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Design of Parking Lot Pavement for Heavy Container Carriers with Geosynthetic Reinforcement – Case Study

Y.R. Patil, Strata Geosystems (India) Pvt. Ltd., Mumbai, India
S.D. Vedpathak, Strata Geosystems (India) Pvt. Ltd., Mumbai, India
S.P. Bagli, Strata Geosystems (India) Pvt. Ltd., Mumbai, India
G.N. Dalmia, Strata Geosystems (India) Pvt. Ltd., Mumbai, India

ABSTRACT

This Paper presents a case study for the design of a parking lot using geosynthetic reinforcements. The parking lot is essentially for standby heavy container carriers at one of the container yards at Nhava-Sheva Port in Navi Mumbai, India, operated by the Jawaharlal Nehru Port Trust (JNPT). The site is along the West Coast of India adjacent to the Thane Creek and experiences the full brunt of the South West monsoons. The subsoil comprises of reclaimed soil fill overlying the typical Bombay residual Marine Clay to a greater depth. Conventionally, a pavement section comprising of dry paver blocks followed by dry lean concrete and granular subbase was proposed. To facilitate fast construction along with an economic solution, a flexible pavement including geosynthetic reinforcements was provided below the surface paver blocks. The geosynthetics included High Density Polyethylene (HDPE) geocells for load bearing and Polypropylene (PP) geogrids for traction forces. The HDPE geocells are rhomboidal cellular confinement systems fabricated from ultrasonically welded, textured and perforated strips. Geocells have the characteristics of spreading vertical force over a wider area, thereby reducing the bearing pressures on the subgrade. Geocell perforations also help in providing drainage to the pavement section below the surface. A layer of biaxial rigid geogrid was also incorporated in the sand layer, a component of the flexible pavement section. The geogrid was provided to address deformations that can be brought about due to traction when the heavily loaded vehicles take turns, accelerate and brake on the pavement. French drains have also been provided to cover uninterruptedly paved vast area which experiences heavy rainfall. The construction of 33 hectares of the parking area commenced on November 2017 and the areas were released for use in phases from August 2018.

1. INTRODUCTION

Nhava Sheva port, managed by the Jawaharlal Nehru Port Trust is the largest container port in India. It is on the mainland of the island of Mumbai. The existing Mumbai port on the island can no longer handle the ever-increasing commerce and hence this port was established across the harbor. The port has been established on reclaimed land by filling from material borrowed from the nearby hills, comprising of residual highly disintegrated highly weather rock locally known as murum. The port handles heavy container traffic. This requires access and parking area for multi-axel high powered container carriers. These pavements are designed keeping in mind the long-term performance requirement of the roads and parking lot.

The Port area receives very heavy rainfall. The average annual rainfall is as high as 1,800mm, with a historical maximum rainfall of 548mm over 24 hours in the recent past. Owing to the locational and mandatory environmental constrains, use of conventional materials was difficult considering the cost of transportation. Various options were proposed by the Consultants to improve the geotechnical parameters of the existing reclaimed sub-surface for the parking area. The option considering geosynthetic reinforcement along with paver blocks for the road pavement sections was considered as the optimal solution both economically and technically.

Similar approach has also been applied for container yards, container carrier parking lots, approach roads and bulk storages at Sao Paulo (Brazil), Kandla Port, Bangalore, and Kidderpore Docks at Kolkata in India (Vedpathak et al. 2018).

1.1 Overview

The site location with respect to the city of Mumbai has been shown in Figure 1 below. The image on the left side shows aerial view of the Mumbai city and the location of the port with respect to the city and west coast. The image on the right side shows enlarged view of the port location and parking lot at the site.

a) Aerial view of Mumbai with marking of port location b) Enlarged view of port location

Figure 1 Location of Nhava Sheva port (Courtesy: Google Earth)

2. ISSUSES AND SOLUTION

The main concern of the site was to provide a pavement section considering the low safe bearing capacity of the site location. It was essential to provide a heavy section or to reduce the pressures from top to make sure that the loads transferred to the ground will not cause deformations beyond limiting values over the service life of the area. The conventional section proposed by consultant was to top the fill by 300mm granular sub-base and this would be overlaid by 300mm dry lean concrete layer. The concrete layer would be topped by 100mm thick concrete paver blocks with 50mm sand for levelling purpose. This section has been shown in Figure 2 below.

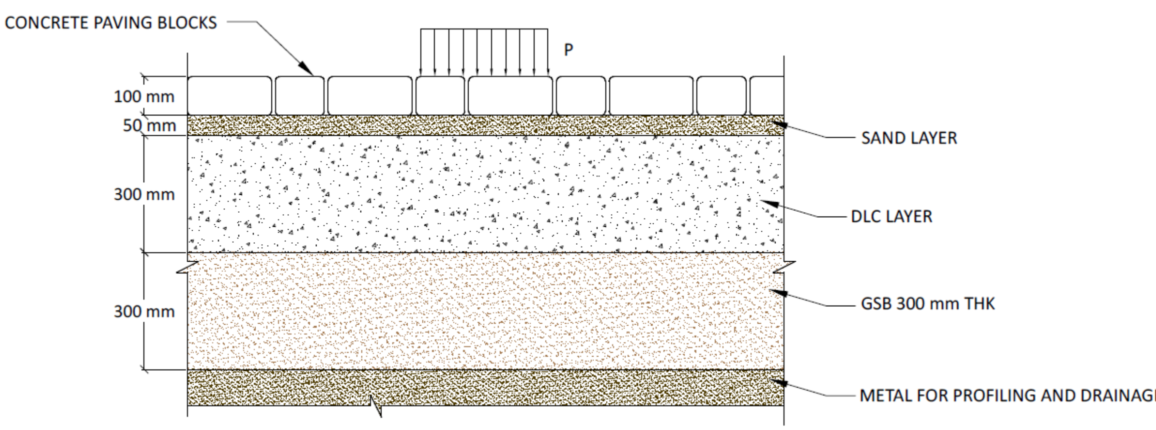
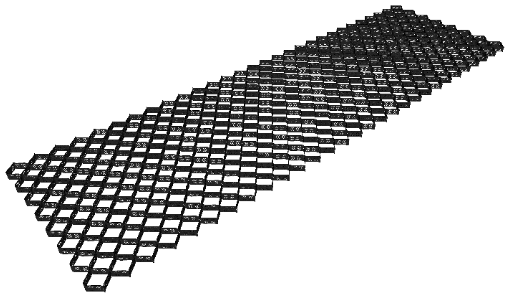


Figure 2 Conventional proposed section for parking lot

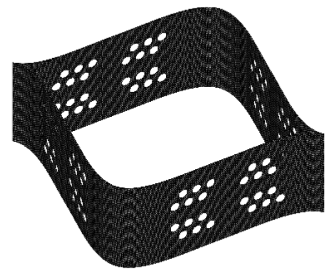
One method of reducing finite loads is to spread the load over a larger area. From this consideration, geocells were recommended. Furthermore, considering the heavy powered vehicles plying over the area which would generate heavy traction and turning forces, rigid geogrids were also considered within the section to maintain the integrity of the surface.

2.1 Geocells

Geocell is a three-dimensional, lightweight, rhomboidal shaped confinement system. Geocells used in this project are fabricated through ultrasonic welding of strips made of High Density Polyethylene (HDPE) material. Geocells being three dimensional, they can spread the loads on a wider area and help in reducing the thickness of overall section with conventional natural materials. A typical cell of geocell and panel of geocell has been shown in Figure 3 below.



a) 3D view of expanded panel of geocells



b) 3D view of single cell of geocell

Figure 3 Geocells

2.2 Geogrids

Geogrids considered in this application of resisting planer forces are rigid geogrids. These geogrids are manufactured from extruded Polypropylene. The geogrid develops resistance to horizontal traction forces through interlocking and tension within the geogrid which gets its anchorage through interlocking with the fill material.

2.3 Proposed Solution

A solution was proposed by the Authors with the use of geocells and a layer of biaxial geogrid to provide economical solution in terms of both cost and time and the same was approved by the consultant. The proposed pavement section consisted of one layer of geocell, infilled with granular sub-base material and topped with another 150mm thick granular sub-base layer as seen in Figure 4.
This top 150mm thick granular sub-base layer was reinforced with one layer of rigid biaxial geogrid. This biaxial geogrid was provided to ensure the pavement does not deform under the vehicular movements such as acceleration, breaking and turning over the paver blocks. This layer was overlaid with a sand layer and paver blocks to finish the top surface. A nonwoven geotextile separator was provided below the sand layer for separation between sand and granular sub-base material.

3. ANALYSIS

The geosynthetic designers carried out a comprehensive analysis of the pavement section considering the dynamic and static loading of the container vehicles over the design service life of the pavement. The class of vehicles for container carriers are considered as per IRC 6 Section II. Geocells were used in the design to spread the vehicle tyre pressures over a wider area and hence to reduce the thickness of the conventional pavement section. The major change in the geosynthetic reinforced section from the conventional one was to remove the dry lean concrete layer completely. Removal of dry lean concrete layer did not only help in economizing the section but also helped in saving the time as concreting a large area is a very time-consuming process.

Considering the area is reclaimed land, the paved area may experience differential settlements which would be further noticeable with the fracturing of the dry lean concrete. The flexibility of the geocells help in smoothening the effects of differential settlements on the paved surface. This is an added advantage to the system which provides long term benefit, as maintenance cycle repetitions can be reduced to a large extent. The geosynthetic reinforced section provided has been shown In Figure 4 below.

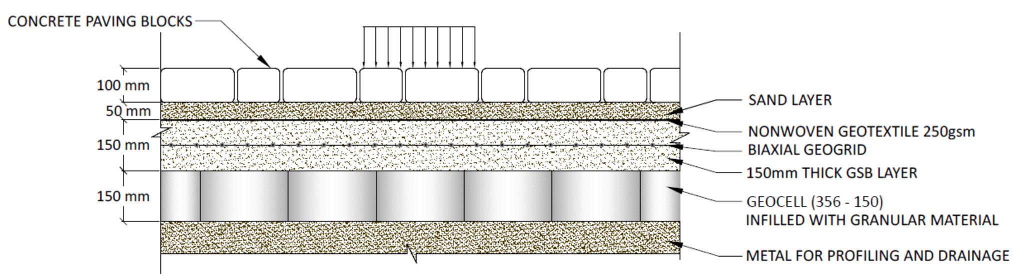


Figure 4 Final adopted section

The section illustrated in Figure 4 above consists of following layer top to down –

1. Concrete paver blocks (100mm thick)
2. Sand layer (50mm thick)
3. PET Nonwoven geotextile (150 gsm)
4. 150mm thick granular sub-base layer
5. Biaxial geogrid within the 150mm thick GSB layer
6. 150mm deep geocell layer with 356mm weld spacing infilled with granular sub-base layer

Analysis showed that the reduce pressure below the designed pavement section was well within the safe bearing capacity of the original ground.

4. CONSTRUCTION

Construction sequence of pavement at the Port using geocells is shown in Figure 5 sequentially.

a) Dressing of Subgrade

b) Laying of geocell panels

c) Infilling of geocells

d) Laying of Paver blocks to finish the surface

e) Aerial view (Google Earth) of construction of final stage of geocells laid

Figure 5 Construction Sequence

Construction of phase 1 started in November 2017 and the phase is in operational condition as shown in Figure 6 below from the google earth view dated, May 2019.

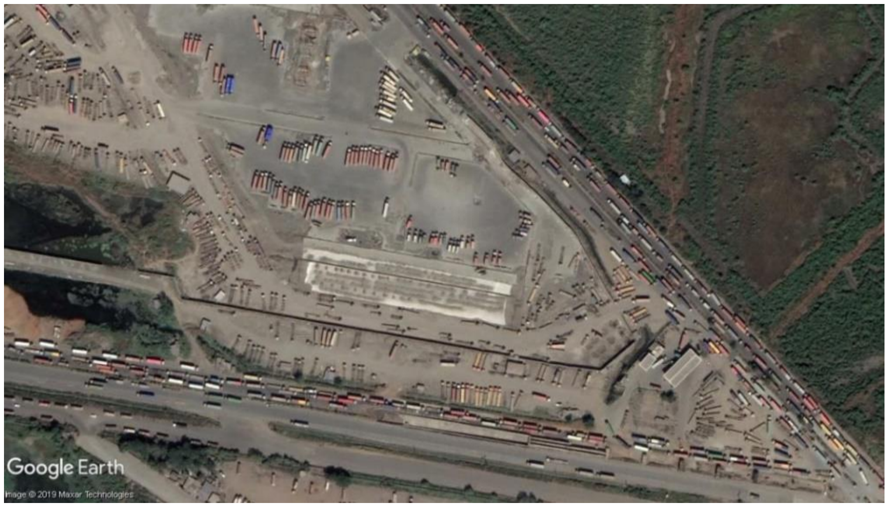


Figure 6 Google Earth view - Completed Phase 1

The completed phases of the parking lot are functional since August 2018 and this has sustained over the heaviest monsoon season since the rainfalls have been recorded over the past 65 years in the year 2019 without any signs of distress considering that the geocells and french drains also acted as excellent drainage material.

5. PERFORMANCE

The objective of the engineering of the paved surface with geocells and geogrids is to provide a distress-free surface notwithstanding heavy container carrier movements which would include heavy acceleration and breaking and sharp turning circles. A site review of the performance after 18 months of operation indicates paver block surfaces without distress as seen in Figure 7 below. The site has experienced two monsoons which are heavy in the Konkan region with the latest rainfall season experiencing. The performance may be compared with an adjoining area where no reinforcement was used and the surface experienced distress in the form of local deformation and displaced paver blocks.

Figure 7 The paved surface including turning circles with heavy container carrier traffic, after 18 months of operation

6. CONCLUSION

In adverse geotechnical conditions of reclaimed land over very soft marine clay in tidal areas, it is possible to provide for heavy transient loads without the heavy stress reaching the weak soils using geosynthetic reinforcements in the section. Geocells have proven to be excellent in this application as geosynthetics help to spread load over the wider area. The rigid geogrids have helped in sustaining the pavement surface over the heavy powered vehicle traffic. With the use of the section with geocells, the conventional DLC was eliminated which reduced the cost, reduced the time of construction and improved the sustainability of the section.

7. ACKNOWLEDGMENTS

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