Rehabilitation Works Of The Existing Asphalt Pavement And Connecting The Existing Asphalt Pavement With The Newly Constructed Pavement, Motorway E-75, Section Tabanovce – Kumanovo From Km 0+764.70 To Km 8+388.43, Part Of The Corridor X

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- **ABSTRACT** :

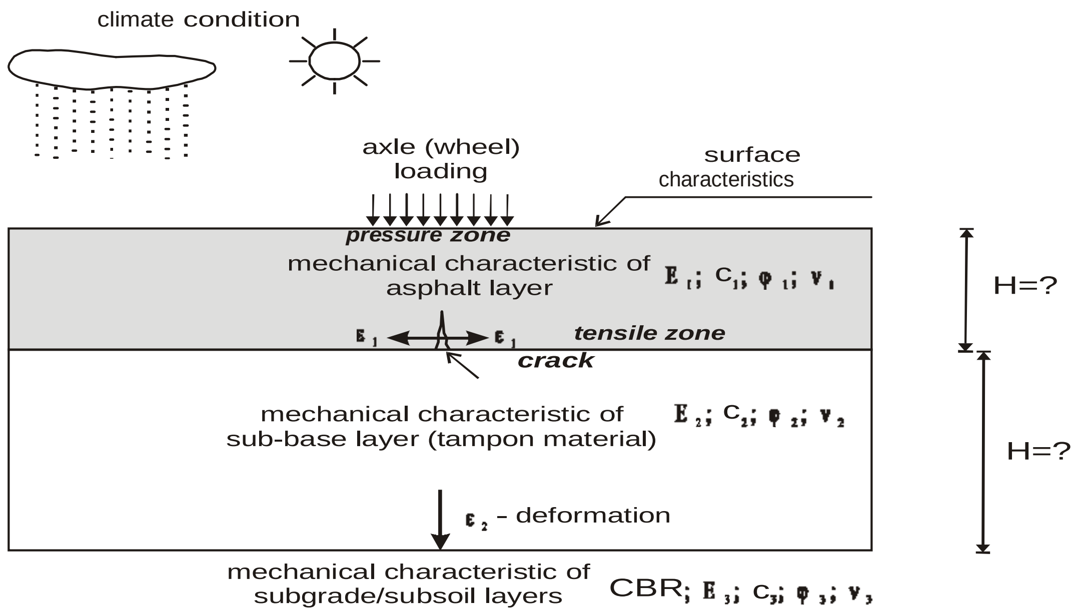
The Corridor X is part of the pan-European network of corridors. The starting point of the corridor is in Salzburg, Austria and the end point is in Thessaloniki, Greece. The corridor passes through Austria, Slovenia, Croatia, Serbia, Macedonia and Greece. The Construction of the Corridor is supported by the international financing institutions like the European Bank for Reconstruction and Development (EBRD) and the International Bank for Reconstruction and Development (IBRD). The paper refers to one of the sections in R. Macedonia that is under the construction, section between Tabanovce and Kumanovo in length of 7.62 km.
Part of the pavement works consisted of rehabilitation of the existing pavement with applying polymer grids, specially designed for such purpose. In the paper the entire procedure of the pavement design will be presented, with particular attention on the quality requirements of the materials that should be for the road construction. Numerical analysis of the pavement was accomplished using the software package PLAXIS. The results of these analyses are presented in the paper, namely: stress fields and zones where the plasticity limit of the materials was reached. The cross section was treated with and without polymer grids. The number of the polymer grids in the cross section was also varied, as well as its location. The presented procedure of the pavement design could be tailored to the specific needs of the project and implemented on the various road rehabilitation projects

Keywords: *road rehabilitation, pavement, pavement design, polymer grids*

1. Introduction

Dimensioning of the pavement structure is a complex engineering problem, because the influential parameters are numerous, different and variable during the exploitation period, i.e. stress-deformation state of pavement structure in exploitation is period affected by many factors. Besides the task of bearing capacity and usability in different operational conditions, climatic influences and field conditions, pavement structures must answers the conditions for flatness and (friction-adhesion), for safe and comfortable driving, for all kind of vehicle (axle) loading of traffic.

Complex of influential parameters for dimensioning (design) of pavement structures is shown in next picture.



Picture 1. Parameters which influents the dimensioning of pavement structures

Design of pavement structures are usually considered a variant for a phased construction and rehabilitation (reconstruction) or upgrade of pavement structure, in order to achieve maximum effects with minimal investments and in terms of maintenance (use) and management of roads.

Flexible pavement structures are deformed during crossings of usability mobile loads, while the road surface under the influence of burdens in its vicinity is deformed, thus forming settlement with small dimensions size and relatively large flexion (from one millimetre to several millimetres depending the case). As a result of load pressures on the ground in the lower layer is localized in a small area around the load axis. To allocate a larger area and reduce the pressures on this small area around the axle (under the pneumatics), it is necessary to increase the dimensions of pavement structure or to apply modern quality materials (special asphalts with polymer-bitumen, arbocel, carbon fibbers, geosynthetics, etc.).

Surface asphalt layers should withstand normal and tangential stress which is created by the vehicle tires and to transfer pressure on the lower layers of pavement structure which will not be larger than the allowed, that is to transfer it in the elementary subsoil as well subsoil crash.

Improvement of the mechanical and rheological properties of asphalt layers is usually made by using polymer modified bitumen's, and application of polymer grids (they distribute the loads to a larger area and less stress is obtained, as well as reduction of the cracks reflection from the old asphalt layers) in reconstruction or upgrading, as well as temperature influences.

In continuation through simulation of several typical phases for different positions of traffic load of vehicles the condition of pavement structure will be displayed.

The analysis is performed by a finite element method - FEM with software package PLAXIS 8, where two-dimensional analysis was treated or flat state of stresses and deformations.

For this particular case a section of pavement structure width of 11 m is considered, with the level of underground water which is recorded at site. Pavement Structure is simulated with axle load of 82 kN distributed in 4 pneumatics (4x 20.5=82 kN) considering the pneumatics and the inflation pressure. Given the current state of pavement structure of the existing road, the performed site and laboratory testing of represented materials, as well as traffic load for the predicted highway solution, more possible solutions of the pavement structure are considered. It is taken into account the standard axle load of 82 kN, for a vehicle in the middle lane and especially for the vehicle in fast lane, respecting the rank of the road. The characteristics of materials are taken based on the results from the tests, as well as materials intended to be built in the pavement structure.

Table 1

	E (kPa)	ν	**c (kPa)**	**φ (°)**
AB-11/16	9 500 000	0,46	250,00	35,00
BNS 22 sA	6 000 000	0,45	200,00	36,00
Old asphalt	4 000 000	0,42	180,00	32,00
Old sub-base	100 000	0,30	5,00	36,00
Old subgrade	50 000	0,20	3,00	29,00
Sub-base	130 000	0,32	5,00	38,00
Improved subgrade	80 000	0,30	10,00	30,00
Subgrade for fast lane	50 000	0,30	2,00	28,00
Subsoil	20 000	0,30	15,00	17,90

For part of the materials values are accepted that exist in the literature and similar surveys, where the non-joined materials are taken into account and apparent cohesion (which is obtained in laboratory tests), which suits for closed types of structures, or compact built into a structure for further exploitation. Below will be describe several specific cases analysed with absolute values.

2. Analyses for specific cases of pavement structure

Case I Traffic overload of the fast lane

For the predicted case, pavement structure for specific section when we have vehicle on the fast lane is analysed for a case without applying the polymer grid and for the case using a polymer grid by applying 2 polymer grids. In the case of two polymer grids, the lower grid is considered to be around 10 m in order to obtain overlapping with the fast lane and involving loads from vehicles, and the above grid to be 5 m, which will cover the most relived part of the ride on the fast and middle lane as well as the area around the concrete edge beam. In the case of one grid, it is placed at a distance of 2 m from the edge of the end of stopping lane and with overlapping of about 60 cm with the fast lane. The appendixes are given for specific values obtained by the analysis and shown in tables.

Table 2

	Without grids	**With one polymer grid**	**With two polymer grids**
Uy (m)	$11{,}50\times10^{-3}$	$11{,}33\times10^{-3}$	$10{,}55\times10^{-3}$
Ux (m)	$3{,}66\times10^{-3}$	$3{,}61\times10^{-3}$	$3{,}35\times10^{-3}$
dUy (m)	$37{,}72\times10^{-6}$	$36{,}85\times10^{-6}$	$33{,}74\times10^{-6}$
Gam-xy (%)	$633{,}46\times10^{-3}$	$608{,}59\times10^{-3}$	$555{,}73\times10^{-3}$
dEps-yy (%)	$4{,}61\times10^{-3}$	$5{,}33\times10^{-3}$	$5{,}12\times10^{-3}$
dEps-xx (%)	$2{,}92\times10^{-3}$	$2{,}92\times10^{-3}$	$2{,}70\times10^{-3}$
Sig-xy (kPa)	849,42	832,06	778,10
Sig-yy (kPa)	968,63	946,23	899,00
Force in the grid 1(kN/m’)	–	17,03	4,23
Force in the grid 2(kN/m’)	–	–	16,64

Comments of the results

The results obtained are given insight into the stress-deformable situation where it is best to apply the two polymer grids, then one grid is less favourable and without the use of grids. From the appendixes can be seen especially area around the concrete edge beam, which remains in the pavement structure, which is an unfavourable situation for normal tangency shear stress, displacement, and manifesting the plastic points. In the appendixes are given forces occurred in polymer grids and incremental displacement, which is important in terms to satisfy the required parameters for polymer grid, for improvement of deformable-stress condition.

If we have in mind that it is a simulation of passing one vehicle, then, when it will multiply for more crossings can be concluded that the application of the polymer grids is acceptable for a given analysis as a technical solution.

Case II Traffic overload of the middle lane

For the predicted case, road structure for specific section when we have vehicle on the middle lane is analysed in case without applying the polymer grid, using a polymer grid and by applying 2 polymer grids. In the case of two polymer grids, the lower grid is considered to be around 10 m as would be obtained by replacing with the fast lane and involving loads from vehicles, and the above grid to be 5 m, which will cover most relived part of the ride on the fast and middle lane as well as the area on the concrete edge beam. In the case of one grid, it is placed at a distance of 2 m from the edges of the end of stopping lane and replaces about 60 cm with fast lane which we get 7 m grid of the profile (min 6,50 m i.e. 6,60 m). The appendixes are given for specific values obtained by the analysis and shown in tables.

Table 3

	Without grids	**With one polymer grid**	**With two polymer grids**
Uy (m)	$12{,}66\times10^{-3}$	$12{,}54\times10^{-3}$	$11{,}65\times10^{-3}$
Ux (m)	$4{,}09\times10^{-3}$	$4{,}05\times10^{-3}$	$3{,}73\times10^{-3}$
dUy (m)	$33{,}59\times10^{-6}$	$32{,}92\times10^{-6}$	$30{,}37\times10^{-6}$

Gam-xy (%)	1,85	1,79	1,48
dEps-yy (%)	$14{,}48\times10^{-3}$	$11{,}62\times10^{-3}$	$10{,}73\times10^{-3}$
dEps-xx (%)	$2{,}61\times10^{-3}$	$1{,}88\times10^{-3}$	$1{,}84\times10^{-3}$
Sig-xy (kPa)	890,71	851,00	823,00
Sig-yy (kPa)	880,69	869,23	760,78
Force in the grid 1 (kN/m’)	–	15,44	3,89
Force in the grid 2 (kN/m’)	–	–	15,86

Comments of the results

The results obtained given insight into the stress-deformable situation where it is best to apply the two polymer grids, then one grid is less favourable and without the use of grids is the least. The attachments show the situation with normal and tangency shears stress, displacement, and manifesting the plastic points. In the appendixes are given forces occurred in polymer grids and incremental displacement, which is important in terms to satisfy the required parameters for polymer grid, for improvement of deformable-stress condition.

If we have in mind that it is a simulation of passing one vehicle, then, when it will multiply for more crossings can be concluded that the application of the polymer grids is acceptable for a given analysis as a technical solution.

Case III Traffic overload of the fast and then the middle lane with changeable length of the upper polymer grid

For the predicted case, pavement structure for specific section, when we have vehicle once in the fast lane and then on the middle lane is analysed. Upper polymer grid is made to be about 1,5-2 m above the concrete edge beam between the new AWC and AC, and the polymer grid is incorporated between old asphalt course and new AWC (set on 2 m distance from the edge of the stopping lane and overlapping with the fast lane about 60 cm, where we get about 7 m grid of the profile (min 6,50 m or 6,60 m). In this case the analysis is done with two positions of the vehicle, the fast and middle lane. The appendixes are given for specific values obtained by the analysis and shown in tables.

Table 4

	Vehicle on fast lane	**Vehicle on middle lane**
Uy (m)	$10{,}93\times10^{-3}$	$12{,}53\times10^{-3}$
Ux (m)	$3{,}48\times10^{-3}$	$4{,}05\times10^{-3}$
dUy (m)	$35{,}15\times10^{-6}$	$32{,}79\times10^{-6}$
Gam-xy (%)	$580{,}70\times10^{-3}$	1,55
dEps-yy (%)	$5{,}16\times10^{-3}$	$10{,}91\times10^{-3}$
dEps-xx (%)	$2{,}78\times10^{-3}$	$1{,}84\times10^{-3}$
Sig-xy (kPa)	823,20	836,60
Sig-yy (kPa)	924,12	769,42
Force in the grid 1 (kN/m’)	4,72	$74{,}75\times10^{-3}$
Force in the grid 2 (kN/m’)	16,82	15,09

Comments of the results

The results obtained are given insight into the stress-deformable situation, the situation and normal tangency shears stress, displacement, and manifesting the plastic points. With the analysed cases, can be seen behaviour of the pavement structure, thus gain insight into the characteristic size of the stress-deformable condition or behaviour of the road structure for different strengthening and location of the vehicle load. In the appendixes are given forces occurred in polymer grids and incremental displacement, which is important in terms to satisfy the required parameters for polymer grid, for improvement of deformable-stress condition. Compared with previous cases, can be seen the critical parts that occur in zones where second grid is placed, in particular the strength that occurs in the polymer grid that ends with a greater pick, which is inconvenient for the pavement structure.

If we consider that it is a simulation of passing one vehicle, then, when it will multiply for more crossings can be concluded, that the application of the polymer grids for larger areas is acceptable for a given analysis as a technical solution, also it must take into consideration the techno-economic aspects which will be determined by the Investor.

Case IV Traffic load characteristic of certain moves adjustable length upper polymer grid

For the predicted case, road structure for specific section, when we have different positions on the vehicle (centring is carried out which may occur in the exploitation period in the first case flange concrete dip in the middle of the vehicle, and in the latter case vehicle wheel comes over concrete beam). Upper polymer grid is made to be about 1,5-2 m above the concrete strip between new AWC and AC, and the polymer grid is incorporated in to old asphalt and new AWC (set of 2 m distance from the edge of the stopping beam and with replace of about 60 cm with fast lane, where we get about 7 m grid profile (min 6,50 m or 6,60 m). The appendixes are given for specific values obtained by the analysis and shown in tables.

Table 5

	With centred vehicle	**Vehicle on middle lane**
Uy (m)	$12,31\times10^{-3}$	$12,53\times10^{-3}$
Ux (m)	$3,90\times10^{-3}$	$3,97\times10^{-3}$
dUy (m)	$36,38\times10^{-6}$	$39,10\times10^{-6}$
Gam-xy (%)	1,33	$859,89\times10^{-3}$
dEps-yy (%)	$6,70\times10^{-3}$	$4,74\times10^{-3}$
dEps-xx (%)	$2,30\times10^{-3}$	$2,58\times10^{-3}$
Sig-xy (kPa)	854,27	856,40
Sig-yy (kPa)	817,99	844,77
Force in the grid 1 (kN/m’)	3,31	4,41
Force in the grid 2 (kN/m’)	17,97	17,43

Comments of the results

The results obtained are given insight into the stress-deformable situation, the situation and normal tangency shears stress, displacement, and manifesting the plastic points. With the analysed cases, can be seen behaviour of the pavement structure, thus gain insight into the characteristic size of the stress-deformable condition or behaviour of the road structure for different strengthening and location of the vehicle load. In the appendixes are given forces occurred in polymer grids and incremental displacement, which is important in terms to satisfy the required parameters for polymer grid, for improvement of deformable-stress condition. Compared with previous cases, can be seen the critical parts that occur in zones where the influence of the load (vehicle).

If we consider that it is a simulation of passing one vehicle, then, when it will multiply for more crossings can be concluded that the application of the polymer grids is acceptable for a solution especially that vehicles are moving in the driving lane, cases for the given analyses.

Case V Traffic load on two lanes without polymer grid and applying the polymer grid

For the predicted case, road structure for specific section, when we have vehicle once on the fast lane and then on the middle lane without polymer grid and 2 polymer grids or just one polymer grid is analyzed. For the upper polymer grid optimization is made in case of laying and length of about 3 m above the concrete edge beam between the new AWC and AC, and the polymer grid is incorporated between old asphalt and new AWC (set of 2 m distance from the edge of the stopping lane and replacing with the fast lane about 60 cm, where we get about 7 m grid of the profile (min 6,50 m or 6,60 m). In this case the analysis is done with two places of the vehicle, the fast and middle lane. The appendixes are given for specific values obtained by the analysis and shown in tables.

Table 6

	Without grids	**With one polymer grid**	**With two polymer grids**
Uy (m)	$13{,}35\times10^{-3}$	$13{,}33\times10^{-3}$	$12{,}54\times10^{-3}$
Ux (m)	$3{,}84\times10^{-3}$	$3{,}80\times10^{-3}$	$3{,}52\times10^{-3}$
dUy (m)	$38{,}08\times10^{-6}$	$36{,}88\times10^{-6}$	$27{,}13\times10^{-6}$
Gam-xy (%)	$632{,}07\times10^{-3}$	$606{,}27\times10^{-3}$	$560{,}79\times10^{-3}$
dEps-yy (%)	$4{,}97\times10^{-3}$	$3{,}17\times10^{-3}$	$2{,}49\times10^{-3}$
dEps-xx (%)	$2{,}00\times10^{-3}$	$1{,}47\times10^{-3}$	$1{,}40\times10^{-3}$
Sig-xy (kPa)	919,00	837,37	813,00
Sig-yy (kPa)	971,82	915,84	870,06
Force in the grid 1 (kN/m’)	–	13,72	1,35
Force in the grid 2 (kN/m’)	–	–	12,29

Comments of the results

The results obtained are given insight into the stress-deformable situation, the situation and normal tangency shears stress, displacement, and manifesting the plastic points. With the analysed cases, can be seen behaviour of the pavement structure, thus gain insight into the characteristic size of the stress-deformable condition or behaviour of the road structure with or without polymer grid. In the appendixes are given forces occurred in polymer grids and incremental displacement, which is important in terms to satisfy the required parameters for polymer grid, for improvement of deformable-stress condition. Compared with previous cases, can be seen the critical parts that occur in zones where the influence of the load (vehicle) and the condition with and without polymer grid.

If we consider that it is a simulation of passing one vehicle, then, when it will multiply for more crossings can be concluded, that the application of the polymer grids for larger areas is acceptable for a given analysis as a technical solution, also it must take into consideration the techno-economic aspects which will be determined by the Investor.

3 Conclusions and recommendations:

Based on the performed analyses, are given following conclusions and recommendations:

- The analyses were performed by commercial software package PLAXIS 8 with finite elements method;
- The parameters are adopted based on the executed site and laboratory tests, as well as existing data for similar facilities;
- Several typical analysis were performed so it would have received an insight into the stress-deformable condition of the pavement structure, and they were reviewed and treated with additional layers of asphalt, but they are more complicated in terms to fulfils grade of pavement (scrape / scratch / asphalting, and financial), and do not affect much to improve the condition of pavement (strengthening);
- During the simulation is sure to gain insight into phase pavement structure state for different states of load of vehicles and strengthening the pavement structure with polymer grid;
- Analysis and simulations were performed for different types of structures for the section, for cases with strengthening with additional thickness of asphalt and applying of polymer grids. Taking into account the impairment of the existing old road (cracks, routing, strips, holes etc.) connection of the old road with the new fast lane and location of concrete edge beam, techno-economic analysis and observations regarding the consideration solutions as more acceptable variant is adopted using polymer grids;
- Regarding the treatment of existing concrete edge beam is considered from several aspects: if it were out, it will need to move with greater incision of the old asphalt that will perform and some weakening parts since the beam holds base layer, so its removal will create weak conditions in that zone. Therefore it is recommended to go by placing polymer grid between the old and the new asphalt layer AWC (and depending on the financial conditions of client as a better option that we can raise polymer grid between the AWC and AC, to go with two polymer grids, which in future would reduce funds for maintenance and also will influence the increase of traffic safety);
- Generally, the basic analysis performed, it can be concluded that the favourable condition of the pavement structure is obtained by applying the polymer grids. Taking into account the different location of burdens (the vehicles are moving in the zone of driving lanes) and damages which are on the old road (mostly the whole area) with large scale of grids to get better stress-deformable state, which is particularly important in terms of longer operating time period. As a minimum requirement and criteria required to set a polymer grid, in terms of setting the second polymer grid that will get more and durable pavement structure, which will greatly influence the current maintenance period at the exploitation (respecting the

rank of the road - highway), we believe that should be taken into account techno economic and security aspects for which the client decides.

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