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# Laboratory Evaluation of Geogrids Used for Stabilizing Soft Subgrades

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***Abstract*—**This paper aims to assess the efficiency of using geogrid reinforcement for subgrade stabilization. The literature of applying geogrid reinforcement technique for pavements built on soft subgrades and the previous experiences were reviewed. Laboratory tests were conducted on soil reinforced with geogrids in one or several layers. The soil specimens were compacted in four layers with or without geogrid sheets. The California Bearing Ratio (CBR) test, in soaking condition, was performed on natural soil and soil-geogrid specimens. The test results revealed that the CBR value is much affected by the geogrid sheet location and the number of sheets used in the soil specimen. When a geogrid sheet was placed at the 1st layer of the soil, there was an increment of 26% in the CBR value. Moreover, the CBR value was significantly increased by 62% when geogrid sheets were placed at all four layers. The high CBR value is attributed to interface friction and interlock involved in the geogrid/ soil interactions. It could be concluded that geogrid reinforcement is successful and more economical technique.

***Keywords*—**Geogrid, reinforcement, stabilization, subgrade.

## I. Introduction

PAVEMENT constructed on soft subgrade is prematurely subjected to excessive permanent deformation, rutting, and cracking, and hence cannot achieve the expected performance. Soil stabilization methods have been used to overcome the problem of soft subgrade soils. The stabilization methods commonly employed in areas with soft subgrades include excavation-substitution, stabilization with chemical additives and mechanical reinforcement using geogrids.

Recently, stabilization-using geogrids for improving properties of weak subgrades are increasingly used. The use of geogrids is proven to be more effective and beneficial since observations indicate better performance (i.e., less rutting associated with increased numbers of load repetitions) for pavements constructed with geogrid-reinforced subgrades [1].

A common and efficient practice is to combine the excavation-substitution and geogrid reinforcement techniques [2]. In this approach, only the top layer of subgrade is excavated and then substituted with geogrid-reinforced aggregate. The tensile-resistant properties of the geogrid provide mechanical support and stiffness to the aggregate layer. This improves the subgrade response in terms of bearing capacity and plastic deformation.

The main objective of this study is to evaluate the efficiency of using geogrid reinforcements for stabilization of poor subgrades. To achieve this objective, the mechanical interaction of the geogrids with soil and aggregate was evaluated by performing CBR tests.

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## II. Literature Review

### A. General

Geosynthetics are man-made plastics shaped that available in a wide range of forms and materials. This includes main product categories: geotextiles, geogrids, geonets, geocells, geofoam, geomembranes, and geocomposites. These products are currently used in many civil engineering applications such as roads, airfields, railroads, embankments, retaining structures, reservoirs, canals, and dams. Geosynthetics are generally used to solve many civil engineering problems.

### B. Geogrids

Geogrids are commonly made of polymer materials, such as polyester, polyvinyl alcohol, polyethylene or polypropylene [3]. They may be woven or knitted from yarns, heat-welded from strips of material or produced by punching a regular pattern of holes in sheets of material, then stretched into a grid [3]. Koerner [3] reported that the key feature of geogrids is that the openings between the adjacent sets of longitudinal and transverse ribs, called “apertures,” are large enough to allow for soil or aggregate materials strike-through from one side of the geogrid to the other (see Fig. 1).

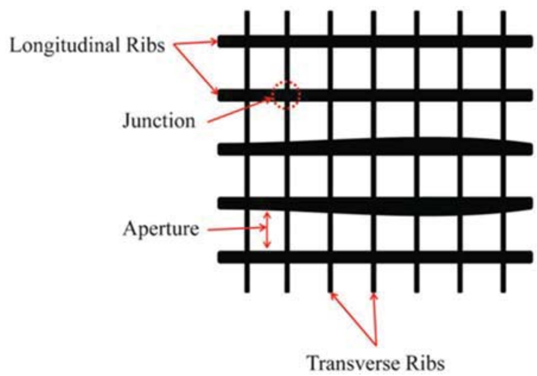


Fig. 1 Geogrid components [3]

Geogrid products include woven and coated geogrids, welded geogrids, and geogrid composites. Structural biaxial geogrids can be used to reinforce earth fill over soft ground and provide a stable subgrade under flexible and rigid pavements, unpaved roads, and railroad track beds [4].

The major functions of geogrids are separation, reinforcement, filtration, and drainage [5]. Separation and filtration/vertical drainage are secondary functions of a geogrid. The ability of a geogrid to separate two materials is less than that of a geotextile. However, the primary function of geogrids used in subgrade stabilization is reinforcement [4].

Geogrids provide the potential to reduce construction cost of pavement by partially replacing expensive, thick granular material layers [6]. Geogrid is most effective when placed below the subbase material and on the subgrade surface. In this location, the geogrid provides reinforcement by laterally restraining the subbase, thereby improving the bearing capacity of the pavement system and decreasing the shear stresses on the subgrade soil [6].

### *C. Geogrid Reinforcement Mechanism*

A subgrade soil beneath a paved or unpaved surface can fail under load in two ways: localized shear failure and bearing capacity failure [4]. Localized shear failure typically occurs in the form of severe deformation or rutting in soft subgrades when loading exceeds the subgrade strength. Geogrid reinforcement of granular fills over soft soil can prevent localized shear failure of the subgrade and therefore significantly increases the effective bearing capacity of the subgrade [4].

A geogrid's primary stabilization mechanism is lateral restraint of the aggregate materials through a process of interlocking the aggregate and the apertures of the geogrid [6]. The level of lateral restraint that is achieved is a function of the type of geogrid and the quality and gradation of the aggregate material placed on the geogrid. To maximize performance of the geogrid, a well-graded granular material should be selected that is sized appropriately for the aperture size of the geogrid. When aggregate is placed over geogrid, it quickly becomes confined within the apertures and is restrained from punching into the soft subgrade and shoving laterally [4]. This results in a "stiffened" aggregate platform over the geogrid.

Carroll et al. [7] investigated the reinforcement mechanisms of geogrids used in paved roads. They indicated that geogrid reinforcement reduces permanent deformations in flexible pavement systems and allows up to 50% reduction in the required thickness of a granular base based on equal load-deformation performance (see Fig. 2).

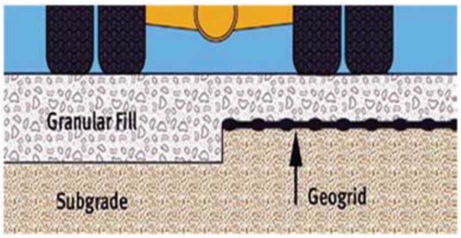


Fig. 2 Granular fill thickness reduction achieved through a biaxial geogrid layer [4]

According to [8], placement of a geogrid layer at the bottom of the subbase course allows shear interaction to develop between the aggregate and the geogrid as the subbase attempts to spread laterally. The mobilized shear load is transferred from the aggregate to the geogrid. The relatively high stiffness of the geogrid helps delay the development of lateral tensile strains in the portion of the subbase adjacent to the geogrid. Lower lateral strains in the subbase produces less vertical deformation of the roadway surface.

### *D. Previous Investigations*

Many investigations [9]-[17] have been carried out to evaluate the efficiency of utilizing geogrid reinforcements in subgrade stabilization in a variety of civil engineering applications.

Singh and Gill [9] carried out experimental work to determine the optimum position of providing geogrid reinforcement in subgrade soil by conducting CBR and unconfined compressive tests. They found that, by providing geogrid reinforcement at 0.2H from top give considerable, improvement in CBR value and stress strain behavior of subgrade soil. Moayedi et al. [10] studied the effectiveness of geogrid reinforcement placed at three different positions (i.e. at a distance of 50, 25 and 5 cm from the bottom of the model). They found that shear stress and normal stress increased when the geogrid was placed at a distance of 50 cm from the bottom. They also observed that the vertical deflection under the centre of the load reduced with the use of geogrid just under the asphalt layer and hence concluded that the effectiveness of geogrid is more pronounced when it is placed at the bottom of the surface layer.

Barksdale et al. [11] studied the deformation of weak subgrades (i.e. CBR < 3%) under loading. They observed that when a geogrid was placed at the bottom of the subbase course there was a reduction of 52% in permanent subgrade deformations. Also the total rutting in the subbase material and subgrade soil was reduced by 20 to 40% as a result of using geogrid reinforcement. Al-Qadi et al. [12] evaluated the effect of using geogrid reinforcement on pavement performance. The pavement surface was loaded to 550 kPa while displacements were recorded. The results showed that the geogrid-stabilized pavement sections sustained 1.7 to 3 times more than that obtained without geogrid for 25 mm of permanent deformation. Webster et al. [13] studied the geogrid reinforcement of flexible pavements for light aircraft. They found that geogrid reinforcement placed between the aggregate and subgrade layers improves the performance of the pavement. Their results have verified that for weak subgrade (i.e. CBR of 1.5 to 5.0%), geogrid reinforced pavements can carry about 3.5 times more traffic load repetitions than non-reinforced pavements.

Naeini and Moayed [14] studied the CBR values for three different clay soils with or without geogrid reinforcement in one or multilayers. The result shows that CBR was considerably increased by using geogrid reinforcement in two layers when compared with unreinforced, but less value when compared with single layered reinforcement. Perkins et al. [15] found that geogrid reinforcement increases the modulus of the base layer and improves the vertical stress distribution over the subgrade. Hufenus et al. [16] performed full-scale field tests on geogrid reinforced unpaved roads on soft subgrades. They found that geogrid reinforcement increases the bearing capacity of the pavement and reduces rut formation.

Tang et al. [17] studied the effects of geogrid properties on subgrade stabilization by performing large-scale direct shear tests. They showed that the effectiveness of geogrid reinforcement is highly dependent on the physical and mechanical properties of the geogrids and on the properties of the interface between the geogrid and the surrounding materials. They evaluated the interface efficiency of geogrid reinforcement by performing direct shear tests. Their results showed a good correlation between the tensile strength at 2% strain, junction strength and other parameters obtained from the large-scale direct shear tests. According to [17], relationships between the geogrid properties and the interface efficiency of the geogrid reinforcement are useful in the assessment of geogrids.

## III. Materials and Methodology

The current study was undertaken to investigate the effect of using geogrids on improving the strength of compacted clay subgrade. Laboratory tests include Atterberg's limits, particle size distribution, proctor compaction and CBR tests have been conducted on soil with and without geogrids.

### A. Materials Used

In this study, the soil used was collected from Almenshia in Khartoum. The properties of this soil were determined and presented in Table I. As per unified soil classification system it has been seen that the soil is classified as clay of high plasticity and is designated as CH (i.e. sandy clay). From particle size distribution of the soil, it has been shown that it is mainly consists of 55% clay and 25% sand.

TABLE I
Properties of Soil Used

| Test | Property | Value |
|---|---|---|
| Particle Size Analysis | Gravel, % | 2 |
| | Sand, % | 25 |
| | Silt, % | 19 |
| | Clay, % | 55 |
| Atterberg's Limits | Liquid Limit, % | 61 |
| | Plastic Limit, % | 24 |
| | Plasticity Index | 37 |
| Compaction | Maximum Dry Density, g/cm3 | 1.60 |
| | Optimum Moisture Content, % | 20.0 |
| CBR | Soaked CBR, % | 3.4 |
| Specific Gravity | | 2.73 |
| Classification (USCS) | | CH |

The geogrid used is plastic sheet of white colour. It is collected from Norandy Trading Company Limited, Khartoum. Geogrid sheets were placed in one or several layers of the soil specimen. The soil was compacted in four layers in CBR mould and for each layer one geogrid sheet was inserted. Fig. 3 shows simple sketches of geogrids positions in soil specimen. It is to be noted that the geogrid is not damaged even after soaked CBR test.

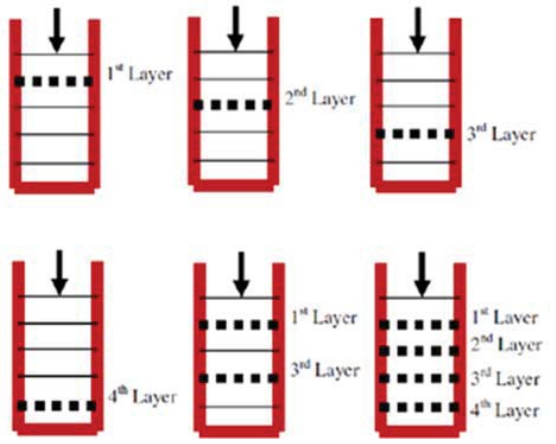


Fig. 3 Geogrid positions in the soil layers

### B. Methodology

Compaction tests were carried out to determine the maximum dry density (MDD) and optimum moisture content (OMC). The soil specimens compacted at MDD and OMC were used for the further CBR tests. The CBR test conducted in soaked condition and the procedure followed in accordance with BS [18]. The Geogrid sheets were placed at one or more layers in the specimen as shown in Fig. 3. The geogrid sheet was placed in one layer at 1st, 2nd, 3rd or 4th layer. The geogrids were used in multi-layer including 1st and 3rd layers, and at all the layers.

## IV. Results and Discussion

The test results are presented in Table II and shown in Fig. 4. From this figure, it is clearly observed that the soaked CBR value is much affected by the geogrid sheet position and the number of sheets used in the soil specimen. The CBR value obtained for natural soil is 3.4%. By placing geogrid at 1st layer, the CBR value increased to 4.3% which is an increment of 26%. In Fig. 4, it can be observed that the CBR value when the geogrid is placed at 1st layer is maximum compared to the other three individual layers. The CBR value of 4.4% is obtained when the geogrid is placed at 1st layer and 3rd layer. Here the percentage increase in CBR value is 29% compared to that of natural soil. Further, the CBR value of 5.5% is obtained when the geogrid is placed at all four layers which is an increment of 62% compared to that of natural soil.

TABLE II
CBR Test Results of Natural and Reinforced Soils

| Specimen | Geogrid Position | S. CBR (%) |
|---|---|---|
| Natural Soil | | 3.4 |
| Soil-geogrid of Single Layer | 1st Layer | 4.3 |
| | 2nd Layer | 4.0 |
| | 3rd Layer | 3.7 |
| | 4th Layer | 3.5 |
| Soil-geogrid of Several Layers | 1st and 3rd layers | 4.4 |
| | 1st, 2nd, 3rd, 4th layers | 5.5 |

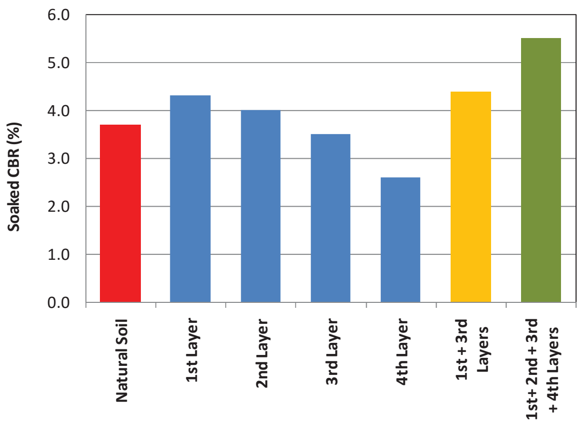


Fig. 4 Variation of soaked CBR values with and without geogrid layers

## V. Conclusion

The results obtained in this study show that the inclusion of geogrids in cohesive soils has a considerable effect on bearing strength. The following conclusions can be drawn:

- The geogrid sheet location and number used in the soil layers are significantly influence the CBR value. Inclusion of geogrid at 1st layer increased the CBR value by 26% compared to natural soil. Also, the CBR value greatly increased by 62% when the geogrid sheets were placed at all four layers.
- Geogrid reinforcement placed between the subbase and subgrade layers improves the performance of the pavement by reducing subgrade deformation and subbase rutting.
- Subgrade stabilization by geogrid reinforcement provides benefit through better distribution of applied loads and increased bearing capacity. Thus, improves the service life of pavement with reduced the thickness of the pavement structure.
- Subgrade stabilization is much affected by the geogrid properties and the interface efficiency of the geogrid reinforcement.

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