International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 12
April 2018

Static And Dynamic Analysis Of Geogrid Reinforced Unpaved Road

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Abstract

With Emphasis on greater connectivity, there is a need of unpaved road to achieve economy. In this study a large scale laboratory plate load test was conducted on a circular footing resting on with and without geogrid reinforced bed. Sand and granular materials are used as subgrade and subbase layer. The experiments were conducted for both static and dynamic loading .Test result reveals that with the addition of geogrid the settlement has reduced up to 40-60% as compared to unreinforced section. The experimental static results have validated with numerical modelling using both Finite element method and Finite difference method (Plaxis2D and FLAC2D) and dynamic results have validated by using empirically by Giroud and Han"s equation. Based on the experimental and numerical studies, predictive models are proposed using two recently developed artificial intelligent techniques, Genetic Programming (GP) and Multiple adoptive Regression Spline (MARS).

Introduction

The concept of geosynthetic material was first invented by a French architect and engineer Henri Vidal in the 1960s. In 19th century geosynthetics material was introduced in the geotechnical engineering applications. Different type of geosynthetics materials are extensively used in various forms such as geogrid, geotextile, geocell, geomesh, geonet etc. These are used in the pavement design to address the functions of separation, filtration, lateral drainage and reinforcement. To increase the tensile property of the soil, geogrid have been used in the flexible pavement as reinforcement. Several researchers worked on the geosynthetic reinforced pavement system (Giroud and Noiray 1981, Zornberg 2012) and they suggested that, the distress mechanism induced by the traffic and environmental loads can be decreased. Performance of pavement can be improved due to the geosynthetics reinforcement (Giroud and Han 2004, Bueno et al. 2005, Benjamine et al. 2007).

Flexible pavement generally consists of subgrade, subbase, base and surface course, and pavement structures are made to carry the superimposed load such as traffic load and to well distribute the load safely to the subgrade. In the conventional method of flexible road construction, distress may occur in pavement due to the traffic load or climatic condition. Repetition of traffic load will lead to the structural or functional failure. Environmental loads, such as variations in temperature or moisture in the subgrade can cause surface irregularities and structural distress. Also in case of the conventional method more quantity

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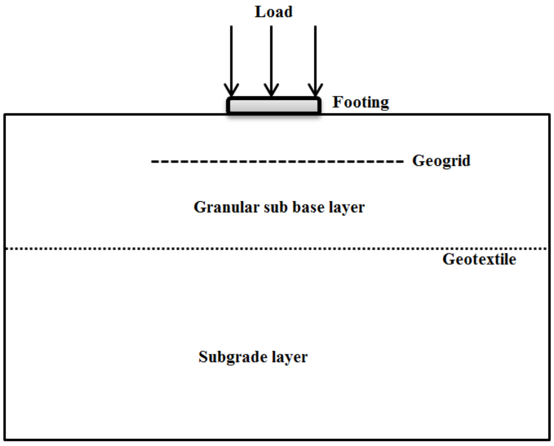
of material used for the construction of roads and not providing the predicted serviceability. It is necessary to decrease the distresses mechanism in layers, optimize the quantity of material.

In the recent years, various researchers have made conclusion in the use of reinforcement in pavement or foundation bed. There are three primary benefits in using the geogrid, (i) reduce the cost of construction, (ii) reduces the thickness of the pavement, (iii) improvement of the life period of pavement. In order to address the primary issue like fatigue crack in flexible pavement, the geogrid reinforcement is usually used in the interface between subgrade and base course layer or base course and top of the footing.



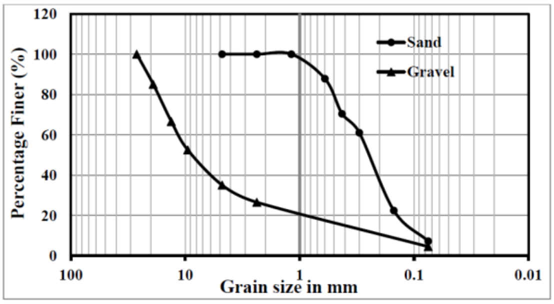
Flexible pavement section

Objective

- Analyses of geogrid reinforced pavement based on model test.
- The result of model study has been validated using numerical methods and analytical methods. Based on the observed results and numerical analysis, a database of settlement and bearing capacity of reinforced pavement is developed, Prediction model equation for bearing capacity and settlement has been presented using the above database using two recently develops AI technique ; genetic programming (GP) and multivariate adaptive regression spline (MARS).

Experimental Investigations

A discussion about the preparation of the subgrade and granular subbase, experimental setup is discussed. The effect of various parameters studied includes granular subbase depth, strain behaviour of geogrid during static test. The influence of these parameters on the bearing capacity and strain on geogrid is illustrated. The behaviour of the geogrid reinforced granular subbase is explained in terms of strain variation on the geogrid and bearing capacity values.



Grain size distribution curve

Index parameter of the sand

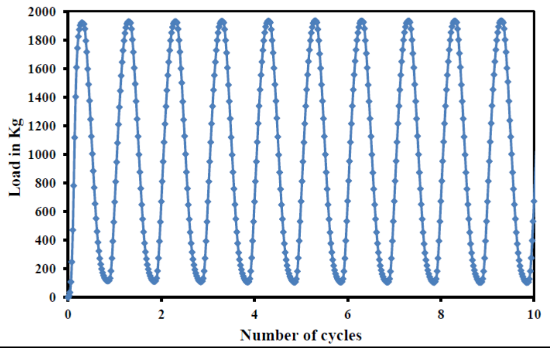
Parameter	Value
D_{10}	0.082
D_{60}	0.30
Coefficient of curvature (C_c)	1.17
Coefficient of uniformity (C_u)	3.66
Maximum dry density of sand(kN/m^3)	20.60
Minimum dry density of sand(kN/m^3)	14.32
Internal Friction angle (ϕ)(Degree)	31

Experimental Setup

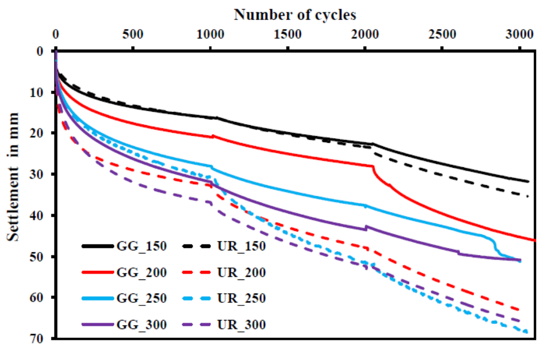
The experiments were conducted in the test tank of size 1500 mm length x 1500 mm width x 1000 mm height made up of cast iron. The tank was fitted to the loading frame which is connected to the automated load operating system. A circular shaped steel plate with 15 mm thickness and 150 mm diameter was used as the model footing. The bottom of the footing was made rough by coating a thin layer of sand with epoxy glue. The load was applied on the footing through an automatically operating system and load cell was placed in between the footing and actuator to measure the imposed load. Subgrade and granular subbase layer is separated with help of geotextile throughout the experiments. Schematic representation of test setup is shown in Figure.3.3. In the figure loading frame, load cell, actuator, pressure cell and LVDT is shown along with the test bed showing sand bed and GSB bed. In case of pavement with reinforcement, the geogrid reinforcement was placed at a depth of 0.3 times depth of granular subbase below the footing.

Test Procedure

The concentrated vertical load was applied on the footing with the help of ball bearing arrangement. Through the precise measurements, the footing was placed exactly at the centre of the test tank in order to avoid the eccentric loading. The load applied to granular subbase was measured through load cell placed between the footing and the actuator. Four LVDT were placed on the either side of the centreline of the circular footing to record the footing settlement. During experimental study, Static loading tests carried out for all the depths of granular subbase varying from 150mm to 300mm. In case of static loading, load increment was 0.049 kN per second and increased up to 34.33 kN. The magnitude of the load and settlement were recorded using automatic data acquisition system. A static pressure was first applied to the footing followed by application of the dynamic load. After application of static load immediately the LVTD set to be zero and the dynamic load applied.



Loading pattern with respect to no of cycles



Number of cycles vs settlement

Analytical Study

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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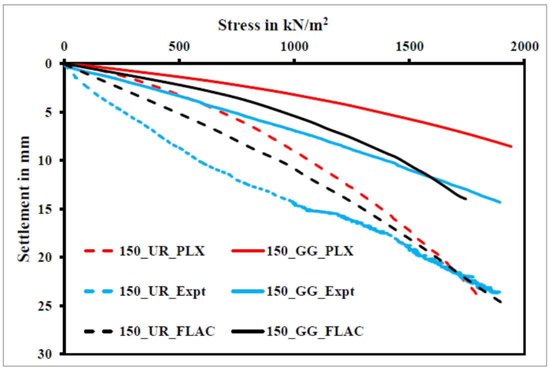
Many experimental studies have demonstrated the benefit of using geosynthetics in the roadway base reinforcement (Perkins 2002, Al-Qadi *et al*. 2008). The empirical design methods are often limited to the materials, pavement structures and load levels used in the original experiments. In the present study the experimental results for the static load was analysed using numerical modelling using both finite element method (FEM) and finite difference method (FDM). The commercial software Plaxis 2D uses FEM and in FLAC2D FDM is used. The dynamic test results are compared using empirical method, Giroud and Han (2004).

Plaxis 2D

Plaxis2D is a numerical program based on finite element method which was first invented by1987 at Delft University of Technology in Netherland. This software is intended for analysing two dimensional problems of deformation and stability in geotechnical engineering. The Plaxis2D software contains three sub programs namely the input program, the calculation program and the output program. It performs analysis with either an assumption of plane strain or axis-symmetry with 6-noded or 15-noded triangular elements. In the Finite Element Method, for the measurement of deformations of a soil with their respective state, a mathematical framework is assigned to the soil. These govern the force displacement relationships and are called material models. In Plaxis2D, there are a number of material models available. However, within the scope of this master‟s thesis, only the Linear Elastic, Mohr-Coulomb model has been presented.

Input model used in Plaxis2D

Input parameters	Elastic Modulus (Mpa)	Cohesion (kPa)	Angle of fiction (Degree)	Mass-density (kg/m^3)	Poisson's ratio
Sand	13	1	31	1800	0.25
Granular subbase	65	10	40	2100	0.3



Stress vs settlement curve

Conclusions

Based on the above study the following conclusions can be made

- It was observed that in case of static load, there is reduction of settlement upto 40% with addition of the reinforcement at the interface of subgrade and subbase. It was also observed that percentage of settlement reduction varied from 7.14% to 41.66% with increase in the depth of granular subbase from 150 to 300mm, showing the importance of subbase layer.
- But in case of dynamic case settlement increased with increase in depth of granular sub base layer and decreased with

provision of reinforcement irrespective of the number of cycles. The increase in settlement with increase in subbase layer may be due to the fact that the vertical load may transfer to the granular subbase at the immediate application of load and gradually it transfers into the subgrade.

- It was observed that the settlement of model footing resting of reduced by 40 to 60% shown that by using geogrid reinforcement the settlement has reduced 40-60% as well as increase the bearing capacity with both Static and Dynamic case. The stress strain behaviour of geogrid reinforcement during Static loading has observed.
- Based on the numerical validation of the experimental results as per FEM and FDM method it was observed that for static load case, it was observed that for unreinforced case there is wide variation in FLAC2D (8.6 to 35%) with that of experimental results in comparison to Plaxis2D result (25-30%). Whereas, for the reinforced case less variation was observed with FLAC 2D (7-20%) than that of Plaxis 2D (7-30%). For the dynamic load case reverse trends were observed between present experimental results and the existing empirical method.
- For the static load case prediction models are presented for the bearing capacity of footing with thickness of the granular subbase, settlement of the circular footing, elastic modulus of base course, elastic modulus of subgrade as the inputs, using MGGP and MARS. Both MGGP and MARS models are efficient with correlation coefficient (R) value as 0.99 and 0.98, respectively. Based on different statistical parameters like coefficient of efficiency, MAE, AAE and RMSE, it was observed that MGGP model is more efficient than MARS model.
- Sensitivity analysis of the model equation shows that the settlement of the pavement has been found more important factor followed by the thickness of GSB, elastic modulus of subgrade and subbase.
- Similarly for the dynamic load case, model equations are presented for settlement of the footing using thickness of the GSB, number of cycle and load as the inputs. Based on statistical performance criteria R, E, AAE, MAE and RMSE, MARS model was found to more efficient than MGGP model.
- The sensitivity analysis of the model equations shows that load is the most important factor as followed by the number of cycles and thickness of the GSB.

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