Soft Ground Improvement using PRS Neoloy Geocells and Biaxial Geogrids for Critical Oil Roads in Hoima, Uganda (Case Study based on Hoima-Butiaba-Wanseko Road Project 111Km)

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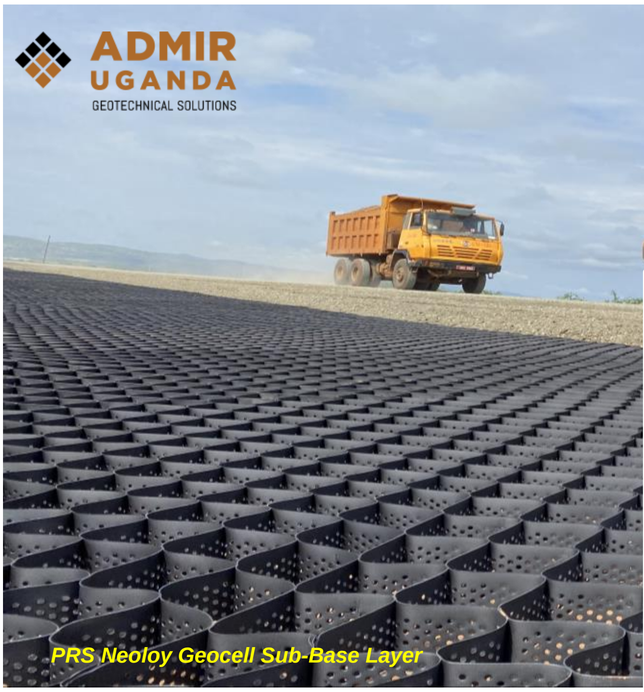


PRS Neoloy Geocell Sub-Base Layer

Geogrid Layer for Subgrade Improvement

The Road Project Details

The Hoima-Butiaba-Wanseko Road (111km) is situated in the Oil rich Albertine Graben (Bunyoro Region) and is part of the National Roads Network linked to the rest of the network by Hoima - Kiboga road (95Km) and Masindi – Biiso road (51km). The road lies in Hoima and Buliisa Districts and connects Hoima City to the shores of Lake Albert at Wanseko. The road passes Hoima Town council, sub counties of Kitoba, Kigorobya and Biiso in Hoima district and Buliisa and Wanseko in Buliisa District where oil exploration is underway.
The road project is currently under construction by Chongqing International Construction Corporation Uganda (CICO) under supervision by UNRA.

Admir Uganda Ltd; a subsidiary of Admir Africa and Admir Technologies (Israel) provided the Design Review Solution and Material Supply. Dynaco Ltd was the nominated subcontractor for the specialist Geogrid and Geocell material installation. PRS Geo-Technologies (Israel) is the manufacturer of PRS Neoloy Geocells and aided in the Pavement Design Review and supply of the Neoloy Geocells installed.

The Project Challenge

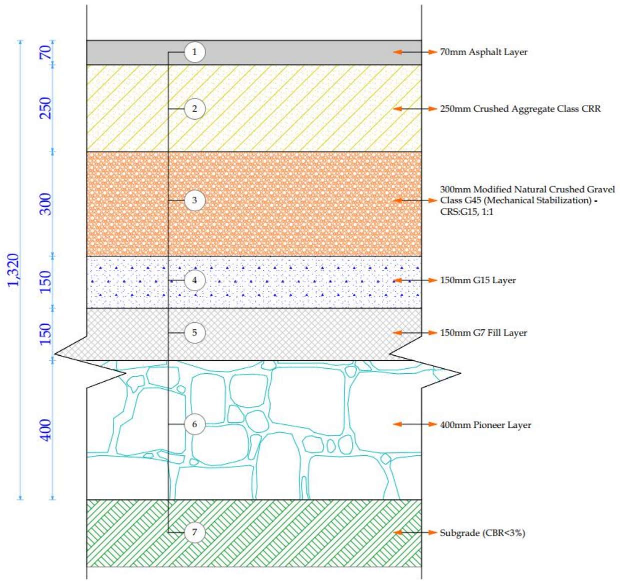
The in-situ subgrade of the road from km 44 was generally poor continuously characterised by silty soils of low CBR (<3%) lying in the western Rift Valley flood plains. The conventional construction approach of roads in the vicinity had shown early subgrade failures and movements in areas where embankments were built over weak subgrade.

The Design Review

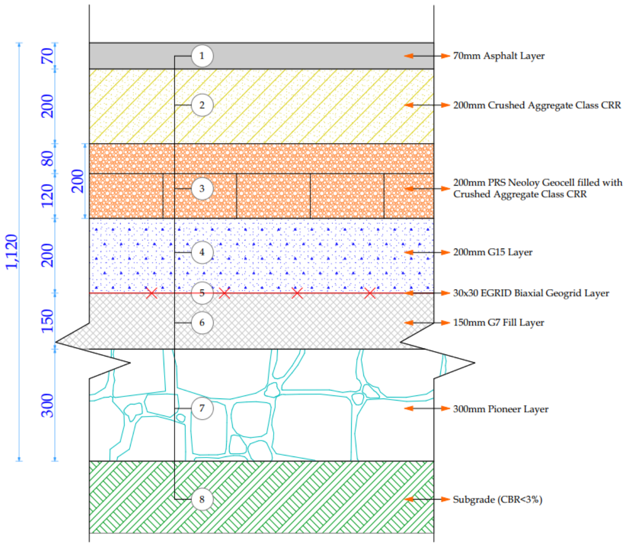
A pavement structure review was undertaken in accordance with International Standards (BS8006, EBGEO, EN 14475) and MoWT Road Design Manuals, 2010 to develop an optimized pavement incorporating Geogrids and PRS Neoloy Geocells using the mechanistic empirical design approach. The design considered surface deflection, fatigue, rutting, vertical compressive strain on the subgrade, consolidation and settlement analysis.

The Solution

The sections characterized by silty soils were improved through the incorporation of a stiff layer of Geogrids at the subgrade and Geocells at the subbase to take up the tensile stresses generated in the embankment. This objective was to minimize total and differential settlement in the pavement. Other intended benefits were; reduction of total pavement thickness, cost savings from rock fill depth reduction, faster construction, improvement of native subgrade modulus with an approximate factor of seven and improvement of pavement durability through reduced maintenance cycles.



Original Design Pavement Structure



Revised Geosynthetic incorporated Pavement Structure

Existing Subgrade Condition

Pioneer Layer Preparation

Installation of Geogrid Upper Subgrade Layer

Installation of PRS Neoloy Geocell Sub Base Layer

Finished & Compacted Base Layer

Installation of Final Asphalt Layer

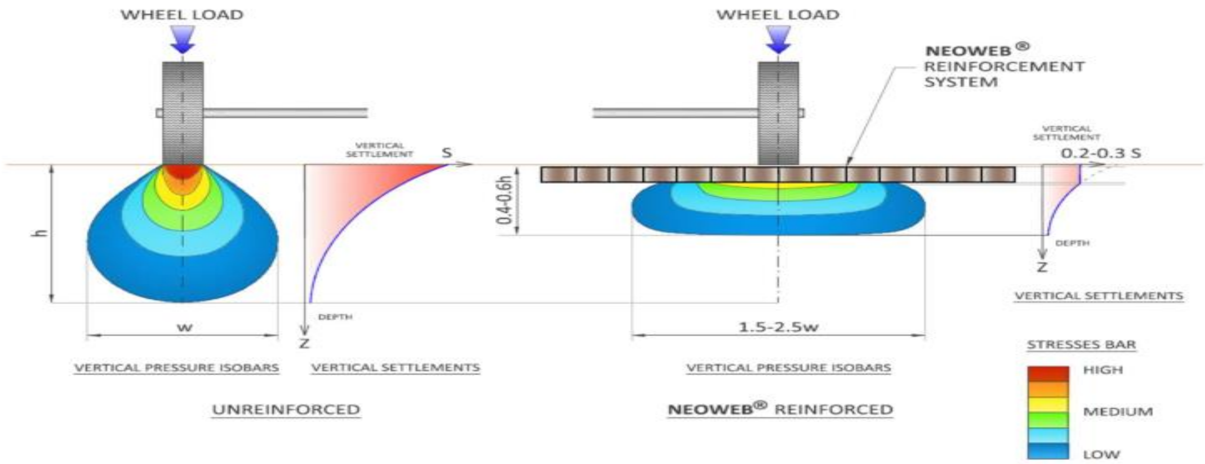


Illustration of PRS Neoloy Geocell Effective Reduction of wheel Load Vertical Pressure

Key Pavement Design Data

The problematic section of the project road lies in the rift valley with a subgrade comprised of stiff silty clay, sandy clayey silt or silty sand near the water front. The CBR values determined in the field by DCP mainly ranged from (<3% - 56%). Laboratory determined values ranged from 1% to 12.0% at a compactive effort of 93% AASHTO T180. The plasticity index of these subgrade material ranged from low to intermediate plasticity (11.0% to 22.0%). Occasionally, some of the silty clay soils plasticity index exceeded 30%.

Traffic loading was determined using estimates of traffic and growth rates predicted for the road over a 20-year design life. Two pavement types (DBST - Double Bituminous Surface Treatment and AC – Asphalt Concrete) based on Ministry of Works & Transport Pavement Manual (January, 2010) had been recommended.

The Design Criteria involved;

1. Subgrade Analysis, Surface and Modulus Factor Improvement (SIF and MIF).
2. Pavement Classification.
3. Traffic ESALs (Equivalent Single Axle Loads)
4. PRS Geocell Reinforcement Calculation and Design Infill.
5. Pavement Structure (Improved Modulus Factor, Ratio, Design Loads & Improved Bearing Capacity of Individual Layers).

3 | SUBGRADE

Wet/saturated Condition

California Bearing Ratio: $CBR^{w}=$ 2.50 %

Resilient Modulus: $M_R^{w} =$ 31.6 MPa = 4,589 psi

Duration of Wet/saturated Condition: $Dur^{w}=$ 6.0 months/year

Dry/frozen Condition

California Bearing Ratio: $CBR^{d}=$ 3.00 %

Resilient Modulus: $M_R^{w} =$ 35.6 MPa = 5,156 psi

Duration of Dry/frozen Condition: $Dur^{w}=$ 6.0 months/year

Relative Damage

- For Wet Season: $u_f^{\,w} = (1.18\times10^{8})(M_R^{\,w})^{-2.32}$ = 0.37739

- For Dry Season: $u_f^{\,d} = (1.18\times10^{8})(M_R^{\,d})^{-2.32}$ = 0.28789

Average Relative Damage: $u_f^{\,avg}=$ 0.33264

Design Resilient Modulus: $M_R = \left[\dfrac{u_f^{\,avg}}{(1.18\times10^{8})}\right]^{-1/2.32}$ = 33.4 MPa = 4,845 psi

Design California Bearing Ratio: CBR = 2.72 %

Calculation Data for Subgrade Modulus and Design CBR

The analysis of PRS-Neoweb Reinforcement System is based on the principles of modulus improvement of reinforced material and on the subgrade improved bearing capacity for reinforced pavement.

The Geocell design approach is based on research projects and theoretical methods from a large-scale research named ***"Design of PRS Neoweb Geocell Reinforced Bases"*** conducted by Prof. Jie Han, Xiaoming Yang, Robert L. Parsons and Prof. Dov Leshchinsky. The study examines the behavior of PRS Neoweb Reinforced Bases in general, and also over a soft soil. The study presents the methodology for paved and unpaved roads. Asphalt paved road is the basis methodology for the subjected design.

Conclusions and Recommendations

The key objectives achieved in the project design review and incorporation of Geogrids and PRS Neoloy Geocells are;

1. Reduction of the pavement thickness.
2. Use of locally available fill material as infill to the Geocells (G45 Blend).
3. Thinner Pavement structure thus faster construction and lighter weight on subgrade.
4. Improved road performance thus lower maintenance cycles.
5. Confined drainage system (Through the confined Geocell layer of CRR).
6. Reduced residual stress action on subgrade

Recommendations for construction of roads in weak soils;

1. Incorporation of Geotextiles (Geofabrics) as a filter and separation layer at the subgrade before embankment fill. This prevents the effect of pumping of fines into the coarser layer.
2. Use of rock fill as a stabilizing layer to create a platform in the weak soils. However, the incorporation of geosynthetics offers a reduction in the depth of rock fill in such weak soils through the improvement of the subgrade capacity.
3. Incorporation of stiff multi layers of Geogrids or Geocells in order to attenuate the shear stresses generated from traffic axle loads. These further offer savings through reduction in the thickness of the pavement structure and improve pavement durability.
4. Use of Wick Drains (Vertical Drains) to facilitate accelerated consolidation for road construction in weak soils. Vertical Drains act as alternatives to surcharge loading where the voids and moisture contained in the sub surface layers are drawn to the soil surface using geofabric wicks drains in the ground. Maximum consolidation is achieved through this mechanism faster to enable construction of the pavement structure.

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