# A Review of Geogrid Working Platform in Soft Ground in Malaysia

## Analyse du comportement de plateformes renforcées par géogilles en Malaisie

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ABSTRACT: This paper discusses the development of geogrid applications in soft ground in Malaysia. The Sungei Way trial during 1984 was conducted to assess the performance of geogrid in road pavement field trial conditions and a forerunner to the use of geogrid in working platform on soft grounds in Malaysia. Two layer biaxial geogrids system was first used in 1987 to rehabilitate an offshore fabrication yard in Pasir Gudang in Johor in Malaysia. Recently. geocell mattress and mechanically stabilised layer (MSL) formed with TriAx geogrids were used in offshore fabrication yard in Vung Tau in Vietnam. Similar concept was then adopted for a container yard in Gebeng, Kuantan in Malaysia constructed in 2011. The settlement performances of all heavy duty working platform reinforced with biaxial and TriAx geogrids with geocells were all satisfactory.

RÉSUMÉ: Cet article présente le développement d'applications des géogrilles en terrain meuble en Malaisie. Des essais à Sungei Way ont été effectués au cours de l'année 1984 pour évaluer la performance d'une géogrille lors de la construction d'un revêtement routier dans des conditions in-situ. C'est le test précurseur pour l'utilisation de géogrilles en plateforme de travail sur sols mous en Malaisie. Un système de géogrilles biaxiales à deux couches a été utilisé pour la première fois en 1987 pour réhabiliter le chantier de fabrication offshore de Pasir Gudang à Johor en Malaisie. Récemment, un matelas geocellulaire et une couche stabilisée mécaniquement (MSL) formée par des géogrilles TriAx ont été employés dans le chantier de fabrication offshore de Vung Tau au Vietnam. Un concept similaire a ensuite été adopté dans un chantier de conteneurs construit à Gebeng (Kuantan, Malaisie) en 2011. Les performances de comportement des plateformes d'ouvrages lourds renforcées par des géogrilles biaxiales et TriAx avec géocellules ont toutes été satisfaisantes.

KEYWORDS: geogrids, working platform, soft grounds, reinforcement, road pavement, ground stabilisation.

## 1. INTRODUCTION

This paper discusses the development of geogrid in soft ground in Malaysia. The Sungei Way trial during 1984 was conducted to assess the performance of geogrid in road pavement field trial conditions (Ooi et al., 2004). The results of the Sungei Way trial were verified by the more rigorous Transport Research Laboratory (TRL) full scale laboratory trials (Chaddock, 1988). Based on the results of the full scale trials, it was concluded that punched and stretched biaxial geogrids (i.e., stiff biaxial geogrids) in granular base or subbase is effective in achieving the following results: -

a) Interaction by interlocking between the geogrid and the granular material is mobilised with minimal deformation of the geogrid;
b) Tensile strains and deformations in subgrade are minimised;
c) Interlock provided by the geogrids confines the granular materials and minimises their lateral displacement; and
d) Reduction in rut depth for similar pavement life.

The trials have shown the physical form of geogrid (e.g., rib thickness, stiffness and shape, aperture size, rigidity and stability, junction strength and secant modulus at low strain as subsequently reported by Webster (1992)) and its ability to interlock effectively have major effect on performance of the mechanically stabilised layer (i.e., soils stabilised with geogrids). The important findings arose out of the full scale trial on the benefits of using stiff biaxial geogrid in the road pavement led to the construction of loading platform using geogrid to overcome the deformation and rutting of platform surfaces during service. In particular, the deterioration of platform surfaces caused by ground softening as a result of ponding of water on the platform of offshore fabrication yard during rainfall season. In ground stabilisation, especially for working platforms, the loading applied to the geogrid is multi-directional. A geogrid that can offer the properties of stiff biaxial geogrids and possess near-uniform tensile stiffness in all radial directions would be best suited for such application. Watts and Jenner (2008) conducted as series of large-scale laboratory load tests to assess the effectiveness of geogrids to stabilise granular working platforms and concluded the use of geogrids will significantly increase the bearing capacity of working platforms. The research also shows that triaxial geogrid with near-uniform tensile stiffness in the radial sense (i.e., TriAx) outperformed the biaxial geogrid and almost doubled the bearing capacity offered by the un-stabilised granular blanket of similar thickness.

Apart from using multiple layer of geogrids to stabilise granular material in working platform application, geocell mattresses are also used in some cases. Geocell mattress is a series of interlocking cells formed using stiff polymer geogrid reinforcement to contain and confine granular material providing stiff and rough foundation to an embankment that maximises the bearing capacity of the soft soil beneath it. Jenner et al. (1988) used the slip line fields to assess the improvement in bearing capacity of soft ground under geocell mattress installed at the base of an embankment. This provided a useful analytical method of assessing the horizontal stresses in the geogrid elements.

In Malaysia, the first loading platform using mechanically stabilised layer (MSL) for the fabrication yard to use geogrid was in Pasir Gudang, Johor in 1987 (Figure 1). Two layers of stiff biaxial geogrids were used to stabilise a metre thick of compacted quarry waste layer that form the top portion of the loading platform. During lifting operation the crawler crane track can exert contact pressure of up to 500 kPa (Yong et al., 1990, Chan, 2000, Ooi et al., 2004). Many similar loading platforms were built later. Recently, MSL has been combined with geocell mattress for the construction of a heavy duty working platform over soft soil in Vung Tau in Vietnam using one metre thick of geocell mattress to support a two metre thick MSL as a loading platform for the heavy crawler crane exerting a contact pressure of 500 kPa (Ong et al., 2011). The two loading platform performances are compared and it is found that both loading platforms performed satisfactorily with settlement of less than 50 mm. In 2011, geocell mattress and MSL were used in another project on soft ground for a container yard in Gebeng, Kuantan in Malaysia. In this case one metre thick of geocell mattress were used to support the container pavement of 760 mm thick aggregate base course stabilised with two layers of TriAx geogrid (MSL) and interlocking paving block finishes.

Figure 1. General condition of working platform without gegorids. (after Yong, Chan et al., 1990)

## 2 PASIR GUDANG FABRICATION YARD

The rehabilitation of the muddy platform started by removing the top 700 mm of residual soil fill (Figure 2). One layer of the biaxial geogrid was then placed on top of the compacted clay fill at excavated level. Backfilling using compacted quarry waste, a granular material, carried out after suitable subsoil drains were laid (Figure 3). Another layer of biaxial geogrid was placed before filling with compacted quarry waste for a further 300 mm.

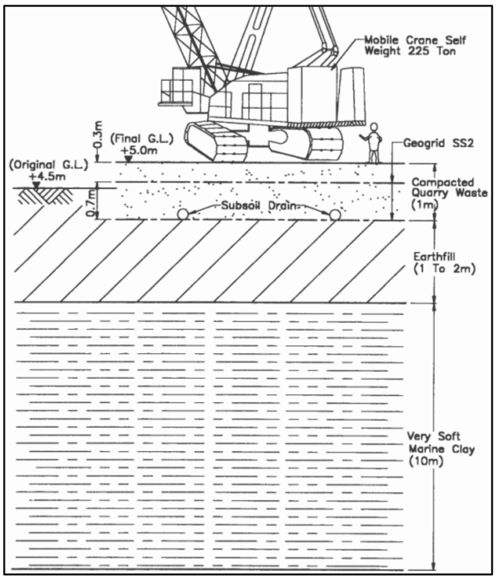



Figure 2. Schematic section of rehabilitated working platform. (after Chan, 2000)

The completed platform formation was tested and at 30 passes of the 2.3 MN crawler crane carrying 700 kN load and the resulting deformation measured was 37 mm (Chan, 2000), with decreasing rate of deformation after each pass, which was acceptable by the fabricator. Settlements on the subgrade and outside the crane track were measured (Figures 4 & 5). The rehabilitated fabrication yard was in use after handing over to the fabricator (Figure 6).

Figure 3. Platform rehabilitation work in progress. (after Yong, Chan et al., 1990)

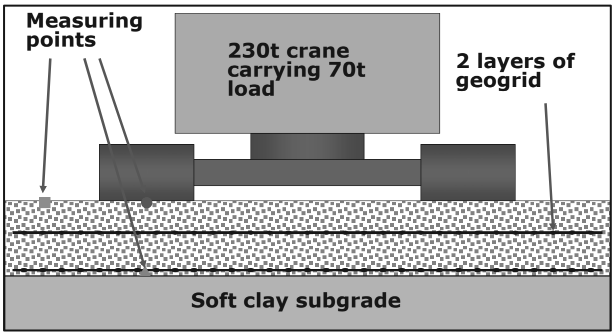



Figure 4. Settlement measuring points.

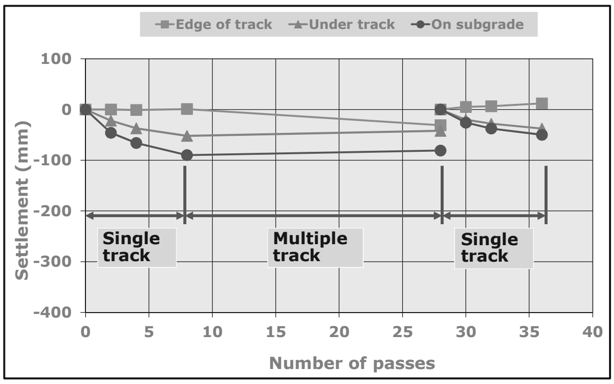


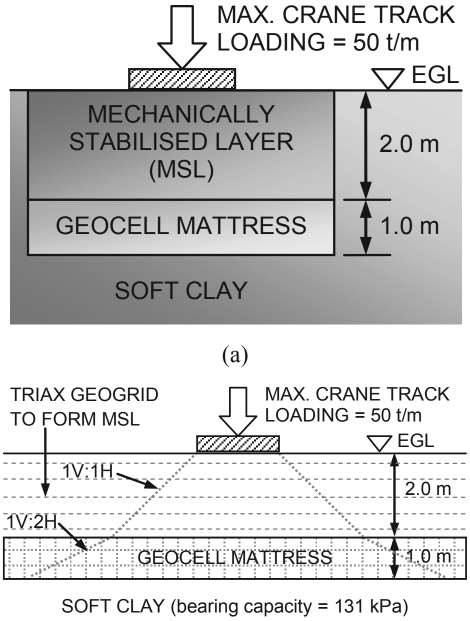

Figure 5. Plot of settlement versus number of passes.

## 3 WORKING PLATFORM IN VUNG TAU

In Vietnam, the geocell mattress with MSL was adopted for the construction of the working platform for an offshore facilities fabrication yard in Vung Tau, Vietnam (Ong et al., 2011). The working platform was required to take loading from heavy crawler crane tracks up to 50 t/m². The exhibited design uses conventional reinforced concrete pile-raft foundation system to support the working platform. However, in order to accelerate the construction works, alternative solutions using geocell mattress with MSL was selected not only will it reduce the construction time but also being more economic and sustainable. This geocell mattress with MSL was designed to form a working platform to support the movement of crawler cranes with 2 m wide and 13.7 m long crane tracks separated by a clear distance of 7.6 m. The maximum load to be supported on each track area is up to 50 t/m². The foundation soil is 10 m thick soft bluish clay with an average undrained shear strength of 23 kPa from vane shear test results.

Figure 6. Rehabilitated fabrication yard in use.

In the calculations, the angle of load spread for the fill material reinforced with TriAx geogrid within the MSL is taken to be 1 vertical to 1 horizontal (i.e., 1V:1H) whereby the load distribution through the geocell mattress was taken as 1 vertical to 2 horizontal (i.e., 1V:2H) to model the very stiff nature of the construction (Figure 7).




(a)

(b)

Figure 7. Geocell mattress and MSL platform (after Ong et al., 2011)

Five layers of TriAx geogrids were used to form the 2 m thick MSL. Stiff uniaxial geogrids were used to form the interlocking cells of the 1 m thick geocell mattress and a layer of TriAx geogrid was placed at the base. The aggregate to be used as backfill material for the MSL and geocell mattress was specified as well graded granular material with particle size less than 75 mm. Full scale plate bearing test (PBT) was conducted to ascertain the performance of the geocell mattress in meeting the acceptance criterion (i.e., total settlement less than 100 mm under loading of 50 t/m²). The loading on the steel plate was increase in six steps: 10 t/m², 20 t/m², 30 t/m², 40 t/m², 50 t/m² and 60 t/m². Settlement versus applied load and settlement versus time were plotted. It was found that the specified settlement requirement was satisfied with total settlement of 41 mm under 60 t/m² load.

## 4 CONTAINER YARD IN GEBENG, KUANTAN

In this project, a working platform in the form of container yard was built on soft subgrade with California bearing ratio (CBR) of 1% to 2%. The container yard was designed to support the following loadings:

- 6 m by 2.4 m container with maximum weight of 30 tonnes. Maximum staking of containers was 2 containers.
- Container handler machine with maximum axle load of 105 tonnes. Therefore maximum wheel load of 525 kN including dynamic factors.
- Total number passes of the container handler machine was designed as 250,000 during service life.

The terms of reference are:

- To reduce thickness of unbound granular layer platform.
- To mitigate differential settlement.
- To provide stable storage area and to increase load spread using geocell mattress and mechanically stabilised layer (MSL) with TriAx geogrids.

The analysis conducted indicated that the loadings from the trafficking movement due to container staker would be more critical than the static loadings due to the staking of 2 containers. Thus, the requirement for total platform thickness was assessed based on heavy duty pavement design (Knapton, 2008). By using geocell mattress and MSL, the thickness of granular fill required to construct the container yard has been reduced up to 810 mm. This resulted in substantial savings in terms of construction time and cost.

For the heavy duty pavement construction of the container yard, 1 m high geocell mattress was placed on one layer of TriAx geogrid at subgrade level. The geocell mattress is to provide a firm and relatively rigid platform with a perfectly rough interface between the mattress and the soft foundation. This stiff platform is created by the high tensile strength of polymer grid material used in the cellular construction to confine the granular fill which enables an even distribution of load onto the foundation. On top of the geocell mattress is MSL of 500 mm to 750 mm compacted well graded granular fill with 3 layers of TriAx geogrids. Granular layers reinforced with TriAx geogrids perform as composite due to the interlock phenomenon. The configuration of the geogrid ribs and the integral junctions provide lateral restraint to the aggregate particles as they partially penetrate the apertures by a process of interlock. This interlock effectively stiffens the aggregate and enables any imposed load to be distributed over a wider area. The container platform was finished with interlocking paving blocks. The construction of the container yard is expeditious starting from placement of TriAx geogrids, forming of geocells, filling with granular materials according to prescribed grading envelope, construction of MSL geogrid reinforced layers and installation of the paving blocks (Figures 8 to 12).

## 5 DISCUSSION AND CONCLUSION

Comparison is made in the pavement details and settlement performance of the working platform (Table 1). From Table 1 it can be seen that all the 3 platforms consist of soft clay layer of thickness varying from 4.5 m to 10 m. The crane track pressure exerted on the working platform was up to 500 kPa and axle load exerted by the reach stacker on the working platform is 105 tonnes. Granular fill of varying thicknesses were used in all three working platforms. It appears that MSL constructed using biaxial and TriAx  geogrids with granular fill with or without geocell mattress performed satisfactorily in terms of platform settlement performances to support the heavily loaded crawler crane or stacker machine for the fabrication or container yard.

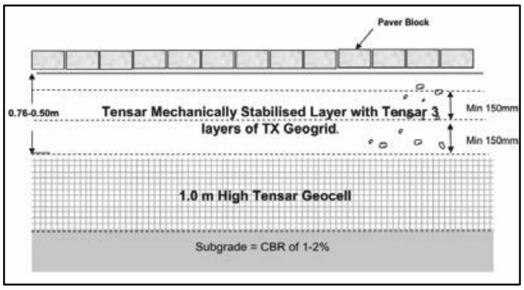



Figure 8. Typical section of proposed pavement

Figure 9. Laying of TriAx geogrids

Figure 10. Install diaphragm with Tensar uniaxial gegorid and filling of geocells with granular materials.

Figure 11. Construction of MSL with granular materials.

Figure 12. Placement of interlocking paving blocks.

Table 1. Comparison of the working platforms

| | **Pasir Gudang, Johor** | **Vung Tau, Vietnam** | **Gebeng, Kuantan** |
|---|---|---|---|
| Subsoils | 10 m soft clay | 10 m soft clay | 4.5 m soft clay |
| Working Platform | Fabrication Yard | Fabrication Yard | Container Yard |
| Handling Equipment | Crawler Crane (250T) | Crawler Crane (track pressure 50t/m$^2$) | Reach Stacker (105T axle load) |
| Pavement Details | 1m thick quarry waste | 1 m high geocell; 2 m thick MSL with TriAx | 1 m high geocell; 500-750 mm thick MSL with TriAx |
| Geogrids | 2 layers SS2 | 5 layers TriAx | 3 layers TriAx |
| Granular Materials | Quarry Waste | 75mm down aggregates | 75mm down aggregates |
| CBR | 2% | 1% | 1%-2% |
| Settlement | < 40 mm | < 100 mm | Recipe design |

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