Numerical simulation of the role of a geocell inclusion on deformation behavior of a pavement structure laid on a fissured clayey subgrade

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Abstract*– The Service Level (LS) of a pavement road is directly related to the mechanical behavior of the subgrade where the pavement structure is supported. Overconsolidated and cracked clayey subgrades show some great complexity when in the design of the pavement structure, mainly because of the different pathologies that are caused by the deformations on the subgrade when the traffic loads are applied and when these deformations represent a main risk to each of the layers of the pavement structure. The conventional design of the pavement structure, under these conditions usually makes necessary to design with big thicknesses on each of the layers which compound the structure, these can result in expensive and complex designs. Due to this, it is required to establish a mitigation method which reduces significantly the stress values on the subgrade, in order to increase the service life and the LOS of the structure, and also to optimize the layer thicknesses. The pavement structure is taken to a 2D-Model using a multilayer structure with the software Phase2, as mitigation method it is included between the granular subbase and the base course a reinforcement geocell, which act as a semi-rigid slab that distributes evenly the loads over the area.

Keywords: clayey subgrades, geocell reinforcement, pavement, simulation, two-dimensional modeling.

I. INTRODUCTION

On pavement structures of roads at western “Sabana de Bogotá”, occur different pathologies (mainly subsidence and depressions) (See Fig. 1) which are associated with the desiccation of the clayey subgrades found in the zone [1], [2] and [3], these pathologies considerably reduce the LOS. This reduction occurs principally by the desiccation of the lacustrine overconsolidated clays that compounds the subgrade, induced from natural and anthropic factors. From this phenomena, it is possible to find some failure surfaces all along the subgrade which leads to imminent failure at some point and time [4], as result of this the pavement structure can’t support the traffic loads properly because the subgrade becomes fissured and the soil mass turn discontinuous. In order to analyze the global response of the multilayered system in this condition, it is necessary to simulate the behavior of the pavement structure which is shown in Fig. 2, (extracted from the road Siberia- Tenjo). In order to reduce the damage on the road surface and to improve the LOS, it is proposed the use of a geocell as a reinforcement of the granular shells. This reinforcement will improve the stiffness and rigidity of the structure, increasing the bearing capacity of the subgrade, and reducing the magnitude of the strains on the subgrade [5].

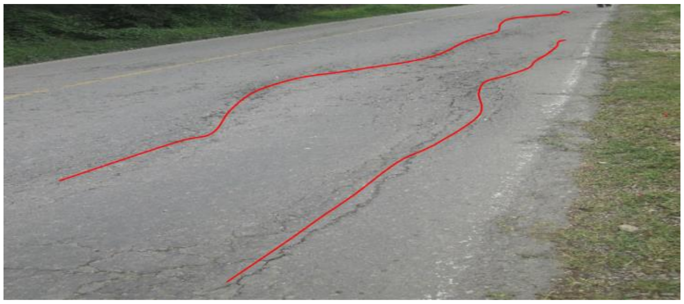
Fig. 1 Pathologies on the surface of roads at western “Sabana de Bogotá” due to dessication.


Fig. 2. Stratigraphic section of the pavement structure Siberia - Tenjo
Surface course: 5cm Base course: 20cm Subbase course: 40cm

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II. PROPOSED MODEL

To evaluate the impact made by the geocell as reinforcement, a numerical simulation of the loaded pavement structure was made. It is expected to obtain a significant reduction of the vertical deformation in the reinforced structure compared to the actual one.

To do this, the software *Phase 2, V8.0* from *Rocscience* was used, within the analysis, the *Mohr -Coulomb* failure criterion is taken as reference in all materials. In order to accomplish the simulation, the model input data required is the following: cohesion (c), friction angle (φ), Young modulus (E), Poisson's ratio (ν) and tensile strength (τ). Typical values from a previous study (2014) of the zone are taken [6].[7].[8].

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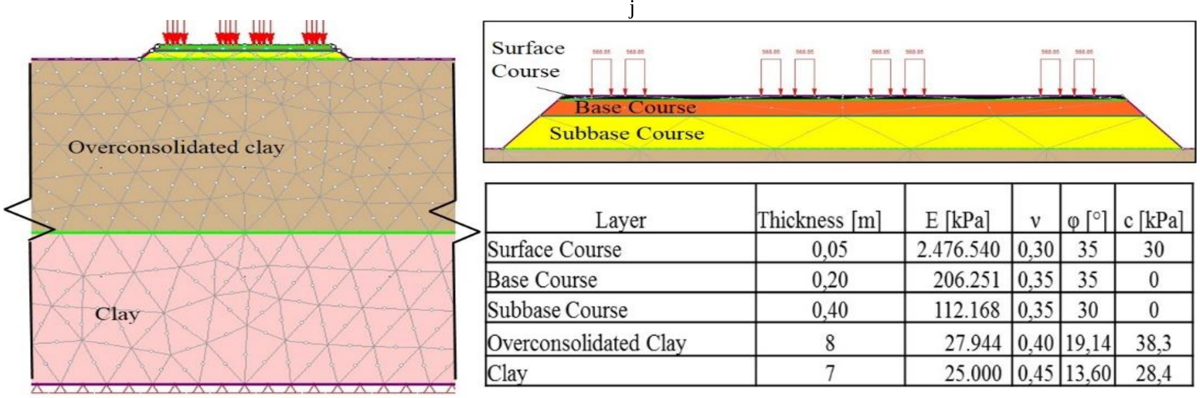

Layer	Thickness [m]	E [kPa]	ν	φ [°]	c [kPa]
Surface Course	0,05	2.476.540	0,30	35	30
Base Course	0,20	206.251	0,35	35	0
Subbase Course	0,40	112.168	0,35	30	0
Overconsolidated Clay	8	27.944	0,40	19,14	38,3
Clay	7	25.000	0,45	13,60	28,4

Fig 3. Imput data and proposed model

The simulation considered a multi-layered pavement structure placed over overconsolidated clay according the stratigraphy of the zone [9]. Despite of the fact that the pavement lays above a semi-infinite subgrade, some limits are stablished, in order to estimate only the effects produced by the traffic loads. On the other hand, considering the soil confinement, 2nd graded restrictions are defined to restrain the lateral displacement along the X-axis in both directions.

The loads used in the model, correspond to the equivalent loads made by two trucks with 2 simple- 4-wheel axle each. Taking into account the most critical state, it was simulated the moment when the two trucks simultaneously transit the same point of reference. The simulation was performed under two conditions: the first one corresponds to a simple, non-reinforced pavement structure; while in the second one a geocell of 125 mm height was added as reinforcement between the base and the subbase shells (The specifications used are shown in Table I [10]). After that, a deformation analysis was executed and the results of each stage are compared, in order to date the effects of the reinforcement in the displacements of both structures.

TABLE I
STRENGTH PARAMETERS - NEOWEB TYPE-B

Parameter	Specification
Strength on the welding joint (kN/m)	15
Ultimate strength (MPa)	24
Ultimate strength (Hollowed wide band) (kN/m)	15

Fuente PAVCO

Furthermore as an early approximation of a cracked soil mechanical behavior, a simple model (Fig 4.) with the same physical properties as in Fig 3 model is proposed, however this model has several discontinuities along its surface, these discontinuities are modelled as single soil columns (1m width, 5m depth, and 5 cm spaced between each other); a simulation with the same loads as in the previous models will be run, and the results will be compared.

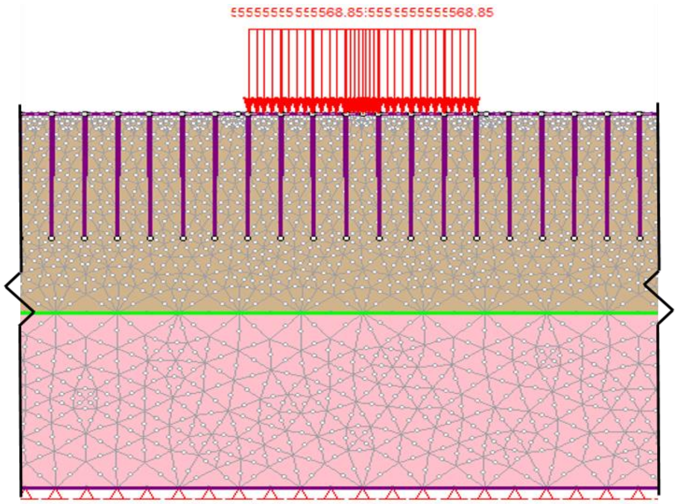

Fig 4. Cracked Soil Model

III. RESULTS AND CONCLUSSIONS

Once run, among various results it is analyzed the vertical deformation caused by the effect of the traffic loads. According to Fig.4, which corresponds to the non-reinforced model, it is shown that the maximum stress value is found just on the asphalt course and it decreases gradually when the depth increase. Due to the pavement structure properties, and the overconsolidated clayey subgrade, it is possible to see that the clay layer beneath the overconsolidated clay is also affected. However, the damage done to this layer doesn't represent a big relevance in pathologies generation of the pavement structure.

When the reinforced structure is analyzed, it is visible a considerable reduction of the vertical deformation due to the inclusion of the reinforcement as shown in Fig.5. It is also visible that the deformation bulb decreases its influence area, this leads to a hypothesis of a true effectiveness of deformation control, when the pavement structure is reinforced with geocells.

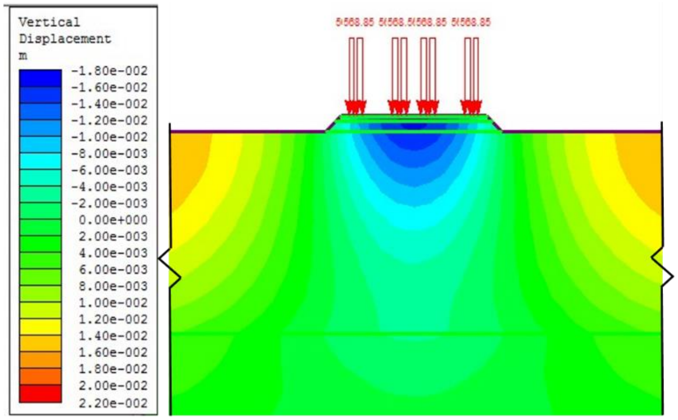

Fig 5. Non-reinforced pavement structure – vertical displacements

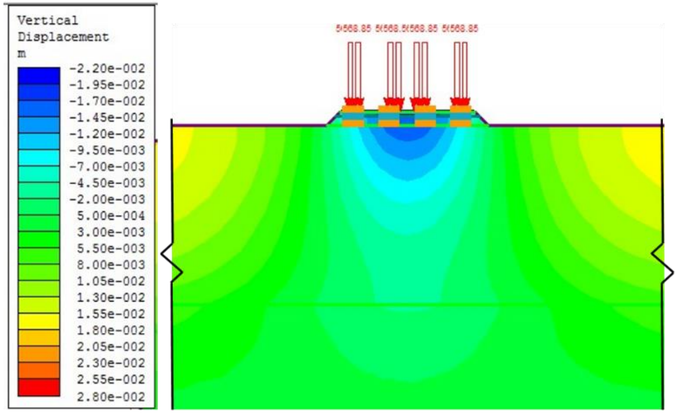

Fig 6. Reinforced pavement structure – vertical displacements

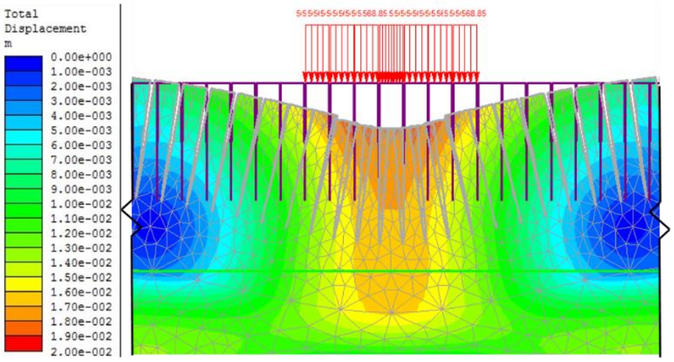

Fig 7. Cracked Soil – Total displacements with deformed mesh.

In Fig. 7 both vertical and horizontal displacements were analyzed, due to the unconfined state of the soil columns under the loaded structure a significant horizontal displacement can be observed. The horizontal displacements gradually decrease as the columns are placed away from the loaded structure. In terms of vertical displacements, due to the discontinuity of the underneath soil, greater values as in the first models are found. Nonetheless these vertical displacements heavily decrease when they reach the normally consolidated clay layer.

The presence of this discontinuity leads to a different approach of the possible reinforcement used in these situations, considering that in this kind of scenario much greater displacement values are achieved and proposed geocells are not enough to mitigate them.

FEM simulation allows a better approximation on the mechanical behavior of a loaded soil, sadly it is highly limited since none all actual variables are considered when analyzing, also the proposed boundaries and primarily the boundary conditions limit how far it is able to reproduce exactly the real circumstances of the terrain. This is why it is important to consider more variables and different aspects such as desiccation, dynamic loads, for future research.

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