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APPLICATION OF GEOGRIDS AND GEOCOMPOSITES IN DESIGNING WORKING PLATFORMS ON COHESIVE SUBGRADES; CASE STUDY: HARVEY NORMAN BULKY GOODS DEVELOPMENT, AUSTRALIA

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ABSTRACT

In the construction of heavily trafficked areas such as working platforms, a stable subgrade with sufficient bearing capacity is required. Economical and environmental advantages of construction methods with geosynthetics, especially on soft soils are already well known. Soil masses that need to be excavated, transported and installed can be dramatically reduced by the inclusion of geosynthetics. The best example is the improvement of soft subgrades with geogrids or geocomposite products. In this paper, the general design procedure is presented for working platforms using geosynthetics according to Building Research Establishment (BRE). A project constructed in SE Queensland Australia using a unique geocomposite is then discussed in further detail. This geocomposite which is a combination of a geogrid with a high secant strength and an integral nonwoven geotextile, encapsulated between the cross laid welded bars, was successfully installed directly on top of the subgrade with CBR value as low as 1%, providing not only improvement of the subgrade bearing capacity, but also a positive separation and filtration layer between fine subgrade materials and imported granular platform materials. A 350 mm granular platform was then installed on top of the Combigrid®. This method could make the construction of thin granular platform layer on the soft subgrade possible, reducing construction costs and construction time for the client and the contractor. Also, the reduced requirement for imported quarried materials in the working platform had significant additional environmental benefits.

Keywords: Working platform, geogrid, geocomposite, cohesive subgrade

INTRODUCTION

The expression, working platform is, restricted to ground-supported working platforms, for tracked plant, constructed of granular material. Working platforms are critical for plant stability, and safety is a vital issue. Most working platforms perform well, but overturning of rigs has occurred more frequently than it should. Experience has shown that it is far more likely that rigs will overturn owing to localised problems rather than to a generally inadequate platform thickness across the whole site. Localised weaknesses can be associated with the existence of ‘soft spots’ in the subgrade, under the platform, or with weak areas within the platform formed by inadequate backfilling of holes that have been excavated by other contractors working on the site. Similarly, ‘hard spots’ caused by old foundations or basements can cause difficulties. Where a weak subgrade is particularly soft or loose, some form of stabilisation or ground treatment may be considered to improve the properties of the ground (BRE 2004).

For a working platform, the soil and groundwater conditions in the upper 2 m are particularly important. Where there is a granular subgrade, the presence of a water-table close to the ground surface will have a critical effect in reducing bearing resistance (BRE 2004).

In some situations it may be economic to incorporate geosynthetics to strengthen the working platform as an alternative to using a greater thickness of platform material.

In this paper, the design procedure for working platforms using geosynthetics has been reviewed according to the Building Research Establishment (BRE) design guide published in the United Kingdom (UK) and was commissioned by the UK Federation of Piling Specialists, together with a recently constructed project is presented as a case history.

APPLICATION OF GEOSYNTHETICS IN WORKING PLATFORMS

Often the required bearing capacity on subgrades cannot be achieved, such that additional measures have to be undertaken. As an economic solution to improve the subgrade strength, the installation of geosynthetics for reinforcement, filtration and separation may be successfully adopted.

Geosynthetics are generally placed between the subgrade and the material forming the working platform. Some designs may require additional geosynthetic layers to be placed within, but alternatively may be placed within the platform .to provide additional support on particularly soft soils or where the equipment working on the platform is large.

On cohesive formations, upward migration of fine material into the working platform may cause it to degrade, particularly in wet conditions. A granular filter layer or a geotextile can be used to minimise the migration of fine material from the subgrade into the platform material. Geotextiles are normally used to separate a granular platform from a cohesive subgrade and to act as a filter (BRE 2004).

Geogrids are normally used to strengthen the platform. Vehicular loads applied to the road surface create a lateral spreading motion of the aggregate. Tensile lateral strains are created at the interface subgrade/geogrid as the aggregate moves down and sideways due to the applied load (BRE 2004).

In addition to general strengthening over the whole area of the platform, localised strengthening and additional maintenance may be needed at particular locations. It is important to distinguish geosynthetics which have been incorporated into the platform to provide tensile strength from those intended as separation layers, unless a combined geosynthetic is used. Owing to the ductile nature of polymeric reinforcement, ultimate tensile capacity may occur at very high strain beyond the serviceability requirements of the reinforced soil, and design should be based on the strength at a specified small strain or by applying a factor to the ultimate strength. Also the likelihood of damage to geogrids during installation should be taken into account (BRE 2004).

DESIGNING WORKING PLATFORMS WITH GEOSYNTHETICS

If the existing soil is not sufficiently strong to carry the loads of the piling rig, a design of the geogrid reinforced working platform as an economic alternative is required to distribute the loads to an acceptable rate for the in-situ subgrade. The platform design method follows a logical sequence from assessment of plant loading through to platform thickness (BRE 2004).

The bearing resistance R_d of the cohesive in-situ subgrade underneath the tracks when a load is applied directly to the subgrade surface can be calculated as follows (BRE 2004):

$$R_d = s_c N_c c_u \tag{1}$$

where s_c is the shape factor, c_u is the subgrade undrained shear strength and N_c is the bearing capacity factor. The bearing capacity factor for a cohesive subgrade is $N_c = (2 + \pi)$, and where the load is applied at ground surface over a rectangular area of dimensions W and L, the shape factor is given by (BS EN 1997-1:2004):

$$s_c = 1 + 0.2[W/L] \tag{2}$$

where a load is applied to a working platform with relatively shallow thickness which has been placed on the weak subgrade, the simple approach for calculating the bearing resistance of this two-soil system can be based on the analysis of punching failure. In this analysis the bearing resistance R is considered to be the sum of the shear required to punch through a vertical plane in the granular platform material and the bearing capacity of the subgrade (Fig. 1) (BRE 2004).

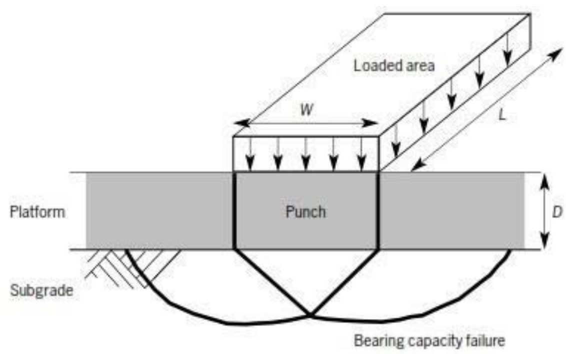

Fig. 1 Punching failure mechanism

Using the simplified analysis developed by Meyerhof and his co-workers for a footing punching through a dense sand layer overlying soft clay, the following expression is obtained for the bearing resistance of a platform on a cohesive subgrade (Meyerhof 1974):

$$R = c_u N_c s_c + (\gamma_p D^2/W)\, K_p \tan\delta\, s_p \tag{3}$$

where D is the thickness of the platform material, W is the track width of the plant, N_c is the bearing capacity factor for a cohesive subgrade, $K_p\tan\delta$ is the punching shearing resistance coefficient of the granular platform material and can be determined from Fig. 2 as a function of the angle of the shearing resistance of the material (φ'), γ_p is the bulk unit weight of the platform material and s_c and s_p are the shape factors, which are functions of W and L and:

$$s_p = 1 + [W/L] \quad (4)$$

Where geosynthetic reinforcement is incorporated at the base of the working platform to take tensile loads, the required thickness of platform can be reduced. The design tensile strength of the reinforcement (T_d) should be evaluated by applying a minimum factor of 2 to the ultimate tensile strength (T_{ult}) of the reinforcement so that:

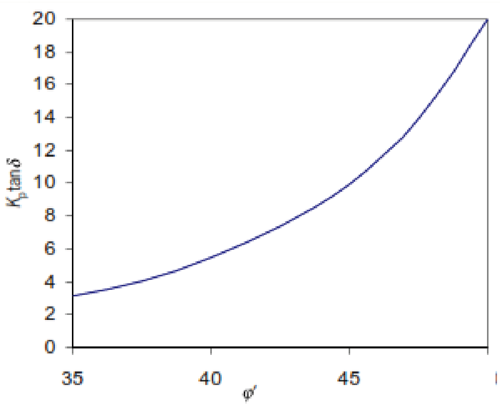

Fig. 2 Design values of $K_p \tan\delta$ (BRE 2004)

$$T_d = T_{ult}/2 \quad (5)$$

Where the reinforcement is not stiff, a higher factor or the strength at 5% strain should be used (BRE 2004).

The bearing resistance provided by the reinforcement has to be assessed and it is proposed that this is calculated in a simplified way based on the punching failure mechanism, such that the additional bearing resistance is calculated as $2T_d/W$. For a platform on a cohesive subgrade we will have (BRE 2004):

$$R = c_u N_c s_c + (\gamma_p D^2/W)\, K_p \tan\delta\, s_p + 2T_d/W \quad (6)$$

The interaction of the base course material with the geogrid results in a measurably higher internal friction angle at low lateral compression like in road constructions (Ziegler and Ruiken 2010). The tests have shown that internal friction angles higher than $\delta = 60°$ are detectable for the compound construction (Ziegler and Ruiken 2010). Of course it should be considered that the punching shear failure mechanism is only applicable where the working platform is significantly stronger than the underlying subgrade. Also the routine design calculation method based on punching shear is not appropriate where (D/W) >1.5 and Slopes are greater than 1 in 10 or for ground conditions 20 kPa < c_u < 80 kPa (BRE 2004).

Routine working platform design calculations with geosynthetics have the following stages: determine ground conditions, determine design load cases according to characteristic loads from EN 996:1996 and design load factors (BRE 2004), derive bearing capacity and shape factors and punching shear coefficient, check support of platform material alone, determine required thickness of platform using geosynthetic reinforcement and final evaluation of results (BRE 2004). As a final check, the design thickness of platform should satisfy the following conditions (BRE 2004): ignoring the effect of the reinforcement, both load cases q_{1d} and q_{2d} are < R_d where:

$$q_{1d} = 1.25 q_{1k} \quad (7)$$
$$q_{2d} = 1.05 q_{2k} \quad (8)$$
$$R_d = c_{ud} N_c s_c + (\gamma_p D^2/W_d)\, K_p \tan\delta\, s_p \quad (9)$$

where q_{1d} is the design load case 1 (standing, travelling), q_{2d} is the load case 2 (handling, penetrating, extracting) and q_{1k} and q_{2k} are characteristic load cases 1 and 2. If these two requirements are not met, the thickness of platform should be increased until they are. As a limitation, the minimum platform thickness should be the lesser of 0.5W or 300 mm (BRE 2004).

CASE HISTORY

Project and Problem Description

In 2011, it was planned to build granular piling rig access platforms to facilitate the installation of piles for support of the new Harvey Norman bulky goods project in Maroochydore in Australia to increase the low subgrade strength and to provide sufficient bearing capacity for the imposed loads of the cranes.

After site investigations, the consultant confirmed that the current condition of the site surface would not be satisfactory for the safe operation of the proposed precast piling rig imposed load of 280 kN/m^3. It was also advised that the grey clay exposed on the surface of the site had been badly affected through saturation as a result of the

2010 local flooding. Subsequent continual wet weather was not allowing the perched groundwater to drain away, leaving the platform saturated. Three boreholes were drilled at the site in August 2008 finding a silty sand at the surface in BH1 located toward the northern end, a clayey silt (low plasticity with a trace of sand) in BH2, and low plasticity silty clay in BH3 at the southern end of the site. These surface soils alone were not capable of supporting the required 280kPa bearing capacity required for the pile rig. A further constraint was that the platform thickness was limited to 350 mm above the existing subgrade elevation to avoid interference with the intended levels of the proposed basement car parking concrete slab on ground.

Geosynthetic Improvement Solution Using geogrid/geocomposite

The main purpose of the geogrid reinforced piling platform is to reduce the imposed bearing pressures of the piling rig to acceptable rates for the given bearing capacity of the in-situ subgrade. As the subgrade was a weak subgrade and the thickness of the platform was limited, the geosynthetic reinforced platform on existing subgrade was chosen as the economic alternative solution for the initial design for providing suitable (i.e. safe and stable) access for the piling rig, which was 200mm excavation and 500mm thick platform installation consisting of good quality unbound pavement gravel.

With reference to the given information, a subgrade CBR value of min. 1% (equal to $c_u > 30$ kN/m^2) has to be considered for the bearing capacity of the in-situ soft subgrade. The design was focused on the specific machine type with the total weight of 77200 kg. The design of the reinforced working platform was carried out with full consideration of BRE design manual and design principles defined in DIN 4017:2006 to reach a sufficiently high safety factor against bearing failure.

The bearing resistance R_d of the cohesive in-situ subgrade underneath the tracks can be calculated as follows (BRE 2004):

$$R_d = s_c N_c c_u = 154.2 \text{ kN/m}^2 \qquad (10)$$

with s_c equal to 1 (safer value), c_u equal to 30 kN/m^2 and N_c equal to 5.14 for $\varphi \geq 0°$. The fill material for the working platform was a well graded crushed aggregate with an assessed internal angle of friction of approx. 40°. After consideration of the potentially variable conditions on site (compaction, grain size distribution, internal friction angle of fill material) a relatively conservative internal friction angle for the compound construction (geogrid + fill material) of $\delta = 50°$ was considered on the safe side for this design.

In case that a h = 350 mm thick geogrid reinforced working platform is used, the area of influence on the in- situ subgrade can be calculated as follows:

$$A = 2\,(L + 2\,h \tan(\delta))\,(W + 2\,h \tan(\delta)) \qquad (11)$$

where:
A = 22.83 m² with:
L = Length of crawler track, here: 5.75 m
W = Width of crawler track, here: 0.90 m

Considering the required bearing capacity to be achieved according to the design brief was 280 kN/m^2, the net bearing pressure q_{res} imposed on the subgrade at under side of the 350mm thick geogrid reinforced crane working pad platform was calculated as:

$$q_{res} = 280 \text{ kN/m}^2\ LW/A = 35.7 \text{ kN/m}^2 \qquad (12)$$

According to DIN 4017:2006, the safety factor against bearing failure is taken to $\eta = 2.0$. In the particular case of the above mentioned project, the safety factor η against bearing failure can be calculated to:

$$\eta = q_{ult.} / q_{res} \qquad (13)$$

Then η = 75 kN/m² / 35.7 kN/m² = 2.1. The calculation shows that the solution adopted satisfies the minimum required safety factor for bearing failure of $\eta = 2.0$ according to DIN 4017:2006.

To prevent fines from migrating into the base course a filtration and separation nonwoven geotextile underneath the geogrid is recommended. For the selection of the geogrid reinforcement to be used underneath working platforms, Rüegger et al (2003) defines an extensional stiffness of 40 kN/m or 8 kN/m tensile strength at 2 % strain respectively.

Geogrid/Geocomposite Selection

Upon final approval, some 50000 m^2 of Combigrid® 40/40 Q1 151 GRK 3 was installed successfully on site under the crane platform directly on the soft subgrade, to improve the subgrade bearing capacity as well as to prevent fines from migrating into the platform materials. The cross section is shown in Fig. 3.

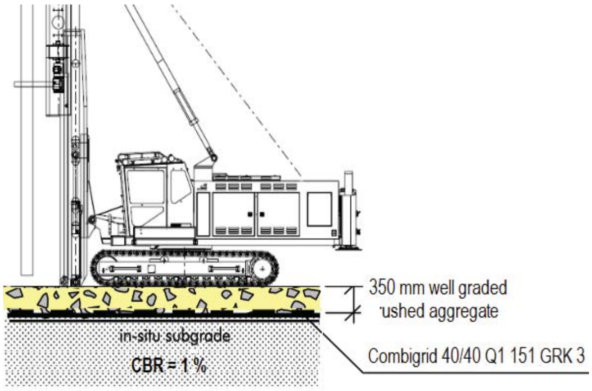

Fig. 3 Reinforced working platform

This geocomposite has a min. tensile strength of 16 kN/m at 2% strain which is much more than 8 kN/m and fulfills the recommendation from Rüegger et al (2003). This product consists of a Secugrid® geogrid as the reinforcement component; with a needle-punched nonwoven geotextile firmly welded between the reinforcement bars, for soil stabilisation, separation and filtration. This geocomposite combines all of these functions into one single product. It offers the advantages of two materials with the simplicity of installing a single product. It is also extremely quick and easy to install, thus reducing installation costs considerably. The appropriate strength of the geogrid was selected according to the stress strain properties required above and the subgrade bearing capacity. Figs. 4 and 5 show some installation pictures.

Fig. 4 Installation

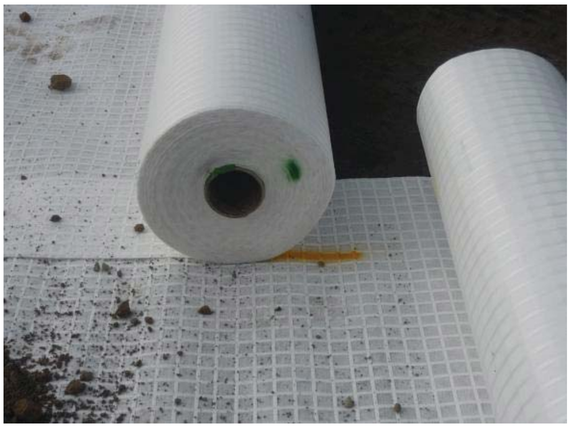

Fig. 5 Installation and overlaps

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REFERENCES

British Research Establishment-BRE (2004). Working Platforms for Tracked Plant: Good Practice Guide to the design, Installation, Maintenance and Repair of Ground-Supported Working Platforms. Report BR470.

BS EN 1997-1 (2004). Eurocode 7: Geotechnical design – Part 1: General Rules.

DIN 4017 (2006). Calculation of design bearing capacity of soil beneath shallow foundations.

Meyerhof G.G. (1974). Ultimate bearing capacity of footings on sand layer overlying clay Canadian Geotechnical Journal, 11,(2): 223–229.

Rüegger R. and Hufenus R. (2003). Building with Geosynthetics – A Handbook for Geosynthetic Users. Swiss Association for Geosynthetics.

Ziegler M. and Ruiken A. (2010). Examination of the Performance of Geogrids with wide-scaled Triaxial Tests. Project Number 0703, RWTH, Aachen.