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Evaluation of Geogrid in Unpaved Road Constructed on Sand Subgrade under Cyclic Loading

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ABSTRACT

Several defects may appear in unpaved roads under cyclic loading. From engineering point of view ruts are the most important defects. The behavior of unpaved road under repetitive loads with a geogrid on a sand subgrade was investigated through a laboratory testing program. Twenty two large scale laboratory model tests under the effect of cyclic loading were conducted on road section. Parameters investigated in the testing program include base layer thickness, aperture size of the grids, subgrade degree of compaction, and geogrid location. The experimental results indicated that the inclusion of geogrid sheet placed at the interface reduced the rut depth by 16% to 31% depending on the base course thickness. The most advantageous location of one geogrid layer was in the top quarter of the base course layer. The results show that in all cases of cyclic loading in the laboratory model tests, the use of geogrid improved the bearing capacity and reduced the rut depth in comparison with the unreinforced case.

Keywords: unpaved road, Geogrid, cyclic loading, rut depth

1. Introduction

A typical unpaved road system includes two layers: base course layer and subgrade layer. Geosynthetics were used to improve the performance of such roads (Al-Qadi et al., (1998), Giroud and Noiray (1981), Giroud et al., (1984), Bhosale and Kambale, (2008), Narejo (2003), Hossain and Schmidt (2009), Maxwell et al. (2005) and Wu et al. (2019).

Raymond (1992) performed a series of laboratory tests on several base materials vary in compressibility. Most of these tests were done using Ottawa sand as a subgrade soil and check tests were done using other materials such as crushed limestone and rounded dense stone. The tests were performed with and without reinforcement. The location of the reinforcement layer varied from 25, 50, 75, and 125 mm from the surface. The results of these tests concluded that the presence of a geosynthetic layer reduced the settlement compared with the case without inclusions under the same conditions. The higher the stiffness of the base material and larger footing width, the lower was the value of settlement. The location of the reinforcement layer effectively influenced the value of the settlement. The settlement was reduced as the reinforcing layer got closer to the footing, and the bearing capacity increased.

Fannin and Sigurdsson (1996) carried out field tests on geotextile and geogrid reinforced unpaved road section of varies thickness. They proved that the incorporation of geosynthetics between base course and subgrade improve the performance of this composite section and has no significant improvement for thicker base course layer.

Kamel et al. (2004) conducted a series of laboratory tests on three types of soil (fine sand, sandy clay, and clayey silt) and two types of geogrids. The tests were performed with a single layer of geogrid placed at different positions with respect to the total height of the sample. The laboratory tests proved that the use of one layer of geogrid at different depths helped in increasing the amount of CBR value of the soil, the suitable position of the geogrid layer is at 72-76% from the top of the sample, and The uses of geogrid mainly increase the modulus of elasticity.

2. EXPERIMENTAL SETUP

The laboratory test sections were constructed in a square rigid tank with dimensions of 1500 mm in length, 1500 mm in width, and 900 mm in depth. Fig. 1 shows the components of the experimental model setup. A typical unpaved test section consisted of a layer of aggregate base and a layer of sand subgrade as shown in Fig. 2. Test sections were subjected to cyclic loading with a pressure of 480kPa on a model rigid steel plate of 200 mm diameter. The surface deformation and number of load cycles during tests were monitored by displacement transducer **(**LVDT) and data acquisition. The details of the laboratory model test are explained in details in Salama (2014). The rut depth (vertical deformation) in some of these tests was measured for up to 10,000 cycles of loading and unloading. The subgrade is placed in the test tank in lifts and compacted to a required density. For reinforced section the geogrid layer is laid at over the clay layer. After this, the base course layer was placed in lifts and compacted till reaching the required thickness.

3. MATERIAL PROPERTIES

3.1 Base Layer

The angular crushed limestone was obtained from local quarry in Masr El-Kadeemaa. The essential tests were performed to get the properties of the aggregate base course.

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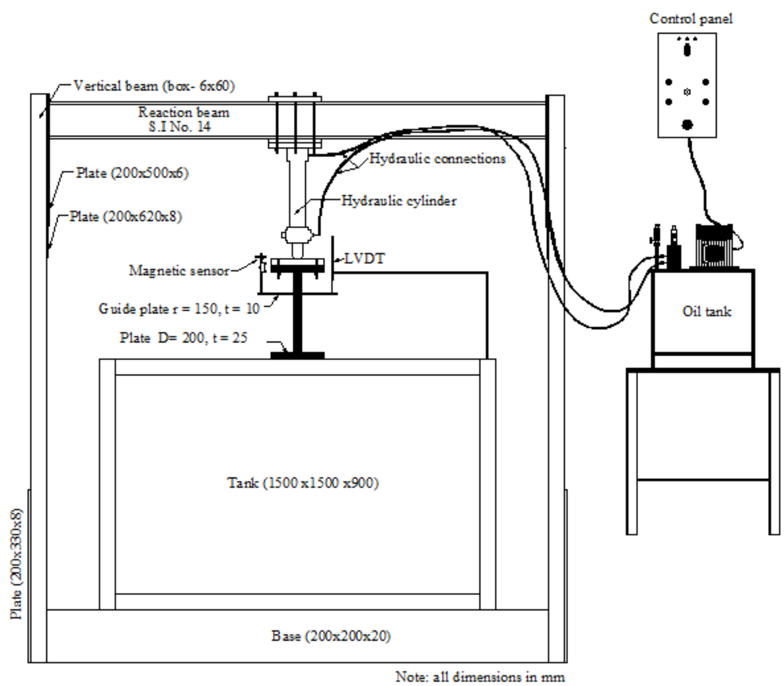

Figure 1. Components of the experimental setup.

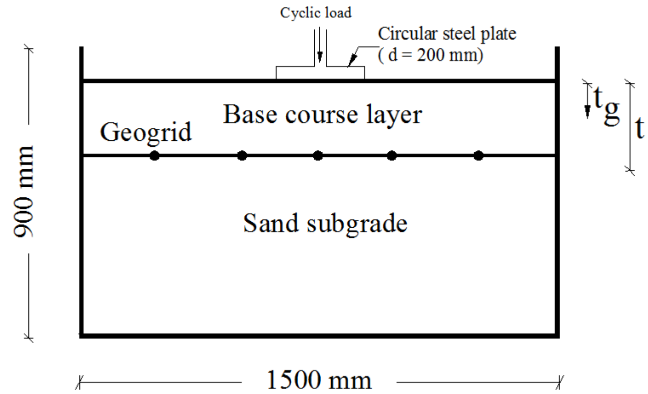

Figure 2. Typical test section.

The uniformity coefficient, coefficient of curvature, and the average grain size are 1.7, 1.04, and 18 mm, respectively. The aggregate is classified as poorly graded (GP) according to Unified Soil Classification System. The particles had a specific gravity of 2.68 and their maximum dry density is 19.9kN/m^3. During all loading tests the aggregate was compacted to a dry density of 18.8kN/m^3. The angle of internal friction at this density of compaction from direct shear tests was 36^o.

3.2 A Subgrade Layer

The sand used as a subgrade was brought from a location at 6th of October City. The properties of sand subgrade determined by laboratory tests are listed in Table 1.

3.3 Geogrid

Different types of Netlon Synthetic Fibers manufactured by Al-Shrouk Industry were used in the testing program. The most one used in the tests known as CE131. The physical and mechanical properties of the geogrid are reported in Table 2 as supplied by the manufacturers.

Table 1. Parameters considered for sand in testing program

Parameter		**Valu**
Maximum dry density $(\gamma_d)_{max}$ (kN/m^3)		19.5
Minimum dry density $(\gamma d)_{min}$ (kN/m^3)		14.6
Specific gravity (Gs)		2.58
Maximum void ratio (e_{max})		0.78
Minimum void ratio (e_{min})		0.32
Grain size distribution	Uniformity coefficient (c_u)	2.67
	Coefficient of curvature (c_c)	0.612
	Mean grain size	0.425
	Effective size diameter (D_{10})	0.18
Unified soil classification system		SP
Internal friction angle (ϕ) at degree of		42.5°

Table 2. Physical and mechanical properties of Geogrid

property	**CE131**
Form	Sheet
Colour	Black
Polymer	HDPE
Width (m)	2
Length (m)	30
Mesh aperture size (mm)	27 x 27
Mesh thickness (mm)	5.2
Structural weight (g/m^2)	660
Tensile strength (kN/m)	5.8
Elongation at maximum load (%)	16.5
Load at 10% extension (kN/m)	5.2
Elongation at ½ peak strength (%)	3.7

4. TESTING PROGRAM

The typical cross-section of testing set-up is shown in Fig. 3. The testing program was composed of five series of tests. A geogrid layer was placed at the interface in all test series except the third series where the geogrid placed within the base layer to study the effect of geogrid position. The tests have been performed under the application of cyclic loads of 480kPa on a plate of 200mm diameter. The details of these series of tests are shown in Table 3.

Table 3. Laboratory model tests for unpaved road section on sand subgrade

Variable / Studied parameter	Base thick. (mm)	No. of reinf. layers	Degree of compaction (%)	Position of reinf. layer (t_g/t)	Type of geogrid
Test Series I: Thickness of base layer , t	100, 150, 200, 250, and 300	None	90	Without geogrid	CE131
		One layer		At interface $t_g/t = 1$	
Test Series II: Position of reinf. layer (t_g/t)	200	One layer	90	t_g/t = 0.25, 0.5, and 0.75	CE131
Test Series III: Degree of compaction	200	None	85, 90, and 95%	Without geogrid	CE131
		One layers		at interface $t_g/t = 1$	
Test Series IV: Aperture size	200	One layer	90	At interface $t_g/t = 1$	CE131CE153 and DN

5. EXPERIMENTAL RESULTS

The influences of different aggregate base thickness on the road section in unreinforced and reinforced cases are shown in Figs. 4 and 5, respectively. Reinforced section with one layer at the interface performed significantly better than unreinforced sections by decreasing the rut depth by pronounced values at the same number of cycles. This improvement can be attributed to the presence of the aperture as it interlock with the aggregate and prevents the lateral spreading (confinement effect) so the thickness of the base layer remains intact and distributes the vehicle load over a wider area on subgrade soil surface.

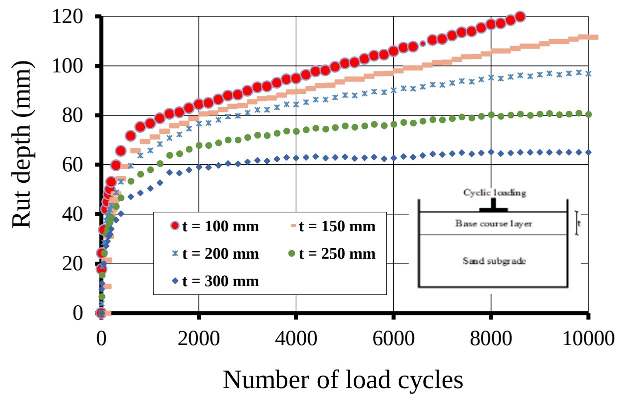

Figure 4. Surface deformation in unreinforced case.

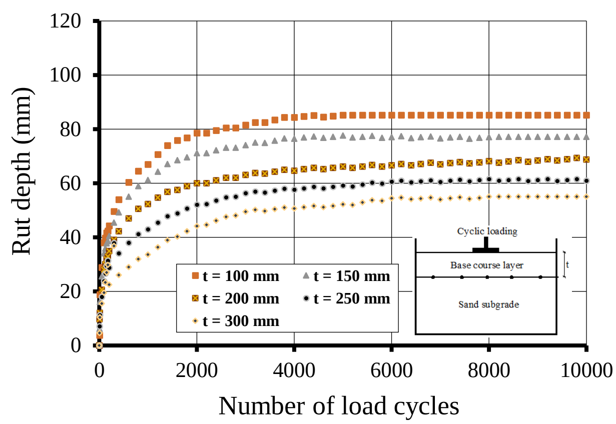

Figure 5. Surface deformation in reinforced case

The suitable location of the geogrid reinforcement layer leads to high benefits from its use. Fig. 6 shows the effect of position of one geogrid reinforcement layer on the relation between the rut depth and the number of load cycles, test series II. The results concluded that the optimum position of one geogrid reinforcement layer is at the upper quarter of the base course layer and not at the interface as previously showed by Barksdale et al., (1989), Chan et al., (1989), Degroot (1986), McGown and Andrawes (1977) and Rowshanzamir and Karimian (2016).

In the following sections, the results of loading tests carried on the model in terms rut depth versus number of load cycles at three relative densities of 85, 90, and 95% are presented. Figs. 7 and 8 show the relationship between rut depth and number of load cycles for different degrees of subgrade compaction in unreinforced and reinforced cases respectively. Generally the number of load cycles increased with increasing sand subgrade relative density.

The comparison between Figs. 7 and 8 showed that when the degree of compaction of sand subgrade equal to 85% with the use of geogrid reinforcement at the interface achieve the same performance as the degree of compaction of the subgrade reached to 90% without reinforcement.

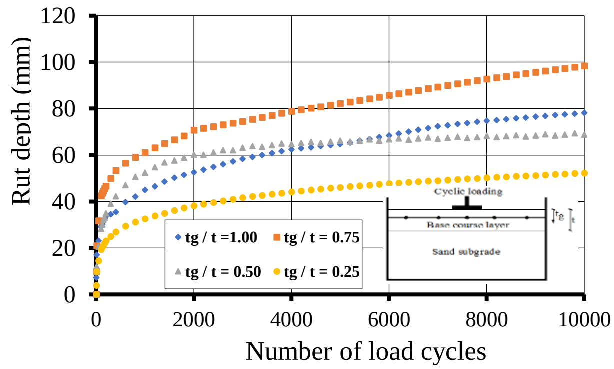

Figure 6. The effect of geogrid position within the base course layer on rut depth.

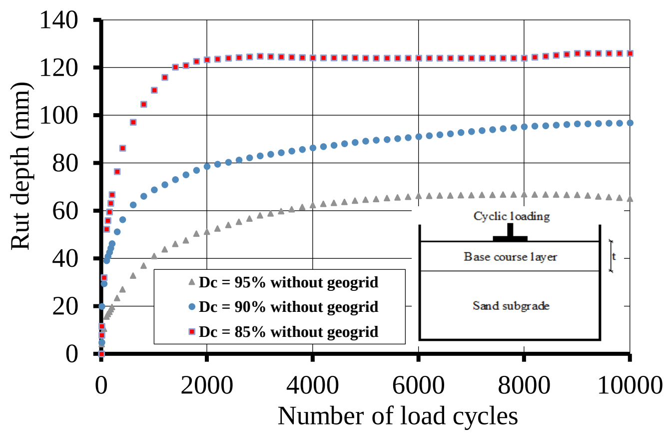

Figure 7. Relation between number of load cycles and rut depth for base thickness of 200mm without geogrids for varied degrees of compaction.

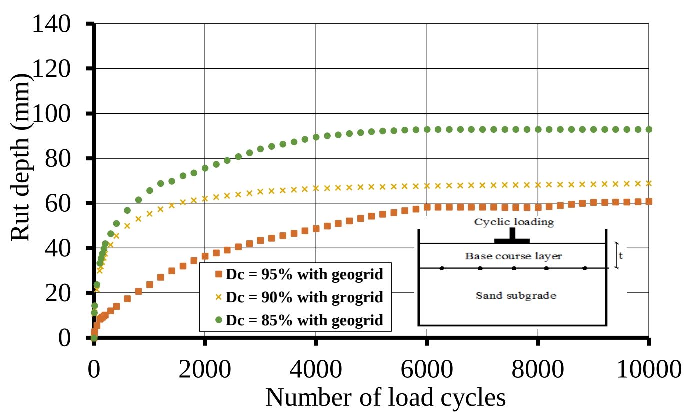

Figure 8. Relation between number of load cycles and rut depth for base thickness of 200mm with geogrids for varied degrees of compaction

Fig. 9 shows the relation between number of load cycles and rut depth produced for base course thickness of 200mm, with different types of geogrids (CE131, CE153, and DN) at the interface. Their aperture sizes were 27mm x 27mm, 33mm x 33mm, and 11mm x 11mm, and their tensile strengths were 6.2kN/m, 5.5kN/m, and

11kN/m, respectively. The use of geogrid with great value of tensile strength (DN) with improper aperture size produced a rut depth greater than that caused by a geogrid with lower value of tensile strength (CE131) but with suitable aperture size. A suitable aperture size, as in CE131, led to the development of good interlocking between the geogrid and the base course. In turn, it developed additional lateral confining pressure induced by the tensile force created in the geogrid. Thus, the subgrade soil sustained higher stress and the deformation decreased.

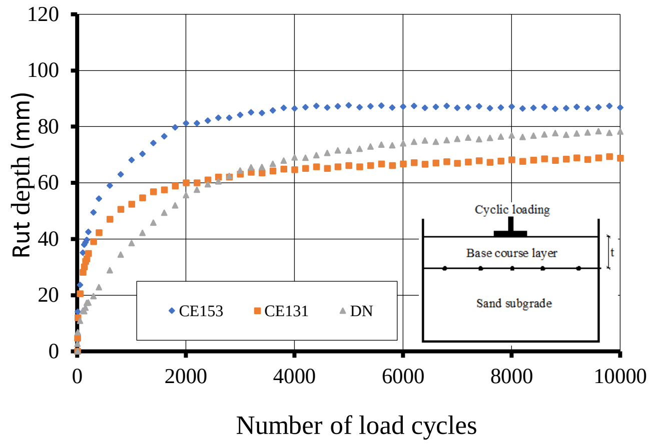

Figure 9. Relation between number of load cycles and rut depth for base thickness of 200mm with different types of geogrids.

CONCLUSIONS

The testing results obtained from this experimental research program demonstrated that :

1. The geogrid reinforcement layer placed at the interface effectively increases the service life reduces the rut depth by about 16% to 31% depending on the base course layer thickness.
2. The most advantageous location of one geogrid layer was in the top quarter of the base course layer.
3. Generally the number of load cycles increased with increasing sand subgrade relative density.
4. The use of geogrid was more beneficial for the sand subgrade with less degree of compaction.
5. The use of geogrid with improper aperture size and higher tensile strength cause a rut depth greater than that caused by geogrid with low value of tensile strength but with a suitable aperture size.

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