Design method for temporary working platforms using geosynthetics

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ABSTRACT: Working platforms are temporary structures that provide a suitable foundation for heavy construction plant, working machines (e.g. piling rig and cranes) and temporary construction elements (e.g. temporary lifting bridge or staging areas). Working platforms can be greatly improved by including high strength geosynthetics. This paper will describe some design consideration for these types of foundation structures which have a critical safety role in the construction industry. Some successful case histories will be presented at the end of the paper. Those case histories will present the soundness of this design method which is now well known around Europe, North America, and Asia.

Keywords: crane; piling; geogrid; stabilization; design method

1 INTRODUCTION

Traditionally the design of granular working platform for heavy construction plant and working machines has not been carried out in a consistent manner across the industry. Historically, the methods have generally considered what might loosely be described as "empirical", and have been based on previous projects of suitable materials and thickness. Furthermore, the design is frequently only derived from past experience. This has, on occasions, resulted in catastrophic failure and significant incidents.
While current design approaches proved generally reliable, it is recognized that there is a lack of consistency on how and when they are applied, resulting in different degrees of economy (and sometimes un-economic design). The described design method is not based on an empirical approach but is based on a theoretical model that is proved to be ideal and reliable for soil decks/platforms on a soft clay subgrade stabilized with geosynthetics. The soft clay subgrade is characterized by the following geotechnical parameters in undrained condition: $\varphi = \varphi_u = 0$ and $c = c_u$.
The successful real experience and case studies will emphasize the effectiveness of the design approach.

2 STATIC METHOD AND GEOGRID DESIGN

2.1 *Static method*

The Static Method is based on applying a defined load on a defined area, based on the load data of construction plant to be used, rather than the different approach based on "area of applied load on the surface of the existing subgrade" and "bearing pressure on the surface of the existing subgrade" (which is supported by the empirical methods).

The design approach assumes that the platform is stabilized with geosynthetics that provide the following mechanisms:
- base course lateral restraint mechanism for horizontal stresses generated by platform soil self-weight (stabilization function);
- base course lateral restraint mechanism for horizontal stresses generated by crawler tracks loading (stabilization function);

- membrane mechanism at the deck – subgrade interface (reinforcement function).

Each of these three mechanisms produces tensile forces in geosynthetic layers.

It is then possible to determine the optimum number and the mechanical characteristics of geogrid and/or geotextile layers required for absorbing the horizontal forces generated by the above listed mechanisms.

This design approach will allow determination of the additional geosynthetics required to stiffen the platform to prevent catastrophic failure. In order to mobilize its tensile strength, the geosynthetic would need to strain and the deformation needed to mobilize this mechanism could exceed the serviceability requirements of the working platforms. These strains can lead to settlement depression between the contact planes.

The layered granular platform compensates for the settlement depressions in each subsequent granular layer, such that the upper surface of the granular platform is installed as a flat plane. The geosynthetics retain a permanent strain which is not critical to serviceability consideration; however, both theory and practical experience suggest that geosynthetic strain shall be limited to 5 %. Depending upon the function of the platform, lower strain values can be selected. For important or critical structures, the geosynthetic strain could be limited to 2 %. For less critical structures, or when the design condition affords slightly larger deformations, geosynthetic strain values between 3 – 5 % could be used.

The limit strain criterion shall be applied to the short term tensile strength of the geosynthetic, as measured in a wide width tensile test according to EN ISO 10319 standard.

The Static Method, which is applicable for designing working platform over soft clay soil, assumes that the bearing capacity q_u of an unstabilized platform on a soft clay sub-grade is:

$$q_u = \pi\, c_u \qquad (1)$$

and assumes that the bearing capacity of a geosynthetics stabilized platform on a soft clay subgrade is defined as:

$$q_u = 2\, \pi\, c_u \qquad (2)$$

where c_u = undrained shear strength.

This design approach is based on the distribution of vehicle wheel / track pressures throughout a geosynthetic stabilized layer. The design method ensures that the pressure at the top of subgrade is less than the allowable bearing pressure of the subgrade soil, divided by a defined Factor of Safety.

The Static Method assumes that the vertical pressures are distributed through the platform soil layer according to the Boussinesq theory (Das, 1990) for uniform load on a rectangular loaded area: hence the width and length of the crawler track will be considered as loaded area, as shown in Figure 1.

The Boussinesq equation provides the induced vertical stress at any point below the rectangular loaded area.

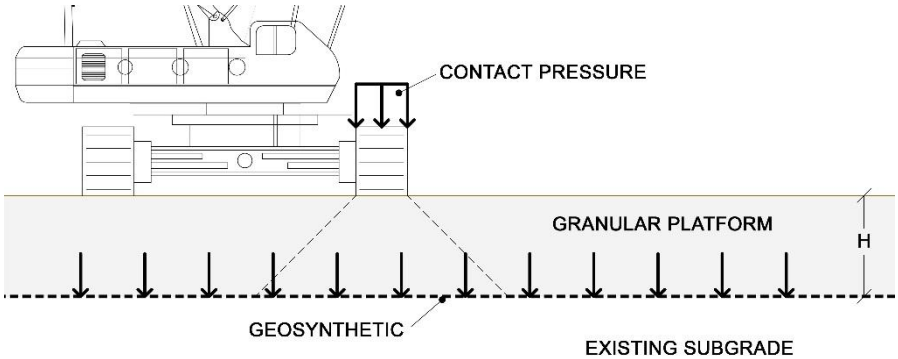

Figure 1. Static Method considers uniform load on a defined loaded area

An empirical relation between CBR value and the undrained shear strength can be used if subgrade CBR value is provided:

$$c_u = 30\ \mathrm{CBR}\ \ (\mathrm{kPa}) \qquad (3)$$

The required platform thickness (H) can be plotted versus the undrained cohesion (c_u) of the subgrade for both stabilized and unstabilized soil (Figure 2). If geosynthetics are introduced into the system, the thickness of the foundation decreases dramatically.

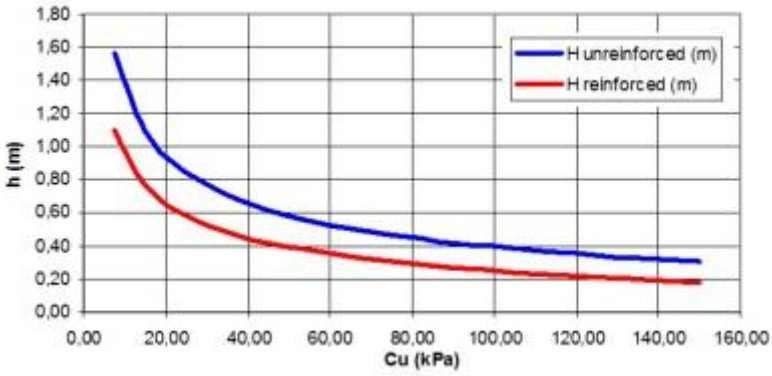

Figure 2. Typical plot of the required platform thickness (H) versus the undrained cohesion c_u of the subgrade considering the geosynthetics stabilized platform (red line) and the unstabilized platform (blue line).

2.2 *Geogrid design method*

The tensile forces produced in the geosynthetic layers by the described active mechanism and loading, must now be defined. A multi-layer model has been developed for the geosynthetics design.
The general scheme of the proposed design model (Figure 3) includes the following layers:
- asphalt course AC (the wearing course and the binder layer are considered as only one layer of thickness equal to the total thickness of both layers).
- base course BC;
- subbase course SB;
- subgrade SG.

The multi-layer model assumes that the track or wheel load is applied as a uniform vertical pressure $\sigma_{v0} = p$ on a defined area; this load spreads in the layers of the platform structure according to their load spreading angles α_1, α_2, α_3.

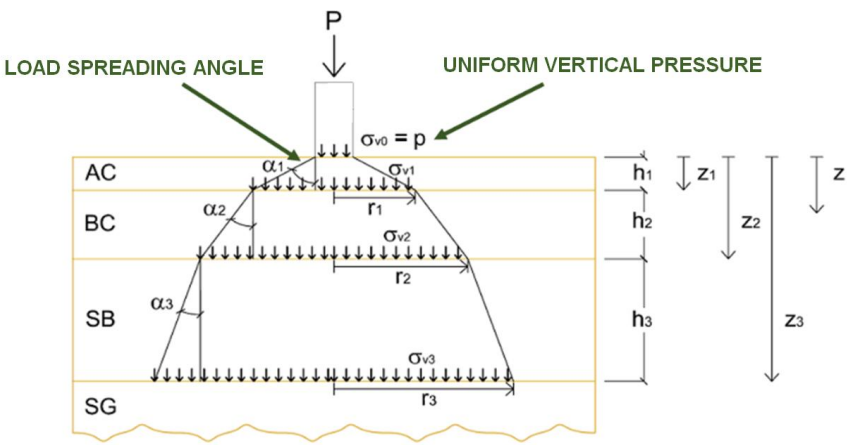

Figure 3. General scheme of the multi-layer model with different soil characteristics

In the proposed method, at least the base course shall be present and shall be stabilized with geogrids; the asphalt course may not be present (in the case of a temporary working platform or unpaved road) and, if present, it is not reinforced; the subbase course may be present or not; when it is present, it may be either stabilized with geogrids or unstabilized.

The tensile force T_{zi}, generated in the i-th geogrid layer by the horizontal thrust of the soil above it, can be easily calculated based on classic geotechnical theory.

The tensile force T_{Pi}, generated in the i-th geogrid layer by the horizontal thrust produced by the crawler track load P, can be easily calculated based on the assumed spreading angles α_1, α_2, α_3.

The first geosynthetic layer, at the interface with the subgrade, is subject to the highest vertical deformations, when the first soil layer is spread and compacted, due to the settlement of the soft subgrade; the next geosynthetic layers, instead, are far less subject to vertical displacements.

Hence, we can reasonably assume that the first geogrid layer is subject to the tensioned membrane mechanism, therefore the first geogrid can be considered as a catenary layer, while for the next layers such mechanism is negligible (Figure 4).

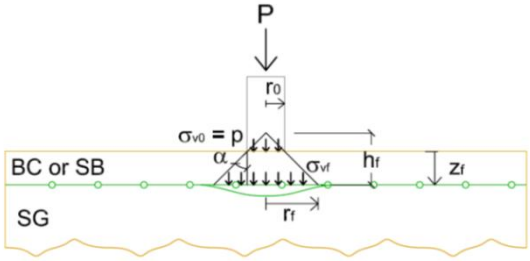

Figure 4. Scheme of the first geogrid layer

The total horizontal force that the i-th geogrid layer should withstand is then:

$$T_{tot\text{-}i} = T_{zi} + T_{Pi} + T_m \tag{4}$$

where:
T_{zi} = Force due to horizontal soil thrust in the i-th geogrid layer
T_{Pi} = Force due to horizontal stresses generated by crawler track loading in the i-th geogrid layer
T_m = Force due to membrane mechanism at the interface with subgrade
The i-th geogrid layer shall be able to provide a tensile force equal to or larger than $T_{tot\text{-}i}$ at a maximum strain defined by the design (usually within 2 to 5 %).

3 CASE HISTORIES

The Static Method enabled the design of one of the biggest applications of a temporary working platform in the UK, where 120,000 m^2 of geosynthetics material has been laid over a very soft cohesive subgrade and create a suitable hard standing. This temporary working platform project, called Ince Park in Cheshire, was one of the first in the UK designed with the Static Method (Brusa et Al, 2016). The experience gained on this project and the theoretical technical soundness of the Static Method allowed the development of further projects such as the ones presented below.

3.1 *NBAR – North Bexhill access road, Bexhill-on-Sea, East Sussex, UK*

The North Bexhill Access Road project is a 2.4 km single carriageway road designed to accommodate future employment land to the north of Bexhill-on-Sea in East Sussex, South East England. The completed infrastructure project will stimulate business and housing growth around the area. Works began on site in July 2016 and are still ongoing with a planned finished date towards end of 2018. One of the main feature of the project are soil road embankments. The embankment on phase 1, that was completed in winter 2016, sits over soft soil material and it is reinforced using high strength uniaxial geogrids as basal reinforcement. The embankment on phase 2, which started in October 2017, is located over depth alluvium and over peat lenses. Therefore, it was designed over ground improvement columns combined with a high strength uniaxial geogrid acting as load transfer platform.

In both phases, mobile cranes and piling rigs were present on site to support the operations.

The Static Method was then used for the design of the temporary haul roads and hard standings working platforms. The ground conditions encountered on site generally consisted of alluvium overlying solid deposits of the Tunbridge Wells Sand, the Wadhurst Clay and the Ashdown Formation, with a soil strata profile as follow:

- Soft made ground with silty clay pockets and superficial deposit (alluvium) with local pockets of peat down to approx.8.55 m below ground level (bgl).
- Spongy dark brown fibrous peat was encountered between 4.70 and 5.20 m bgl. It was also noted that at both sides of this peat layer, between 3.90 to 6.25 m bgl, fibrous peat pockets were encountered up to 50 mm thick.
- Firm clay with some sandy layer down to 8.55 m bgl
- Stiff to very stiff clay and weathered mudstone beyond.

Further testing confirmed an undrained shear strength (c_u) between 10 kPa to 20 kPa for the sub-strata. Those values were assumed to perform the Static Method design.

For this project, using the Static Method, it was achieved a variable thickness platform from 700 mm up to 900 mm of compacted granular material with the inclusion of two or three layers of high strength polyester woven geotextile (Figures, 5, 6, 7). The high strength geotextile was chosen at the interface with the existing wet subgrade material since it is able to provide the reinforcement and the separation function together in one product.

Compared to traditional design methods such as BRE BR470, the Static Method provided a thickness platform reduction up to 30 % compared to BRE BR470 results.

Figure 5. High strength geotextile (in white) installed over the soft clay sub-strata

Figure 6. General view of the geosynthetics stabilized working platform during the final stages of construction.
Figure 7. Rig machine during operation on site in October 2017

A similar design approach, using the proprietary MacRead Studio software, has been adopted also for design of the soil stabilisation of the site haul roads and compound / car park areas (with a minimum thickness of the stabilized granular layer of 300 mm using woven biaxial geogrids, see Figures 8 and 9).

Figure 8 and 9. Woven geogrids designed and installed for the haul access roads

3.2 *Hoobrook Link Road bridge, Kidderminster, Worcestershire, UK*

In December 2015, the latest phase of the Hoobrook Link Road was finalised with the construction of the bridge over the canal and river. This project included large and heavy beams (nr 4 in total, 75 t each) being lowered into place using the biggest crane in Europe, the LG1750. Hoobrook Link Road now connect the A451 Stourport Road over the Staffordshire and Worcestershire Canal and River Stour, through to the A442 Worcester Road. The road is situated within the South Kidderminster Enterprise Park.

The Static Method, combined with the BS 8006 guidelines, was used to design the reinforced slope required to provide a temporary platform for a piling rig, and subsequently for the two cranes: the Terex AC250-1 (250 t) and theLG1750 (750 t). The Static Method was used also to check and analyse the combinations of:

- the modular trailer and LG1750 travelling loads, and
- the modular trailer and AC250 crane outrigger loads.

Especially due to space site constrains and position of the bridge beams, close by the front face of the 70 degrees reinforced soil slope, the LG1750 crane outriggers were placed over a piled foundation (which was not strictly required for the abnormal loads). CFA piles were driven and installed through the reinforced soil block before the LG1750 lifting operations (Figure 10).

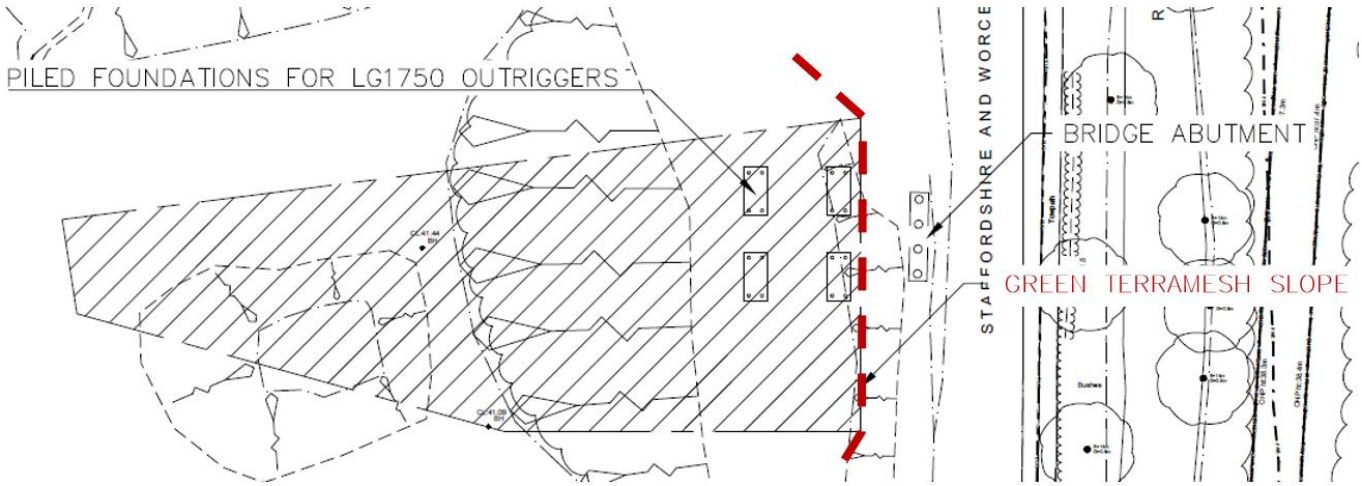

Figure 10. The 70 degrees reinforced soil structure was designed with a double twist wire mesh system combined with uniaxial high tenacity polyester geogrid

Figure 11 and 12. Crane outriggers / pads were placed very close to the front face of the reinforcement soil slope. Therefore, the decision to have the crane pads over CFA foundation piles

Figure 13 and 14. Despite some strong winds and less than favourable weather conditions, the construction team were able to get four 75 t beams hoisted and lowered into position, in two separate lifts

4 CONCLUSION

Temporary granular platforms are required and necessary elements of almost all construction sites but the need to ensure that they are adequate for the intended use is often overlooked. Since the design is frequently only derived from previous experience, this has, on occasions, resulted in significant incidents of overturning plant that caused, at best, cost and delay or, at worst, injury and/or death.

The proposed design method is developed on the theory of static load distribution in unstabilized and stabilized cohesive soil, while the multi-layer geogrid design is based on a specific load distribution model which allows the working strain level and tensile forces in geosynthetics to be calculated and compared with set design values. It is worth mentioning that the proposed method has been used worldwide and checked by third parties for the transparency of the output result. The reduction in thickness achievable by the described design methodology make quite clear the financial and the considerable environmental saving provided.

Economic savings in imported granular fill and subgrade undercut and disposal can be very significant.

The ease of construction afforded by using geosynthetics can speed up the construction of the soil platform, thus reducing the installation time.

Two designed examples were presented considering different types of loads and different types of geosynthetics.

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