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ORIGINAL ARTICLE

Assessment of geogrids in gravel roads under cyclic loading

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Abstract Performance of geogrid in gravel roads subjected to repeated loads was investigated through laboratory testing in the laboratory of faculty of engineering at Shoubra and finite element analysis. Twenty two laboratory model tests under cyclic loading were conducted on road sections consisting of base course layer with and without geogrid reinforcement overlaying weak subgrade. Parameters investigated included base layer thickness, grid aperture size, geogrid tensile strength, number of geogrid layers, and geogrid location. The experimental results indicated that the inclusion of one geogrid sheet placed at the base of course layer reduced the vertical deformation by about 18 to 64% depending on the base course layer thickness. The vertical deformation depth increased rapidly during the initial load cycles; thereafter the rate of settlement is reduced as the number of loading cycles increased. The most effective location of geogrid was found to be in the top quarter of the base course layer. When the results of the laboratory tests were compared with the analytical solution using finite element program ABAQUS, the FE results were in good agreement with the experimental test results.

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1. Introduction

Application of geosynthetics is a well known technique in soil reinforcement. The inclusion of geosynthetics in road construction improves its performance. These improvements may pertain to four functions: separation, filtration, drainage,

and reinforcement. The most benefited functions in road construction are separation and reinforcement.

The separation function of the reinforcing element prevents the base course aggregate from sinking in the subgrade soil. Thus, the base course thickness remains constant without deterioration through the road life. This means that it will be able to distribute vehicle loads in efficient way without causing distress in subgrade. Many researchers such as Loulizi et al. [10] and Narejo [12] studied this theory. The reinforcement function contains three fundamental reinforcement mechanisms; lateral restraints; bearing capacity improvement; and tension membrane effect as stated by Giroud and Noiray [7,8], and Bhosale and Kambale [5].

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Nomenclature

G_s	specific gravity	γ	unit weight of soil (kN/m ³)
w_L	liquid limit	ϕ	internal friction angle (degree)
w_P	plastic limit	ψ	dilation angle (degree)
I_P	plasticity index	E	modulus of elasticity (kN/m ²)
c_u	Undrained shear strength (kN/m ²)	ν	Poisson's ratio
t	thickness of base course layer (mm)		
t_g	position of reinforcement layer measured from base surface (mm)		

Studies were conducted by Binquet and Lee [3,4] and Guido et al. [9] to evaluate the influence of the embedded reinforcing layer on the bearing capacity of soil. They proved that the inclusion enhanced the bearing capacity as well as the load-settlement resistance of the soil when compared with identical condition without reinforcement. Giroud et al. [8], and Bhosale and Kambale [5] showed that the membrane action has two effects: providing upward force to resist wheel load and increasing the subgrade bearing capacity by a downward force on both sides of the wheel load. Fannin and Sigurdsson [6] carried out field tests on geotextile and geogrid reinforced unpaved road section of varying thickness. They proved that the incorporation of geosynthetics between base course and subgrade improved the performance of this composite section but showed no significant improvement for thicker base course layer. Leng and Garb [11] conducted nine cyclic plate loading tests in the laboratory to simulate unpaved road section. They concluded that the inclusion of geogrid over subgrade soil helped in reducing the degradation of base course aggregate layer and total deformation produced in both aggregate base course and subgrade soil. Bhosale and Kambale [5] examined six modeled tests to simulate unpaved road section. They found that the stiffness of geotextile had been reduced with increasing load repetitions.

This paper presents the laboratory model test results and the numerical analysis conducted on both reinforced and unreinforced unpaved road sections subjected to cyclic loading. The aim of the study was to quantify the contribution of geogrid reinforcement in decreasing the vertical deformation depth due to wheel loads and to identify the proper locations of the geogrid layers. Numerical analysis was conducted for the same purpose using finite element software code ABAQUS.

2. Experimental setup

The components of the experimental model setup are shown in Fig. 1. The model test apparatus consisted of test tank, loading system, and instrumentation. The test tank has inner dimensions of 1500 mm in length, 1500 mm in width, and 900 mm in depth. The cyclic loading device depended on a hydraulic system designed to provide a pressure of 480 kPa on a model rigid steel plate 200 mm in diameter. The displacement transducer (LVDT) and data acquisition were used to monitor the surface deformation versus the number of loading cycles during tests [2].

Twenty cyclic loading tests were performed on unpaved road section of aggregate base layer overlying weak subgrade

soil (Fig. 2). The subgrade is placed in the test tank in lifts and compacted to a bulk density of 17 ± 0.1 kN/m³ with water content of $48 \pm 1\%$. Then, the aggregate base layer is compacted directly over the soil bed until it reached the target height and the required dry density (18.8 kN/m³). For reinforced section the geogrid layer was placed on top of the soil layer. Then, the base course layer was compacted in lifts till it reached the required thickness.

3. Material properties

3.1. Base layer

The used construction limestone aggregates in the base layer were poorly graded (GP) according to the Unified Soil Classification System. The aggregates uniformity coefficient, coefficient of curvature, and the average grain size were 1.7, 1.04, and 18 mm, respectively. The particles had a specific gravity of 2.68 and their maximum and minimum dry densities were 2.0 kN/m³ and 1.54 kN/m³, respectively. In all loading tests, the aggregates were compacted to a dry density of 18.8 kN/m³. The angle of internal friction at this density was 36°.

3.2. Subgrade layer

The basic properties of the soil used as subgrade layer in the laboratory model tests are listed in Table 1.

3.3. Geogrid

Five types of geogrids were used in the testing program which are known commercially as Netlon Synthetic Fibers, manufactured by Al-Shrouk Industry, Egypt. The one used most in the tests is CE131. The physical and mechanical properties of this geogrid, as supplied by the manufacturer, are given in Table 2.

4. Testing program

The experimental program included a series of model tests on two-layered soil system, consisted of the selected soil as subgrade and the base course aggregates as backfill material, and tested under cyclic loads of 480 kPa applied on a plate 200 mm in diameter. Five series of tests were conducted under different conditions to study the effect of various parameters as shown in Table 3.

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