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Research Paper

Effect of geosynthetic reinforced embankment on locally weak zones by numerical approach

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ABSTRACT

This paper presents a numerical simulation using PLAXIS code of geosynthetic reinforced embankment over locally weak zones. The case study concerns the reinforcement of the road embankment which crosses a section of about 11 km on sabkha soil of Chott El Hodna in Algeria. This salt flat is dry in summer but gets flooded in winter. The site observations and the geotechnical investigations indicated that the soil of this sabkha is characterised by high compressibility, low bearing capacity and contains locally weak zones of limited extent. The main objective of this paper is to assess the effect of geosynthetic reinforcement on the settlement of the embankment over locally weak zone. The influence of some parameters, namely the compressibility parameter of locally weak zone, the stiffness of geosynthetic, the locally weak zone geometry and the friction angle of embankment fill is also analysed. The results show that the computation with large displacement is more suitable than small displacement for this problem and the differential settlement improvement is due to the combination of the membrane strength effect of the geosynthetic and the arching effect within the embankment fill.

1. Introduction

The construction of embankments on soft soils is a challenge for geotechnical engineers due to possible bearing capacity failure, excessive settlement as well as local and global instability. Geosynthetics reinforcement has been widely used to support embankments over uniform weak foundation soils as highlighted by recently published papers (e.g. [1–27]). Rowe and Li [1] used an elliptical cap soil model to examine the behaviour of geosynthetic reinforced embankments constructed on soft cohesive foundations under undrained and partially drained conditions. They showed that the reinforcement can significantly reduce the maximum lateral deformations, vertical deformation and foundation soil heave during embankment construction. Borges and Cardoso [3] used a numerical model based on the finite element method to study the behaviour of a reinforced embankment on soft ground. In their study, special emphasis is given to the stress states (stress levels and pore pressures), displacements, tensile forces in the geosynthetic and overall stability, during and after construction. Borges and Cardoso [5] also studied the overall stability of three geosynthetic-reinforced embankments on soft soils with two different methodologies: application of a numerical model based on the finite element method; use of a limit equilibrium method. One of the cases is a case history constructed up to failure. Sharma and Bolton [2], Bergado et al. [4] and Hinchberger and Rowe [7] investigated the stability of geosynthetic reinforced embankments through numerical studies. The study of Sarsby [11] concerns the use of 'Limited Life Geotextiles' (LLGs) which are designed on the basis of having a limited working life as basal reinforcement for an embankment built on soft clay. Bergado and Teerawattanasuk [12] as well as Tanchaisawat et al. [21] have demonstrated the 2D and 3D influences of embankment geometries and boundary conditions on soft ground by numerical simulations. Rowe and Taechakumthorn [25] performed a finite element analysis to investigate the time-dependent behaviour of reinforced embankments constructed with viscous geosynthetic reinforcement over soft clay deposits. Chaiyaput et al. [27] conducted numerical simulations to study the behaviour of woven Kenaf Limited Life Geosynthetics (LLGs) reinforced test embankment constructed on soft clay. In their study, the observed data in terms of settlements, excess pore water pressures and deformations or stresses in the reinforcements were compared with the simulated data.

In all of the above studies, the effectiveness of geosynthetic reinforcement to improve the stability and settlement of embankments over uniform weak foundation soils has been investigated. However, the effect of geosynthetic reinforcement on the

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performance of embankments over locally weak foundation soils has received very little attention. Thus, the objective of this paper is to clarify the behaviour of geosynthetic reinforced embankment on locally weak foundation soils which are characterised by sabkha soils in Algeria. These soils are coastal and inland saline deposits that are formed in arid regions. In in-situ state, the sabkha soils have high compressibility and low shear strength. These soils are also heterogeneous and their properties depend on the kind and the amount of salt content. Sabkha soils are associated with many geotechnical problems, due to the presence of digenetic salts of different sizes, shapes and compositions; and the shallow saline ground water. Sabkha soils are very sensitive to moisture whereby complete collapse and large reduction in the bearing capacity are anticipated when these soils are in contact with water [28,29]. Such behaviour is attributed to the fact that some of the cementing materials that bond the mineral grains of sabkha together, such as halite, are highly soluble in water, while others, such as gypsum, aragonite, and calcite are less soluble. The work done by Aiban et al. [29] on different sabkha soils confirms the acute water sensitivity and chemical aggressiveness of sabkhas. The variability of the geotechnical properties of sabkha, in both the horizontal and vertical directions, could also lead to excessive differential settlement [30]. Several field stabilization techniques have been implemented to improve the inferior sabkha properties, with various degrees of success [29]. However, it has generally been found that the use of geosynthetics as reinforcement has the advantages of being practical, economical, and easy to apply [31,32].

In the present paper, the site investigated is the construction of the road embankment linking the two towns of Ain El Khadra and M'Cif, which extends for approximately 23 km. On a section of about 11 km, the road crosses the sabkha of Chott El Hodna located in the north middle part of Algeria (Fig. 1). The in-situ observations showed that in summer surface soil is partially dry and strong enough for very light weight vehicles to cross the sabkha. However, in winter the sabkha is inundated where water table may arise up to 60 cm over ground surface. Due to the poor bearing capacity and the presence of water table, serious difficulties were encountered during the investigation of the subsurface soil and the construction of the first embankment layers. The site was further complicated by the risk of crossing locally weak zones (Fig. 2). The locally weak zones are problematic soils because they have high compressibility. Thus, these zones are not suitable for support of road embankment without the risk of high differential settlements. In this construction site, the use of basal geosynthetic layer to maintain the performance of embankment over soft soil was found to have

Fig. 2. Locally weak zone.

relevant reinforcing effect by increasing the bearing capacity to allow for safe construction of the first layers of the embankment across locally weak zones. Fig. 3 shows a case of crossing locally weak zone noted by the upheave of the geotextile over very soft soils of locally weak zone induced by the embankment load.

Due to this phenomenon, the effect of geosynthetic reinforcement on settlement of embankment over locally weak zone is investigated by numerical approach using the PLAXIS code [33]. The qualitative results show that the computation with updated lagrangian is more suitable than small displacement option for this

Fig. 3. Embankment over locally weak zone.

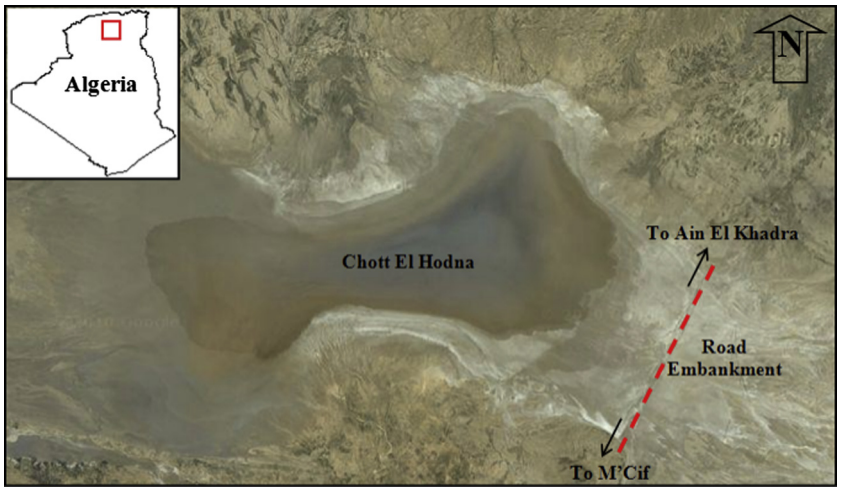

Fig. 1. Location of the analysed road embankment in the sabkha of Chott El Hodna, Algeria.