Title: **CAUSEWAY DESIGN WITH NEOWEB GEOCELLS**

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ABSTRACT

Geocells have been successfully used since the 1970s in different geotechnical applications. Over the years, different materials were experimented with to make geocells; paper, cardboard, bodkin bars, and aluminum were some examples before the high density polyethylene cells came into the picture. Neoloy based geocells commonly known as Neoweb are the latest example in this series. Neoloy is a nano-composite alloy of polyester/polyamide nano-fibers, dispersed in a polyethylene matrix. A 200m long and 6.5m wide unpaved causeway was designed and constructed with Neoweb reinforcement in the Algar Lake area in Alberta, Canada. The road level was lowered to allow clear passage to oversized load carrying trucks. The maximum design load was 280,600kg on 14-line 3.05m (10ft) wide road style Scheuerle trailers. The road alignment followed very weak subgrade known as muskeg which is prevalent in the Northern oilfields in Alberta. The water table is close to the existing ground level. The designed top of the causeway was 1.5m below the existing ground level. A layer Geomembrane was also used to control the flow of water into the causeway. The design was good for the causeway and opened up future avenues for the use of Neoweb. This paper discusses the design, construction and performance of the Neoweb-reinforced causeway.

THE PROJECT

Canada has the world's third largest hydrocarbon basin in the oil sands region of Alberta. The oil sand projects are typically located in the region of very weak top soil. Organic soil (peat or muskeg) extending to a depth of 5m with water content

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up to 400% is common in these areas. The project reported in this paper is located in the Algar Lake area (the location is shown in Figure 1) on the west side about 15km off Highway 63. The geotechnical report along the access road showed that the majority of the alignment passed through weak subgrade, the muskeg in some area extended to a depth of about 6m with the water table at many places right at the ground surface. The access road performed well during winter but the spring thaw brought consistent driving problems. Transport of heavy and huge modules to the drilling site before summer of 2012 was planned. The loads to be carried on a 14-line 10ft-wide (3.05m) hydraulic Scheuerle trailer had gross weight of 280,600kgs and height and width of 7.7m and 6m, respectively. The access road passed under a 144kV Power line where a minimum clearance of 10m from the top of the road surface was desired. This requirement left two options for the project; 1) to raise the power line or 2) to lower the road surface. As there was no immediate possibility of raising the power line the second option was chosen with Neoweb reinforcement for the road base. A 200m long causeway was designed and constructed in March 2012.

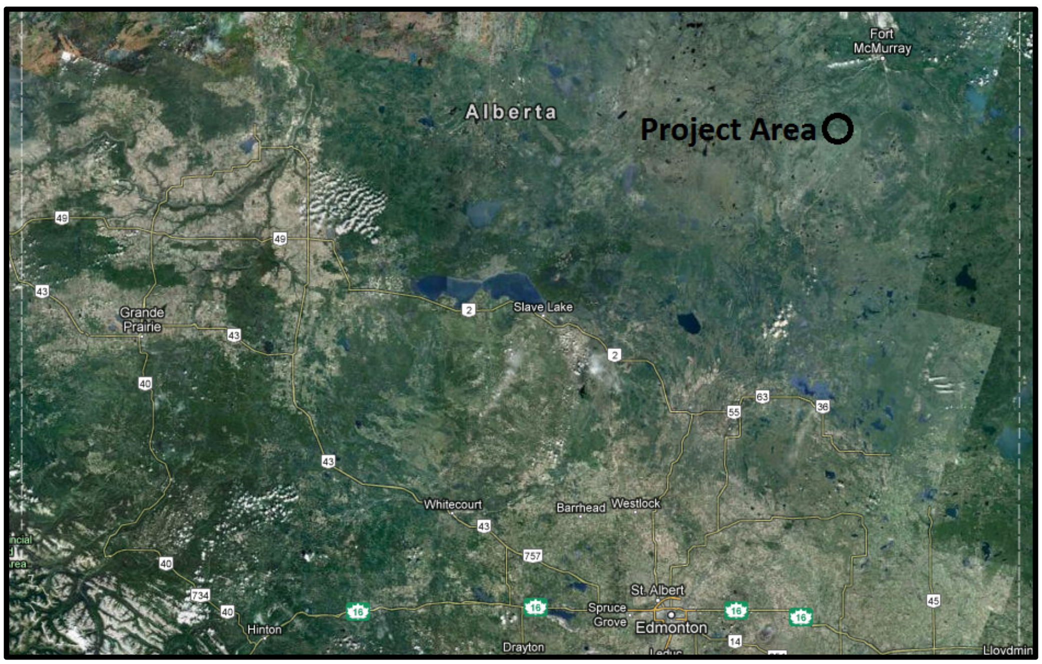

Figure 1: Project Area in Alberta, Canada [1]

Along with designing the causeway with enough passage to support the heavily loaded traffic, there was a challenge to control the water seeping into the causeway resulting from high water table which was about 4m higher than the side ditches of the causeway. The existing road did not have any drainage system and the location was close to the natural drainage line. Therefore, the causeway was designed with geomembrane to control the seepage. The geomembrane liner was provided between existing muskeg and clay fill. Drainage ditches on both sides of the road section were provided to collect the water falling inside the cause way, the water was pumped out using sensor controlled pumps. The other challenge was to restrict the road width within the right of way. The road width was reduced to 6.5m from 8m and a steeper side slope was chosen compared to the existing road. Overall this arrangement performed effectively in controlling the seepage. However, as the purpose of this paper is to discuss the Neoweb-reinforced unpaved road section, the seepage control part of the design is not discussed here.

The unpaved section of the causeway was designed as Neoweb-reinforced gravel. This paper discusses the design, construction and performance of the Neoweb-reinforced causeway.

NEOWEB BACKGROUND

Use of Geocells that started in the 1970s was mainly intended to stabilize beach sand [2]. Over 40 years of experience, numerous research and practical applications of the geosynthetic soil confinement cells have led to better understanding of the reinforcement mechanism behind the honeycomb cellular structure. Over the years, different materials were experimented with to make geocells; paper, cardboard, bodkin bars, and aluminum were some examples before the high density polyethylene cells came into the picture. Neoloy based geocells commonly known as Neoweb are the latest example in this series. It is a polymeric nano-composite alloy of polymer/polyamide nano-fibers dispersed in a polyethylene matrix, which is manufactured by PRS Mediterranean, Inc. in Israel. A series of recently conducted laboratory static and cyclic plate loading test and moving wheel tests with accelerated pavement facility on Neoloy based geocells at the laboratories of the University of Kansas and Kansas State University had suggested benefit of Neoweb-reinforced road bases in terms of reduced rut depths, improved stiffness and bearing capacity and wider load distribution [3, 4, 5, 6, 7, and 8]. Based on the findings of those tests a design method for Neoloy based Geocell-reinforced unpaved roads has also been suggested [3]. Details on Neoweb can be found in many recent research publications [3, 4, 5, 6, 7, and 8].

Design of Neoweb-reinforcement for load support in the road base of paved and unpaved roads, haul roads, slope protection works, crane pads, tank foundations, driveways, and laydown areas has been successfully done in Alberta. In the Albertan oil sand area good quality road construction materials are either difficult to find or very costly. In such cases Neoweb that can use inferior construction material to give a superior construction has proved to be a sustainable option.

CONSTRUCTION MATERIAL

Neoweb is characterized by flexibility at low temperatures similar to HDPE and elastic behavior similar to engineering thermoplastic. The Neoweb used in this project had tensile strength of 21.5kN/m and the elastic modulus at 2% strain was

620MPa. The Neoweb had the height and thickness of 150mm and 1.1mm, respectively. PRS- 330-150 Neoweb which has the properties as given in Table 1 was used for the causeway construction. A layer of 800N woven geotextile was used for separation at the bottom of the Neoweb. The fill material in the Neoweb was 75mm minus gravel and the wearing course was 40mm minus gravel (Alberta designation 2-40). Figure 2 shows the picture of Neoweb and gravel used for the cause way construction.

TABLE 1: PROPERTIES OF NEOWEB

Description	Value
Short term strength at yield	>21.5 kN/m
Long term resistance to plastic deformation, allowable strength for design (50 years)	>8.0 kN/m
Creep reduction factor (50 years)	<2.7 kN/m
Coefficient of thermal expansion	<80 ppm/^{0}C

Figure 2: Neoweb and Gravel Infill Material

DESIGN METHOD

A design formula as shown in Equation (1) was used to design the section of the causeway [3]. The design method uses the basic design philosophy of design method proposed by Giroud and Han [9, 10] for planner reinforcement. The Giroud and Han formula was calibrated for three dimensional Neoloy-based Geocells using static and cyclic plate load and full scale moving wheel loads using accelerated pavement testing in the laboratory at the University of Kansas and Kansas State University.

$$h = \frac{\left(0.868 + 0.52\left[\frac{r}{h}\right]^{1.5} \log N\right)}{\left\{1 + 0.204\left(R_E - 1\right)\right\}} \times \left(\sqrt{\frac{P}{\pi r^2 m\, 5.14\, c_u}} - 1\right) r \qquad (1)$$

Where

h = required base course thickness

r= radius of tire contact area (m)

N= number of wheel passes

P = wheel load (kN)

c_u = undrained cohesion of the subgrade soil (kPa)

R_E = modulus ratio of base course to subgrade soil

m = bearing capacity mobilization factor

The causeway was designed for 100,000 equivalent single axle load (ESAL). Each pass of the hydraulic Scheuerle trailer was converted to total ESAL. There were 112 wheels in 14 axles of the trailer and the tire pressure was 862 kPa. The subgrade California Bearing Ratio (CBR) was taken as 3% and the CBR of the base course as 60% for the design purpose. The failure criterion for the road section was set at 75mm of rut. The section was designed as two layers of 150mm high Neoweb-reinforced 75mm minus gravel and a 75mm thick wearing course of 2-40 gravel. The designed section is shown in Figure 3.

CONSTRUCTION

The construction needed excavation of the existing road and the ground surface enough to accommodate the geomembrane liner and clay cover on top. After excavation, a layer of geomembrane was then placed right on top of the muskeg which had less than 1% CBR. The geomembrane was then covered with 60cm thick clay liner. The clay liner was compacted to the possible extent only so as to avoid any mechanical damage to the geomembrane placed right on top of the muskeg. The completed clay fill had about 3% CBR. Two layers of Neoweb were laid on top of the clay liner separated by 800N woven geotextile. The lower layer Neoweb was used as construction layer for the heavy construction equipment. This construction layer was compacted to 95% of the standard Proctor maximum dry density (SPMDD). The upper layer of Neoweb and the wearing course was compacted to 98% of SPMDD within 2% of the optimum moisture content. The steps during the construction are shown in Figure 4 and the completed causeway is shown Figure 5.

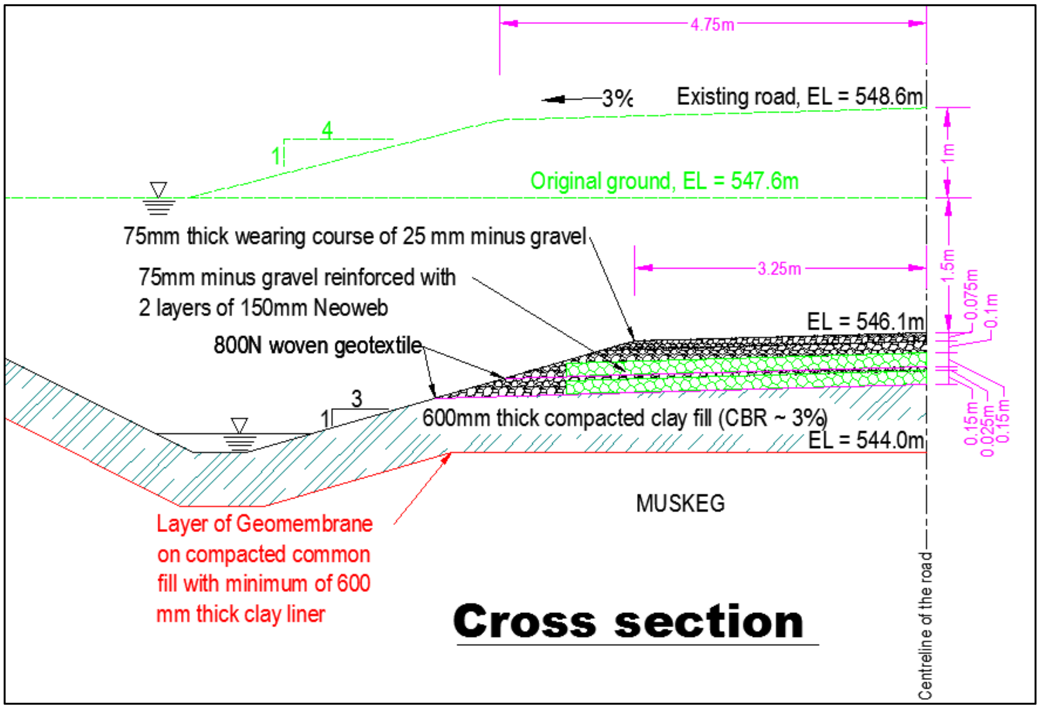

Figure 3: Design Section

Figure 4: Construction (top left: Frozen muskeg, top right: Water at Ground Level, bottom left: before Installing Neoweb, bottom right: Installed Neoweb)

Figure 5: Completed Causeway

PERFORMANCE OF THE NEOWEB-REINFORCED SECTION

The causeway was visually monitored immediately after construction. It was visually monitored again in April and May 2012. By this point in time, the ground was no longer frozen. After three months of operation the rut depth on the road section was less than 25mm and there were no signs of surficial failure. The causeway was in excellent condition in May 2102 when it was last monitored. Figure 6 shows the road condition after 3 months of traffic. Traffic to the end of May consisted of daily light vehicle traffic, heavy construction equipment, drilling equipment moving to the drilling area, and construction materials moving to the new pilot plant being built.

Figure 6: Causeway Surface after 3 Months of Use

The causeway functioned as designed. It is noteworthy that the roads connecting to each end of the causeway had failed by the end of May. These roads were built using conventional methods.

CONCLUSIONS

The Neoweb-reinforced section performed satisfactorily for the causeway. The design formula, validated in the laboratory, used to design the Neoweb-reinforced section also performed satisfactorily. The visual observations and attached pictures show that the Neoweb reinforced-section stood firm during the critical time of soil thawing.

The design method gave a satisfactory design and produced a practical solution for the access road in the muskeg area in Alberta.

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