Numerical Analysis of the Effect of Geocell Reinforcement above Buried Pipes on Surface Settlement and Vertical Pressure

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***Abstract*—**Dynamic traffic loads cause deformation of underground pipes, resulting in vehicle discomfort. This makes it necessary to reinforce the layers of soil above underground pipes. In this study, the subbase layer was reinforced. Finite element software (PLAXIS 3D) was used to in the simulation, which includes geocell reinforcement, vehicle loading, soil layers and Glass Fiber Reinforced Plastic (GRP) pipe. Geocell reinforcement was modeled using a geogrid element, which was defined as a slender structure element that has the ability to withstand axial stresses but not to resist bending. Geogrids cannot withstand compression but they can withstand tensile forces. Comparisons have been made between the numerical models and experimental works, and a good agreement was obtained. Using the mathematical model, the performance of three different pipes of diameter 600 mm, 800 mm, and 1000 mm, and three different vehicular speeds of 20 km/h, 40 km/h, and 60 km/h, was examined to determine their impact on surface settlement and vertical pressure at the pipe crown for two cases: with and without geocell reinforcement. The results showed that, for a pipe diameter of 600 mm under geocell reinforcement, surface settlement decreases by 94 % when the speed of the vehicle is 20 km/h and by 98% when the speed of the vehicle is 60 km/h. Vertical pressure decreases by 81 % when the diameter of the pipe is 600 mm, while the value decreases to 58 % for a pipe with diameter 1000 mm. The results show that geocell reinforcement causes a significant and positive reduction in surface settlement and vertical stress above the pipe crown, leading to an increase in pipe safety.

***Keywords*—**Dynamic loading, geocell reinforcement, GRP pipe, PLAXIS 3D, surface settlement.

I. Introduction

BURIED pipes play an important role in city infrastructure. However, they must support the weight of the surrounding soil, and therefore, they must be protected and properly installed to avoid serious ramifications to the pipe system, the above pavement, and the buildings. Buried pipes and/or conduits have improved the standard of living for people since the beginning of civilization. Furthermore, engineers and planners take subsurface infrastructure into account before developing buildings and houses for a community. In addition, the underground water systems can be seen as the city's arteries and the sewer systems are the city's veins that carry the waste [1].

Generally, reinforcing the subbase layer will increase its stiffness and, therefore, reduce the surface settlement. A number of researchers have used numerical simulation on the buried pipes problem. Geocells are commonly used geosynthetic reinforcements, they can provide lateral constraint to the granular materials. The geocells are placed at grade, in-filled with well grade soil, and they are then compacted. The cellular structures of the geocells improve the vertical and lateral confinement, and tensioned membrane effect, which leads to an increase in the bearing capacity and an increase in the stress distribution [2]. So, permanent deformations or rutting beneath the traffic loading can be reduced. Typically, the geocell-base/subbase framework is underlain by a geotextile to separate the in-filled base/subbase material from the subgrade. Reference [3] carried out laboratory tests and numerical simulation on the use of geocell reinforcement with rubber mixture to protect underground pipes under repeated loading. Their results showed that reinforcement can reduce surface settlement for different conditions. Reference [4] used the finite element software PLAXIS 2D to analyze the performance of unreinforced and geogrid reinforced pavement under static and dynamic loads. Their results showed that the reinforced layers have a moderate improvement over the unreinforced layer under static load but no improvement was shown under dynamic load. Their results also showed that adding another geogrid layer led to no significant improvement. Reference [5] dealt with simulation of the buried pipe problem numerically by finite elements method using the newest version of PLAXIS-3D software. A three-dimensional analysis was made by PLAXIS-3D program for [6], which has all the properties needed, such as the modulus of elasticity, Poisson's ratio, and angle of internal friction. Results obtained from the program for the vertical crown deflection for the model without geogrid are higher than those obtained by two-dimensional plane strain by about 21.4%, while with geogrid, results showed that this percent becomes 12.1% although generally both have the same trend. Predictions of pipe-soil system behavior with applied pressure obtained from the two-dimensional finite element's analysis indicate an almost linear displacement of pipe deflection; while a non-linear behavior, especially at higher loads, was found from the three-dimensional analysis.

Reference [7] conducted laboratory experiments on a flexible Poly Vinyl Chloride (PVC) pipe with a small diameter

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