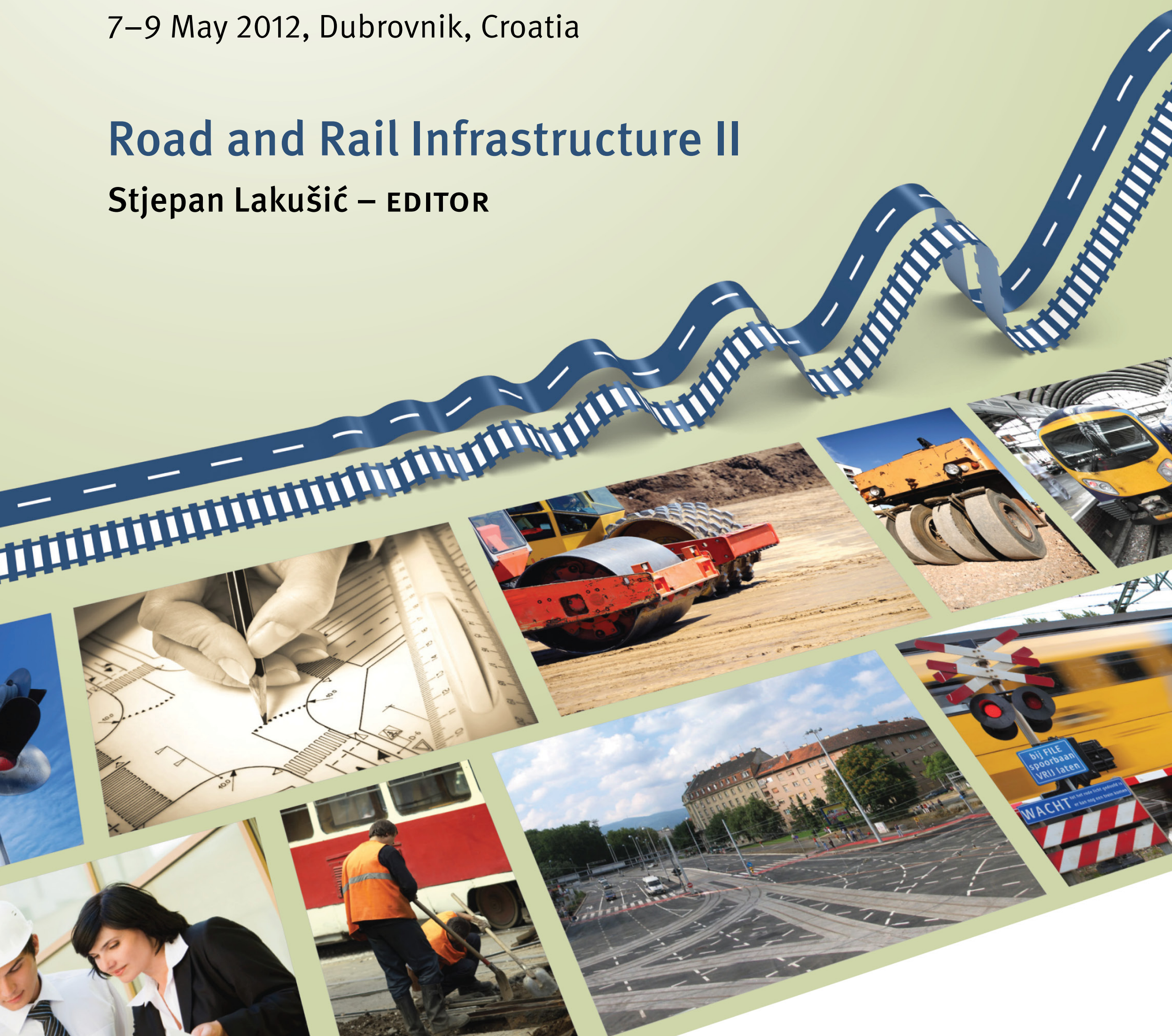
CETRA2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



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ANALYSIS OF THE FLEXIBLE PAVEMENTS TRANSITIONS USING FINITE ELEMENT METHOD

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Abstract

The Finite Element Method (FEM) is used in many engineering fields by use of advanced computer programmes. In the last years researchers are also evaluating pavement structures with the mentioned method.
The transition of different pavement structures caused the behaviour of the materials to result in differential settlement response when loaded. In this paper, a three–dimensional finite element model was developed in Ansys Programme and statics analyses were performed to evaluate the interface responses among dual wheel bridge and flexible pavement. Soil behaviour was also simulated in this study and results for different structures, in 3D FEM, were compared with a linear elastic model in ELSYM5 programme in order to validate the new model.
Different pavement structures with varying base mechanical properties were developed to review the pavement response to static load in flexible pavements transitions. This difference in base material, in most cases, causes the problem of a differential settlement.
This paper tries to develop a research of flexible pavement response to one static load, in this case a dual wheel, on a bridge approach without a slab transition. Also, a comparison of compaction variations was conducted and a survey on deflections was performed.

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

1 Introduction

Bridge approaches usually are zones of differential settlement between the structure of the bridge and the abutment, due to great displacement of the pavement structure in comparison to the bridge foundation, causing the effect of 'the bump at the end of the bridge'.
Some problems with the execution of the landfill in the abutment on the bridge approach exist. The pavement structure implemented over the landfill, in most cases, has an inadequate layers compaction. During the compaction, despite of all the effort to avoid damage in the structure near the bridge, there is a differential settlement on the bridge approach.
Safety and comfort, which a highway should provide to the user, are related to a range of factors involving users and road characteristics. Among these, the pavement's functional condition and operation speed are significant. The functional condition of the pavement, especially in the bridge approach where the driver meets an unexpected situation, in most cases does not provide safety and comfort.
The bridge approach problem unfortunately presents a reduction in safety for road users, especially at higher speeds. There the effect of the bump at the end of the bridge should be imperceptible to the driver, not causing a risk of control loss or damage to the vehicle. Other problems are the maintenance costs and premature degradation of pavement.
The interventions that are used as solutions of these problems cause partial interruption of traffic, which results in user discomfort. The interventions are usually performed in the

pavement layers where filling of the settlement might level the grade at the bridge approach. This is not a simple intervention.
The mentioned bridge approach problem has other factors involved, the erosion of the embankment or soil settlement of the foundation. To minimize these effects other solutions are used for construction, such as the use of slab transition.
The presence of a slab transition at the bridge approach has the effect of enabling the differential settlement that occurs by accommodation of the embankment [1]. The slab is designed to keep the road in level, distributing the settlement of the landfill along its length as shown in Fig. 1.

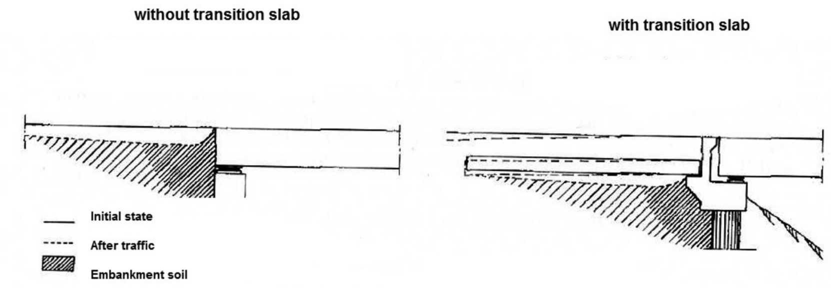

Figure 1 Differential settlement at the bridge approach [2]

2 Literature review

Review of the topic literature showed that the differential settlement between the bridge and the pavement structure is almost inevitable, once has a small settlement of the abutment design. Also, the pavement is designed to distribute stresses over the subgrade which is usually composed of granular material which has a deformation greater than that we see on the bridge.
The studies of Long et al [3] demonstrate that the differential settlement or discomfort for the user by the bump at the end of the bridge occur at different locations in the bridge vicinity, and depends primarily on the type of geometry of the encounter and the cause of settlement. The studies conducted in Illinois, USA, demonstrated settlement of bridges with or without transition slab at the abridge approach.
The discomfort caused by the bumping of vehicles in the end construction of the bridge, is noted by the road user 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 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 a lack of criteria for acceptance of values of the settlement, Long et al [3] suggest 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 slope acceptance value near of 1/200 for bridges, which guarantee safety and comfort.
Technical notes SETRA [2] discuss consideration of weather to use or not slab transition. Decision is related to the initial costs and future maintenance of the settlements.
According to Brazilian manual for bridge design [5], all bridges must have a transition slab with a thickness no less than 250 mm and a length of four meters, which must be connected to the structure or abutment through concrete joints and layed over a compacted soil in its entire length.

In the handbook for bridge inspection [6], there has been the concern with difference in stiffness between the embankment and bridge structure, even with the use of slab transition. Slab transition will eventually fail and cause an impact of vehicles at the end of the bridge.
Some factors involved in the occurrence of the effect of bump on the approach are summarized in Fig. 2. [4]
The settlement of the natural subgrade is a common phenomenon in the bridges structure. It usually occurs 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 is needed, which will give subsidies for the identification of the solution to be used in this problem.
The material of the landfill must be chosen properly. Available materials near the construction site may not have a satisfactory performance. The proper compaction of material is another important factor for the bump effect reduction. Also, one may use lighter materials in the landfill in order to prevent settlement in the subgrade. The bridge foundations are usually profound and have little natural subgrade settlement. This fact is of great importance for the implementation of the bridge embankment.

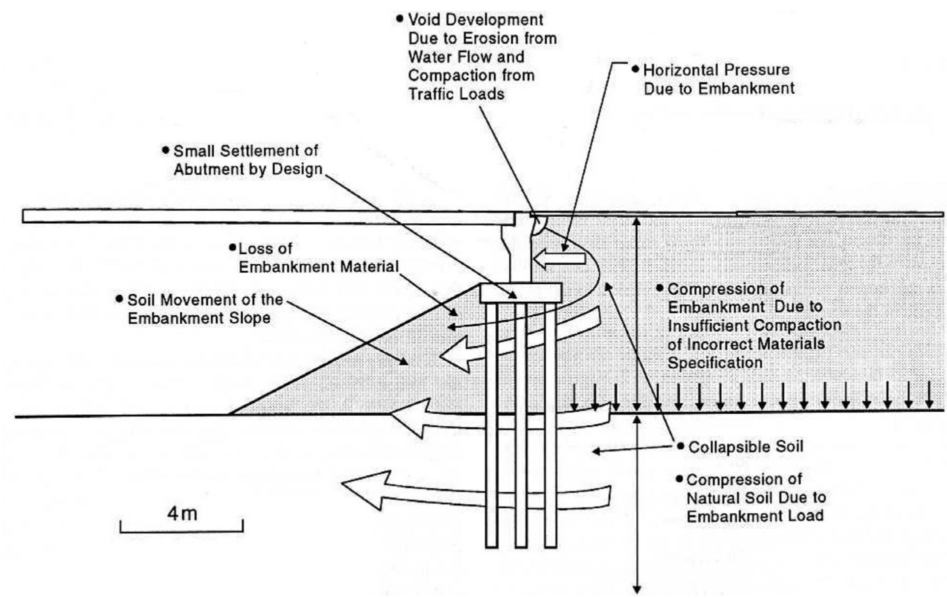

Figure 2 Problems leading to the existence of a bump [4]

In studies by Seo [7] involving the slab transition, it was observed that the frequency of loading on the slab transition is proportional to the growth of the bump and that short transition slabs result in higher displacement of the slab.
As Puppala concluded [8], the factors causing the effect of the bump are consolidation of foundation soil in the landfill, poor compaction and consolidation of fill material associated with an inefficient drainage and soil erosion.
The implementation of an appropriate drainage system in the vicinity of the bridge enables the water from penetrating into the soil of the embankment causing voids with loss of material and the consequent settlement.

3 Validation of the finite element model

A static analysis was performed to evaluate the model developed by Ansys Program, comparing its results with the results of ELSYM5 program, and to evaluate either using a linear elastic model is appropriate in this situation.
The program ELSYM5 [9] is based on a model of perfectly elastic layers in three dimensions. The structure can be loaded by one or more loads distributed on circular surfaces with constant pressure. The response of the structure is illustrated by 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, elastic material is defined by homogeneous and elastic deformation that is assigned to each layer by its modulus of elasticity (E) and Poisson's ratio (μ). [10]
Analysis was performed on asphalt layers 5 cm and 10 cm thick. Validation of the base was performed for thickness of 15, 20, 25 and 30 cm. The material characteristics of the asphalt concrete, base and subgrade are shown in table 1. High uniform pressure of 0.56 MPa was 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 v	0.45	0.40	0.35
Thickness [mm]	50 / 100	150 / 200 / 250 / 300	-

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

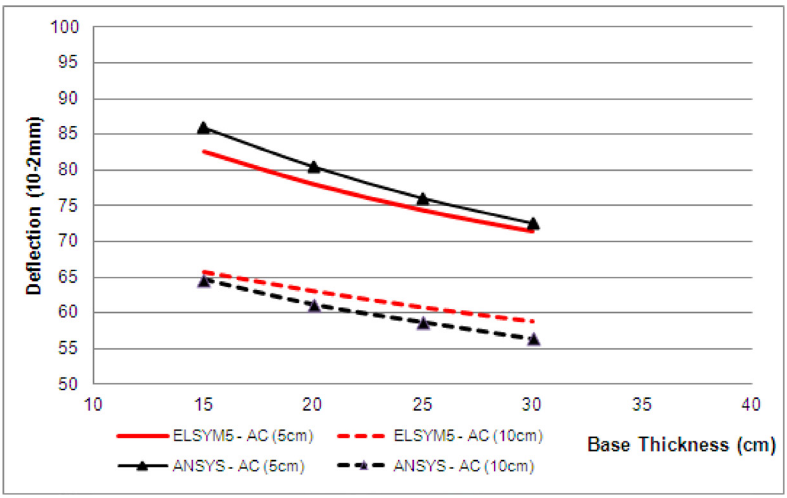

Figure 3 Comparison of displacement in the pavement structure

4 Finite element analyses

For a better understanding of the settlement in embankments near the bridge approach, a numerical model for each case study was constructed in a way that fifty milimeters from the bridge abutment were three examples of compactions with variation in elastic modulus (to demonstrate a poor, normal and good compaction). The properties of the material are presented in table 2. The numerical models were performed using the finite element method, as shown in Fig. 4.

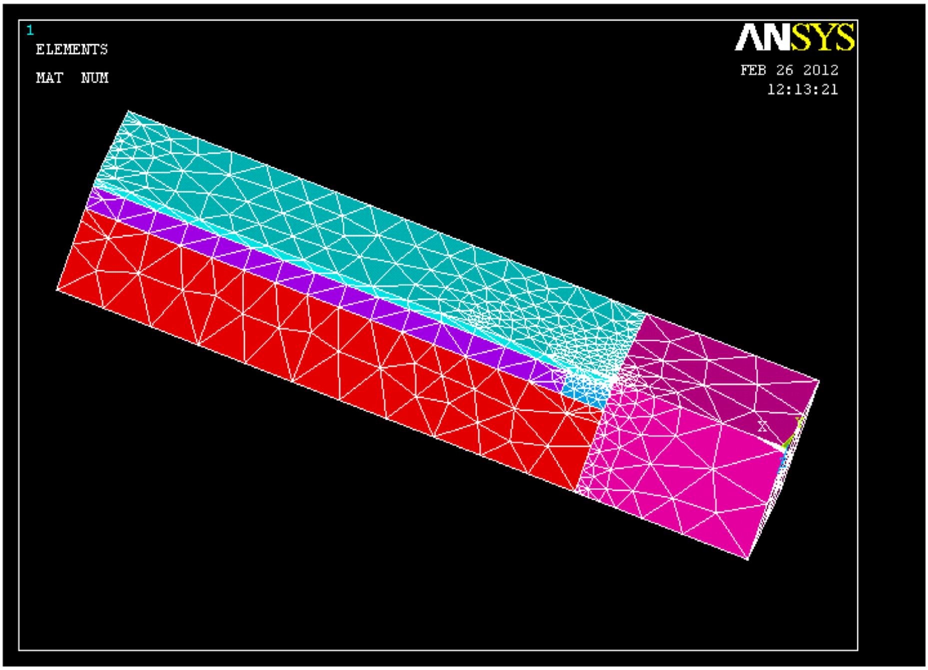

Figure 4 Numerical model of bridge approach in Ansys program

Table 2 Material characteristics of the numerical model

	Concrete Asphalt	Base	Base	Subgrade	Bridge
Elastic Modulus E [MPa]	2,400	300	150 / 300 / 450	100	30,000
Poisson's Ratio v	0.45	0.40	0.45	0.35	0.25
Thickness [mm]	100	300	300	-	-

Analyses were performed using a static load of a dual wheel with 8.2 kgf along the approximation and the bridge, as presented in the following Fig. 5.

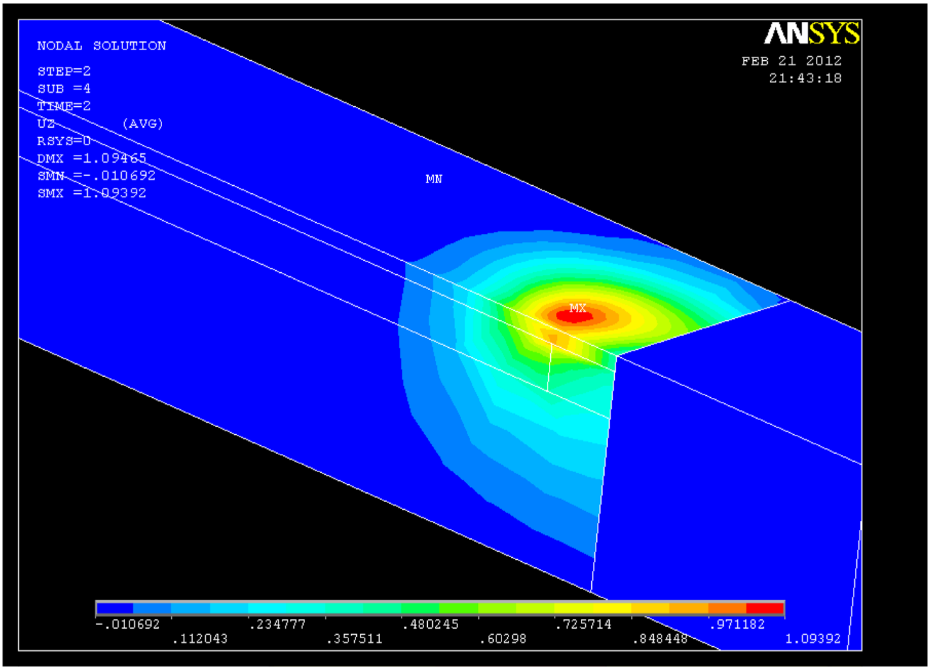

Figure 5 Numerical results of displacement in bridge approach

Table 3 presents the numerical results (calculated vertical displacements along the bridge approach) for each of the cases studied. It can be noted that a differential deformation between the bridge and embankment occured, especially in the bridge approach even in case of good compaction (case III).

Table 3 Numerical results from the bridge approach model

Example	Over de Bridge	Distance until the bridge beginning [mm]		
		0	**500**	**1500**
I – Poor compaction	8×10^{-3}mm	403×10^{-2}mm	109×10^{-2}mm	81×10^{-2}mm
II – Normal compaction	8×10^{-3}mm	298×10^{-2}mm	101×10^{-2}mm	81×10^{-2}mm
III – Good compaction	8×10^{-3}mm	258×10^{-2}mm	96×10^{-2}mm	81×10^{-2}mm

5 Conclusions and recommendations

In the vicinity of the bridge, in most cases, occurs 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 characteristics, among others.
Therefore, the main cause of differential settlement, causing the effect of the bump at the end of the bridge, is the deformation of the landfill material. This deformation is a consequence of lack of technological control, adequate procedures or choice of soil, and it causes formation of settlement in the bridge approach.
The validation of the three dimensional finite element method using Ansys is performed with the program Elsyn5 – the models present similar results to the same condition. In the analysis of the bridge approach, it was observed that there is always a differential settlement between the landfill and the bridge, even in case of enhancing compaction near the abutment.
In the last 20 years, recommendations were proposed 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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