A Finite Element Method For Bridge Approach

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ABSTRACT

The Finite Element Method (FEM) was used in many fields of engineering with the advanced of computers programs, and in lasts years have begun to evaluate pavements structures. In the transition at different structures of pavement, the behavior of the materials has resulted in the differential settlement response when they are loaded.

A three-dimensional finite element model was developed in Ansys Program and performed statics analyses to evaluate the responses of interface among the bridge abutment and flexible pavement for dual wheel. Was simulated a pavement behaviour in this study and results for different structures in 3D FEM were compared with a linear elastic model in ELSYM5 program.

Different structures of pavement varying the mechanical properties of the base in each case, were developed to review a pavement response to static load in the transitions of flexible pavements. This difference in material of base causes the problem of a differential settlement in the most cases.

This paper tries to develop a research of response at bridge approach without slab transition in flexible pavement to one static load. In this case a dual wheel, in a comparison was conducted from a variation in the compaction near the structure of bridge.

Keywords - Flexible pavement, Finite Element Method (FEM), Ansys program application

I. INTRODUCTION

At the bridges approaches are usual to verify a differential settlement between the structure of bridge and the abutment, especially due to the great displacement of the pavement structure compare to the bridge foundation, causing the effect of "the bump at the end of the bridge".

Although of the all worries in the execution of the landfill in the abutment on the bridge approach, the structure of the pavement is implemented over the landfill, which in most cases, have an inadequate compaction in the layers, because the compaction equipment avoids cause a damage in the structure near of the bridge, therefore, there is a differential settlement on the bridge approach.

The safety and comfort that a highway should provide the user are related to a range of factors involving the user's and road characteristics. Of these, the functional condition of the pavement and speed of operation were significant. Functional condition of the pavement, especially in the bridge approach, in most cases does not provide safety and comfort, where the driver meets with an unexpected situation.

The bridge approach problem promotes a reduction in safety for road users, especially at faster speeds, where the effect of the bump at the end of the bridge should be imperceptible to the driver, not exposing a risk of loss control or damage to the vehicle. Another problem is the maintenance costs to minimize the problem at the bridge approach and especially premature degradation of pavement.

The restoration of this place needs partial interruption of traffic, which results in a discomfort to the users of the road. They are usually performed in the pavement layers to fill the settlement in an effort to level the greide at the bridge approach, which isn´t one simple intervention.

In the formation of the problem in the approach have as other factors, the erosion of the embankment or soil settlement of the foundation for either, other solutions to minimize these effects are used in the construction, as the slab transition.

The presence of a slab transition at the bridge approach has the effect of avoiding the differential settlement that occurs by accommodation of the embankment [1], but the slab is designed to keeping the planicity of the road, distributing the settlement of the landfill along its length as shown in Fig. 1.

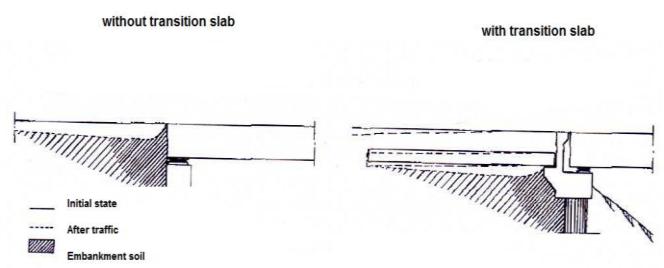

Figure 1. Differential settlement at the bridge approach [2]

II. REVIEW OF LITERATURE

In a review of the literature on the topic, verify that the differential settlement between the bridge and the pavement structure is almost inevitable, once has a small settlement of the abutment design. Moreover, the pavement is designed to distribute stresses over the subgrade in place, usually about granular material which has a deformation greater than that meet in the bridge.

The studies of Long et al [3] demonstrate that the differential settlement or discomfort for the user by the bump of the end of the bridge occur at different locations in the bridge approximation, primarily by the type of geometry of the encounter and the cause of settlement. For the study sites in Illinois, USA, demonstrated settlement in bridges with or without transition slab at the abridge approach.

The discomfort caused by the bump of vehicles in the end of the bridge, is noted by the user of the road when settlements have slopes greater than or equal to 50 mm However, the studies of Long et al [3] present a better parameter that expresses this discomfort to the user, which is measured by the change of slope on the approach slab, that is measured by the differential settlement divided by the total length.

Therefore, in the falte of criteria for acceptance of values for the settelemnt, Long et al [3] suggests values near of 1/125 for change of slope, measures for improvement should be evaluated to minimize the effect of the bump and discomfort to the user. According this definition of measure of bridge approach, Briaud et al [4] suggests changes of slop near of 1/200 for acceptance of bridges, which are guaranteed safety and comfort.

In technical notes the SETRA [2] are discussed consideration in the decision to use or not the slab of transition, that is related to the initial costs and future maintenance to repair of the settlements.

The manual of bridge design from Brazil [5], all bridges must have a transition slab with a thickness not less than 250 mm and a length of four meters, connected to the structure or abutment, through concrete joints, and over a compacted soil in the entire length.

In the handbook of inspection of bridge [6], there has been the concern with this difference in stiffness between the embankment and bridge structure, even improved with the use of slab transition, eventually fail and causing a impact of vehicles at the end of the bridge.

Some factors are involved in the occurrence of the effect of bump on the approach that can be summarized in Fig. 2. [4]

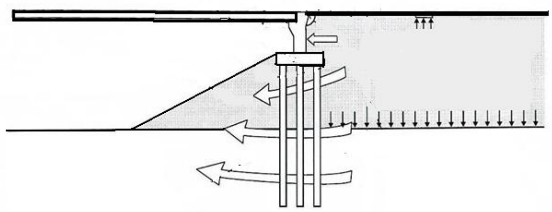

Figure 2. Problems leading to the existence of a Bump [4]

The settlement of the natural subgrade is eventually a common issue in the bridges structure, hat usually occur after the beginning of loading to the landifll and requests from traffic, but in some soil types may occur along time. Therefore, an analysis of differential settlement of the embankment and bridges foundation along the time, which will give subsidies for the identification of the solution to be used in this problem.

About the material of the landfill must be taken care with the available materials near the construction, because they may not have a satisfactory performance. The proper compaction of material is another important factor to reduce the effect of the bump. Also, one may use lighter materials in the landfill in order to prevent settlement in the subgrade. The bridges foundations are usually profound and have little natural subgrade settlement, what must be a greater importance in the implementation of the bridge embankment.

In studies by Seo [7] involving the slab transition, was observed that the frequency of loading on the slab transition is proportional to the growth of the bump and short transition slabs result in higher displacement of the slab.

As Puppala studies [8], the factors causing the effect of the bump are a consolidation of foundation soil in the landfill, by the poor compaction and consolidation of fill material, associated a inefficient drainage and soil erosion.

The implementation of an appropriate drainage system in the bridge approximation, maintains away from water that can penetrate the soil of the embankment, causing voids with loss of material and the consequent settlement.

III. VALIDATION OF THE FINITE ELEMENT MODEL

A static analysis was performed to evaluate the model developed in Ansys Program, comparing with the results in ELSYM5 program, either using a linear elastic model.

The program Elsym5 [9] is based on a model of perfectly elastic layers in three dimensions, where the structure can be required by one or more loads distributed on circular surfaces and constant pressure. In the response of the structure have results of stress, strain and displacement at defined points.

A flexible pavement can be represented by layers of materials, composing the structure. In this method of elastic material is assumed one behavior homogeneous and elastic deformation to each layer, from the modulus of elasticity (E) and Poisson's ratio (μ). [10]

Thickness of 5 cm and 10 cm were performed to asphalt layer. To the base was used thickness of 15 cm, 20cm, 25cm and 30 cm in this validation. The material characteristics of the asphalt concrete, base and subgrade are shown in table 1 and a high uniform pressure of 0.56 MPa applied in the circular area of 10.79 cm, spaced 34 cm from each other, at the condition of dual wheel.

Table 1. Material Characteristics of Pavement Structure

	Concrete Asphalt	**Base**	**Subgrade**
Elastic Modulus ***E*** [MPa]	2,400	150	70
Poisson's Ratio ***ν***	0.45	0.35	0.35
Thickness [mm]	50 / 100	150 / 200 / 250 / 300	-

The numerical models were performed using the Ansys Program, a three dimensional finite element method with a 20-node elements. In this analise was used a axisymmetric finite element with 1,500 mm to horizontal and vertical directions. The comparison of the numerical results for linear elastic model obtained for different layers thicknesses are shown in Fig. 3 to vertical displacement.

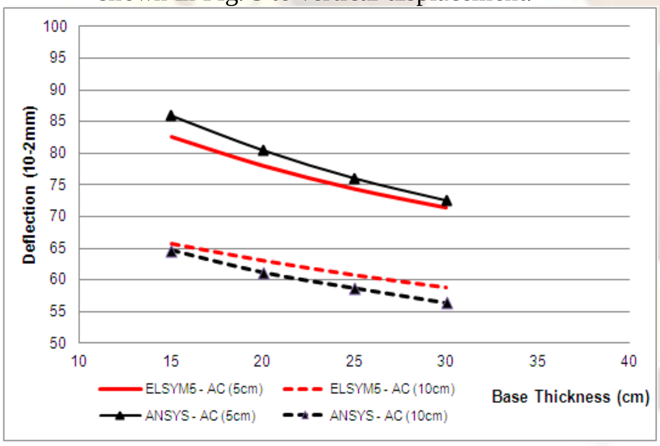

Figure 3. Comparison of displacement in the pavement structure

IV. FINITE ELEMENT ANALYSES

For a better understanding of the settlement in embankments near the bridge approach, a construction of a numerical model for each case study were constructed, in the table were presented the properties of the materials in structure.

Table 2. Material Characteristics of the numerical model

	Concrete Asphalt	**Base**	**Subgrade**	**Bridge**
Elastic Modulus ***E*** [MPa]	2,400	300	100	30,000
Poisson's Ratio ***ν***	0.45	0.35	0.35	0.25
Thickness [mm]	100	300	-	-

Numerical models were performed using the Ansys Program, a three dimensional finite element method with a 20-node elements. In this analyse was used a axisymmetric finite element with 2.000 mm to horizontal in axis Y and vertical direction. At direction Y was used 4.000mm to perform a bridge approach, as showed in Figure 4.

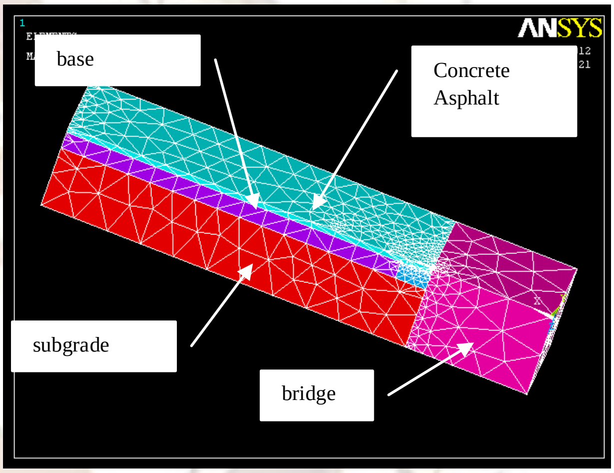

Figure 4. Numerical model of bridge approach in Ansys program

Near the bridge abutment were analysed three examples of compactations with variation in elastic modulus to demonstrate a poor, normal and good compaction, as showed below.

Table 3. Variation in Elastic Modulus near the bridge

Compaction	Elastic Modulus ***E*** [MPa]
I – Poor	150
II – Normal	300
III – Good	450

Therefore, analyses were developed to a static load of a dual wheel with 8.2 kgf along the approximation and the bridge, as presented in the following Fig. 5.

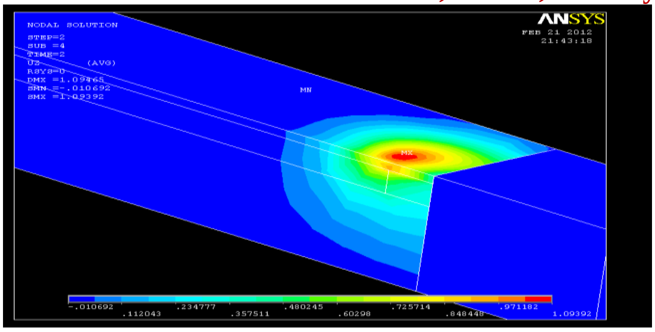

Figure 5. Numerical results of displacement in Ansys Program

In the figure 6 are presented the numerical results for each of the cases studied, which were calculated vertical displacements along the bridge approach. Can be noted a differential deformation between the bridge and embankment, especially in the bridge approach even a good compaction demonstrated in case III.

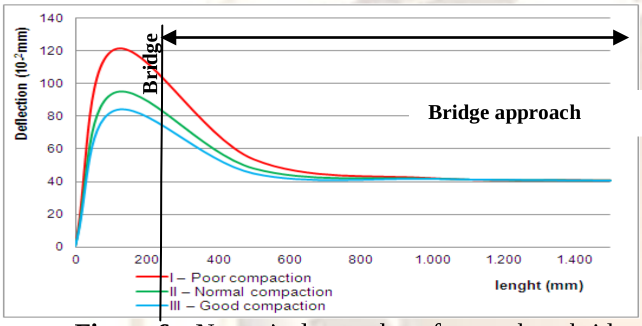

Figure 6. Numerical results from the bridge approach mode

V. Conclusions and Recommendations

The approximation of the bridge has in most cases, the formation of a differential settlement between the structure and the pavement, caused by the greater deformation of the embankment that may be due to several factors, such as erosion, loss of material and disruption of the subgrade soil natural, among others.

Therefore, the main cause of differential settlement, causing the effect of the bump in the end of the bridge is the deformation of the material of landfill, which because of lack of technological control, adequate procedures or choice of soil, it forms settlement in the bridge approach

It can be verified the validation of the three dimensional finite element method using Ansys with the program Elsyn5, where the model presents similar results to the same condition. In the analysis of the bridge approach, it was observed that always happen a differential settlement between the landfill and the bridge, even enhancing compaction near the abutment.

There are proposed recommendations in the last 20 years in different countries to reduce the occurrence of landfill settlements near the bridge, but in Brazil this fault still occurs frequently in new constructions.

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