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THE INFLUENCE OF THE FOUNDATION SOIL QUALITY ON THE OPERATIONAL BEHAVIOR OF FLEXIBLE ROAD STRUCTURES

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Abstract: *Unlike other constructions with smaller sites, the probability of encountering a diversity of geological and geotechnical elements is greater in the case of a road, and difficult areas may be found. Thus, the behavior of road systems, alongside a number of factors such as traffic load, weather conditions, road layers type and thickness, material quality etc., is largely influenced by the type and nature of foundation soil and their behavior in service as response to specific loads. The paper aims to examine the influence of foundation soil quality on the deformation of road systems in service, using the ABAQUS 6.8-3 numerical modeling, which is a commercial modeling program based on the finite element method.*
Key words: *foundation, deformation, modeling, layer, discretization*

1. INTRODUCTION

Embankments are constantly exposed to external agents, which exert a decisive influence on their behavior. Humidity and temperature variation during the year determine the increase or decrease of the load-carrying capacity of embankments, in result the strength and stability of the road system (Haida et al., 2004).

Water, under its different forms, exerts a decisive influence on the behavior of embankments, and may result either from rainfall infiltration or from capillary rise of groundwater.

Climatic variations, material fatigue, the foundation soil properties and their different behavior in certain stages of operation, etc., determine change in the road material properties as well as the foundation soil properties, so that the values that characterize their elastic behavior (dynamic modulus of elasticity, E, Poisson's ratio, μ) are subject to variation.

The study analyzes the behavior of road structures in relation to the foundation soil characteristics.

In order to study the behavior of the road system under climatic change it has been proposed to study the road system behavior in two distinct situations: for a good foundation soil (E = 100 MPa, μ = 0.27) and for a weak foundation soil (E = 50 MPa, μ = 0.35) (Costescu & Belc, 2009).

2. RESEARCH HYPOTHESES

The modeling of the foundation soil and determining the depth, to which traffic loads cause tensions and deformations in the embankment, required the study of tension distribution in the foundation soil in the areal problem, assuming a uniformly distributed load in the semi-space between tire and road surface.

The 115 kN standard axle (OS 115) used in the calculation for sizing the road structures in Romania presents the following characteristics: dual wheel load: 57.5 kN, contact pressure: 0.625 MPa and circular radius of the equivalent tire-track contact surface area: 0.171 m (Lucaci et al., 2010).

It is well known that vertical tensions in the foundation soil, determined through the Boussinesq model, decrease with the increasing of depth. If we try to define in depth the road system (road structure + the active area of the embankment) which may be influenced by traffic loads, it may be extended to depths of about 1.80 ... 2.30 m measured from the tread, analytically calculated considering a uniformly distributed load, with a value of 6.25 daN/cm^2 on a circular area with a radius of 17.1 cm, when the load distribution though the road structure is being made with an angle of 45^0.

Numerical modeling of road structures based on the finite element method (FEM) was made using CAXA parabolic elements (shell elements with eight nodes in which the unknown field variation was considered to be of order II , or shell elements with four nodes in which the unknown field variation was considered to be of order I). The domain's discretization in finite elements used in the analysis is shown in Figure 1.

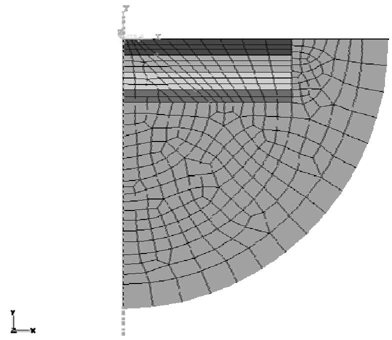

Fig. 1. Domain discretization in finite elements

The tridimensional response was simulated by the authors using "axisymetric deformable" CAXA type finite elements, which are part of the ABAQUS software.

The simplified numerical model is defined using a revolution axis, the Y-Y axis, and introducing the appropriate symmetry conditions (ie U1 = UR2 = UR3 = 0) (ABAQUS Documentation).

Elements were used in connection with the standard finite element used to model the road system area of interest and for the foundation soil modeling as semi-infinite space, infinite elements were used (CINAX5R).

A road system corresponding to a flexible structure was modeled, with the composition and characteristics of the foundation soil determined through open drills and laboratory analysis.

A flexible road structure was modeled with the following characteristics:

- bituminous layer, thickness 7 cm, E = 3000 MPa, μ = 0.35;
- ballast layer, thickness 15 cm, E = 667 MPa, μ = 0.27;
- foundation layer made from the original pavement, thickness 10 cm, E = 350 MPa, μ = 0.27;
- foundation soil - silty sand, semi-finite thickness, E = 65 MPa, μ = 0.30.

The road system was modeled in two different hypotheses regarding the cooperation between layers, and this way it was considered a perfect co-operation between layers, respectively free interfaces (no co-operation between layers).

3. RESULTS

The research was made by the authors on experimental roads and the informations were processed with the ABAQUS software and the results are presented in the figures below.

Figure 2 presents the state of deformation in the road system using numerical modeling for the road structure, with an overall unfavorable foundation soil in the hypothesis of a perfect bound between the layers, respectively unbounded layers in Figure 3.

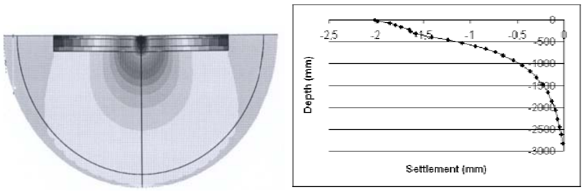

Fig. 2. Hypothesis of unbounded road layers, weak foundation soil

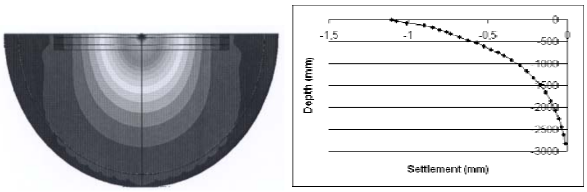

Fig. 3. Hypothesis of perfectly bounded road layers, weak foundation soil

Figure 4 presents the deformation state in the road system, when the road structure is flexible, DN 59C, with a favorable foundation soil for the perfect bound between layers hypothesis, and unbound layers in Figure 5.

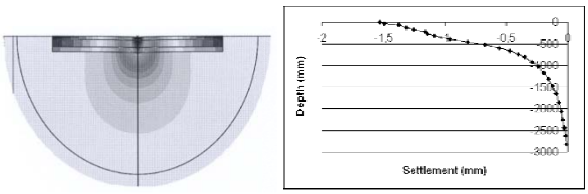

Fig. 4. Hypothesis of unbounded road layers, good foundation soil

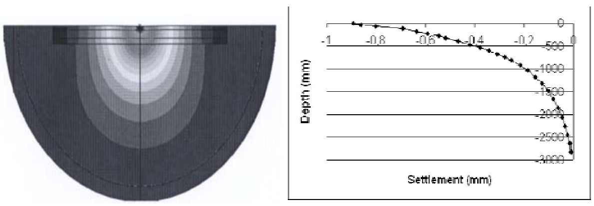

Fig. 5. Perfectly bounded road layers hypothesis, good foundation soil

Foundation soil quality influences the vertical deformations of the flexible road systems with flexible structures in smaller proportion in the lower part of the bituminous layers and in a greater proportion at the level of the road bed.

Thus, it appears, in both cases of the bound between the layers, that a good foundation reduces the specific deformation by about 15% at the base of the bituminous layers and about 25% at the level of the road bed.

A weak foundation soil causes the increase of the vertical deformations by about 10% at the base of the bituminous layers and about 15% at the level of the road bed. From a depth of about 2.00 m in the foundation, the soil's quality influence is felt no longer.

A better foundation soil causes a significant reduction of the vertical deformations in the road system at the road bed level and in the body of the embankments compared to the ones in the road structure (Figure 6).

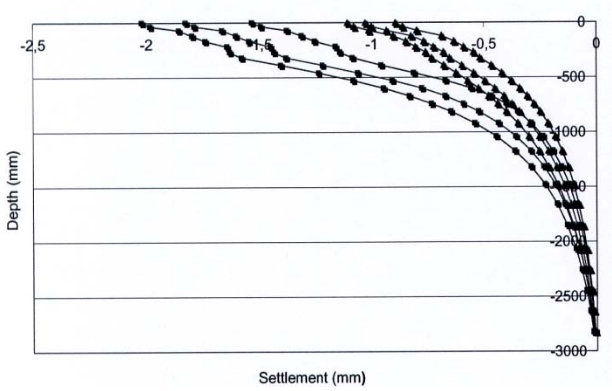

Fig. 6. State of deformation to changes in the foundation soil characteristics

4. CONCLUSIONS

The case of flexible road structures, from the perspective of the bounds between road layers (perfect bound, respectively unbound) reveals a close behavior of the road systems, noticing that in the case of free interfaces, the deformations values are about 80% higher in the bituminous layers and over 100% higher at the foundation soil level, than in the case of a perfect bound between layers.

The foundation soil quality influences the vertical deformations of flexible road structures in lesser proportion in the lower part of the bituminous layers and a greater proportion at the road bed level. From a depth of about 2.00 m in the foundation soil, the influence of its quality is no longer felt.

A good quality of the foundation soil makes the deformations of the road system to decrease, thus inducing a better behavior in service of the flexible road systems structures. A better foundation soil causes a more significant decrease of the vertical deformations of the road systems at the road bed level and in the body of the embankment, compared to the ones in the road structure.

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