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# EXPERIMENTAL EVALUATION OF SOIL REINFORCEMENTS IN UNPAVED ROAD

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In this study, a series of 24 laboratory tests were conducted on a footing resting on crushed stone with 17.68 kN/m$^3$ dry unit weight overlying sandy soils of two relative densities corresponding to (60% and 80%). The subbase layer is of crushed stone with a thickness of 5, 7.5 and 10 cm. Ten tests were conducted under static load with and without geogrid. All the other 14 model tests were carried out under harmonic load which was applied in a sequence determined prior (40% of static load). Tests were conducted at (2) Hz frequency according to the loading value. The process of the loading was continued until the number of cycles reached 10$^4$. The results indicated that, for static load and with the inclusion of the geogrid, as the thickness of the subbase layer increases, the percentage of increase in bearing capacity was reduced. In general, using geogrid reinforcement with subbase thickness of 7.5 and 5 cm causes an increase in bearing capacity approximately 1.5 to 2 times greater than for unreinforced respectively. This means that by using geogrid reinforcement, the thickness of subbase can be reduced which causes a reduction in construction cost.

*Keywords*: Geogrid, Static, Dynamic loading, Crushed stone, Sandy soil, Bearing capacity.

## 1 INTRODUCTION

In general, unpaved roads consist of an unbound crushed stone as a subbase overlying an existing, typically weak subgrade. The types of fill used for the subbase layer vary from locally available materials or waste material to good quality crushed stone. Generally, the sub grade has a poor bearing capacity or may range from medium strength to very low strength. The road may be not paved for the following reasons:

- In developing countries, the cost may be the main factor.
- For temporary access road, so the road has a very brief design life.

The unpaved roads usually are poor quality, potholed, unable to with stand loads of heavy vehicle or equipment. One way to improve soil properties for pavement construction is to reinforce the material with geosynthetic. Geosynthetic used in unpaved roads are essentially geotextile and geogrid. This work focuses on the use of geogrid as reinforcement, which improved interface resistance due to interlocking as compared to geotextile. This interlocking between the crushed stone and geogrid provided the confinement which minimizes lateral movement of crushed stone particles and increases the modulus of the base course, which causes a wider vertical stress distribution over the subgrade and consequently a reduction of the vertical and lateral deformation.

In recent years, the use of geosynthetic materials in road construction has increased drastically. The first use of fabrics for reinforcing roads was investigated by the South Carolina Highway Department in 1926 as reported by Koerner (2005). Giroud and Noiray (1981) used an improvement factor of $(\pi + 2)$ for geotextile reinforced unpaved road and $(3\pi/2 + 2)$ for geogrid reinforced unpaved road. Krishnaswamy and Sudhakar (2005) carried out a test to study the effect of using geotextile in increasing the California Bearing Ratio. Gali and Nair (2014) performed laboratory and field studies on unreinforced and reinforced unpaved low volume roads section constructed over weak subgrade using different types of geosynthetic reinforcement. Like geotextile biaxial geogrid and geocell layer at the interface of subgrade and base course in order to increase the load carrying capacity and reduction in rut depth. The main conclusions were drawn, that using Geosynthetic are effective in increasing the load carrying capacity and reducing rut depth. Researchers like Elleboudy *et al.* (2017), Calvarano *et al.* (2017), and Mousavi *et al.* (2017) use numerical analysis to study the performance of geogrid reinforced of the unpaved road under static and repeated load through ABAQUS and 3D-Plaxis Software. From the literature, it was evident that the application of geosynthetic reinforcement in the pavement has not been extensively studied. In this paper, the experimental study was carried out to evaluate the effect of using geogrid reinforcement in improving the load carrying capacity and deformation of the unpaved road under the static and dynamic load. In the model tests, a load of 40% of the static load was applied repeatedly for $10^4$ cycles and the settlement of the plate was measured.

## 2 EXPERIMENTAL SETUP

The model test apparatus consisted of a test tank, loading system, and instrumentation. The test tank has inner dimensions of 1000mm length, 750 mm width and 700mm depth. Each part of the container is made of steel plates of 5 mm thick. A load was applied through a steel plate of 200 mm width, 400mm length and 5 mm thickness. Different materials were used in performing the experimental model which is subgrade soil, crushed stone, and geogrid.

### 2.1 Subgrade Soil

Sand used in the present study was brought up from Bedra City at Wasit Province, southern East of Baghdad in Iraq. The subgrade soil used was classified as poorly graded sand (SP) according to the Unified Soil Classification System. The maximum unit weight was 19.4 kN/m$^3$ and the minimum unit weight was 15.8 kN/m$^3$. The angle of internal friction was 31.5$^0$ for 60% relative density and 38.7$^0$ for 80% relative density.

### 2.2 Crushed Stone

The subbase layer rests over a sandy soil with maximum dry unit weight equal to 17.68 kN/m$^3$. The crushed stone of various sizes was collected and sampled according to grading I of granular sub-base design as given by R6E (Iraqi Standard Specification 1983). The subbase is classified as GP according to the Unified Soil Classification System (USCS). Figure 1 depicts the grain size distribution of the crushed stone used in the present study.

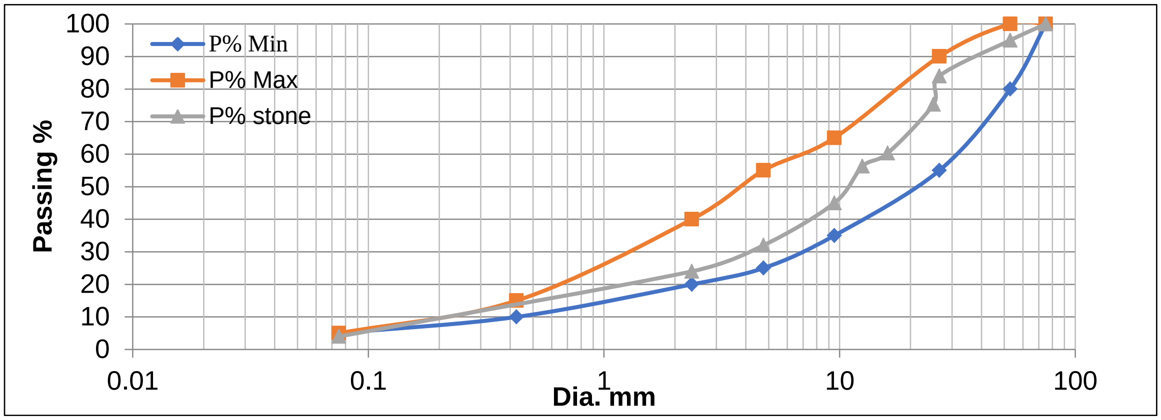

Figure 1. Grain size distribution of crushed stone.

## 2.3 Reinforcing Materials

The geosynthetic reinforcement usually placed above weak subgrade to improve the performance of this layer. These improvements can be listed into four functions: Separation, filtration, drainage, and reinforcement. The most affected functions are separation and reinforcement. The Separation function of the reinforcing element prevents the base course 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 inefficient way without causing distress in the subgrade. In this study, the used geogrid was manufactured by Al-Latifia Factory, the plastic mesh having engineering properties; mass per unit area is 700 g/m$^2$, tensile strength at 2% strain is 5.1 kN/m and tensile strength at 5% strain is 9.1 kN/m. One layer of geogrid is used, and it is placed at the base course/subgrade soil interface.

## 3 TESTING PROGRAM

The experimental program included a series of model tests on two-layered soil system, these tests were carried out under static and harmonic load. The static load was applied gradually through the hydraulic jack that actuating at the controlled displacement of 0.03 mm/sec. Dynamic loads applied according to the testing program, the harmonic loading was applied in a sequence determined prior (40% of static load). Tests were conducted at (2) Hz frequency according to the loading value. The process of the loading was continued until the number of cycles reached $10^4$.

## 4 RESULTS AND DISCUSSIONS

Table 1 summarizes the results of unpaved road bearing capacity under static load. For all models tests, the failure is defined as the load causing a settlement corresponding to 10% of the footing width (Terzaghi 1943). It is clearly shown that the soil with a relative density of 60%, the geogrid reinforcement causes an increase in the bearing capacity from 1.5-2 times greater than unreinforced for 7.5 cm and 5 cm of subbase layer respectively. This is due to the improvement of load distribution and lateral restraint of base material which is related to the geogrid/crushed stone material interaction which prevents lateral spreading of the base material and imparts tensile stiffness to the base. For subbase layer thickness of 10 cm, a small increment in bearing capacity, this is may be due to higher deformations are required for the mobilization of reinforcing tensile strength due to higher subbase layer thickness. It can be seen that for soil with

80% relative density, there is no significant increase in the bearing capacity due to small deformation. Table 2 summarizes the results of unpaved road surface settlement under harmonic load took at 1000 cycle. Figures A-1 to A-8 in Appendix A has presented the test results of the unpaved road under static and dynamic test.

Table 1. Bearing capacity of unpaved road under static load with and without geogrid reinforcement.

| | **Subbase thickness (cm)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **h = 5 cm** | | | **h= 7.5 cm** | | | **h= 10 cm** | | |
| | **Bearing Capacity (kPa)** | | | | | | | | |
| **Relative Density of subgrade** % | **Without Geogrid** | **With Geogrid** | **% of increase in bearing capacity** | **Without Geogrid** | **With Geogrid** | **% of increase in bearing capacity** | **Without Geogrid** | **With Geogrid** | **% of Increase in bearing capacity** |
| 60 | 152 | 300 | 97 | 225 | 375 | 67 | 329 | 375 | 14 |
| 80 | 373 | 382 | 2.4 | 446 | 545 | 22 | 653 | 710 | 9 |

Table 2. Surface settlement under cyclic load with and without geogrid reinforcement at the end of 1000 cyclic.

| | **Subbase thickness (cm)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **h = 5 cm** | | | **h= 7.5 cm** | | | **h= 10 cm** | | |
| | **Settlement in mm at 1000 cycle** | | | | | | | | |
| **Relative Density of subgrade** % | **Without Geogrid** | **With Geogrid** | **Set. Redn%** | **Without Geogrid** | **With Geogrid** | **Set. Redn%** | **Without Geogrid** | **With Geogrid** | **Set. Redn%** |
| 60 | 6.5 | 5.8 | 10 | 5.4 | 4.5 | 16 | 4.8 | 4.3 | 10 |
| 80 | 4.0 | 3.9 | 2.5 | 3.6 | 3.2 | 11 | 3.3 | 2.9 | 12 |

## 5 CONCLUSIONS

The main conclusions from the inclusion of geogrid at the interface subbase/subgrade are:

- Unpaved road under static load provides an increase in the bearing capacity and reduced the settlement. The maximum increment varies from 1.5-2 times greater than unreinforced one. While in the case of unpaved road subjected to a dynamic load, the maximum reduction in the settlement is only 16% using geogrid reinforcement compared to the unreinforced case.
- The thickness of the subbase layer has a significant effect on the performance of geogrid. Specific deformation is required for geogrid to have fully mobilization of reinforcing tensile strength.
- The geogrid prevents the intermix of base and subgrade by a geogrid performing the function of separation. Finally, geogrid reduces construction cost by reducing the thickness of the subbase layer.

## Appendix A. Experimental Test Results

The experimental test results for the unpaved road under static and harmonic load with and without geogrid are shown in Figures A.1 to A.8.

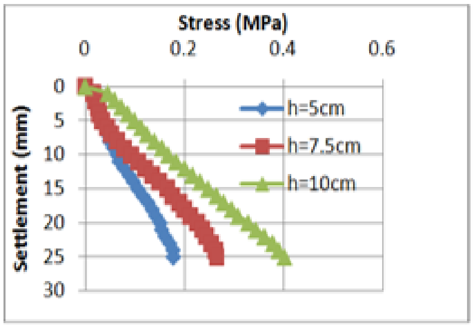

Figure A.1. The effect of the subbase layer thickness on the bearing capacity (RD. = 60%) without geogrid under static load.

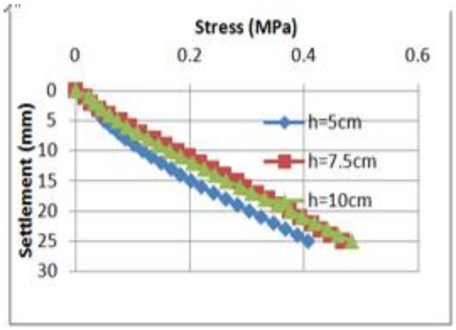

Figure A.2 The effect of geogrid reinforcement on the bearing capacity with different subbase layer thicknesses (RD = 60%) under static load.

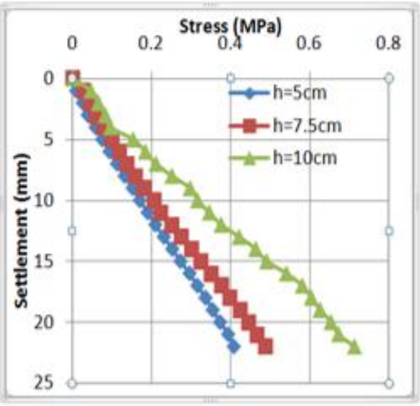

Figure A.3. The effect of the subbase layer on the bearing capacity with different subbase layer thicknesses (RD = 80%) under static load.

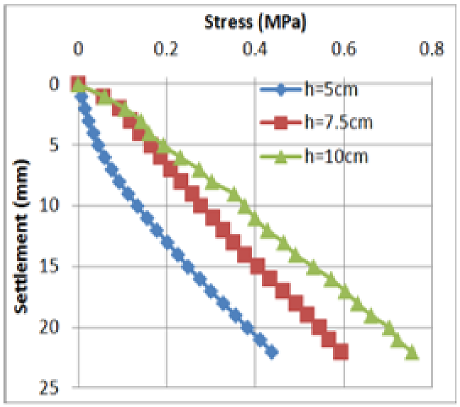

Figure A.4. The effect of the subbase layer on the bearing capacity with different subbase layer thicknesses using geogrid reinforcement under static load.

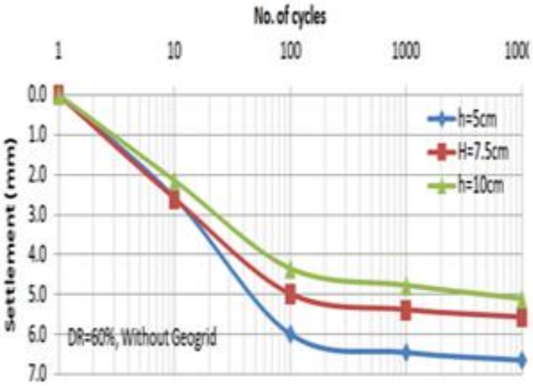

Figure A.5. The effect of dynamic load on the bearing capacity with different subbase layer thickness (RD = 60).

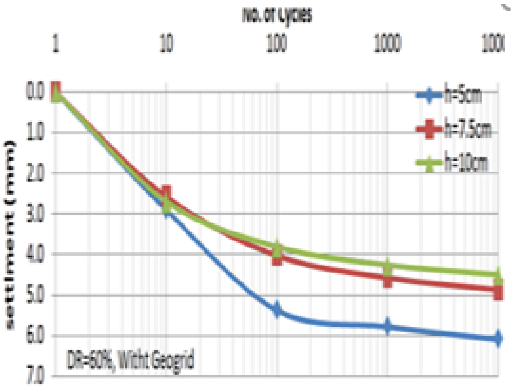

Figure A.6. The effect of dynamic load on the bearing capacity with different subbase layer thickness (RD = 60).

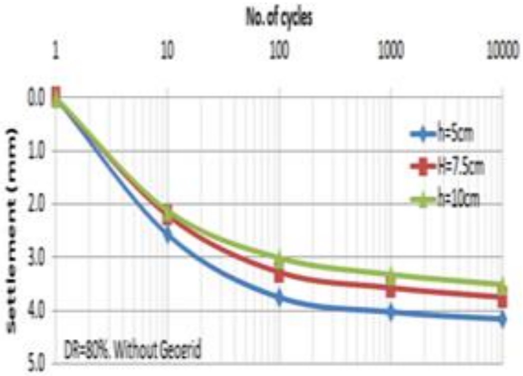

Figure A.7. The effect of dynamic load on the bearing capacity with different subbase layer thickness (RD = 60).

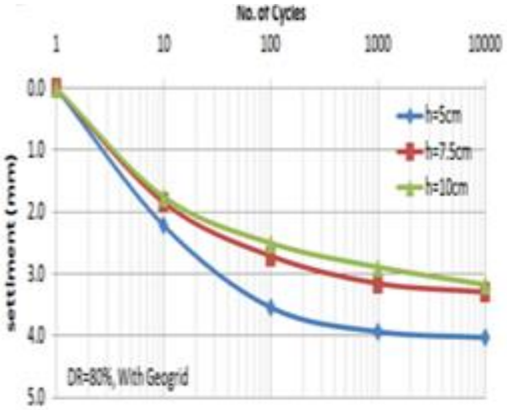

Figure A.8. The effect of dynamic load on the bearing capacity with different subbase layer thickness (RD = 60).

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