Improvement of subgrade strength and serviceability for new container terminals using geogrid reinforcement

Augmentation de la portance et de l'utilisation des plateformes pour les nouveaux terminaux à conteneurs avec les géogrilles de renforcement

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ABSTRACT

Due to the globalization of the world economy existing ports are being developed and new ports are being built in order to cope with the increasing volume of goods in transit. New container terminals or port extensions are mostly built on reclaimed land from the sea. As the nourishments with their low or medium density of the fill provide insufficient bearing capacity to take up the final loads of the container terminals, the long-term stability and trafficability of the gained land must be improved. An economic measure to improve the bearing capacity of existing and newly developed terminal areas is the use of geogrid/nonwoven composite material as reinforcement and separation layers. As the geogrid can absorb greater tensile stresses than the base course itself, the tension in the reinforced base course is reduced. This leads to a more efficient load distribution within the base course and thus to less vertical deformation (settlement and rutting) at the pavement surface, which thus significantly increases the serviceability of these intensively used traffic areas. This paper will give an overview on the state-of-the-art using geogrid/nonwoven composite materials to increase the bearing capacity of the base course at various international port projects as e.g. in Turkey and the Sultanate of Oman.

RÉSUMÉ

En raison de la mondialisation de l'économie, les ports se développent et de nouveaux ports sont en cours de construction pour accueillir l'augmentation du trafic de marchandises. Ces nouveaux terminaux ou extension de ports sont généralement construits sur la mer. Les remblaiements de faible et moyenne densité n'atteignent pas la capacité de portance suffisante pour ces terminaux à conteneurs. La stabilité à long terme et la capacité de trafic doivent être augmentés. Une solution économique pour améliorer la portance des aires de stockage consiste à utiliser un géocomposite géogrille / géotextile non-tissé pour le renforcement et la séparation des différentes couches de matériaux. Comme les géogrilles peuvent reprendre plus d'efforts que la seule couche de fondation, les contraintes sur une couche de fondation renforcée sont réduites. Cela conduit à une meilleure répartition de la contrainte dans la couche de fondation et donc à moins de déformations verticales (ornières et tassements différentiels) à la surface du revêtement, ce qui améliore considérablement l'exploitation de ces zones de circulation intensive. Ce document vous donnera un aperçu des applications des géocomposites géogrille / géotextile non-tissé en amélioration capacité de portance de couches de fondations dans différents projets internationaux tels qu'en Turquie et au Sultanat d'Oman.

Keywords: Geogrid, Geocomposite, Reinforcement, Container terminals, Bearing capacity

1 INTRODUCTION

1.1 *General*

Container storage areas carry large traffic volumes and typically have concrete or paved surfacing over a base layer of aggregate. The combined surface and base layers act together to support and distribute traffic loading to the subgrade. Problems are usually encountered when the subgrade consists of soft clays, silts and organic soils. These types of soils are often water sensitive and, when wet, unable to adequately support traffic loads. If unimproved, the subgrade will mix with the road base aggregate, which leads to a reduction of strength, stiffness and drainage characteristics, promoting distress and early failure of the roadway. Contamination with fines makes the base course more susceptible to frost heaving.

1.2 *Separation of subgrade and base course*

A geotextile which is placed between the subgrade and the base course layer provides physical separation of subgrade and base materials during construction and during operating life of the trafficked area (see Figure 1).

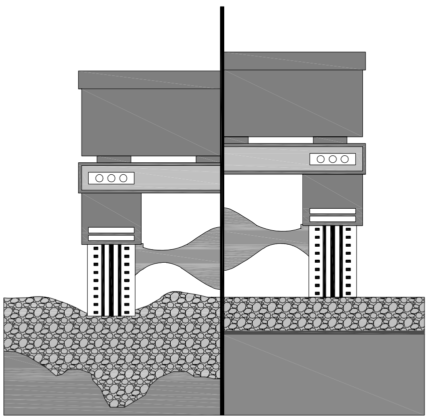

Figure 1. Illustration of geotextile separation function

Proceedings of the 17th International Conference on Soil Mechanics and Geotechnical Engineering
M. Hamza et al. (Eds.)

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doi:10.3233/978-1-60750-031-5-2264

The separation function of the geotextile is defined by a prevention of mixing, where mixing is caused by mechanical actions. The mechanical actions generally arise from physical forces imposed by construction or operating traffic and may cause the aggregate to be pushed down into the soft subgrade and / or the subgrade to be squeezed up into the base aggregate.

A properly designed geotextile separator allows the base aggregate to remain "clean", which preserves its strength and drainage characteristics.

The use of geotextile separators ensures that the base course layer in its entirety will contribute and continue to contribute its structural support of vehicular loads; the separator itself is not viewed to contribute structural support to the aggregate layer.

Yoder and Witczak (1975) state that as little as 20% by weight of the subgrade mixed in with the base aggregate will reduce the bearing capacity of the aggregate to that of the subgrade. This highlights the importance of a geotextile separator with regard to the performance of base aggregate layers on fine-grained subgrades.

1.3 *Reinforcement of base courses using geogrid reinforcement*

Vehicular loads applied to the surface of trafficked areas create a lateral spreading motion of the unbound aggregate layers. Tensile lateral strains are created at the interface subgrade/geogrid as the aggregate moves down and sideways due to the applied load. Through shear interaction of the base aggregate with the geogrid, a.k.a. inter-locking, (see Figure 2), the aggregate is laterally restrained or confined (see Figure 3) and tensile forces are transmitted from the aggregate to the geogrid.

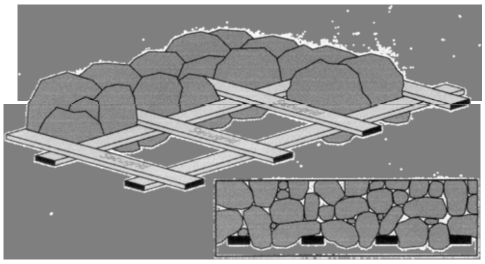

Figure 2. Interaction of aggregate with geogrid

As the geogrid is much stiffer in tension as the aggregate itself, the lateral stress is reduced in the reinforced base aggregate and less vertical deformation at the road surface can be expected. This interaction between geogrid and base course material increases the shear strength and thus the load distribution capacity of the used base course material.

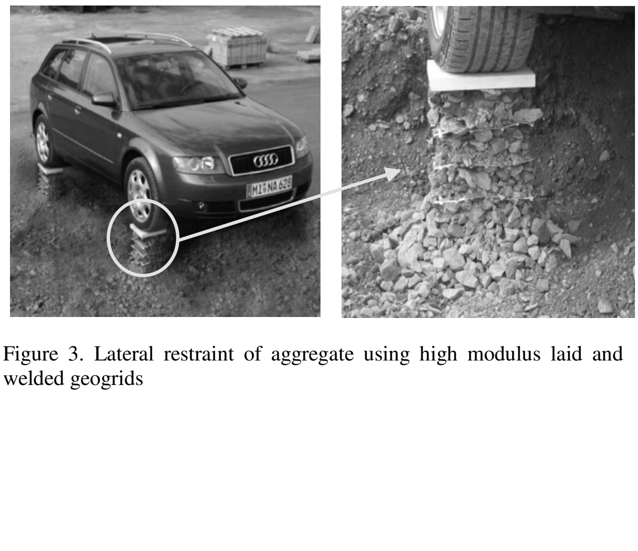

Figure 3. Lateral restraint of aggregate using high modulus laid and welded geogrids

The increased load distribution capacity reduces vertical stresses on the subgrade, which finally reduces the deformation (rutting) on the surface of the aggregate layer. This correlation enables the reduction of reinforced base course thicknesses in comparison to un-reinforced layers (see Figure 4).

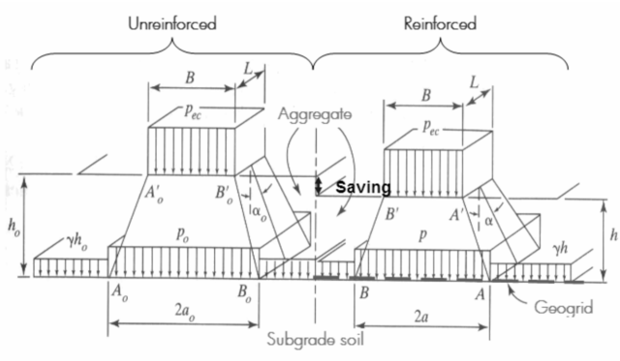

Figure 4. Increase of load distribution capacity with the use of geogrids (Giroud & Noiray 1981)

In many projects, good quality base course aggregate is not available on site or close to the site. As a result, high transport costs of imported, expensive good quality base aggregate have a great influence on the total project costs. Especially under those conditions geosynthetic reinforcement and separation products can help to save money by reducing the amount of imported fill material needed to achieve the specified bearing capacity for the expected loads on the base course.

To combine the function of reinforcement and separation in one product, so called Geocomposites have been developed. Geocomposites as e.g. Combigrid® (see Figure 5) allow faster construction rates compared to separately installed geogrid and geotextile components.

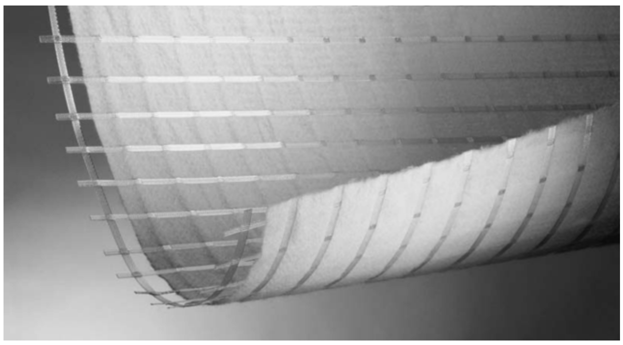

Figure 5. Combigrid® Geocomposite (geogrid reinforcement & needle punched nonwoven geotextile, firmly bonded between the cross laid reinforcement bars)

2 CASE HISTORIES

2.1 *Mersin Port, Turkey*

Mersin is situated on Mersin Bay, a broad body of water that is open southward to the Mediterranean Sea. Mersin Harbour is close to the extreme north end of the bay and is constructed on a southeast-facing shore line. It is the main port for the Eastern Mediterranean Region's industry and agriculture. The port's rail link and its easy access to the international highway make it an ideal transit port for trade to the Middle East. With its modern infrastructure and equipment, efficient cargo handling, vast storage areas and its proximity to the free trade zone, Mersin is one of the important ports in the East Mediterranean. The facilities at the port handle general cargo, containers, dry and liquid bulk and Ro-Ro Port.

Figure 6. Mersin Port, Turkey

In 2004 it was planned to rehabilitate certain lots of the container terminal because of large rut depths at the pavement surface which had been caused by mobile cranes, trucks and containers. The differential deformations at the pavement surface had a major influence on the traffic safety and even on the safety of the stacked containers. Containers, which were stacked up to 5 high, even fell off, which finally lead to a shortage in the terminals' storage capacities.

As a consequence, the Railway Authority, who was the responsible body for the operation of Mersin Port, decided to take action for rehabilitating the affected lots in the harbor's container storage area.

Figure 7. Installation of composite base course reinforcement

The chosen rehabilitation measure was the use of composite geosynthetic base course reinforcement, because of the easy installation and handling and mainly because of economical advantages. A sample lot of 5,200 m² was realized at first in December 2004. Then an additional lot of 34,000 m² was realized using the same solution till 2006.

The former slab, which was constructed 20 years ago, together with the fill material underneath were removed up to level of the former in-situ subgrade. The thickness of the removed layer was approximately 1.4 m. On the soft in-situ subgrade, a Combigrid® Geocomposite made of a nonwoven needle-punched geotextile and a high modulus laid and welded geogrid, as shown in Figure 5, was installed. On the same day, a well graded aggregate base course with a thickness of 1.0 m was installed on top of the Geocomposite. Finally the new 0.4 m thick concrete slab was installed.

The lack of separation between the original base aggregate and the in-situ subgrade combined with insufficient compaction of the in-situ subgrade had caused the described ruts at the pavement surface over time. With the use of the composite reinforcement, mixing of the fine grained subgrade and the coarse base aggregate is prevented by the geotextile and secondly confinement of the base aggregate is achieved resulting from the installed geogrid component. The geogrid will further reduce differential settlements due to an increased load distribution of the reinforced base aggregate.

2.2 *Oman Polypropylene LLC Plant at Sohar Port, Sultanate of Oman*

Oman Polypropylene LLC started to build its Polypropylene plant at the end of 2004. For the development of the port at Sohar, which is located at the Gulf of Oman, an area of approx. 24 hectares was artificially created by dredging operations.

The total 2,000-hectare Sohar port and industrial zone will house mega industrial facilities ranging from an oil refinery and aluminium smelter to steel mills. The zone will be one of the world's biggest greenfield petrochemical and metal-based industrial hubs. Oman Polypropylene LLC is integrated with the refinery. The project will add value to Sohar Refinery's propylene stream to produce polypropylene that can be used in an array of downstream industries.

Figure 8. Oman Polypropylene LLC Plant, Sultanate of Oman

Soil investigations have encountered loose to very loose sand and organic silt layers in a depth of approx. 6m. For the development of access roads and storage areas it was therefore required to increase the bearing capacity of the weak subgrade.

As the most economical approach, it was decided to use geogrid reinforcement to provide the required subgrade support for the expected traffic and storage loads. The aggregate base course was installed in two layers of well graded crushed granular material, each 300 mm thick. A base layer of a composite reinforcement layer together with an intermediate laid and welded geogrid reinforcement layer, both having 40 kN/m tensile strength, ensured an increased modulus of the reinforced granular layers and finally a stable platform for the planned roads and storage areas on the originally soft subgrade.

Figure 9. Installation of composite base course reinforcement

The separation geotextile component of the used composite base course reinforcement ensured the integrity of the base course by preventing fines from migrating into the aggregate layer or aggregate from being pushed into the soft subgrade. Altogether approximately 150,000 m^2 of the described composite reinforcement were installed in this project.

4. CONCLUSION

The increase of global trade and transport of goods creates growing demands to handle cargo. To accommodate growing cargo volumes, existing ports are extended and new ports are being built. Soft subgrades are often the basis for the foundation works of new container terminal's pavement systems. As economic construction method geogrids are often used in this case to improve the insufficient bearing capacity for the expected traffic and storage loads. Geogrids first of all allow and secondly improve the compaction of foundation layers on soft soils. The technology of geosynthetic reinforced aggregate layers provides an economic construction method for the development of new container terminals. With the improved structural load-bearing capacity of geogrid reinforced aggregate layers, stress concentrations on soft subrades can be reduced, which minimizes differential settlements at the pavement surface and automatically improves the transport safety of container-handling equipment.

Increasingly so called "Geocomposite" materials are used which consist of a nonwoven geotextile component and a geogrid reinforcement layer. The geotextile with its separation and filtration function ensures that the base course layer in its entirety will contribute and continue to contribute its structural support of vehicular loads as it prevents the aggregate to be pushed down into the soft subgrade and / or the subgrade to be squeezed up into the base aggregate. The geogrid increases the shear strength and thus the load distribution capacity of the used base course material.

The use of the described composite geosynthetic reinforcement in subgrade stabilization projects enables savings with regard to required installation time when compared to separately installed geotextile separator and geogrid components. Secondly a reduction of base course thickness can be achieved compared to unreinforced sections, because of the improved load distribution capacity which is achieved with the use of composite geosynthetic reinforcement. Besides the economical aspect, also the ecological aspect needs to be highlighted. As "good quality" aggregate is often not available close to the construction site or not in the required quantity, the possible reduction of base course thickness with the use of composite geosynthetic reinforcement reduces transport costs and the consequential environmental impact.

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