Maintenance and Rehabilitation

LARGE SCALE TESTS FOR GEOGRID REINFORCED UNPAVED ROADS

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Abstract

ABSTRACT: This paper intends to present and discuss the performance of geogrid reinforced and unre-inforced granular fill layer in unpaved road systems using large scale cyclic plate load tests. A large scale cyclic plate load test facility was developed for studying the permanent deformation (rutting) characteristics. Cyclic loads at a fixed frequency were applied on reinforced and unreinforced laboratory unpaved road sections through a rigid circular plate. An unpaved road structure consisting of granular road material over a soft clay soil subgrade. To prepare reinforced sections geogrid was placed within the granular road material at the desired location. Also, geotextile was placed at the interface between road material and soft clay soil subgrade for separation. The model unpaved road structure was con-structed in a steel tank and resilient modulus test. A total of 5 large scale laboratory and 20 resilient modulus tests were conducted to evaluate the effects of geogrid reinforcement. The test results indicate that considerable improvement in bearing capacity was observed when geogrid was placed within the granular road material at all levels of deformations. Permanent deformation (rutting), plastic surface de-formation and vertical stress development under cyclic loading was greatly reduced and by the inclusion of geogrid. The optimum placement position of geogrid was found to be within the granular road mate-rial at a depth of one-third of the plate diameter below the surface. Keywords: cyclic plate loading test, geogrid, geotextile, resilient modulus test, permanent deformation, soft clay

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Large Scale Tests for Geogrid Reinforced Unpaved Roads

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ABSTRACT: This paper intends to present and discuss the performance of geogrid reinforced and unreinforced granular fill layer in unpaved road systems using large scale cyclic plate load tests. A large scale cyclic plate load test facility was developed for studying the permanent deformation (rutting) characteristics. Cyclic loads at a fixed frequency were applied on reinforced and unreinforced laboratory unpaved road sections through a rigid circular plate. An unpaved road structure consisting of granular road material over a soft clay soil subgrade. To prepare reinforced sections geogrid was placed within the granular road material at the desired location. Also, geotextile was placed at the interface between road material and soft clay soil subgrade for separation. The model unpaved road structure was constructed in a steel tank. A total of 5 large scale laboratory tests were conducted to evaluate the effects of geogrid reinforcement. The test results indicate that considerable improvement in bearing capacity was observed when geogrid was placed within the granular road material at all levels of deformations. Permanent deformation (rutting), plastic surface deformation and vertical stress development under cyclic loading was greatly reduced and by the inclusion of geogrid. The optimum placement position of geogrid was found to be within the granular road material at a depth of one-third of the plate diameter below the surface.

Keywords: cyclic plate loading test, geogrid, geotextile, granular fill, permanent deformation, soft clay

1 INTRODUCTION

During life period of pavement structure, there are different kinds of problems. Permanent deformation (rutting) is one of the serious problems. Especially, when unpaved roads are built on soft soils, large permanent deformation (rutting) may occur, which increase maintenance cost. Under repetitive traffic loads, the excessive subgrade deformation eventually leads to large permanent deformation. The large permanent deformation (rutting) reduces driving comfort and it creates difficulties for the drivers. Any subgrade soil with a CBR<%5 is required to be improved. Traditionally, this weak subgrade soil can be excavated and backfilled with goodquality soil, or chemically stabilized (PennDOT, 2010). Besides these traditional methods, geosynthetics offer an environmental friendly and potentially economical alternative solution for reinforcing roads built over weak soil (Abu Farsakh et al, 2016). Using a reinforcement with geogrid which is geosynthetic material in pavement construction has become an increasingly common practice within the past decade. Geogrids provide reinforcement by laterally restraining aggregate layers and improve the bearing capacity, thus decreasing the shear stresses on weak subgrade. In addition, the confinement pro-vided by geogrids improves the distribution of vertical stress over the subgrade and thus reduces permanent deformation (Sakleshpur, 2017). It is typically recognized that geogrids function consists of the following items; providing a separation between the base and subgrade soil, interlocking with the surrounding granular soil, and, providing a membrane-like reinforcement under sufficient deformation (Al-Qadi et al., 2008; Qian et al., 2012). Using geosynthetics as a reinforcement in road construction started in the 1970s. Many studies about the geogrid reinforcement conducted to investigate the benefits of geogrid reinforced aggregate layer (Al-Qadi et al. 2008, Kwon and Tutumluer 2009, Hass et al., 1988; Chan et al., 1989; Al Qadi et al., 1994; Berg et al., 2000; Perkins, 2002). According to the past studies, geogrid can be beneficial but quantifying the effect of geogrid reinforcement has proven to be difficult. So, large scale studies of geogrid reinforced layers are often preferred for evaluating potential benefits of geogrid (Sakleshpur et al., 2017; Sarici et al, 2016; Abu Farsakh et al, 2016). In large scale experimental studies, cyclic plate load test has been widely used by researchers due to its low cost, give realistic results and time savings to evaluate the performance of geogrid reinforced pavement (Wu et al., 2015; Abu Farsakh and Chen, 2011; Al Qadi et al., 1994; Haas et al., 1988; Sarici et al, 2016). Results of the past studies revealed that geogrid can extend the service life, reduce the thickness of base or subbase course layer (reduce the amount of aggregate needed) and delay permanent deformation (rutting).

The previous studies usually have focused on measuring the total permanent deformation. But, stress distribution at base/subbase course layer is a very important output for measuring the performance of reinforcement with geogrid. In this paper, the performance of geogrid reinforced and unreinforced granular fill layer in unpaved road systems was evaluated using large scale cyclic plate load tests. Cyclic loads at a fixed frequency were applied on reinforced and unreinforced laboratory unpaved road sections through a rigid circular plate. An unpaved road structure consisting of granular road material over a soft clay soil subgrade. To prepare reinforced sections geogrid was placed within the granular road material. Also, geo-textile was placed at the interface between road material and soft clay soil subgrade for separation. A total of 5 large scale laboratory tests were conducted to evaluate the effects of geogrid reinforcement.

2 MATERIALS

2.1 *Weak soil for subgrade*

In the tests, subgrade was created which have weak soil conditions (CBR 3-5%). In order to weak soil conditions, the soil was prepared in 19% water moisture. Grading curve of the soil based on sieve analysis and hydrometer test is demonstrated in the Figure 1 and geotechnical properties the soil are shown presented in Table 1.

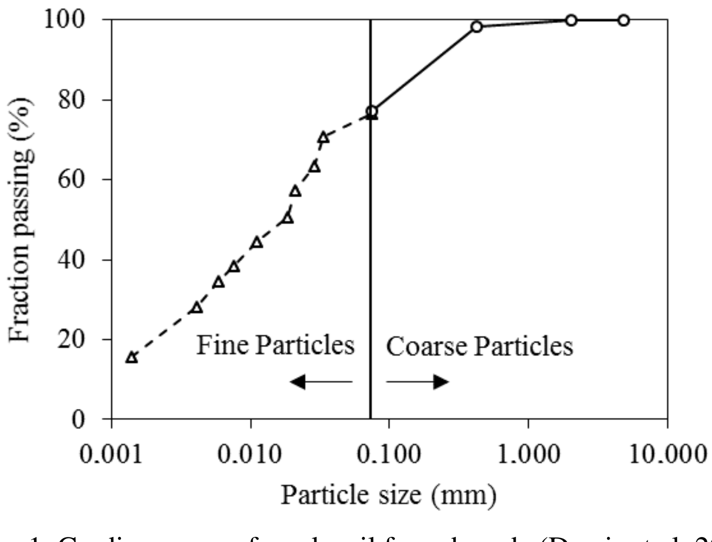


Figure 1. Grading curve of weak soil for subgrade (Demir et al. 2016)

2.2 *Granular base course material*

A mixture of granular materials have different size was used in the base course layer. Particle size distribution of the mixture of granular materials is suitable for used in road according to Road Technical Specification of Republic of Turkey General Directorate of Highways (Figure 2). Large scale direct tests were performed to the granular material at normal stress levels which are 25, 50 and 75 kPa. In the result, friction angle of the granular material was found 62 degree. Properties of granular base course material are shown in Table 2.

Table 1. Geotechnical properties of weak soil (Demir et al. 2016)

Properties	Unit	Value
Liquid Limit (LL)	%	24
Plastic Limit (PL)	%	17
Plasticity Index (PL)	%	7
Optimum Moisture Content (ω_{opt})	%	17
Maximum Dry Unit Weight (γ_{kmax})	kN/m^3	17.94
Soil Particle Unit Weight (γ_s)	kN/m^3	26.70
CBR (at 19% water content)	%	4

Figure 2. Grading curve of granular base course material (Demir et al. 2016)

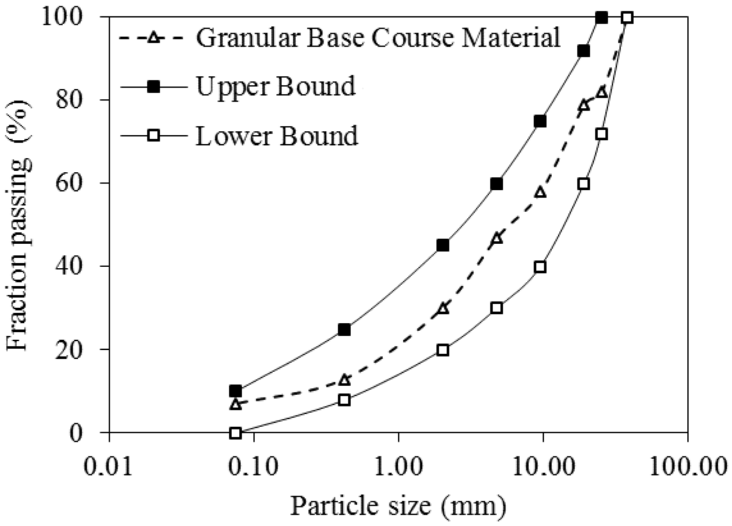


Table 2. Properties of granular base course material.

Property	Unit	Value	
		Modified Compaction	Vibratory Compaction
Maximum Dry Density (γ_{kmax})	kN/m^3	22.48	23.45
Optimum Moisture Content (ω_{opt})	%	4.6	4.0
Liquid Limit (LL)	%	N.P. (Non-Plastic)	
California bearing ratio (CBR)	%	252-246	
Los Angeles Abrasion loss	%	30	
Water Absorption	%	0.82	
Methylene Blue Test	%	1.25	
Friction Angle	Degree	62.07	

2.3 *Geosynthetics*

Triaxial geogrid were used to reinforce the base layer in the large scale cyclic plate load test sections. In addition, woven geotextile were used to separate the base layer from the weak soil. The physical and mechanical properties of geogrid and geotextile, as provided by the manufacturers, are listed in Table 3. Photographs of Geosynthetics are presented in Figure 3.

Table 3. Geosynthetics properties

Properties	Unit	Geogrid	Geotxtile
Raw Material	-	Polypropylene	Polypropylene
Aperture Type	-	Triangle	-
Aperture Dimensions	mm	40x40x40	0.196
Thickness	mm	1.1	0.85
Static Penetration Resistance	kN	-	3.5
Tensile Strength at 5% strain, md/cmd*	kN/m	300	300

* md/cmd: machine direction/cross machine direction

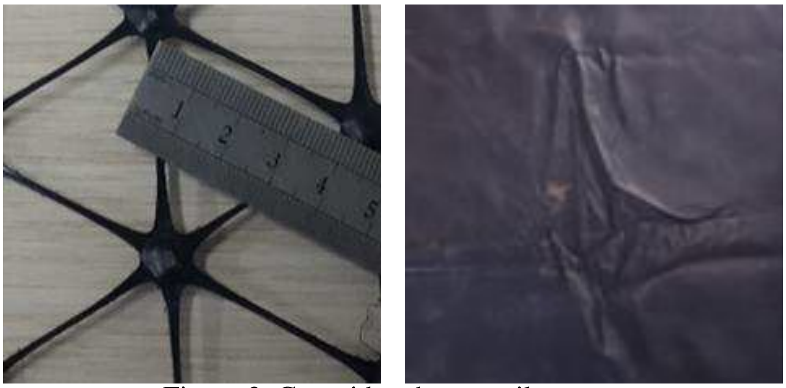


Figure 3. Geogrid and geotextile

3 EQUIPMENT

The tests were carried out in test setup which has steel test box (2.0m x 2.0m x 2.0m), displacement transducers (LVDTs) to measure vertical displacements, a load cell to measure the loads during cyclic loadings and pressure cell to measure the pressures. The vertical stress was applied by a 300 mm diameter steel plate underneath a jack connected to a hydraulic system. During the cyclic loading, maximum applied load in tests was 40 kN, which resulted in a loading pressure of 550 kPa. It is simulated typical truck axle load with contact pressure of 550 kPa (Qian et al. 2011). The load pulse values measured during cyclic loading are presented in Figure 4. The frequency of this load pulse was 0.77 Hz. Figure 5 presents the schematic sketch and photograph of the large scale cyclic plate loading test setup. In this schematic sketch, H is the thickness of base course and u is the placed depth of geogrid.

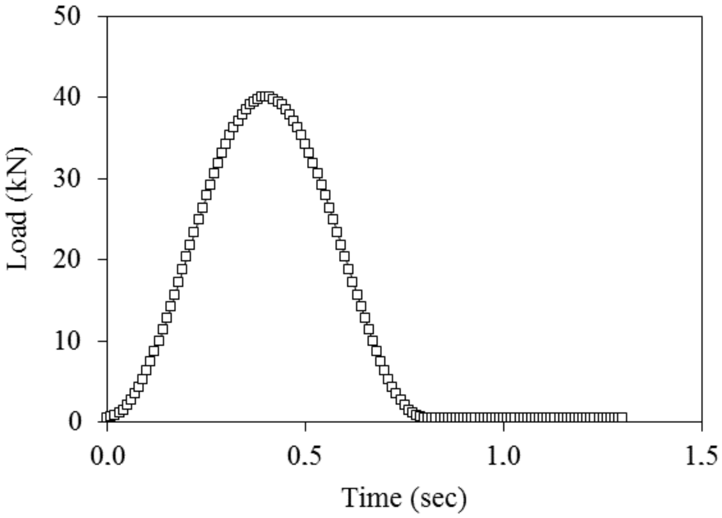


Figure 4. The frequency of cyclic load pulse (Demir et al. 2016)

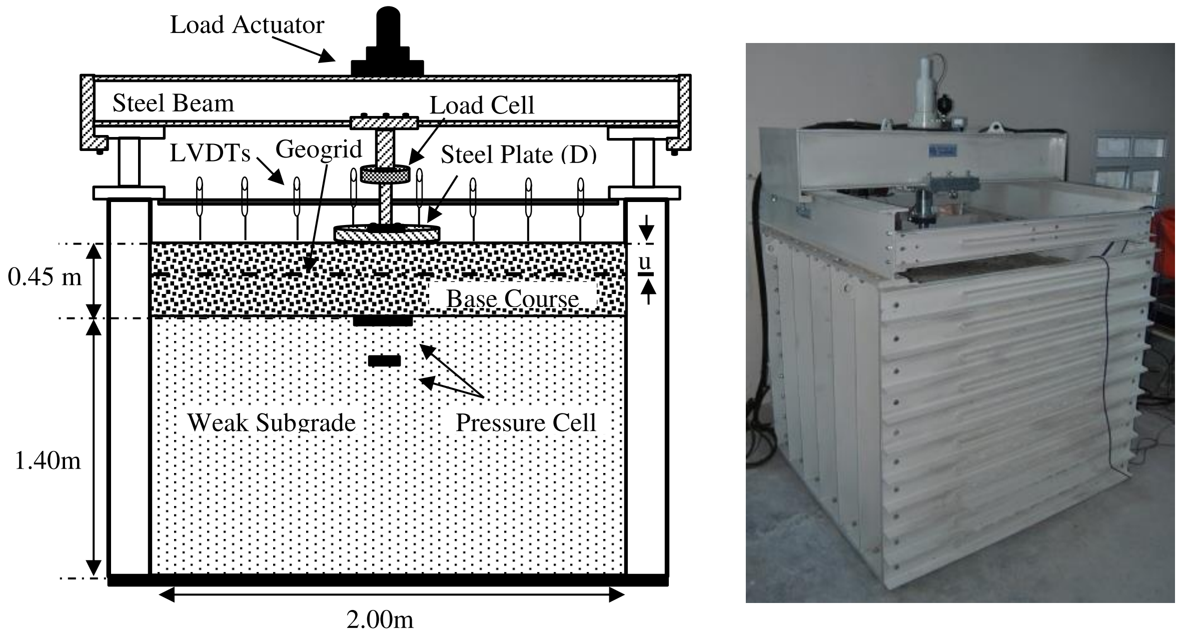


Figure 5. Schematic sketch and photograph of the large scale cyclic plate loading test setup (Demir et al. 2016)

4 TESTING METHODOLOGY

In the tests, subgrade was created which have weak soil conditions (CBR 3-5%). Firstly, in order to weak soil conditions, the soil was prepared in 19% water moisture, was placed in the steel test box and was compacted in layers. CBR value of the subgrade was estimated by the dynamic cone penetration (DCP) test. Uniformity of water content and density were checked by taking undisturbed sample at different locations of the soil. After preparing the 1.40 m height of subgrade, the granular material was prepared in optimum water moisture (%4), was placed in the steel test box and was compacted using a vibratory hammer in layers. The nuclear density gauge apparatus was used to measure the properties of base granular base to ensure required quality. According to result of the tests, granular material dry density was found approximate 98% of maximum dry density. To prepare reinforced sections, geogrid was placed within the base course at the desired location. A total of 5 large scale laboratory tests (4 test for reinforced section, 1 test for unreinforced section) were conducted to evaluate the effects of geogrid reinforcement.

5 RE~~SULTS~~ AND DISCUSSION

In this study, four reinforced with geogrid and one unreinforced large scale plate tests were conducted. The reinforced tests were performed with placing different depth in base course of geogrid (u=0.33D, 0.67D, 1.00D and 1.33D; u is the placed depth of geogrid and D is the diameter of steel plate). Unrein-forced test was conducted to compare with the reinforced tests. The thickness of the base course layer in all of the tests is 0.45m (H=1.50D). A total of 5 large scale laboratory tests (4 test for reinforced section, 1 test for unreinforced section) were conducted to evaluate the effects of geogrid reinforcement.

Figure 6 shows the curves of the permanent displacement versus the number of cycles for the unreinforced and reinforced large scale plate tests. Figure 6 shows the curves of the permanent displacement versus the number of cycles for the unreinforced and reinforced large scale plate tests. It is clear from the Figure 6 that the reinforced granular bases developed less permanent displacement than the unreinforced granular base at the same number of load cycles. In addition, as can be seen in the Figure 6, with decrease in the geogrid location depth, the permanent displacement decreases.

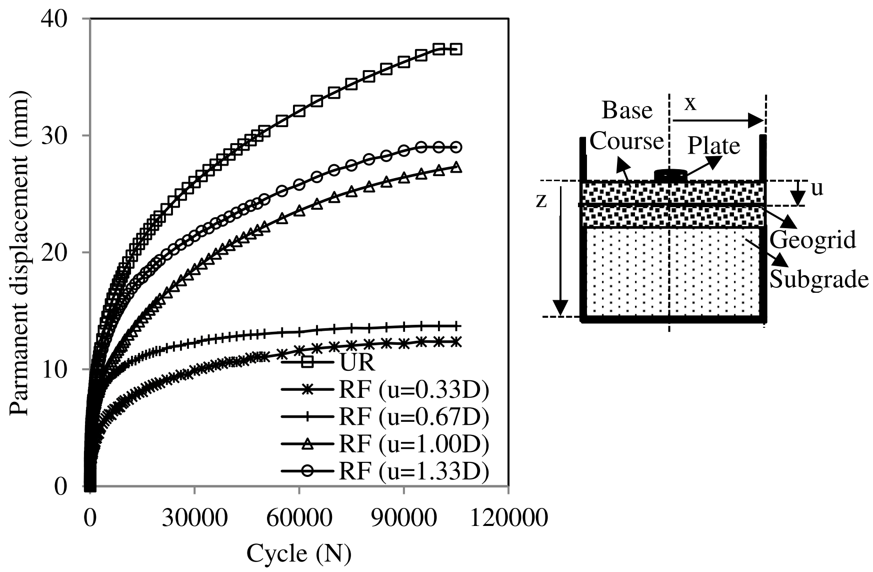


Figure 6. Effect of location of geogrid in base course layer by means of permanent displacement-cycle curve

Figure 7 shows the vertical displacement values at the surface of the base course layer after 10000 cycles loading. As it is moved away from the loading plate, and as decreased the depth of embankment of geogrid, the surface vertical displacement decreased.

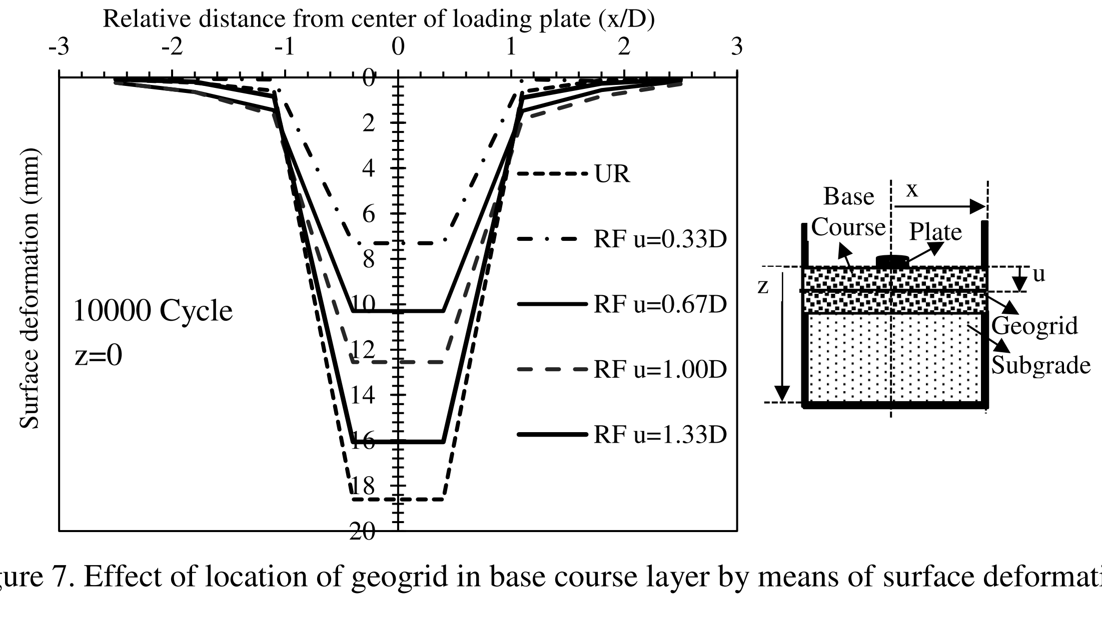
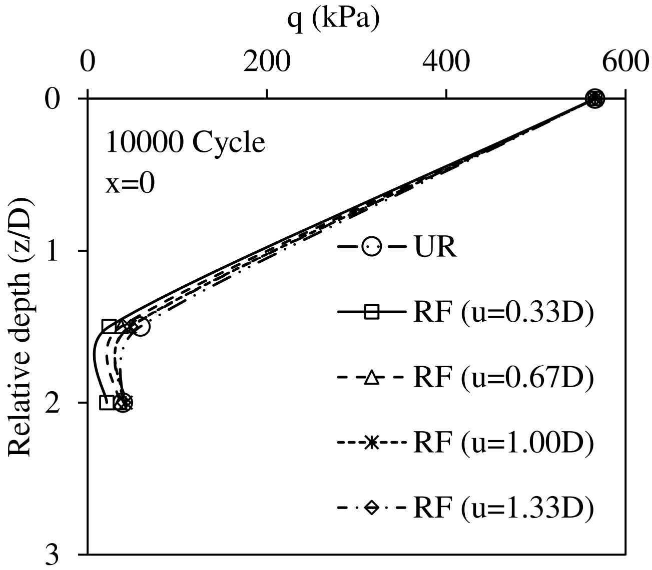


Figure 7. Effect of location of geogrid in base course layer by means of surface deformation

Figure 8 shows the pressure values at three different depths (z=0 at the base course surface, z=1.50 D at the subgrade surface and z=2.00 D in the subgrade; z: depth from surface of base course layer) in underneath of the loading plate after 10000 cycles loading. As it is decreased the depth of embankment of geogrid, the decrease in pressure is increased.



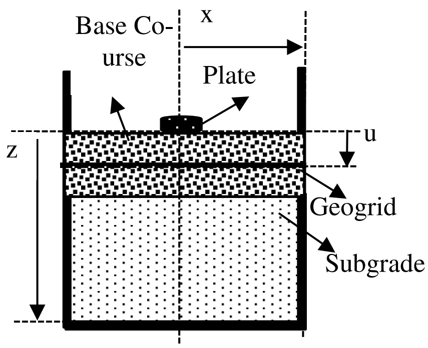


Figure 8. Pressure change curve with depth

6 CONCLUSION

In this study, four reinforced with geogrid and one unreinforced large scale cyclic plate loading tests were conducted. The reinforced tests were performed with placing geogrid at different depth in base course. The main conclusions obtained from the all tests are presented as follows:

- ✓ In all tests, the permanent displacement increase was fast at the early stage of the loading cycles. However, the rate of increase in permanent displacement decreased as long as the increase of the number of load cycles.
- ✓ The permanent displacement of unpaved road section over the weak subgrade can be decreased by the inclusion of geogrid.
- ✓ Geogrid reinforcement decreased surface deformation of base course layer. In all tests, as it is moved away from the loading plate horizontally, the surface deformation decreased. The maximum surface deformation was observed below the loading plate.
- ✓ Since it was compared to the unreinforced test, geogrid reinforcement was reduced the pressure on the weak subgrade surface under base course layer.
- ✓ To get best performance of geogrid reinforced granular base, geogrid may be placed at the upper one-third of loading plate diameters in base course layer.

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