A COMPARISON BETWEEN PERFORMANCE OF EC GEOBLOCK WITH CONVENTIONAL GEOGRID USED AS SOFT GROUND IMPROVEMENT METHODS

Yan Ho Loke[1], Nik Norsyahariati Nik Daud[2*], Wyn Shern Loke[3]

Abstract

As urban development advances, population increases which leads to more demand in structures such as roads, houses and more. Most structures are built with some sort of ground improvement or foundation. One of the most common techniques is to use geogrid to reinforce the structure and the ground due to its performance and cost effectiveness. In the current study a new arrangement of EC Geoblock is proposed for ground improvement and the performance are compared with geogrid. The study consists of two phases: First Phase begins with the simulation through PLAXIS 3D by excavation with depth of 0.55m then laying of geogrid or EC Geoblock and backfilled with selected filling material and ends with application of surface load on top of the strengthened area. Second Phase was proceeded with the variation of 5 scenarios; Scenario I – unreinforced soil, Scenario II – soil reinforced with 2 layers of geogrid with sand backfill, Scenario III – soil reinforced with 5 layers of geogrid with sand backfill, Scenario IV – soil reinforced with EC Geoblock with sand backfill and lastly Scenario V – soil reinforced with EC Geoblock with sand backfill and collapse load of case III. From the results, the best performing method in improving the mechanical properties is Scenario V with the least settlements among all simulations. Therefore, the new arrangement of EC Geoblock is feasible to be used in strengthening the ground in required places before construction of superstructure.

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1.0 INTRODUCTION

As more structures are required to be built on critical ground condition such as soft soil due to reasons such as land scarcity, population growth and to prevent landslides and other ground hazards; a cost-effective way of improving the ground to accommodate the structures are necessary.

Figure 1 shows a soft soil location in Peninsular Malaysia. Two major groups of alluvial deposits have been identified as riverine deposits and the marine, estuarine and brackish deposits. Soft clay which is part of soft soil that has low shear strength, low permeability and highly compressible. This has been experienced by Mohamad *et al.,* (2016) who had studied two sites in Malaysia deals with soft clay. They found out that the instability of the ground during construction works had caused delay and cost overrun in completion of the project in Selangor, whereas occurrence of continuous post construction settlement had affected the integrity and serviceability of the building in Sabah. Structure on unreinforced soft clay will experience high settlement due to the high compressibility property of soft clay. In addition, due to its low permeability, the ability to drain water especially during rain is very poor, thus lead to soil instability.

Currently, many methods have been used to strengthen the stiffness and strength of the soil in its initial states and when subjected to loading. Geogrid is popular due to its cost efficiency and environmentally friendly nature. The study of geogrid can be dated back to as early as the late 1980 (Barker, 1987; Haas *et al.,* 1988). Some examples of using Geogrid includes to prevent damage to road pavement (Ooi *et al.,* 2022), reinforcing embankment on foundation (Mohammed *et al.,* 2022) and more.

The selection of materials used in backfilling after excavation and ground reinforcing is important. Concrete or cement is a common material used in backfilling with good performance but comes with high cost. On the other hand, the surrounding soil which is soft clay is the case is also a feasible choice even though the performance is not as good as concrete. In addition, soft clay can also be mixed with air and cement to form a lightweight material that can be used as backfill material as the performance of the lightweight material performs well as embankment material (Chaiyaput *et al.,* 2023).

In this study, a new method for improving weak ground by using EC Geoblock precast concrete block is proposed and compared with geogrid to assess its performance on ground improvement on soft clay. Finite Element Modelling is a great and cost-efficient way to test the performance of the new proposal. PLAXIS 3D is a great user-friendly commercial software package that have been used to simulate various scenarios involving geogrid, pile, foundation and more (Al Ghanim *et al.,* 2019; Alsirawan, 2021; Salih *et al.,* 2022). Hence, PLAXIS 3D is used to perform the simulation for the current study.

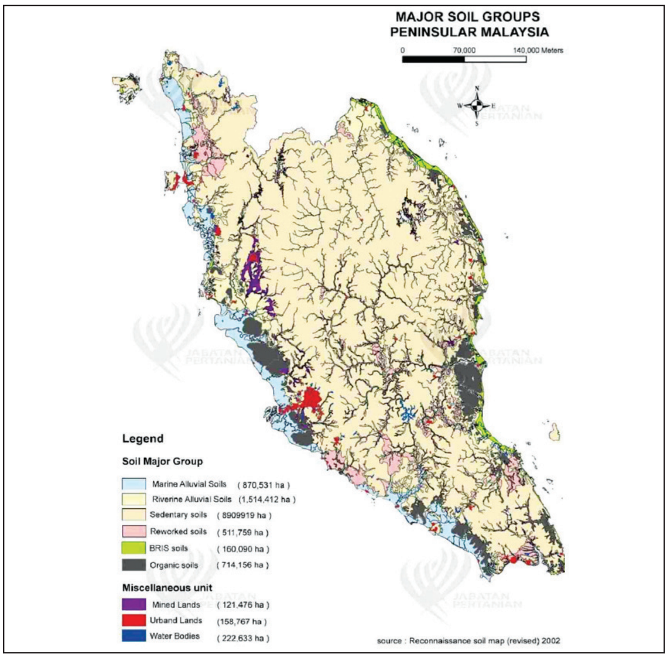

Figure 1: Soft soil location in Peninsular Malaysia (Source: Reconnaissance soil map, 2002 – revised)

2.0 MATERIALS

2.1 Soil Properties

The soil constitutive model used to model two of the soil is hardening soil model. Even though, Mohr's coulomb model has been a popular choice in modelling soil due to its simplicity, it is not chosen for the current study as it failed to account for the non-linearity of soil and stress-dependency of soil stiffness which might lead to erroneous computation of strain that led to bad accuracy in soil deformation modelling. On the other hand, hardening soil model which is an elastic-plastic model is an advance soil model which is capable of simulating both non-linearity and stress-dependency of soil based on power law. Hence, it is the better choice for modeling soil, so the hardening soil model is chosen for the current study. Table 1 summarised the two soil properties, which are soft clay, the main soil profile, and gravel, the filling material of the newly proposed foundation.

Table 1: Properties of soils

Parameters	Unit	Soil Type	
		Soft Clay	Sand
Drainage type	-	Undrained	Drained
Unsaturated unit weight, γ_{unsat}	kN/m^3	16	17.0
Saturated unit weight, γ_{sat}	kN/m^3	17	20.0
Effective cohesion, c'_{ref}	kN/m^2	5	0
Effective friction angle, φ'	°	25	33
Dilatancy angle, ψ	°	0	3
Ref. secant stiffness, E_{50}^{ref}	kN/m^2	2x10^3	35x10^3
Ref. tangential stiffness, E_{oed}^{ref}	kN/m^2	2x10^3	35x10^3
Ref. unloading/reloading stiffness, E_{ur}^{ref}	kN/m^2	1x10^4	105x10^3
Power (stress-level dependency of stiffness)	m	1.0	0.5
Unloading-reloading Poisson's ratio, v_{ur}	-	0.2	0.2

2.2 Specification of EC Geoblock

The "E" and "C" in the name of the blocks represent the shape of the blocks. The C block is half the size of the E block and both of the dimensions are illustrated in Figure 2. The precast blocks are designed to fulfill the following criteria; i) lightweight and small enough to be carried by people, ii) self-interlocking mechanism and iii) able to contain infill materials to create porous or impermeable structure.

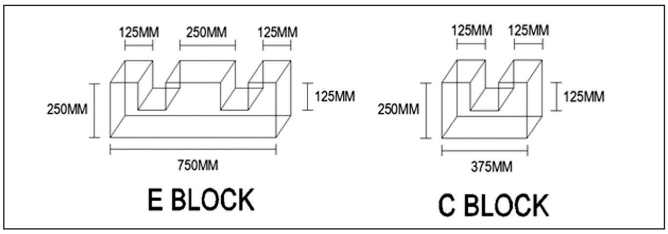

Figure 2: Dimensions of E and C Blocks

2.3 Specification of Geogrid

The axial stiffness, EA of the geogrid used for the study is 950kN/m. The value adopted is based on (Nezamabadi *et al.,* 2017) and also used in (Abdul Halim *et al.,* 2021).

3.0 METHODS

As the study area consists of clay and groundwater level is 1m below ground level, ground improvement is necessary before any forms of construction that exerts load to the ground can happen. In this study, the newly proposed ground improvement technique using EC Geoblock arrangement is compared with geogrid which is a common geosynthetic material used to strengthen soil. The study employs approach similar with study (GeoStruct Academy, 2024). Hence, this approach is deemed effective in determining the bearing capacity.

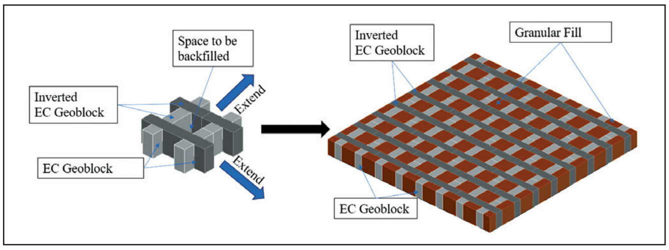

Figure 3: Installation of EC Geoblock

3.1 Geogrid

The process of applying Geogrid begins with excavation of soft clay up to 0.55m below ground surface. Subsequently, geogrid reinforcement is installed at the bottom of the excavated area, followed by backfilling of sand. Lastly, a surface load is exerted to the reinforced area through a 1.2 by 1.2m plate. This section includes a total of three analyses. The three will focus on geogrid, varying the spacing and number of geogrid layers.

3.2 EC Geoblock

The proposed EC Geoblock can be arranged in a way where each block is interlocked together without the use of adhesive. The arrangement will leave a few square voids in which good drainage material in this case gravel can be filled for better draining. The proposed foundation consist of E and C shape block and the installation process starts with excavation of 0.55m. Subsequently, laying the block in vertical direction before inverting the block and placing the blocks in horizontal direction on top of the block in vertical direction as shown in Figure 4. The blocks in the second layer can also be non-inverted so more layers can be added to improve ground stability if necessary. After placing the blocks, the space above and in between block is backfilled with sand before application of surface load through a 1.2 by 1.2 m steel plate.

4.0 RESULTS AND DISCUSSION

4.1 Vertical Settlement

Clay is a type of soil that can be easily compresses, therefore when a structure is built or load is applied on it, there may be severe settling. This could result in soil collapse which is a severe ground hazard. Maximum settlement for the four cases before soil collapse are shown in Figure 4 and Figure 5. It can be seen that, high settlements are observed at the center for initial and geogrid reinforced ground whereas upward soil movement can be seen at EC Geoblock reinforced ground.

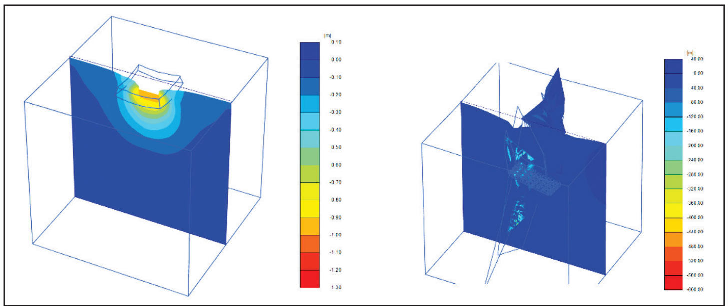

Figure 4: Vertical settlement of 5 layers of geogrid reinforced ground and EC geoblock reinforced ground

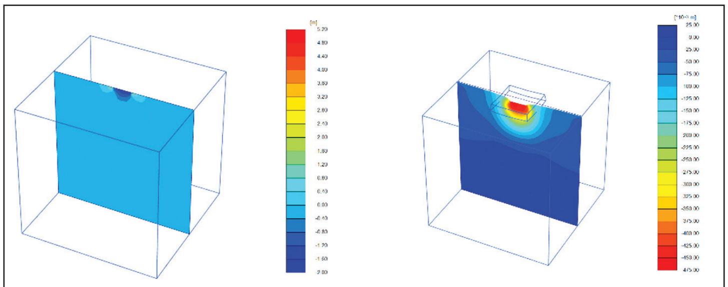

Figure 5: Vertical settlement of unreinforced ground and 2 layers of geogrid reinforced ground

Soil collapses of all four cases are believed to be due to excessive load as each case was loaded until failure. All reinforcements experience large vertical settlement. Upward movement can be seen at the corner of geogrids and geogrid settle at the center without much movement. On the other hand, The settlement of EC Geoblock exhibits a significant offset from the center.

A general total settlement of designing shallow foundation is around 25mm from empirical evidence (Gholamreza Mesri *et al.,* 1996) and current practice (Das, 2023). Settlement exiting the stated limit can lead to structural distress. Based on the load

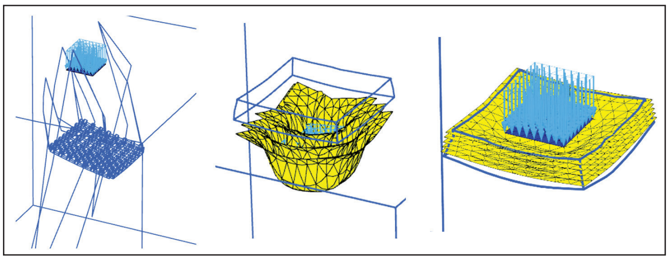

Figure 6: Failure behaviour of geogrid and EC Geoblock

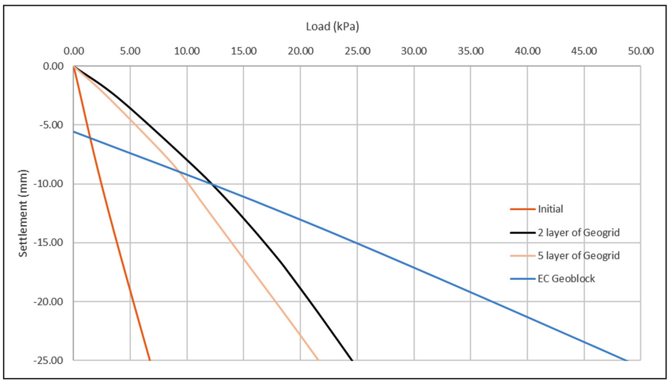

Figure 7: Load-settlement curve

settlement curve illustrated in Figure 7, EC Geoblock is able to withstand close to 50kPa load while the ground reinforced with 2 layer of geogrid can only tolerate close to 25 kPa load. The difference is over between 2 layer of geogrid and EC Geoblock is more than twice. Therefore, EC Geoblock is more efficient and reliable than geogrid which may reach 25mm settlement limit at lower load.

4.2 Bearing Capacity

Soil bearing capacity describe the maximum load that a soil can withstand before it collapses and it is crucial in designing foundation or ground improvement techniques. By using double tangent method on the displacement vs load graph, the bearing capacities of all five cases are determined and summarised in Table 2. In this method, two tangents are drawn: one at the beginning of the load-settlement curve and the other at the point where the curve's curvature changes. The double tangent method is a feasible method as this method have been used in recent articles (Jaiswal & Chauhan, 2021; Mohamed *et al.,* 2023).While double tangent method is able to provide quick estimate, it has limitation when compared to load-settlement curve obtained from simulation where the soil collapse from incremental loading as this method heavily depends on the tangent line drawn which can vary between various individuals. Hence, the bearing capacity for the current study is obtained using the second method.

The soil reinforced with EC Geoblock has the highest soil bearing capacity and soil without reinforcement has the lowest soil bearing capacity. The result revealed that bearing capacity increase with geogrid layers and ground reinforced with EC Geoblock has the highest bearing capacity and settlement. The high bearing capacity from EC Geoblock reinforced ground are mainly due to concrete being a more rigid material than geogrid and great confinement effect provided through the fill material within the spaces of the structure which can assist in reducing lateral spreading (Krishna & Latha, 2023).

Since it is not practical and not common to design shallow ground reinforcement to withstand load close to 10000kPa, the settlement of EC Geoblock reinforced with failure load of case III will be compared against the settlement of case III. The settlement recorded for EC Geoblock reinforced ground is around 0.5554m whereas ground reinforced with 5 layers of geogrid experience 0.9262m of settlement. The settlement of case III is almost twice more than the EC geoblock reinforced ground with same loading applied.

Table 2: Bearing capacity values of each scenario

Scenario	Description	Bearing capacity, *q* (kPa)
I	No reinforcement	150.72
II	2 layers of Geogrid with sand backfill	436.97
III	5 layers of Geogrid with sand backfill	1103.18
IV	EC Geoblock with sand backfill	9925.08

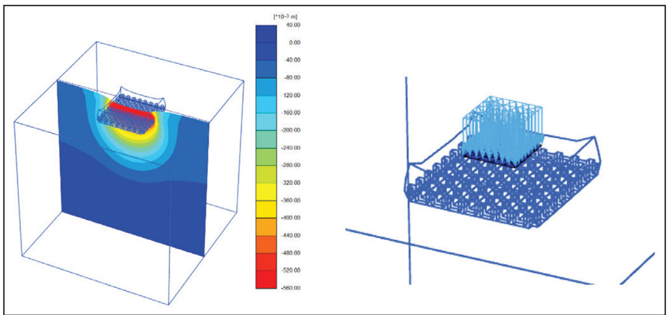

Figure 8: Settlement and deformation behavior of EC Geoblock under collapse load of case III

5.0 CONCLUSION AND FUTURE RESEARCH

FEA of five different scenarios with load application to failure are done in this study. From the simulation, it is proven that EC Geoblock has better performance in vertical settlement and bearing capacity to Geogrid. The data show remarkable almost tenfold increase in bearing capacity than using 5 layers of geogrids. In addition, EC Geoblock exhibited significantly higher load bearing capacity at a defined settlement limit of 25mm capable of withstanding nearly twice the load compared to a five-layer geogrid reinforcement configuration. Furthermore, the interlocking nature of EC Geoblock ensure effective load distribution over a wide area and the voids in between the formation allow great drainage ability to mitigate the risk of soil collapse. Therefore, the evidence supports the adoption of EC Geoblock for ground improvement as a equivalent or better alternative to geogrid reinforcement. Future research can include the testing of multiple layers of the new arrangement of EC GeoBlock or a model test related to the new system.

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APPENDIX

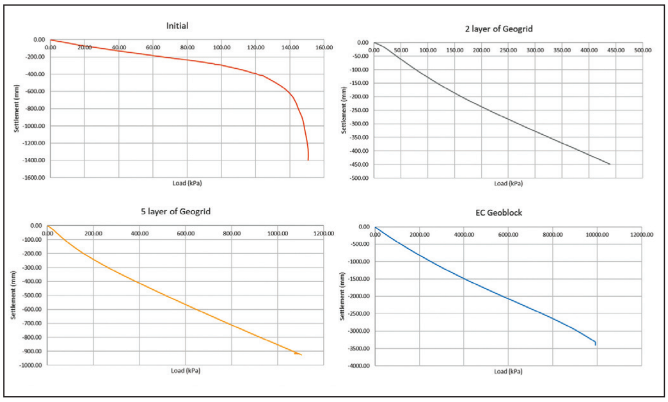

Figure A1: Full load-settlement curve for case I to IV

AUTHOR CONTRIBUTIONS

- **Yan Ho Loke:** Conceptualisation, data collection, methodology, and formal analysis.
- **Nik Norsyahariati Nik Daud:** Conceptualisation, study design, and supervision.
- **Wyn Shern Loke:** Writing—original draft preparation and literature review. ■

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