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Investigating the effect of geogrid on stabilization of high railway embankments

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Abstract

This paper investigates the effect of geogrid on controlling the stability and settlement of high railway embankments using laboratory testing and finite element modeling. To do this, five series of embankments with 50 cm height were constructed, at a scale of 1:20 and then were uniformly loaded on the crest in a loading chamber in dimensions of 240 × 235 × 220 cm. In this regard, the embankments of the first series were constructed without geogrid reinforcing layers. Following to preliminary numerical simulations for determining the appropriate level of geogrid layers installation, the second to fifth series of embankments were constructed. These embankments were reinforced with one to four layers of geogrid respectively and finally, the results of their load in terms of settlements were compared. In these studies, the reinforced embankments with a single geogrid layer had 7.14% raise in bearing capacity and 11.24% reduction in settlement respectively, in comparison with the unreinforced embankment. The obtained results for the third to fifth series of embankments were respectively in order of (19, 36.14), (26.3, 52.8) and (28.9, 53.42)%. In the next stage, by modeling the embankments in the PLAXIS 2D software, the results were validated by the values obtained through laboratory models. In continuation of the study, real embankments with heights of 5, 10, 15, and 20 m were simulated and placed under LM71 loading pattern (Eurocode, 2003). In this respect, the impact of important effective parameters such as number of geogrid layer, soil characteristics, embankment dimensions, interface coefficient between soil and geogrid and tensile strength of geogrid on bearing capacity and settlement have been studied. The numerical results like the experimental ones, confirmed the increase in bearing capacity and settlement diminishing with definite increase in the geogrid layers, so that more geogrid layers do not affect these parameters. With respect to improving the soil characteristics and reducing the height of embankments, the FEM models showed decreasing effect of geogrid tensile strength on embankment crest settlement. On the other side, the value of geogrid-soil interface coefficient has minor effect on both settlement and sliding safety factor.

Keywords: Settlement reduction; Embankment stability control; High railway embankments; Geogrid layer; Laboratory model; Finite element simulation

1. Introduction

Concurrent with the development of railway transportation network during the recent years, the designers have embarked on shortening the routes length and travel time. This has made them to pass the railways through areas with many difficulties, and consequently, construction of technical infrastructures such as high embankments or bridges has become inevitable. From a geotechnical point of view, controlling the stability and settlement of high embankments under operational loads or in special loading conditions, e.g. earthquake, is always a challenging issue for railway tracks designers. A review on the technical literature suggests various methods such as application of

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Nomenclature

u	distance of topmost layer from the loading bed (m)
B	load width (m)
h	distance between geogrid layers (m)
b	width of geogrid layers (m)
N	number of geogrid layers
D	loading distance from edge of slope (m)
β	slope angle from the horizon (°)
C_U	uniformity coefficient of Soil (dimensionless)
C_C	curvature coefficient (dimensionless)
q	uniform loading on the embankment crest $= \frac{4\times Q_{vk}}{(3a+2b)\times B}\ \left(\frac{\text{kN}}{\text{m}^2}\right)$
Q_{vk}	concentrated load of train (kN)
a & b	geometrical parameter equal to 1.6 and 0.8 respectively (m)
α	Impact factor $= \alpha = 1 + 5.21\frac{V}{R}$ (dimensionless)
V	train speed (km/h)
R	diameter of train wheel (mm)

pile, micropile, deep soil mixing, berm construction on the sides of the embankment, injection, tieback installation, etc., for stabilization of the embankments, enhancement of bearing capacity and reduction of settlement. Some of these methods have been mentioned in the UIC Code 719R (1994) under "Earthworks and Track-bed Layers for Railway Lines". Among the research papers on the mechanical stabilization of railway embankments, the experimental and numerical study of micropiles to reinforce high railway embankments by Esmaeili et al. (2013) and railway embankments stabilization by tied back-to-back system by Esmaeili and Arbabi (2015) are of particular merit.

During the recent years, with the development of geosynthetics, they have been abundantly used in road and railway projects. The majority of the projects deal with the placement of reinforcing geosynthetics layers in superstructure layers of roads and railways. In this matter, and particularly regarding the reinforcement of railway substructures, the published technical reports by Coleman (1990), Webster (1991), Helstrom et al. (2007), Penman and Priest (2009), Lee et al. (2012), and Parsons et al. (2012) are noteworthy.

The main objective of this research is recognizing the performance mechanism of reinforcing layers of geogrid materials in high railway embankments. In this regard, the focus of study is sliding control in embankment body and decreasing the crest settlement as main effecting factors in railway embankment serviceability. According to the requirements of the UIC Code 719R, poor graded sand material (QS2) for subgrade and well graded sand (QS3) for embankment were adopted in five series of embankments, each of which had 50 cm height and were in scale of 1:20 with side slopes of 1:1 in loading chamber of 240 × 235 × 220 cm in conjunction with 60 cm of substructure, all uniformly loaded on crest. All reinforced laboratory models were made based on the results of the preliminary numerical modeling to gain optimal level for placing the geogrid layers. To that end, first series of embankments were constructed without geogrid reinforcement and the series second to fifth were reinforced with one to four geogrid layers each. Having finished the laboratory tests, with the development of the numerical model of the embankments in PLAXIS 2D software, the results were then validated by the laboratory results. In the next stage, using validated numerical models, the behavior of 5, 10, 15, and 20 m reinforced embankments by the geogrid under actual railway load was studied. In the final stage, a series of sensitivity analyses on the effective parameters such as the number of geogrid layer, soil characteristics, embankment dimensions, interface coefficient between soil and geogrid and tensile strength of geogrid were performed and their effect on the results of numerical models were investigated.

2. Literature survey

In all research work, which have been carried out in the field of slope stabilization of slope with geogrid, various factors play important role. Amongst, the normalized distance (u/B) of topmost layer from the loading bed, normalized distance (h/B) between the layers, normalized width (b/B) of the layers and number (N) of the geogrid layers, normalized loading distance (D/B) from the edge of the slope as well as the slope angle (β) from the horizon can be pointed out. It should be noted that in the above cases, B is the width of the loading area. The mentioned parameters are depicted in Fig. 1.

Yoo (2001) allocated his research to the investigation of bearing capacity of a strip foundation on a geogrid-reinforced slope. In his research an extensive range of con-

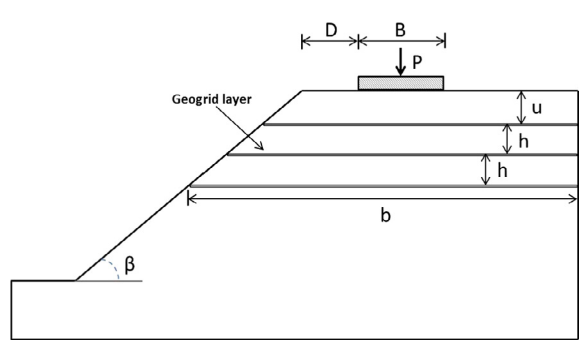

Fig. 1. One way slope reinforced with geogrid layers.

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