Ultimate resistance of geogrid-reinforced working platforms for tracked plants over cohesive subgrade

Colin Lim, Naue Asia

Amir Shahkolahi, Global Synthetics, Australia

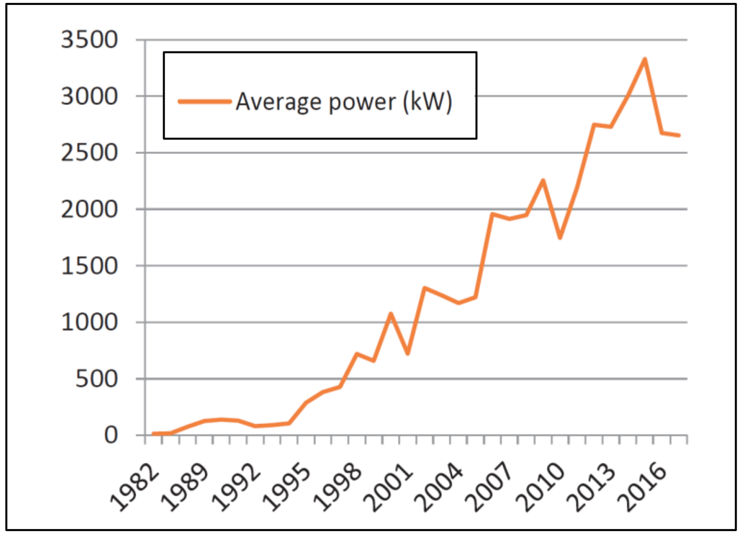
GEOANZ #1 ADVANCES IN GEOSYNTHETICS

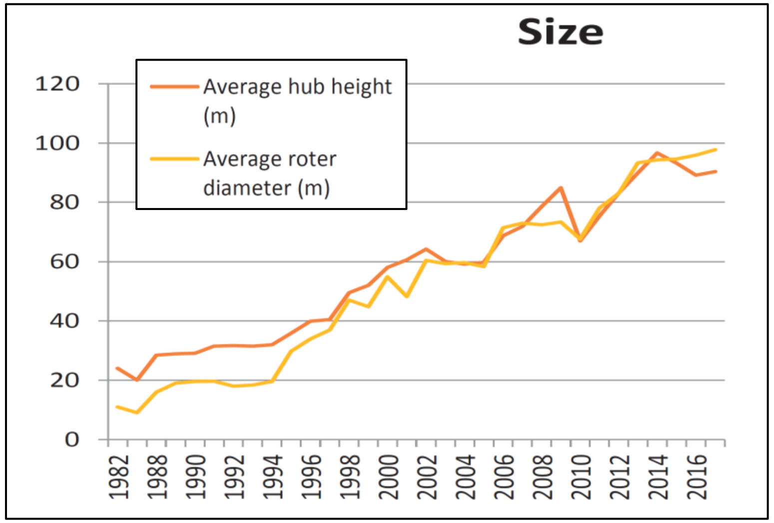
7–9 JUNE 2022 | BRISBANE CONVENTION & EXHIBITION CENTRE

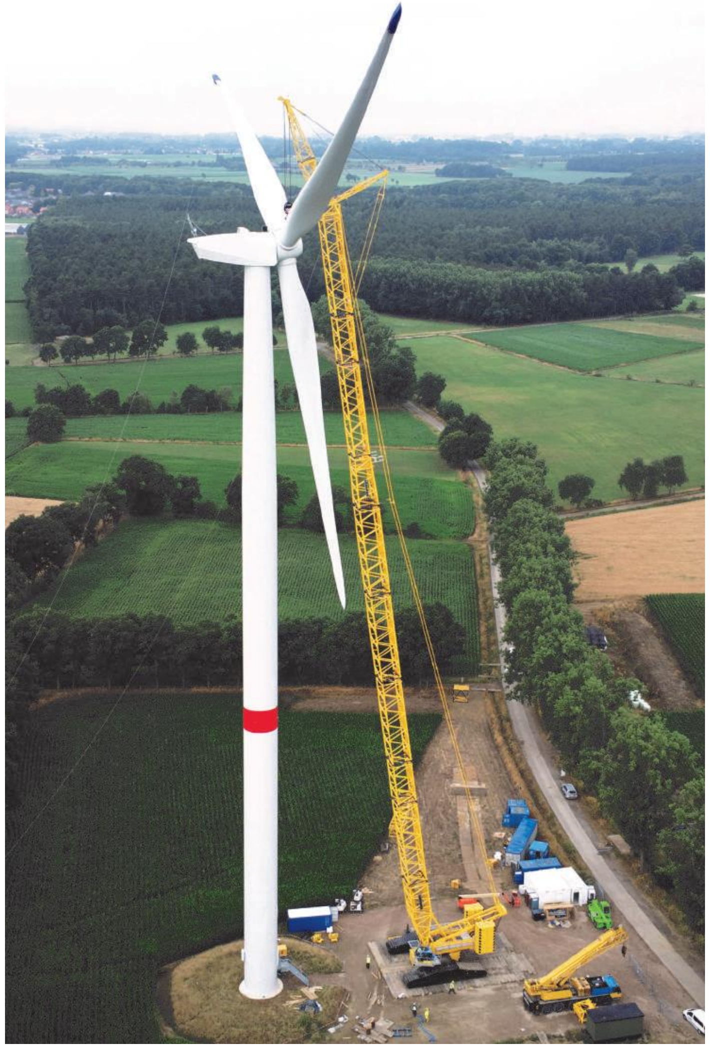
Demand on larger cranes and rigs

The size and height of wind turbines on land have grown considerably during the past decades. The cranes needed to install (and to maintain) these turbines have therefore also undergone huge increases in size and weight, resulting in increased crane loads.
While at the start of the 1980s, wind turbines were some 15 m in height, by the mid-1990s they had already reached heights of 50 m. Today, wind turbines can average 100 m in height.

Current forecasts suggest that the wind turbines of the future will have an average hub height of 150 to 200 m.







Accidents and failures on site

Rotational failure at the edge of platform

Emsworth, Australia at 30th July 2019

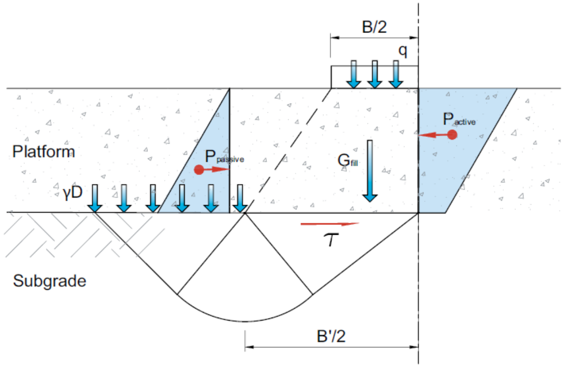
Tilting of the piling rig

Rotational failure at the edge of platform, *Brunei, Asia*

Punching shear failure

Lessons learned from previous failures

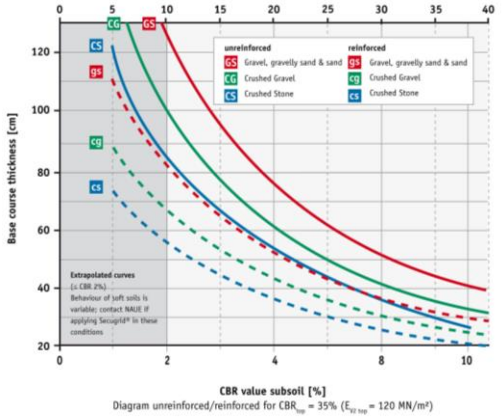
CIRIA SP123



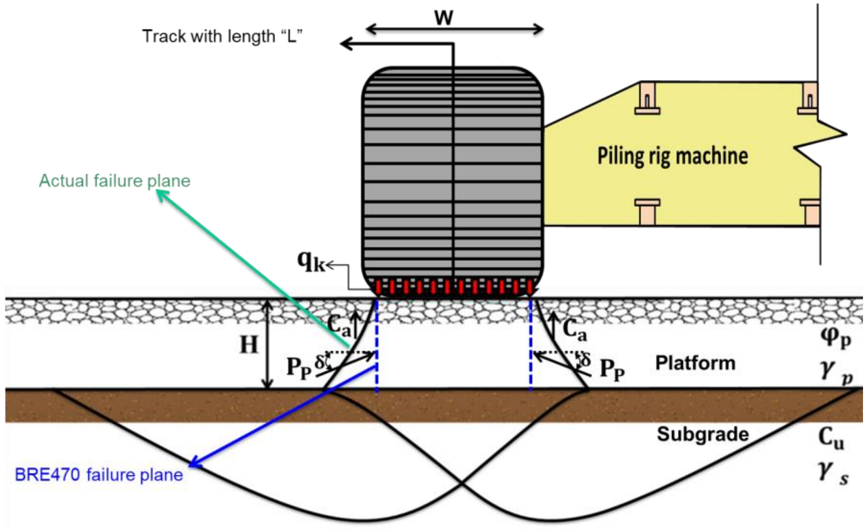
1) ***Punching shear failure of working platform***. This failure occurs commonly in the working platform subject to high compression loads and is characterised by very large settlements (e.g. BRE470 Design Guideline)

Solution: There are several methods in design guidelines and state of the art which can be used to prove the sufficient bearing capacity against punching shear failure i.e. Target CBR model, BRE470, Load distribution model, CIRIA SP123 etc.

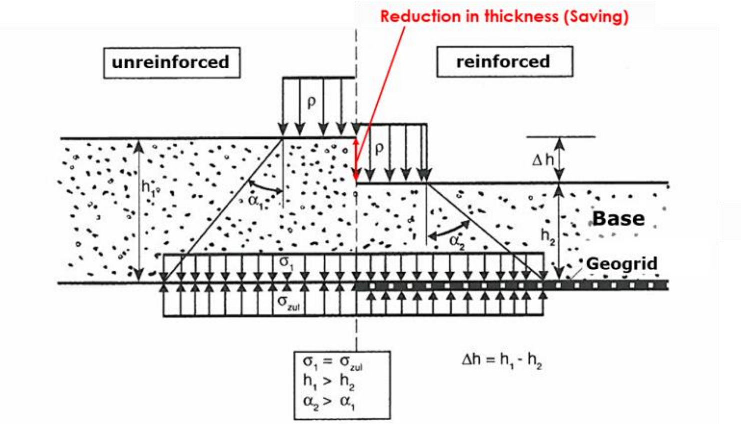
Target bearing capacity method (CBR or E_{V2})



BRE470



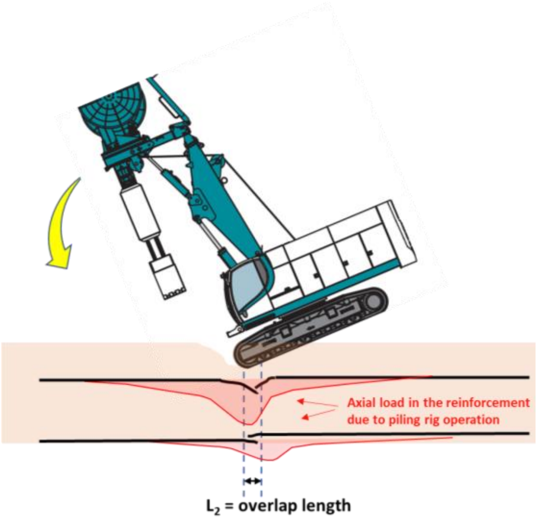
Load Distribution Method



Lessons learned from previous failures

2) Overall and rotational analysis of working platform *on the weak soil* to identify the potential failure lines on which the working platform and the subgrade soil may slide.

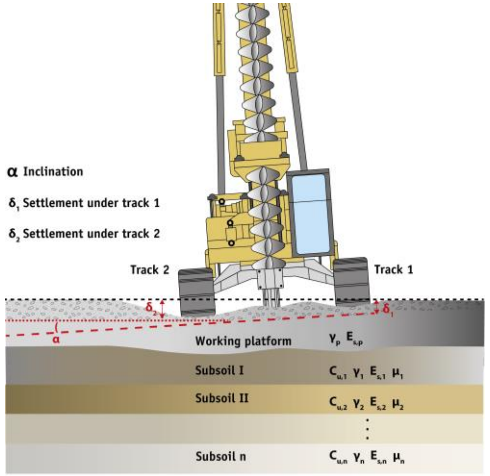
Solution: performance of stability analysis according to theoretical models such as Bishop & Wedge Method or using numerical models such as FE or KEM modelling



3) Immediate deformation and settlement of tracks/pads *on the weak soil*

Solution: performance of settlement analysis using the complex finite element software

- Most of FE models cannot consider the aggregate -geogrid interaction and neglect the stabilisation effect of geogrids.



Large-scale tests at Stuttgart University, Germany

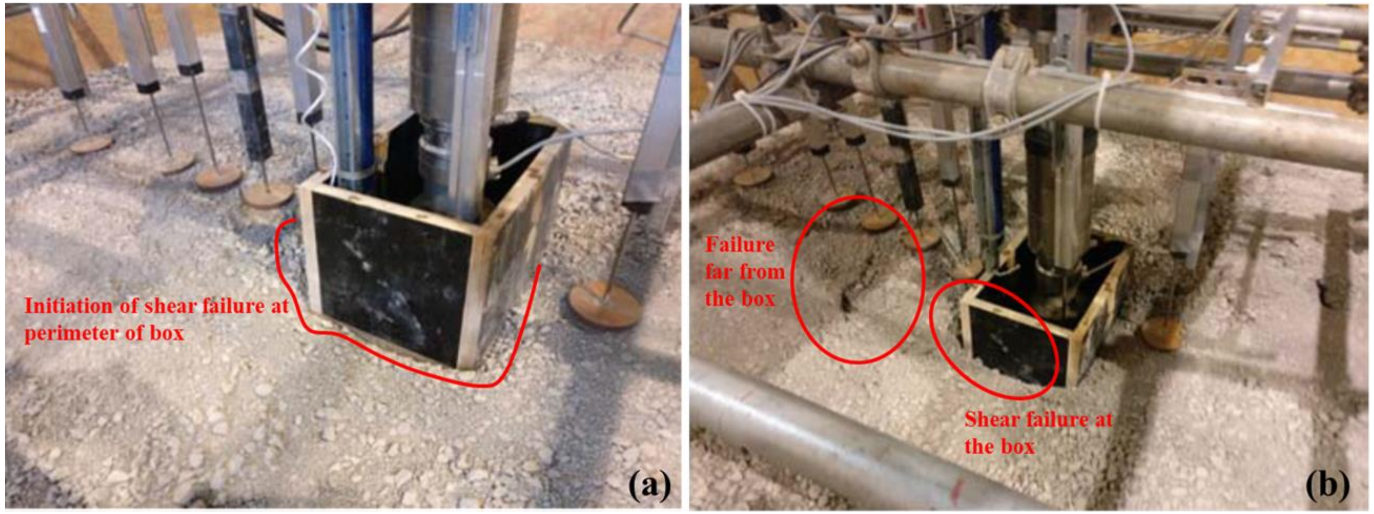
Large scale experiments were performed on geogrid reinforced working platforms by Stuttgart university.

The settlements in several positions underneath the loaded area corresponding to each load step are measured by the displacement transducers. Strain gauges are used to measure the elongations and correspondingly loads in the reinforcement

Loads of increasing magnitude (P=10, 20, 40, 50 etc.) are applied on the working platform to allow for an incremental comparison of results for reinforced versus non-reinforced platforms and to enable a trackback estimation of maximum allowable bearing capacity.

The model is subject to loads from a rectangular shaped plate with the dimension of 25 cm x 35 cm.

The geometry of model is considered to represent a prototype problem with a scale of 1/3. The width of the box and the distance between the footing and the wall is chosen large enough to minimize the boundary effects (footing width / box width < 0.1). Platforms (including un-reinforced, with one geogrid layer, with two geogrid layers) are set up to investigate the effect of reinforcement.



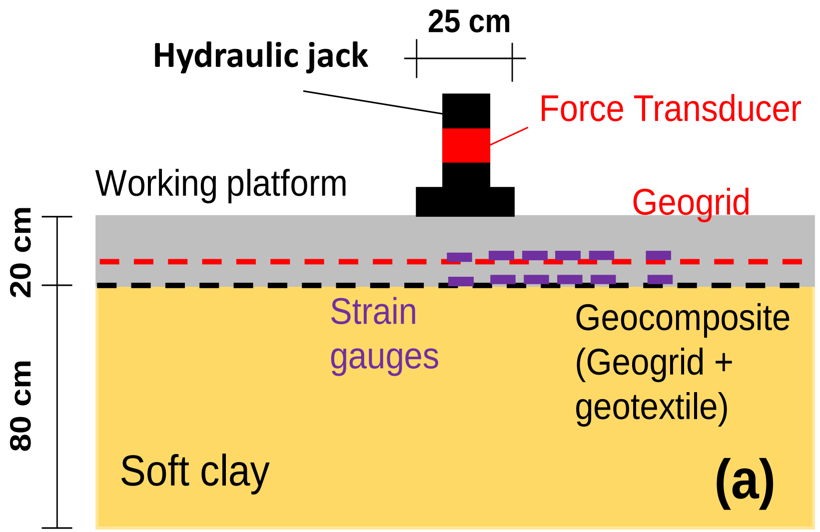
Large-scale tests at Stuttgart University, Germany

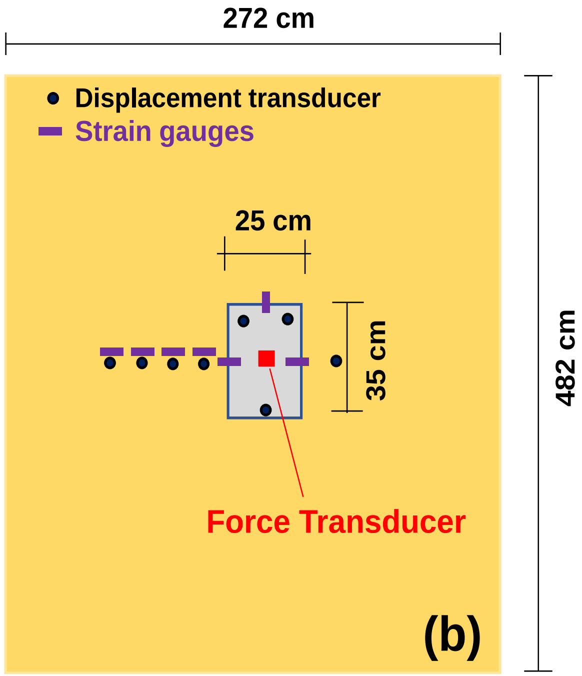
Loads of increasing magnitude (P=10, 20, 40, 50 kN etc.) are applied on the working platform to allow for an incremental comparison of results for reinforced versus non-reinforced platforms and to enable a trackback estimation of maximum allowable bearing capacity.

The model is subject to loads from a rectangular shaped plate with the dimension of 25 cm x 35 cm.

The geometry of model is considered to represent a prototype problem with a scale of 1/3. The width of the box and the distance between the footing and the wall is chosen large enough to minimize the boundary effects (footing width / box width < 0.1).

Several platforms (including un-reinforced, with one geogrid layer, with two geogrid layers) are set up to investigate the effect of reinforcement.





Large-scale tests at Stuttgart University, Germany

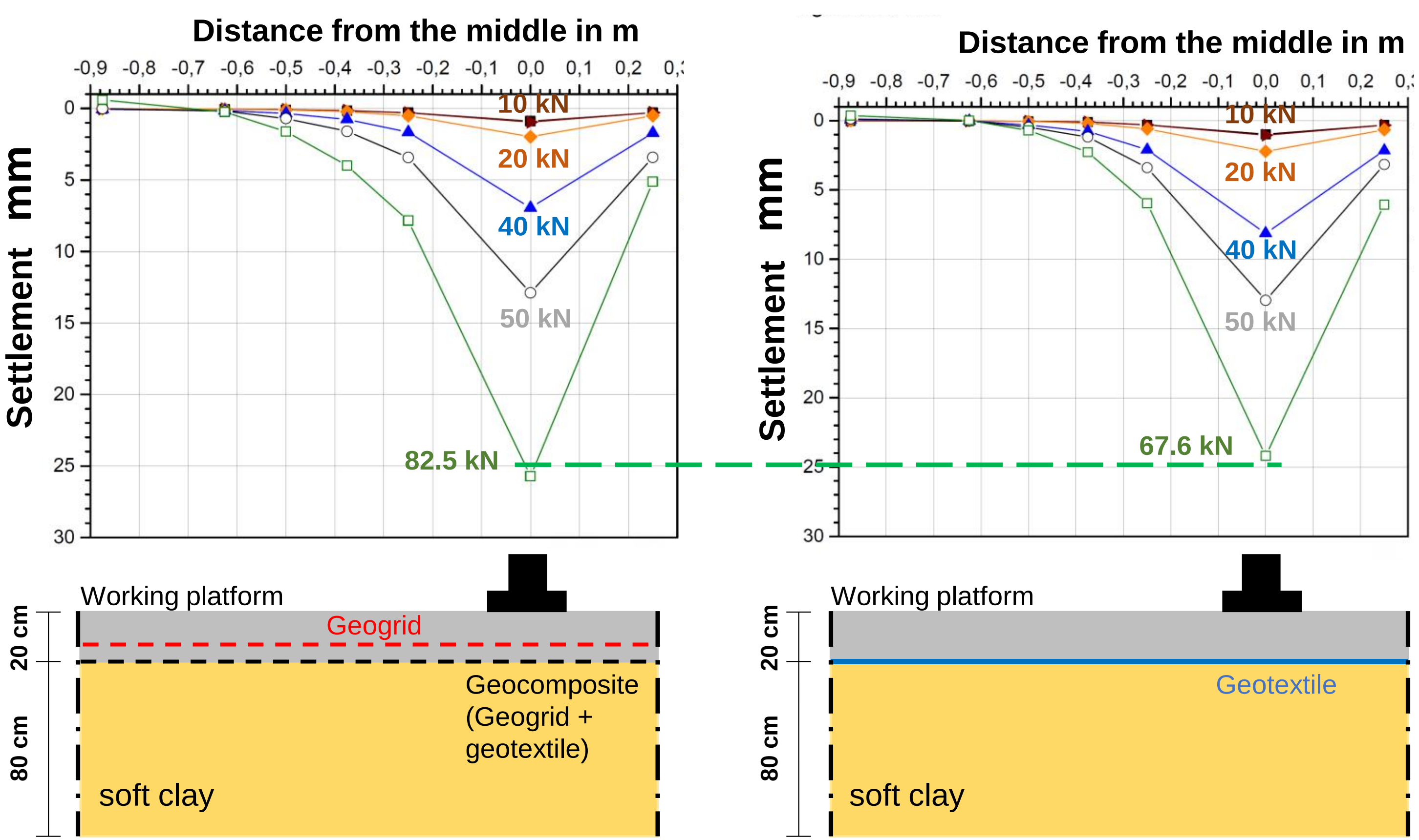
Here, the results from the un-reinforced platform versus platform with two geogrid layers are focused.

The results show that, the ultimate allowable load to be applied on the model with reinforcement (82.5 kN) is moderately higher (ca. 25%) than the load on the non-reinforced model (67.5 kN).

Accordingly, larger deformations were observed in the non-reinforced working platform at the different loading steps, especially before the ultimate bearing capacity of the working platform was achieved (loads smaller than P=25 kN as shown in Figure).

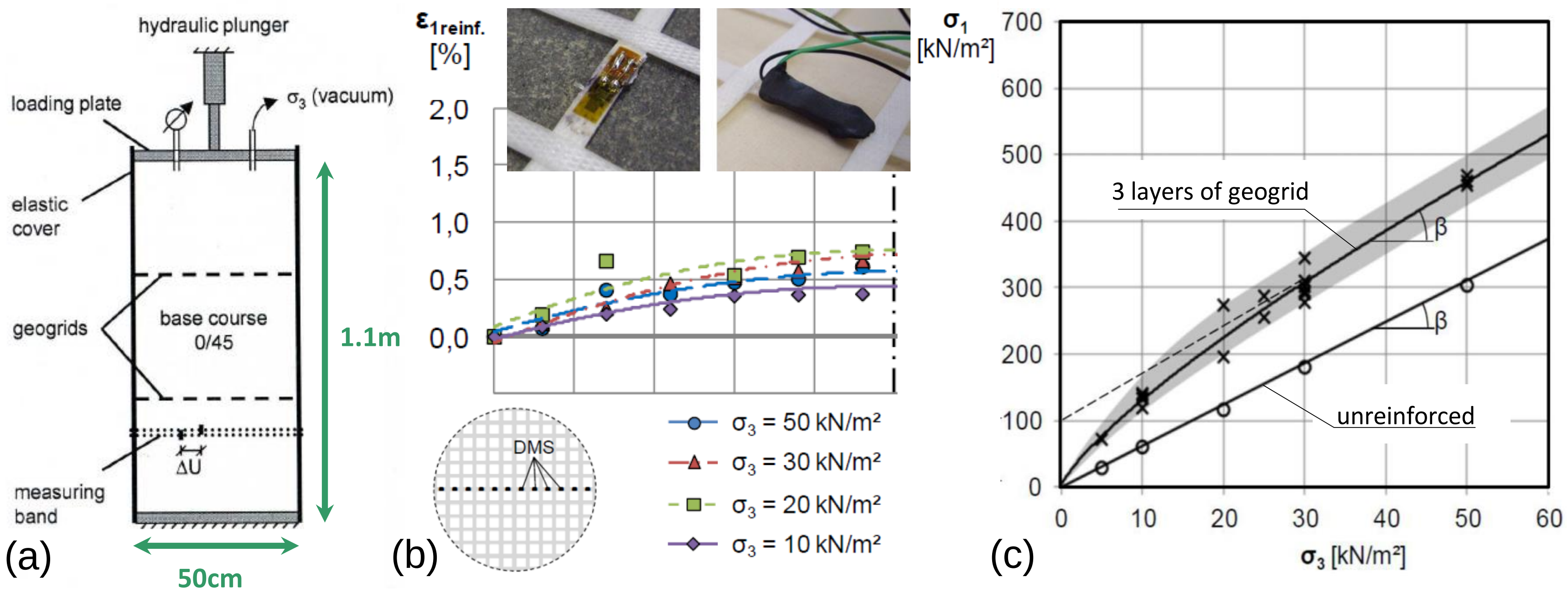
The test results showed that, the extreme loading of the working platform cause large and deep shear failures at the perimeter of plate and further away far from the loaded plate.

The failure is less severe in case of reinforced platform compared to un-reinforced platform



Large-scale tests at Aachen University, Germany

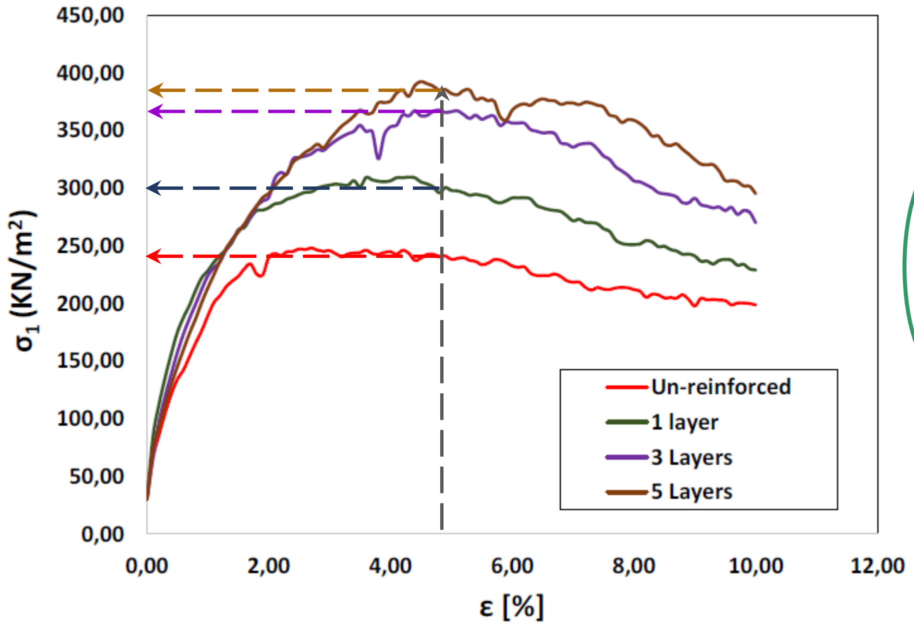
The large triaxial tests of 500 mm diameter and 1.1 m height have been carried out at the Institute of Foundation Engineering, Soil Mechanics and Waterways Construction at RWTH Aachen university for quantification of the effect of geogrid application on the soil characteristics. Figure (a) shows the test setup, while the number of geogrid layers has been varied. Strain gauges have been applied to the welded geogrid. Figure (b) shows the development of strains within the reinforcement at a strain of the soil sample of 2 %. The maximum strain required to stabilize the sample is limited to approx. 0.5%. The results from the tests revealed a significant improvement of soil bearing capacity and modulus of elasticity due to the application of geogrid reinforcement. (Figure c)

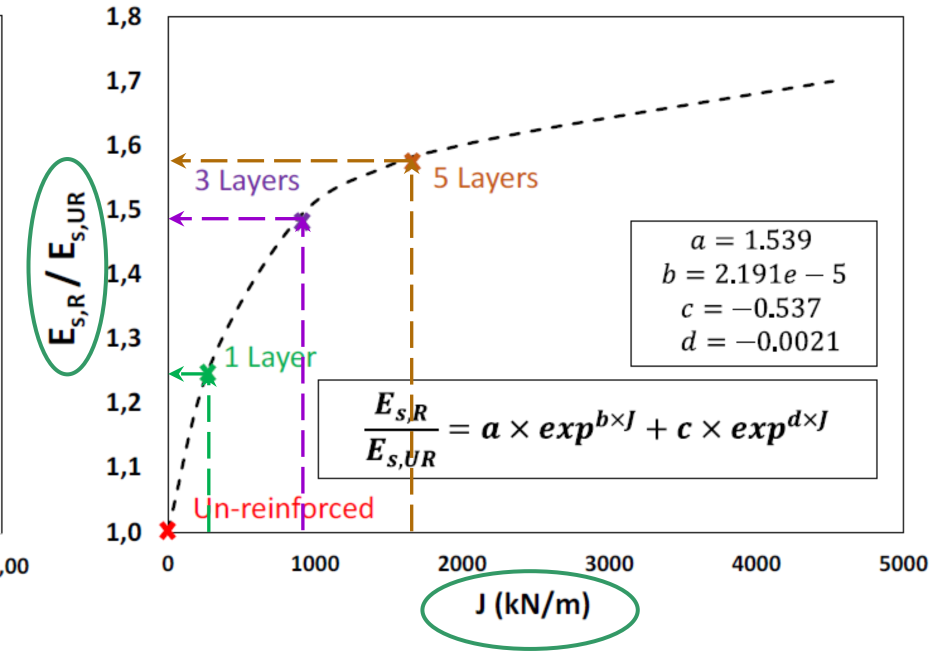


RWTH AACHEN UNIVERSITY

Large-scale tests at Aachen University, Germany

For this purpose, the data from the large triaxial tests at RWTH Aachen university is analyzed to investigate the effect of soil stabilization due to application of 1, 3, and 5 geogrid layers. The results from the triaxial tests are depicted in the left Figure. Accordingly, the equivalent elasticity modulus of the soil has been extracted using the classical geotechnical equation according to triaxial tests and are shown in right Figure. The best fit exponential function has been determined by statistical analysis of the data and the function is proposed for the particular geogrid as used in this study. The result from laboratory tests shows, that the use of laid and welded geogrids with a defined initial tensile stiffness can increase the soil elasticity modulus up to approx. 60%.





Settlement:

$S = S_e + S_c + S_S$

S_e = Immediate / elastic settlement

S_c = Primary consolidation

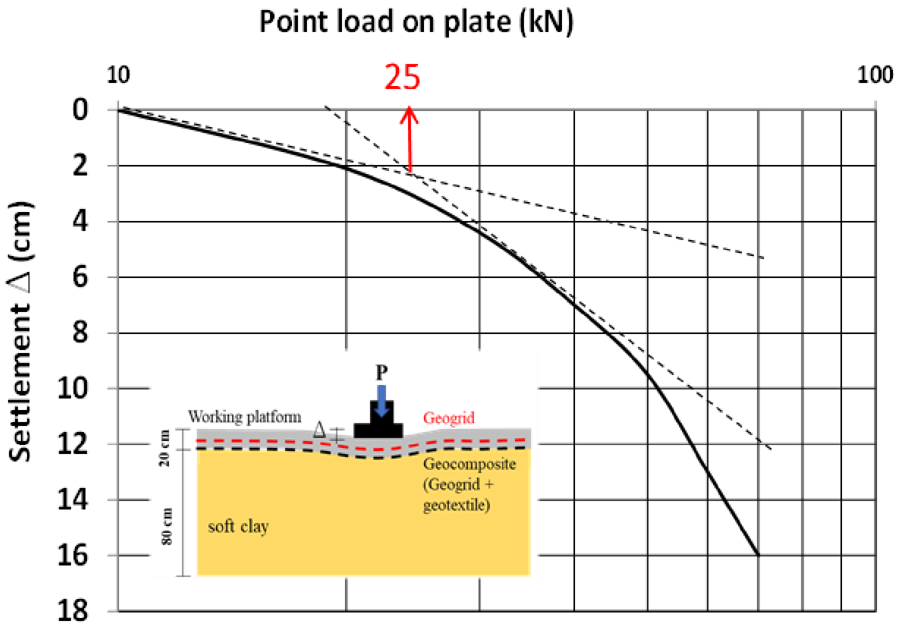
S_s = Secondary consolidation

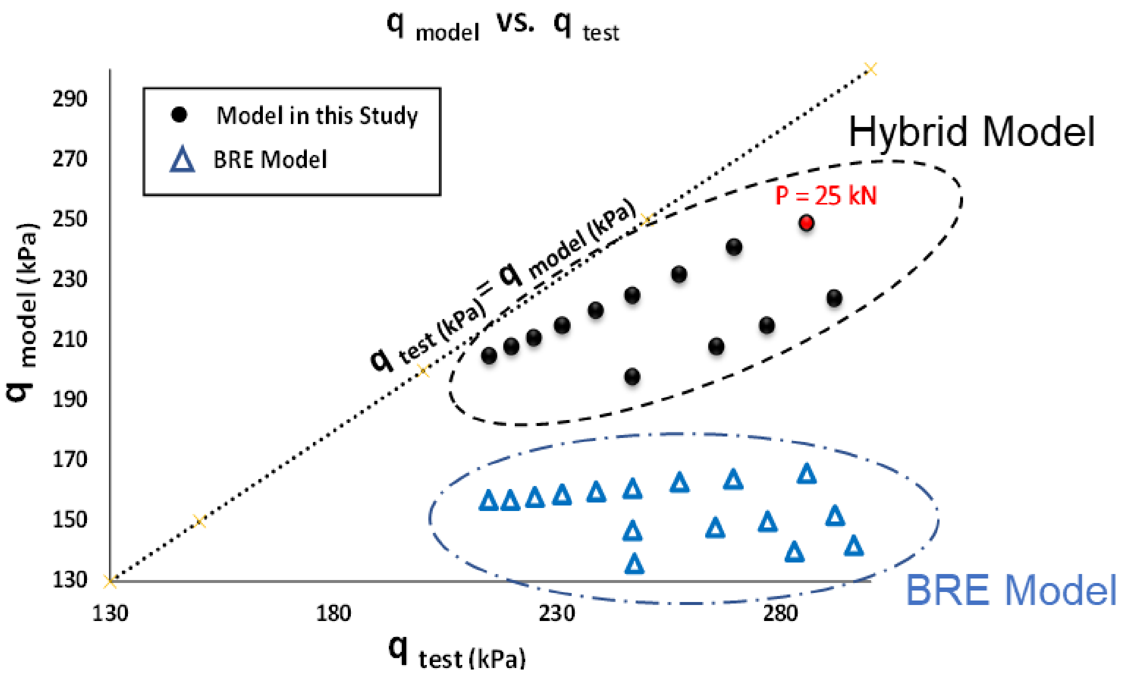
Timoshenko and Goodier (1951)

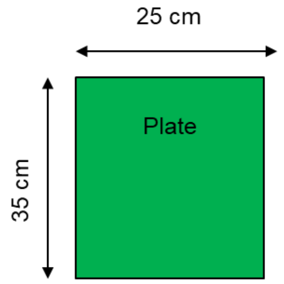
$$s = \frac{q \times w' \times (1-\mu^2)}{E_s} \times 4 \times I_s \times I_f$$

Comparison BRE470 vs. Hybrid Model

The results showed that the, developed model in this study tends to predict safe and optimised results (utilisation factor between 0.7 to 0.95). In contrast, even though that the model in BRE has proposed safe results, the allowable load is much smaller than the platform bearing capacity. Therefore, it can be concluded that, the BRE model has produced very conservative results (utilisation factor between 0.4 to 0.7).







Conclusion

In the development process of the new NAUE Platform software, the following achievements can be identified:

1. Generate a knowledge base through analysis of large scale laboratory tests to improve the understanding of the processes involved in the interaction of laid and welded geogrids and aggregates within working platforms;
2. Develop an optimized and reliable methodological approach for the prediction of the maximum bearing capacity of working platforms by overcoming the weaknesses of the BR470 design methodology;
3. Quantify the effect of geogrid reinforcement on improvement of soil mechanical behavior and accordingly develop equation for the prediction of total immediate deformation of working platforms.
4. Provide a holistic design methodology for ULS & SLS conditions for working platform applications