Use of Polymer Geogrid Composite to support rail track over weak saturated clay subgrade – a case study

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Abstract: This paper presents a case study where a bi-axial geogrid composite solution was used to build an additional 6-track extension for the Canadian National Railway (CN Rail) at the Transcona yard in Winnipeg – MB, where heavy rail cars were expected to pass in this extension area over very soft and wet clay swampy subgrade. The challenge at this site was to design and construct a stable formation on the weak subgrades which can serve as a satisfactory foundation for the tracks trafficked by heavy rail cars. A geosynthetic solution comprising a single layer of robust bi-axial polymer geogrid composite, placed directly over the weak and saturated sub-grade was evaluated to be the most suitable solution and adopted for this site. This biaxial geogrid composite combines the high stiffness/modulus reinforcement properties of the geogrid along with the filtration and separation properties of the non-woven geotextile. This product provided a simple, easy to construct, effective, environmentally friendly and an economic solution to a challenging problem

Key Words: swampy subgrade, polymer geogrid composite, heavy rail cars, environmentally friendly.

1. Introduction

The Canadian National Railway (CN Rail) wanted to build an additional 6-Track extension at CN Rail Transcona yard, Winnipeg in the province of Manitoba, Canada. The site had swampy conditions with wet and soft clayey soils (figure 1). It was observed that a person standing on the ground could easily sink into the soft soil by about 6 inches, indicating soils of very low shear strength. Because of the problems posed by the soft and saturated subgrade soils, which was further complicated by continuous heavy rainfall, CN Rail was forced to delay this construction repeatedly. It was realized that construction could be carried out only after the soft subgrade soils were stabilized. Although various soil stabilization and ground improvement options were available, a geosynthetic solution was considered as the most economical and environmentally friendly solution for this site.

Figure 1. View of the site showing poor ground conditions

2. Geotechnical challenges

The problems associated with the soft subgrade may be grouped into two categories – those during construction and those during service.

Considerable difficulties are involved in placing and compacting capping layers and granular sub-ballast on saturated, soft and compressible subgrades. During placing and spreading, the good quality granular material may mix with the clay subgrade soils. Under the loads imposed by construction equipment, the first lift of fill/capping/sub-ballast may

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punch into the soft subgrade. Because of the poor confinement offered by the weak and compressible subgrade, it may be difficult to achieve the required compaction for the initial lifts of capping or sub-ballast placed immediately above the subgrade.

During service, the stresses imposed by the heavy rail cars could cause shear failure or excessive plastic deformation of the subgrade. This would necessitate frequent maintenance which would disrupt the operations, reduce efficiency and increase cost. Thus, the challenge at this site was to design and construct a stable formation on the weak subgrade which could serve as a satisfactory foundation for the tracks trafficked by heavy rail cars.

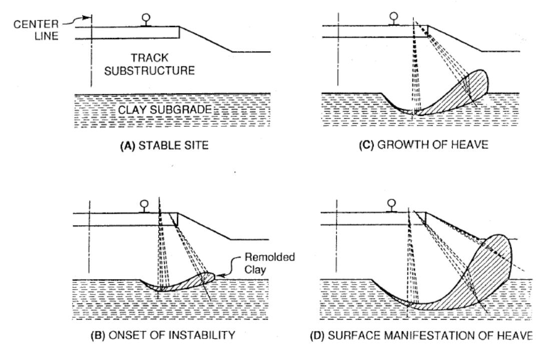
Failure of rail tracks on weak subgrade

The subgrade beneath the tracks is subjected to repeated loading due to the movement of the rail cars. The behaviour of soils subjected to repeated loading was reviewed by O'Reilly and Brown (1991). The deformation experienced by the soil in each cycle of loading consists of an elastic component and a plastic component. The magnitude of the elastic component remains more or less constant, but the plastic component goes on decreasing with increasing number of cycles. Although, the plastic deformation during one cycle is small, the cumulative plastic deformation accumulated under a large number of load repetitions could be substantial.

If the soil is saturated, traffic loads would induce excess pore-pressures in the subgrade. If the permeability of the soil is high, the excess pore-pressures would dissipate quickly. However, if successive cycles of loading are applied before the pore-pressures induced during the previous cycles are fully dissipated, there could be a cumulative build-up of pore pressures. This could happen when the permeability of the soil is low in comparison to the rate at which the repeated loads are applied. In such cases failure could occur at stress levels much below the monotonic failure shear stress through the continued generation of additional pore-pressures during each successive cycle (O'Reilly and Brown, 1991). As the subgrade at this site is saturated clay, cumulative build-up of pore-pressures due to repeated loading is likely to occur.

The modes of failure of track subgrades are discussed by Selig and Waters (1994) and Li (1994). Two mechanisms of failure which are most relevant for the present case are progressive shear failure and excessive plastic deformation. Progressive shear failure or general subgrade failure is the shear failure of the subgrade which occurs through the progressive upwards and sideways squeezing out of the top part of the subgrade (where the stresses are highest) under the repeated traffic loading (figure 2). The cumulative build-up of pore-pressures under the repeated loading could play a major role in initiating failure.

Figure 2. Progressive shear failure of the subgrade



(After Selig and Waters, 1994)

The accumulated plastic deformation of the subgrade soils under repeated loading could result in appreciable vertical settlement of the track. Excessive settlement of the subgrade could lead to deterioration of the track geometry beyond acceptable levels. The track geometry is corrected by packing more ballast under the ties. As further settlement occurs and more and more ballast is added under the ties, deep *ballast pockets* may form under the ties (Li, 1994), which could further aggravate the problem by trapping water (figure 3).

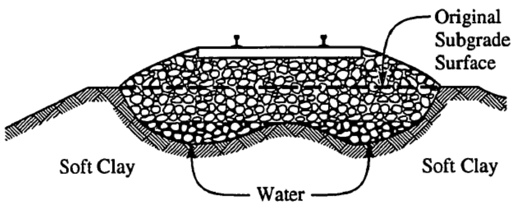


Figure 3. Formation of ballast pockets (after Li, 1994)

3. Subgrade improvement

The major objectives of track substructure design are the prevention of progressive shear failure and excessive plastic strain. In some cases, satisfactory performance could be achieved through the provision of a sub-ballast layer of adequate thickness. But in the case problematic subgrades, provision of sub-ballast alone may not be adequate or economical. Stabilization or improvement of the subgrade soils may be required for ensuring satisfactory performance of the track.

Conventional techniques for soft ground improvement include excavation and replacement, lime or lime cement stabilization, preloading, vertical drains, sand or sand-lime piles, stone columns etc. These would be cumbersome and expensive. In some cases, a working platform may be required for the movement of construction plant and equipment. In many cases, use of geosynthetics offers a simpler, economical and environmentally-friendly solution to the problem. In the present case, in view of the various site constraints and also based on cost, the geosynthetic solution was considered to be the most suitable.

4. The geogrid composite solution

The benefits of using geosynthetics for stabilization of road and rail subgrades are well known. The important functions are separation, filtration and reinforcement. Several products like geogrids, geotextiles, geocomposites, geocells etc. could be used in subgrade stabilization applications. The selection of the most appropriate product is usually made on the basis of the expected functions and a cost-benefit analysis.

In the present case the geosynthetic should be able to perform the following functions:

- Separation of the sub-ballast and/or other granular material from the subgrade
- Act as a filter between the subgrade and the granular material placed over the subgrade
- Reinforce the formation and increase its strength and stiffness.

After evaluation of the possible alternatives, a polymer geogrid composite which could perform all the three functions was selected as the most appropriate product.

The product used was a biaxial geogrid composite consisting of a biaxial geogrid bonded to a nonwoven geotextile. The geogrid is manufactured out of virgin Polypropylene by a unique punching and drawing process resulting in a bi-directionally oriented geogrid possessing integral nodes, high tensile and flexural stiffness, high torsional rigidity and junction efficiency. The excellent mechanical properties enable the geogrid to act as a highly efficient reinforcement material. The geotextile was a continuous filament, needle punched nonwoven geotextile with superior hydraulic properties enabling it to act as an excellent separator and filter. The geotextile is bonded to the geogrid by a precision heat bonding process. This ensures monolithic behaviour of the composite. By combining the superior mechanical properties of the geogrid and the superior hydraulic properties of the geotextile, the resulting composite is able to perform the functions separation, filtration and reinforcement. As a single monolithic product, the composite is easy to handle and install. A close-up view of the product is shown in figure 4 and the properties of the biaxial geogrid composite are summarized in table 1.


Figure 4. Close-up view of biaxial geogrid composite

Table 1. Properties of Biaxial Geogrid Composite

Property	Test Method	Value
Biaxial Geogrid		
Material	Polypropylene	
Ultimate tensile strength (MD & CD)	ASTM D6637	31.0 kN/m
Tensile strength at 2 % Strain (MD & CD)		12.0 kN/m
Tensile strength at 5 % Strain (MD & CD)		22.0 kN/m
Junction efficiency	GRI-GG2	> 95 %
Flexural rigidity	ASTM D1388	2,000,000 mg-cm
Aperture stability	US COE	0.75 m-N/deg
Aperture size	Callipered	34 x 34 mm
Carbon black content	ASTM D4218	2 %
Non-woven Geotextile		
Material	Polyester	
Structure	Continuous filament, needle punched	
Ultimate tensile strength (MD and CD)	ASTM D4595	11.4 kN/m
Elongation at ultimate (MD and CD)		60 %
Grab tensile strength	ASTM D4632	570 N
Trapezoidal tear strength	ASTM D4533	250 N
CBR burst strength	ASTM D6241	2400 N
Permeability	ASTM D4491	0.41 cm/s
Apparent opening size (O_{95})	ASTM D4751	0.12 mm
Mass per unit area	ASTM D5261	200 g/m^2

During construction, the composite prevents the loss of costly manual material into the soft subgrade and prevents its mixing. Together with the first lift of fill placed over it, the composite acts as a construction platform facilitating proper placement and compaction of the granular material and sub-ballast.

The granular material interlocks with the apertures of the biaxial geogrid resulting in a high degree of lateral confinement. This leads to a substantial increase in the strength and stiffness of the track substructure, which is able to distribute the applied wheel loads over a wider area and thereby reducing the stresses transmitted to the subgrade. Due to lower stresses in the subgrade and due to the increased strength and stiffness of the granular foundation, problems like progressive shear failure and excessive settlement are minimized.

5. Construction

By using biaxial geogrid composite, the construction was quite easy and fast. The ground was excavated for the required width and to the required grade. The biaxial geogrid composite was unrolled over the excavated soil surface ensuring the specified overlap between adjacent rolls. This was placed directly over the weak and saturated sub-grade and a 600 mm thick granular (< 50 mm limestone) capping/sub-ballast layer was placed and compacted above it. (figure 5). During construction, care was taken to avoid any damage to the composite by construction equipment. The construction was completed in the summer of 2014.

Figure 5. Granular material placed over the biaxial geogrid composite

6. Performance

Construction could be completed without any problems. The facility has been in operation for a year and so far no problems have been observed and performance has been quite satisfactory (figure 6). Further monitoring is expected to give additional inputs on the long-term performance of the biaxial geogrid composite.

Figure 6. Completed yard in operation

7. Conclusions

Providing a biaxial geogrid composite at the interface between the subgrade and the granular capping/sub-ballast layer was found to be the most suitable solution for solving the problems associated with the construction of a rail track on a weak saturated subgrade. The construction of the facility could be completed without any difficulty and the initial reports on performance appear to be encouraging. Further monitoring is necessary to evaluate the long-term performance.

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