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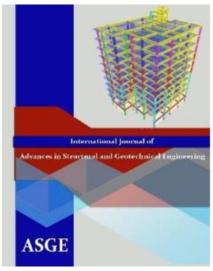



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# A Numerical Study of the Effect of By-product-Crushed Slag Aggregate and Geogrid Technique in Improved Soft Soils Properties


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# A Numerical Study of the Effect of By-product- Crushed Slag Aggregate and Geogrid Technique in Improved Soft Soils Properties

Naema Ali Ali

*Associate Professor,* Construction and Building Engineering Department, Faculty of Engineering, PHAROS Univ. *Alex., Egypt*
*E-mail:* *Dr_Naemaali1@yahoo.com*

## ABSTRACT

The aim of this study to complete investigated of improved the shallow soft soils deposit by using Steel Slag Coarse Aggregate (SSCA) mixture as replacement considering geogrid reinforcement layers. The study is investigating effective depth of geogrid layer and inspects its effect on reduced extreme deformation of loaded soft fine soil using numerical method model. Finite elements, 2D PLAXIS, is used to simulate strip footing resting on improved soil by replacement mixture of optimum percent of Steel Slag Coarse Aggregate (SSCA) in gravelly size with dried natural soil considering thickness equal footing width. The paper presents case study of improved soft soils obtained from site of salt stores at Al-Qubari, Alexandria, which was observed, failed under excess store load. The study indicated that using (SSCA) as partial replacement improved compressibility, when geogrid layer at the lower one third of replacement thickness and increase its capacity loads. Also, when using two layer of reinforcement at depths lower and upper one third of replacement thickness induced slightly reduction in footing settlement or didn't enhance considerable result in decrease settlement.

***Keywords:*** *Replacement, Steel Slag Coarse Aggregate, Improvement, Soft fine soil, Finite elements method, soil reinforcement.*

## INTRODUCTION

Over the entire world many researchers reported that steel slag has many advantages in railway and road construction. The application of steel slag has recommended as assumable artificial source of aggregates in boarded areas of many roads projects. Also, it can be used as an aggregate in interface layers and in unrestrained bases or sub-base, due to its high strength. Steel slag coarse Aggregate (SSCA) in gravelly size was mixed with dried natural fine soil to sidestep the most common causes of poor action when using it as replacement material as distortion when wet and low cohesion combined, [1]. Soft fine soil in natural has a high compressibility and low strength causing many stability and settlement problems when loaded. Improved such soft fine soil should be completed before any construction or support any structure load. Experimental work and finite element analyses for replacement trench pattern extension were developed in much reference, [3, 7, and 8].

Recently an important integral part in construction industry is computer numerical modeled problem of soil. The computer modeling developed to expected settlement and stress distribution in soils under foundation for any project. This can be helping the engineers to understand the deformations prior to construction and ensured design safety. The mathematical models that run through computer program can be accurate enough to simulate any typical c-ϕ soils under design considered. Many numerical models and attempts had been made to investigate bearing capacity and settlement of strip or rectangular footing rest on different types

of soil using finite element or finite difference method generating mathematical models, [2, 4, 5, 8, 11, and 12].
As reported by many studies, the stress-strain relationship is the key to the correct design of internal stability and proper approximation of soil foundation load system. Accurate assessment of load stress and strains will effect in more accurate for soil strength requirements, facing structure load stress, [6, 9, and 10].

This study concerns the improvement of soft soil for carried light structure, infrastructure and roads in the rapid region urban extension on this soil, where heavy structures founded on deep foundation. Plaxis (2D) is an application of finite element used in analysis of deformation and stability in geotechnical engineering projects. The geotechnical problem is simulated by assumed constitutive model which can be conducted to calculate soil deformation and soil stress with efficient.
Numerical analysis used to study reinforcement replacement methods for mitigation of soft soils considering strain key to investigate the optimum depth of geogrid reinforcement impeded in replacement layer in this case study. Different reinforcement depth has been suggested and examined in this paper by placed horizontal geogrid layer at the bottom interface between soil subgrade and improved replacement layer, bottom third, middle third, and top of replacement layer thickness, H=B, to get the optimum depth, (Dg/H).

## SOIL COLLAPSE SECTION OBSERVED IN SITUE AND STUDIED,

In this study a part of collapse and damaged section due to excessive loaded area in field has been studied, considering the actual soil stratification, and geotechnical properties result from lab and site investigated tests in this part of site presented in figure 1. The soil stratified consists of top layer soft Silty Clay extended up to eleven-meter depth overlying sandy soil. Measured actual vertical settlement after removed store surcharge load are recoded to compared with result of numerical study to achieved aculeate soil model and soil properties considered in this study.

**Fig. 1: Location map of the test site and Site Ground surface failure**

Numerical finite element analysis of strip loaded area is carried out support on untreated soil simulated the true behavior of actual loaded area in site. PLAXIS (2D) simulate the site section 1. The clay layers are modeled using the hardening soil, (HS), and sand is modeled using the Mohe-Coulomb model (MC) to predict the material elastic-plastic behavior. Table 1 presents the soil properties. The strip loaded area studied as measured in site, width 8.0 meter width and loaded by approximately 100 Kpa. Ground water was at 1.00 m from the ground surface as found in the location of subgrade soil that used in this analysis. Figure 2. Shows analysis result and verification. Similar to the finite element results of soil properties used in the present study, slightly good comparison was observed between the predicted and measured soil deformation values, considering, section 1.

**Table. 1 Natural soil and replacement mixture, (SSCA), properties used in 2D finite element analysis**

| Properties | Upper Soft Clay layer | Lower Clay layer | Lower Sand layer | Replacement mixture (SSCA) |
|---|---|---|---|---|
| Model | HS | HS | MC | MC |
| Drainage | Undrained | Undrained | drained | drained |
| Thickness (m) | 5.00 | 6.00 | 10.00 | 2.00 |
| $\gamma_b$ (kN/m$^3$) | 15.60 | 18.40 | 17.0 | 2.24 |
| $\gamma_{sat.}$ (kN/m$^3$) | 16.67 | 19.36 | 20.0 | 2.38 |
| $c_k$ | 20 | 58 | $1\times10^{15}$ | 50 |
| $c'_{ref}$ (kN/m$^2$) | 1 | 1 | 1 | 1 |
| $\phi'$(°) | 25 | 30 | 32 | 40 |
| $\psi'$(°) | 0 | 0 | 0 | 0 |
| $e_o$ | 1.428 | 0.88 | 0.50 | 0.50 |
| OCR | 1.30 | 2.56 | - | - |
| $E_{50}$ (Mpa) | 1.20 | 2.20 | - | - |
| $E_{oed}$ (Mpa) | 1.04 | 1.02 | - | - |
| $E_{ur}$ (Mpa) | 5.80 | 3.62 | - | - |
| E' (Mpa) | - | - | 13.0 | 50.0 |
| $E_{oed}$ (Mpa) | - | - | 18.0 | 65.0 |
| $\upsilon'$ | - | - | 0.30 | 0.25 |

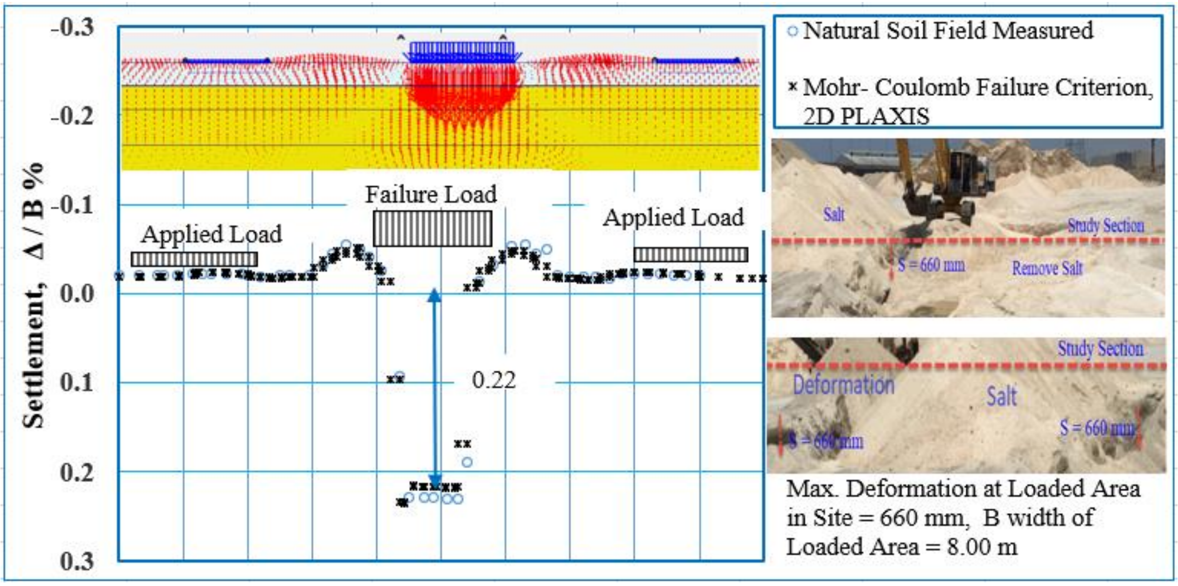
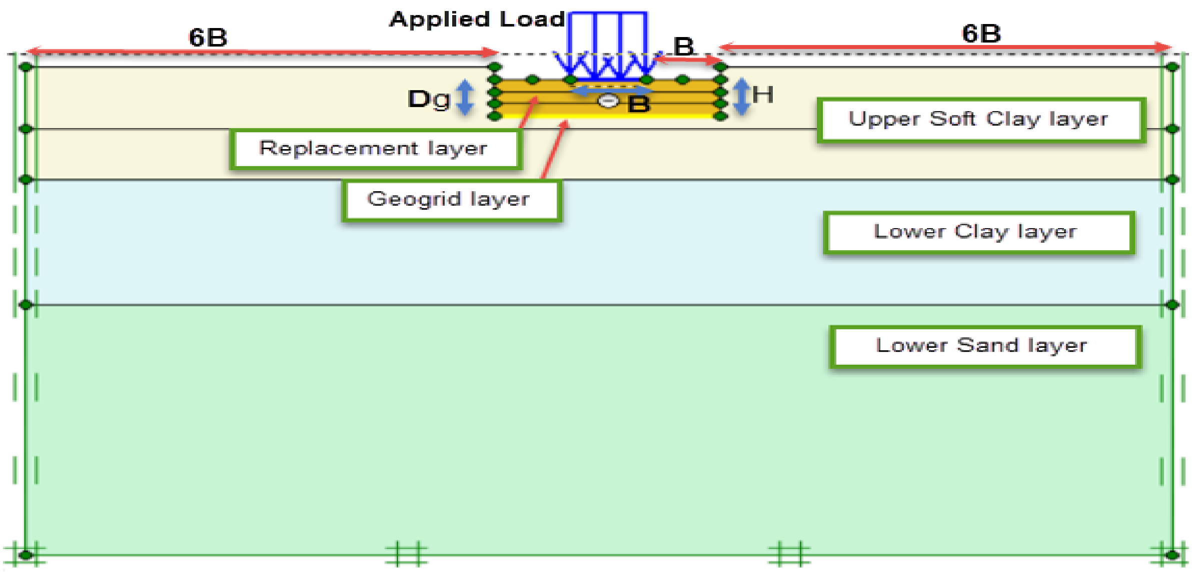



**Fig. 2 : Normalized vertical displacement at failure load step, to ensure section1 Field measured and recorded.**

## CASE STUDY DEPTH OF GEOGRID

To study the effects of various depths Dg of geogrid in replacement layer overlaying soft clay soil and achieve optimum ratio (Dg/H) in this case. Series of analysis using, PLAXIS (2D) to simulate loaded strip footing rest on improved soil with (SSCA) replacement, thickness, H equal width of foundation, (H/B=1.0). Reinforcement geogrid system at different depth will be investigated. The deformation of the improved soil has been predicated to concluded the results of this comparative study. Figure 3. Presents the geometry, boundaries and finite element mesh of the soil layers, improved replacement system and geogrid reinforcement model considered in this case studied after justification. PLAXIS 2D finite element method, by plain strain used to model case of loaded 2.0 meter strip footing width.



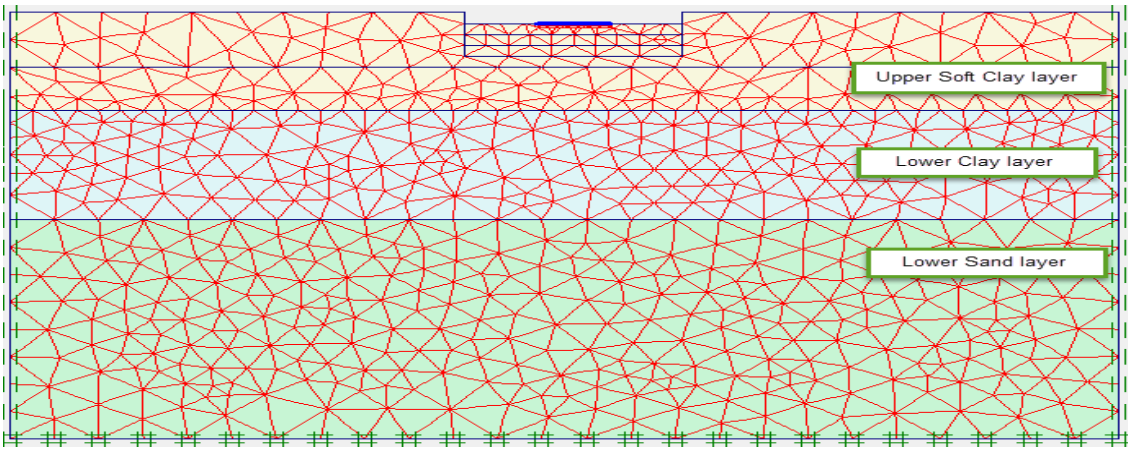



**Fig. 3: Finite element mesh geometry and boundaries for strip footing soil model**

## RESULTS DISCUSSION

The result of this analysis recorded in the flowing figures indicated that the vertical settlement below the loaded strip footing effected by location and depth of geogrid layer, Dg. Figures 4,5 and 5 illustrate the deformed shape and strain induced in model considered. The figures achieve that using geogrid material, decrease the vertical settlement at a small rate with its location depth in replacement layer (SSCA), due to stiffness and weight of replacement layer as, expected.

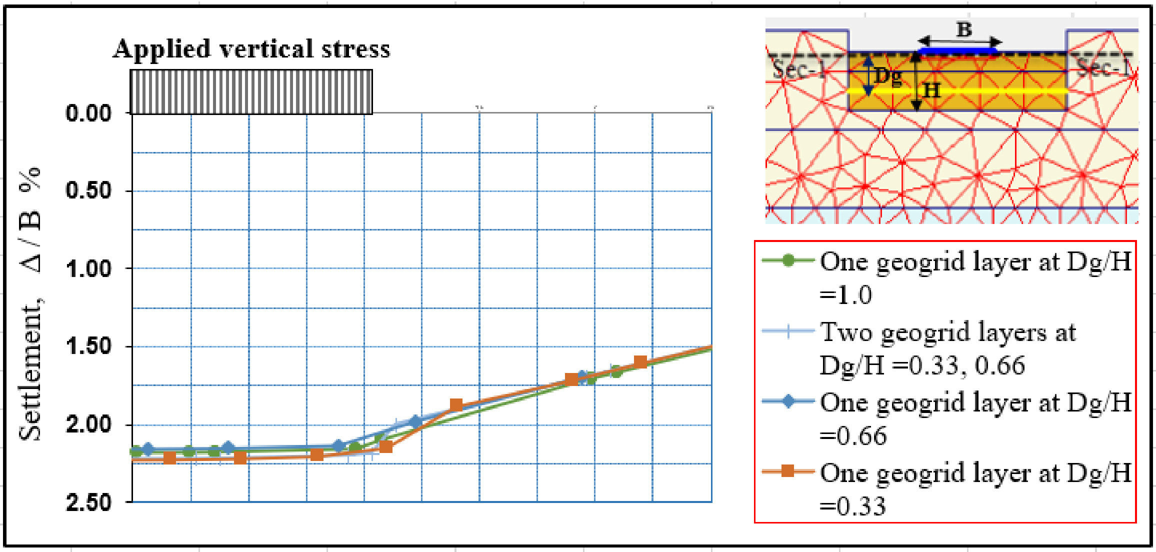



**Fig. 4: Variation normalized vertical settlement below the loaded strip footing at different geogrid depth, (Dg/H)**

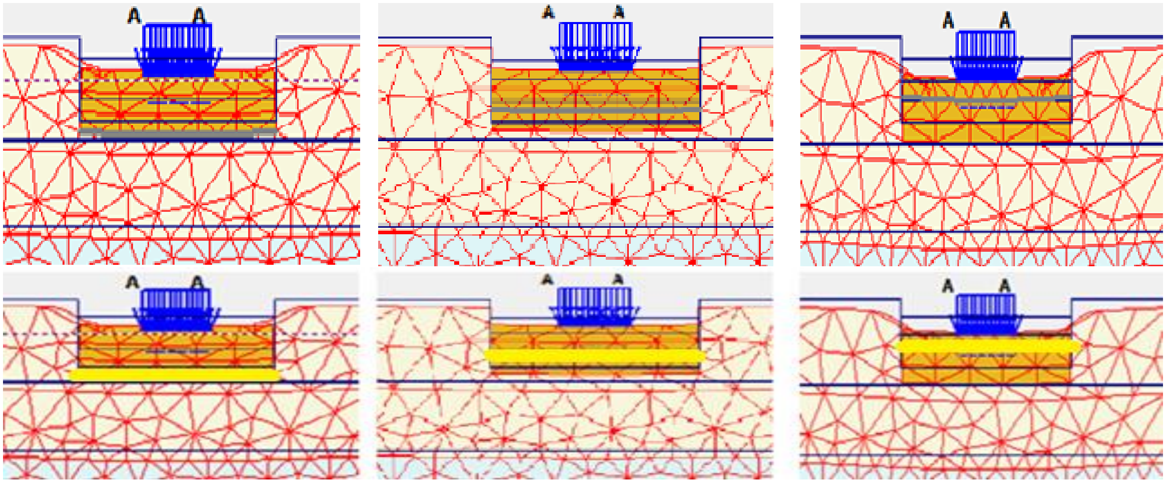


**Fig. 5: Strip footing soil model deformed shapes under uniform distributed load at different geogrid depth, (Dg/H)**

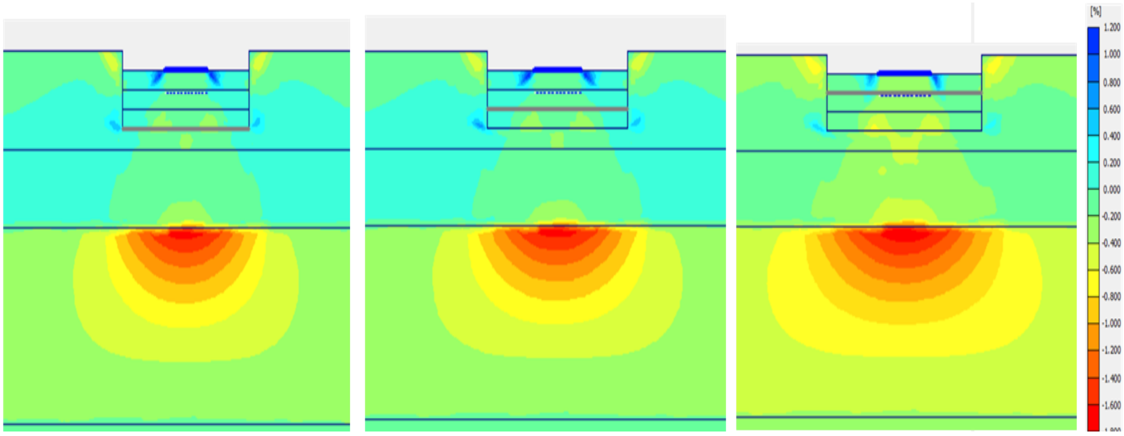


**Fig. 6: Strip footing soil model strain at different geogrid depth, (Dg/H)**

The normalized calculated maximum vertical settlement below the centerline of the loaded strip footing presented in figure 7 indicates the effects of various depth ratio (Dg/H), where one can observed slightly effect for both cases considered two layers of geogrid at (Dg/H= 0.33 and 0.66) and case considered one layer at (Dg/H= 0.33) and geogrid material has not affect in reduced the vertical deformation. But using one layer of the same geogrid material at depth of (Dg/H= 0.66) achieve grater reduction in vertical deformation. Also, using geogrid material at the inter face between natural soil and replacement, (SSCA) layer is not affected in reduction of system deformation.

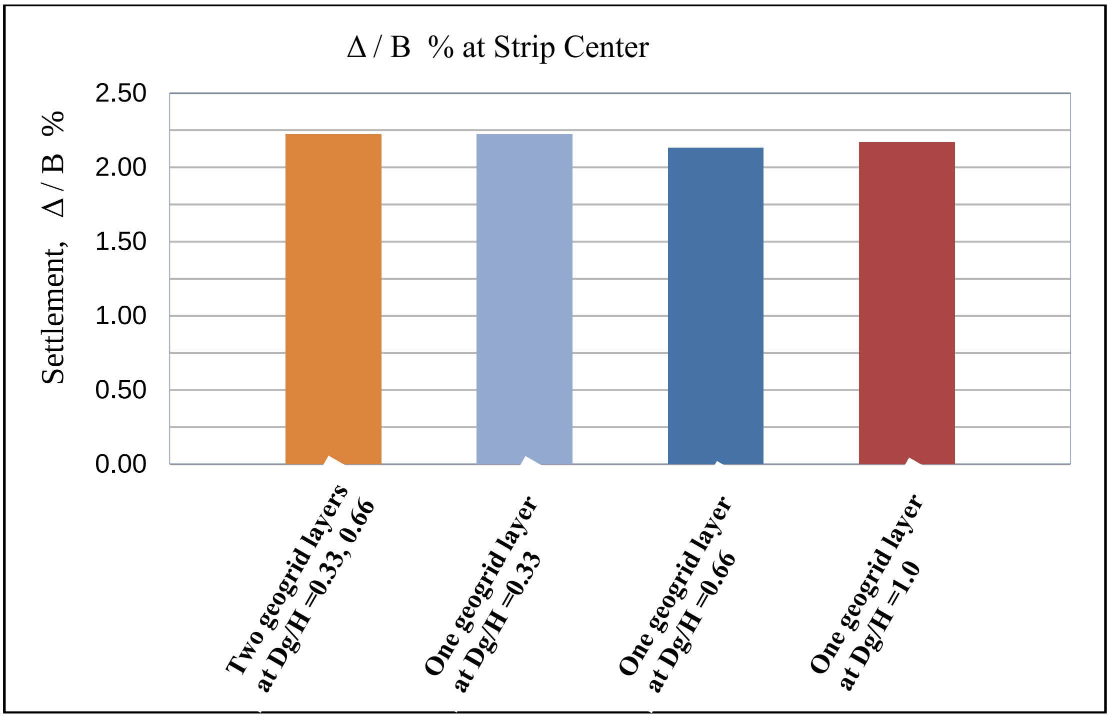



**Fig. 7: Normalized vertical settlement below centerline of loaded strip footing at varies geogrid depth, (Dg/H)**

## CONCLUSION:

Based on the result of this study the following points can be observed:

- Recently modified numerical modeling studies to predict the variation of soil foundation system deformation and bearing capacity respect to plain strain analyses is good tool for acceptable results in geotechnical studies.
- The effects of various depth ratio (Dg/H), geogrid material layer can be achieve reasonable observed effect when (Dg/H= 0.66) for one layer of geogrid. While slightly effect observed for case considered two layers of the same geogrid built at (Dg/H= 0.33 and 0.66) depth.
- The increase in the resistance angle of soil has an advanced effect than the one in the soil adhesion on the bearing and displacement.

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