sand in between the retaining walls. Two parallel railway tracks pass over this backfill.

Guidelines for Soil and Granular Material Stabilisation using Cement, Lime & Fly Ash

The work of the preparation of guidelines was assigned by Indian Roads Congress. The
The height of retaining wall at approach embankment is about 6 m. The railway line, stone masonry retaining walls and the bridge are about 135 years old. Sub-soil investigation revealed that backfill in-between retaining walls mainly consists of silty fine sand ($c=0$, $\varphi=29^\circ$) upto natural ground level (NGL). Below NGL, there is conglomerated soil upto 2 m depth and there after stratum consists of fine sand upto 6 m depth. In the absence of proper records, cross section of retaining wall at one location was explored by adopting GPR technique. This GPR study showed that retaining wall may have a battered face towards earth side having thickness more than 2 m.

Construction of RUB consists of pushing under existing railway track, two numbers of RCC Boxes with internal dimensions (opening) of 10.5 m x 5.75 m each and one number RCC box of 9 m x 4 m, under existing railway track. Width of the embankment between the retaining walls is 15 m. These precast box segments of RUB are to be pushed in highly unstable cohesionless sandy soil backfill in between retaining walls. Also rubble stone
masonry retaining walls on the entry and exit ends of the box are required to be dismantled thereby exposing unsupported earth face of 7.5 m height which is prone to collapse. About 200 to 250 trains pass over this section daily, and there should not be any disruption to rail traffic in any case. To accomplish box pushing for construction of RUB, a novel methodology using ‘Soil Nailing’ has been adopted.

Soil Nailing consists of reinforcing the soil mass by the introduction of a series of thin elements called ‘Nails’ to resist tension, bending and shear forces. The reinforcing elements are made of steel round cross-section bars called as nails. Dismantling of the retaining wall was taken up and at the same time, a series of driven and grouted nails were driven into the sand mass for retaining the same. Box pushing and gradual removal of backfill sand was then taken up and simultaneously driven nails were further pushed inside the sand mass. In this manner, RUB construction has now been successfully nearing completion. Different periods of construction at site are shown in Figs. 9, 10, 11&12.

**Landslides on Dimapur-Kohima-Maram Road (National Highway-39) in Nagaland and Manipur States**

National Highway-39 is the only connecting route between Dimapur and Kohima (The state capital of Nagaland) and had been suffering from slope failures at various locations. The investigation work required geomorphological, structural and geological analysis along with the evaluation of geo-technical properties.
for designing suitable remedial measures to stabilize the slopes at various critical locations including km-162, 174, 179, 180 and 221 (Fig. 13) Topographic map of the area was prepared on a scale of 1:500. This map was used as a base map for the geological, geomorphological (Fig. 14), and structural mapping. Geo-technical evaluation of slope materials was done to perform the stability analysis. Remedial measures were suggested for the different sites on the basis of geo-technical evaluation (Fig. 15). Final report has been submitted to Border Roads Organisation.

**Protection of Unstable Cut slopes along Approach Roads and Railway Lines and Stabilization of the Proposed Dumping Sites**

Konkan Railway Corporation Limited has sponsored a study for protection of unstable cut slopes along the approach roads and railway lines and to stabilize the proposed dumping sites on Katra-Qazigund Section of Udhampur-Srinagar-Baramula Rail Link in Jammu and Kashmir. The objectives of the study included to design suitable remedial measures for stabilization of muck yards for dumping the construction waste from the tunnels (where dumping is already done), design of suitable methods for stabilization of muck yards (where dumping is proposed) and demonstration of the design implementation at two sites. In addition, guidelines for stabilization of the cut slopes along the approach roads and railway line are also to be prepared and submitted to sponsor for implementation.

Field investigations of three of the dumping yards have been carried out and the measures for their stabilisations have been designed for implementation. The dumping yard investigated is shown in Figs. 16, 17, 18 &19.
Design and Performance Monitoring of Test Road Constructed Using C&D Waste

CRRI had earlier carried out ‘Feasibility Studies on Use of C&D Waste for Road Construction – as an Embankment Fill Material, in Base/ Sub-base layers, for Bituminous and Concrete Pavements’ and had found this material to be useful for Base and Sub-base layers. Extending this laboratory work, test road construction of about 150 m length involving widening on both sides of existing road was taken up in
Delhi. The project has been sponsored by IL&FS Ltd. The test road is presently under construction (Figs. 20, 21 & 22) and its performance would be recorded for evolving suitable guidelines for C&D waste usage in road works.

Trials for Soil Compaction with Different Vibratory Rollers to Check their Compaction Efficacy

This study was entrusted to the Institute by JCB India Limited, Ballabhgarh, Haryana. JCB India Limited is one of the leading manufacturers of construction equipments in India, dealing in machines of various types including Soil Compactors, Tandem Vibratory Rollers etc. As a part of company’s continuous efforts to provide their Customers, the best products & services, the company intended to carry out certain trials at one of its site near Pune (Maharashtra), for soil compaction with two different types of vibratory rollers to assess their efficiency in terms of compaction achieved. The soil samples were collected and characterized for their physical and engineering properties from the site where trials for compaction were proposed.

At site near Pune (JCB factory at Talegaon) the test bed were compacted at OMC/MDD with two different types of vibratory rollers. Field density tests after different passes of vibratory rollers were conducted on the trial stretches. The comparison of the efficiency of rollers in terms of degree of compaction achieved and communicated to the Client.

Design and Construction of Embankment and Pavement Layers using Copper Slag.

As reported earlier (Annual Report, 2008-09), this study has been sponsored by Sterlite Industries (I) Pvt. Ltd., Tuticorin (T.N) for the design and construction of experimental test track of one km length using copper slag stabilized with pond ash/soil. Construction of embankment and subgrade using copper slag + soil and copper slag + pond ash is carried out on four lane road of NH-45B, Madurai to Tuticorin expressway. During the construction, quality of construction of different layers of the embankment and subgrade is carried
out by evaluating different parameters viz. density, moisture, proper mixing, thickness of layers, side cover, slope of side cover etc. in the field. Plate load and dynamic cone penetrometer tests were also carried out at different locations on the constructed layers to determine the strength of pavement layers. Fig. 23 (a & b) shows the plate load test and dynamic cone penetrometer test in progress on constructed embankment. Modulus of soil reaction is determined from the result of Plate load test on copper slag + soil mix and copper slag + fly ash embankment. It is observed that modulus of soil reaction is more for copper slag + fly ash mix compare to copper slag + soil mix embankment. Further work is in progress.

**Feasibility study of Jarofix in the Construction of Embankment and Subgrade.**

This project is sponsored by Hindustan Zinc Limited, Chanderia, Chittorgarh (Rajasthan) to study the potential of Jarofix as an embankment and subgrade material with or without stabilization (soil/bottom ash). Jarosite is a waste material produced during extraction of zinc from zinc ore concentrate by hydrometallurgy operations at Hindustan Zinc Ltd. The Jarosite is then mixed with 2 percent lime and 10 percent cement is termed as Jarofix. Fig. 24 shows the dumped Jarofix waste material nearby plant and Jarofix slope stabilised with grass. Detailed geotechnical investigation of Jarofix, soil and bottom ash is carried out. Also, the jarofix material was mixed with local soils and bottom ash in the range of 25 to 75 percent and their geotechnical characteristics were evaluated. Geotechnical parameters of jarofix, soil, jarofix:soil and Jarofix:bottom ash mixes are evaluated and compared with standard specifications of MORTH/MORD for the construction of embankment and subgrade. Geotechnical parameters of jarofix, soil and jarofix:soil mixes evaluated by the laboratory investigation is given in Table. II. The project is under progress.
Table II Geotechnical Properties of Jarofix, Soil and its Mixes with Standard Specification for Embankment

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<td>1</td>
<td>Maximum grain size (mm)</td>
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<td>&lt; 75 mm</td>
<td>&lt; 75 mm</td>
<td>&lt; 2/3 of Compacted thickness</td>
<td>&lt; 75 mm &lt; 2/3 of Compacted thickness</td>
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<tr>
<td>2</td>
<td>LL (%)</td>
<td>59</td>
<td>47</td>
<td>39</td>
<td>35</td>
<td>34</td>
<td>&lt; 70</td>
<td>&lt; 70</td>
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<tr>
<td>3</td>
<td>PI (%)</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>&lt; 45</td>
<td>&lt; 45</td>
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<td>4</td>
<td>Dry density (kN/m³)</td>
<td>16</td>
<td>16</td>
<td>17.6</td>
<td>20</td>
<td>20</td>
<td>&gt; 15.2 kN/m³ upto 3 m height</td>
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<td></td>
<td>&gt; 14.4 kN/m³ upto 3 m height</td>
<td>&gt; 14.4 kN/m³ more than 3 m height</td>
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<tr>
<td>5</td>
<td>FSI (%)</td>
<td>10</td>
<td>10 - 7</td>
<td>10 - 7</td>
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<td>7</td>
<td>&lt; 50</td>
<td>&lt; 50</td>
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<tr>
<td>6</td>
<td>Remarks</td>
<td>Jarofix alone and mixed with soil may be tried for the construction of embankment</td>
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Feasibility Study of Steel Slag Usage in Construction of Embankment and Pavement Layers

This project is sponsored by Goa State Pollution Control Board, Goa. The solid waste which is used in the study is generated as a by-product, during the melting process of mixed materials viz. steel scrap, sponge iron, pig iron, ferro-silicon, silico-manganese and Al-shots is termed as steel slag. Detailed laboratory investigation is carried out to investigate the feasibility of steel slag usage in the construction of embankment and pavement layers with or without stabilisation (local Goa soil). Laboratory investigation is carried out viz. grain size, Atterberg, FSI, Proctor density, Shear...
strength test, CBR test, water absorption, AIV etc. It is observed that steel slag may be tried as an experimental basis in the construction of embankment, subgrade and replacement of aggregate in GSB layers. Fig. 25 shows the steel slag generated in the plant. Steel slag contains around 80 percent sand size particles. Laboratory investigation reveals that it has specific gravity of 2.75, Proctor compaction density = 23.5 kN/m³, OMC = 8 percent, CBR = 70 percent and AIV = 40 percent.

Fig. 25  View of generated slag

Design of Approach Embankment to Signature Bridge across Yamuna River, Wazirabad

The Government of Delhi has entrusted construction of Signature Bridge and its approaches at Wazirabad across River Yamuna to Delhi Tourism & Transportation Development Corporation Ltd. (DTTDC). The eastern approach of this bridge comprises of an embankment of about 1.8 km length and flyover at Khajuri Khas intersection. During September 2008, flooding of the Yamuna basin occurred due to torrential rains. A part of the stretch in which embankment is to be constructed, was still submerged in water even in March 2009. Water stagnation was particularly severe in the stretch nearer to Khajuri Khas intersection (Bhajanpura side) with standing water of about 2 to 2.5 m above ground level. DTTDC approached CRRI to provide design and construction methodology for approach embankment to Signature bridge across Yamuna river, Wazirabad. Detailed field investigations including SCP tests at the proposed site to obtain sub-soil strength profile has been carried out (Fig. 26). Samples of proposed fill materials like pond ash, local soil and Yamuna sand were collected and were subjected to various tests to determine their physical and engineering properties. The stability analysis for the approach embankment to Wazirabad Bridge was carried out using the stability analysis software available in CRRI. The stability

Fig. 26  SCP test being carried out at Signature bridge approach embankment site
analysis showed that embankment side slope of 1V:2.5 H with a berm of 4 m width to be provided at a height of 4 m from ground level would be the most appropriate choice.

A novel construction methodology involving back-dumping of pond ash directly into water pond was also devised. DTTDC has now taken up construction of embankment in water pond area. The embankment under construction successfully withstood floods in Yamuna River in Sep 2009. Presently the construction work is under progress. Typical cross section of proposed embankment is shown in Fig. 27.

**Construction and Quality Control of Approach Embankment to Signature Bridge across Yamuna River, Wazirabad using Fly ash**

The Government of Delhi has entrusted construction of Signature bridge and its approaches at Wazirabad across river Yamuna to DTTDC. The eastern approaches mainly comprise of an approach embankment starting from Khazuri Khas intersection. DTTDC entrusted the work of quality assurance to CRRI. Random checks on the quality of works are being carried out. Advice and guidance regarding quality of works/construction are also being provided to DTTDC. Fig. 28 shows the Flyash embankment construction in water logged area.

**Design of Road Embankment in Submerged/Flood Affected Border Areas of Bhuj, Gujarat**

The National Buildings Construction Corporation Ltd (NBCC) has been entrusted with the responsibility of constructing ‘Border Fencing and Border Roads’ along a part of our country’s International border in Gujarat. India’s International border in Gujarat is situated in Rann of Kutch where Arabian Sea water transgresses and regresses frequently leaving inland marshy and swampy, dotted with small to very large salt water bodies. During the monsoon of 2006, unprecedented rainfall occurred in the border areas of Gujarat and Rajasthan. As a result, large areas were inundated and floodwaters overtopped the border road and border link road at many locations causing heavy damage to the pavement, shoulders and embankment slopes. Due to marshy conditions, it was not even possible to reach these locations to make an assessment of site conditions till now. However,
with drying up of stagnant water over last three years, NBCC requested CRRI to undertake field visits and suggest suitable construction methodology along with embankment design/ slope protection measures for the areas which were hitherto inaccessible. A view of border road to be constructed is shown in Fig. 29. CRRI team carried out extensive field work, recording the damages to embankment and road pavement, site conditions and after analysis of data, design of erosion control measures was carried out. The remedial measures broadly comprise of energy dissipation armour system of gabions and geotextiles to prevent loss of soil. Methodology for construction of border road embankment in a patch of the stretch which is still submerged in water was also devised.

Preparation of Guidelines for Construction of Roads, Culverts and Bridges in Cyclone Prone Areas

Cyclone affected areas of our country are mainly lying in the Gujarat, and all along the eastern coast from West Bengal to Tamilnadu. In the cyclone affected areas, torrential rains follow the occurrence of cyclones, which usually results in floods. Cyclonic winds, which causes high sea waves inundate coastal region deep into the main land. Therefore, constructions of civil engineering structures such as roads, culverts, and bridges, which already need safety precautions in the coastal areas due to the marshy nature of land, further require extra measures to avoid damages due to the
cyclones. At the instance of National Disaster Management Authority, this project was taken up to prepare guidelines for construction of roads, culverts, and bridges in cyclone prone areas, which would be useful for the cyclone prone areas of our country. Compilation of guidelines is under progress.

**Investigation and Design of Roads in Visakhapatnam Port Trust, Visakhapatnam**

The work of investigation of four roads which were failing prematurely due to movement of heavy and multi-axle loaded trucks and poor bearing capacity of sub soil was sponsored by Visakhapatnam Port Trust. In addition to above, investigations were also carried out on sites where new roads were proposed. In order to carry out the field investigations and to assess the causes of failure, a team of scientists visited the site.

During the field investigations, test pits were made in the existing roads and their conditions were observed. The soil and material samples of the different pavement layers were also collected for detailed laboratory investigations. The sub soil samples (both disturbed /undisturbed) were also collected for determining their geotechnical characteristics. In addition to the pavement investigations, information was also collected regarding the traffic and drainage condition on the road. Similar types of investigations were also carried out on the new proposed roads. Based on the consolidation characteristics of soft subsoil, the estimated total consolidation was calculated and in order to minimise the time of consolidation, some ground improvement methods Stone Column, Stage construction and Band drains were suggested. Ground improvement using vibro stone column technique (wet method) was proposed for the faster consolidation of sub soil and for increasing the bearing capacity of sub soil. Both the flexible and cement concrete pavements along with their design and construction methodologies were proposed for new sections as well as on the existing sections. Figs. 30, 31, 32 & 33. show typical road section, material usage, failure and remedial works at Visakhapatnam Port.

*Fig. 30 Failed berth on the sea side*

*Fig. 31  Repair of failed section of in-use two lane road by concrete blocks*
Fig. 32 View of 3rd tippler approach of H2 drive House in OHC along East side of S1 conveyor

Fig. 33 Iron ore material on the surface H6 to SBC Road at OHC