Comparison of Bearing Capacity on Geocell-Reinforced Subgrade

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ABSTRACT: This paper is reported the result of the laboratory tests and field plate load test in order to evaluate the reinforcement effect of geocell for road construction. The geocell-reinforced subgrade gives the increment of cohesion and friction angle with comparison of non-reinforced subgrade. In addition, the field plate load test was performed on the geocell-reinforced subgrade to estimate the bearing capacity of soil. The theoretical bearing capacity of subgrade soil with and without geocell reinforcement was estimated by using the soil internal friction angle. The field plate load tests were also conducted to estimate the bearing capacity with geocell reinforcement. It is found out that the bearing capacity of geocell-reinforced subgrade gives 2 times higher value than that of unreinforced subgrade soil.

1 INTRODUCTION

The geocell is defined as a three-dimensional, permeable, polymeric honeycomb or web structure, made of strips of geotextiles, geogrids or geomembranes linked alternatingly and used in contact with soil/rock and/or any other geotechnical material in civil engineering applications. It is normally used in the construction of access roads, load support, embankment, slope protection, and so on. Recently, the perforated geocell made of nonwoven geotextile was developed and used for drainage and reinforcement. Several studies(Bathurst et, al.(1989,1993), Dash, et, al.(2001)) demonstrated that geocells can significantly increase the bearing capacity and reduce the settlement of soft soil foundations or subgrades. Even though studies have been demonstrated that geocells can provide an outstanding soil confinement and enhance the performance of base course on weak subgrade, the acceptance of geocells for unpaved and paved roads is still limited due to the lack of accepted design methods. Furthermore, very limited research has been done using geocells as the base reinforcement in paved roads.
Therefore, more research is needed to develop reasonable design methods for geocells to be used for subgrade improvement in the unpaved roads and base reinforcement in the paved roads. Prior to this development, it is necessary to better understand the mechanisms of the geocell system and obtain more experimental results to quantify the effect of geocells on stress and deformation reduction on subgrade. This paper reports the results of the laboratory tests and field plate load test in order to evaluate the reinforcement effect of geocell for road construction.

Figure 1. Geocell reinforcement road and subgrade applications

2 REVIEW OF LITERATURE

2.1 Terzaghi's Bearing Capacity Theory

Based on Prandtl's theory(1920) for plastic failure of metal under rigid punches Terzaghi derived a general bearing capacity equation. All soils are covered in this method by two cases which are designated as general shear and local shear failures. The application of the load (Figure 2) tends to push the wedge of soil *abc* into the ground with a lateral displacement of zones II and zones III. The downward movement of this soil wedge is resisted by the resultant of the passive pressure of the soil and the cohesion , acting along the surface of the wedges *ac*, *bc* as it moves. Considering the equilibrium of the wedge *abc*, Terzaghi presented the following bearing capacity expression for general shear failure. General shear is the case wherein the loading test curve for the soil under consideration comes to a perfectly vertical ultimate condition at relatively small settlement as shown by curve 1 in Figure 3. Local shear is the case wherein settlements are relatively large and there is not a definite vertical ultimate to the curve as in curve 2 in Figure 3. Soil is loose relative to a general shear failure. The following assumptions were made in the analysis. Terzaghi's bearing capacity theory, column load P is resisted by shear stresses at edges of three zones under the footing and the overburden pressure, q(=γD) above the footing. The first term in the equation is related to cohesion of the soil. The second term is related to the depth of the footing and overburden pressure. The third term is related to the width of the footing and the length of shear stress area. The bearing capacity factors, N_c, N_q, N_γ, are function of internal friction angle, ϕ. Terzaghi's bearing capacity equations(Strip footings)

$$Q_u = c\,N_c + \gamma\,D\,N_q + 0.5\,\gamma\,B\,N_\gamma \quad (1)$$

Where C is the cohesion of soil, γ is the unit weight of soil, D is the depth of footing and B is the width of footing. N_c, N_q, N_r are Terzaghi's bearing capacity factors depend on soil friction angle, ϕ.

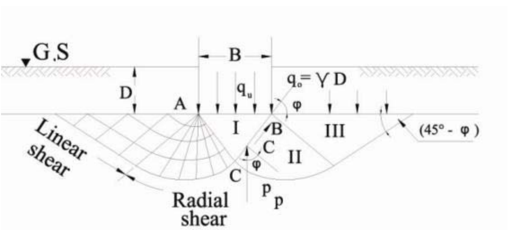

Figure 2. Shear stresses based on Terzaghi's soil bearing capacity theory

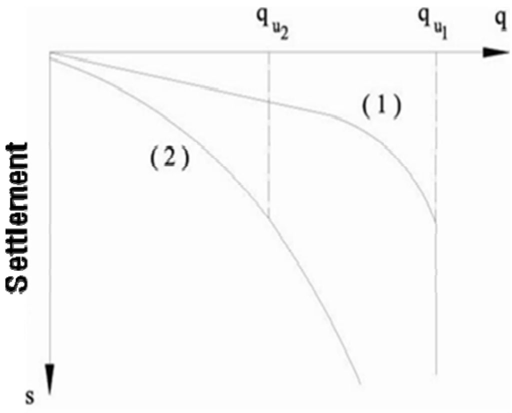

Figure 3. Terzaghi's bearing capacity expression for general shear failure(1) and local shear failure(2)

2.2 Meyerhof Bearing Capacity Theory

The bearing capacity of shallow foundations has been derived by Meyerhof (1951) taking into account the shear strength of the soil above the base level of the footing. He assumed a failure mechanism similar to Terzaghi's but extending up to ground surface as shown in Figure 5.

The following assumptions are made in the analysis. The footing is continuous. The failure surface is composed of a straight line and a logarithmic spiral. The soil wedge ABC beneath the base of footing is in elastic state. The principle of superposition is valid.

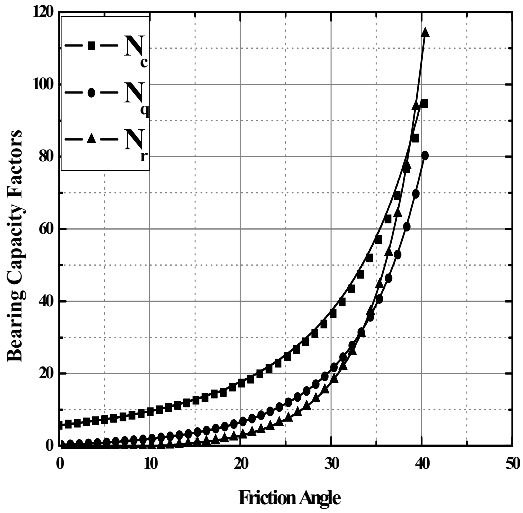

Figure 4. Terzaghi's bearing capacity factors

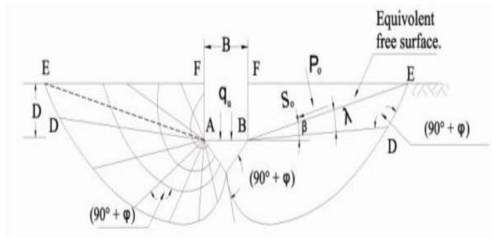

Figure 5. Meyerhof bearing capacity theory

Meyerhof extended the previous analysis of the plastic equilibrium for the surface strip foundation to shallow and deep foundation. In the mechanism of failure shown in Figure 5. There are two main zones on each side of the central zone, ABC, radial shear zone BCD and mixed shear zone BDEF. The shearing resistance of the soil above the foundation level is considered in this analysis. The bearing capacity of shallow foundations with rough bases is expressed as:

$$Q_u = c\,N_c + \gamma\,D\,N_q + 0.5\,\gamma\,B\,N_\gamma \quad (2)$$

where $N_{c,q}$ and N_γ are the general bearing capacity factors which depend on foundation depth, shape and roughness and the angle of internal friction.

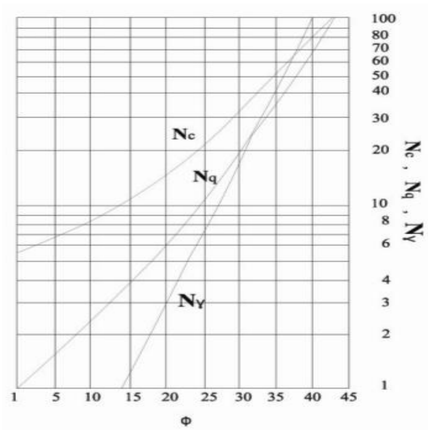

Figure 6. Meterhof bearing capacity factor for shallow strip footing field test and monitoring

To calculate the bearing capacity factors, the inclination of the equivalent free surface and the stresses and acting on this surface must be determined. Meyerhof computed the values of $N_{c,q}$ and N_γ for various angles. These values for shallow strip footing are shown in Figure 6. The general solution given by Eq.(2) is too tedious for routine application. To simplify the solution and to avoid estimation of the equivalent free surface stresses the bearing capacity factors are combined to give.

3 FIELD PLATE BEARING TEST AND BEARING CAPACITY ANALYSIS

3.1 Feild Plate Bearing Test Result

Plate bearing test(PBT) is carried out in the field to comparison on reinforced and unreinforced subgrades soils. Plate bearing test is carried out in accordance with BS 1377 Part 9 : 1990 Standards. From results of the test can be used as design parameter. Results of the test are shown as load-settlement curve, yield pressure, allowable pressure for foundation design, and modulus of subgrade reaction (K) for subgrade design. Additionally, it is performed laboratory test to determine the geotechnical characteristics of subgrade soil. Result of the laboratory test is the unit weight of subgrade soil is 1.9tf/m^3, cohesion is the zero, internal friction angle is the 30°. PBT is adopted the reaction force to 15ton dump truck and dumped aggregate in truck. On reinforced and unreinforced subgrades soils the results of plate bearing tests are shown Figure 7. Case of reinforced subgrade using geocell, ultimate bearing capacity is 8.58kg/cm^2 and the case of unreinforced subgrade, ultimate bearing capacity is 4.56kg/cm^2.

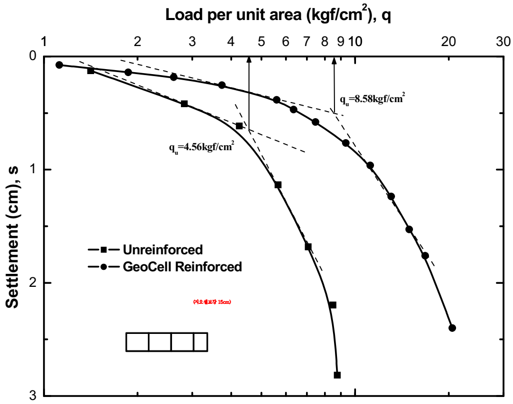

Figure 7. Result of plate bearing capacity test

3.2 Analysis of Bearing Capacity on Reinforced using Geocell

The result of the ultimate bearing capacity is calculated through the bearing capacity equations of Terzaghi(1943) and Meyerhof(1963) on reinforcement and unfeinforced subgrade. The result of calaculated bearing capacity is described in Table 1. The ultimate bearing capacity by Terzaghi's is slightly higher than that of Meyerhof.
This is indicated that the bearing capacity cannot calculate factors to be affected to length of foundation. It is found out that the bearing capacity of geocell-reinforced subgrade gives 2 times higher value than that of unreinforced subgrade soil.

Table 1. Comparison to bearing capacity using result of laboratory test and field test

Item	Ultimate Bearing Capacity (kgf/cm^2)	
	Terzaghi's	Meyerhof
Unreinforecd (Laboratory)	4.38	3.19
Unreinforecd (Field)	4.56	
Reinforced	8.58	
(Field)		

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4 CONCLUSIONS

The laboratory tests and field plate load tests were performed to evaluate the reinforcement effect of geocell for road construction.

It is found out that the bearing capacity of geocell-reinforced subgrade gives 2 times higher value than that of unreinforced subgrade soil. In the future, the reinforcement effect of the geocell rigidity and load-balancing effect of the geocells should be evaluated. Also, the settlement and the distribution of defomation can be estimated by using the finite element method.

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