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EFFECTIVENESS OF THE STEEL MESH TRACK  
IN STRENGTHENING CRACKED ASPHALT PAVEMENTS

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Abstract

In recent years many works have been done in Poland on application of geotextiles and related products to strengthen existing, cracked asphalt pavement structures. Relatively frequently, besides glass, glass-coal and polyester nets, the pavement reinforcing with steel mesh track (to simplify called later as the steel net) is also met, specially on national roads, trafficked with heavy vehicles. The purpose of the paper is to present the selected experiences gained while renewing and strengthening the national roads in the South of Poland. To these works, the steel mesh track of tensile strength 40/50 kN/m was applied. In the paper some design data were given, among others the subgrade analyses, existing layers system, as well as results of the elastic deflections and modulus, measured with FWD apparatus, on the pavement before and after its strengthening. The concept of the reconstruction works comprised the milling of the upper bituminous layer of 4 cm in thickness, laying the profiling course, installing the steel mesh track and bonding it with slurry seal course to the lower surface. As the overlay, two bituminous layers: 4 cm SMA + 8 ÷ 10 cm AC in thickness were placed. After 3 ÷ 5 years of the service, the measuring of pavement deflection bowl with the FWD was conducted and on the base of it, the estimation of its bearing capacity was carried out. Finally, due to the back analyses using the mechanical-empirical calculations, the profit of applying the steel mesh as the reinforcing interlayer in the system of asphalt layers was proved.

Keywords: Bearing capacity of pavement, Reinforcement with geotextiles, Steel mesh track, FWD deflections, interlayer system

1 Introduction

Problem of strengthening the asphalt layers with using steel grid (mesh track) as well as using the synthetic or glass geogrid interlayer has been recognized from early 90-ties, at the beginning mainly from the practical point of view; lately, the theoretical approach to designing of the pavement structure with geosynthetics has been developed. At first, those interlayers were considered as the stress relieving, i.e. anticracking material, laid over the cracked semi-rigid asphalt pavement, to repair the reflective cracking on the pavement surface. This method regarded as very encouraging, became popular in Poland. The first comparative tests carried out in the Belgian Road Research Centre in Brussels [1] in early 90-ties on the efficiency of geosynthetics (for nonsynthetic raw material it is also called geotextile) have brought promising results (Figure 1). Those tests revealed, that the steel mesh placed in the asphalt layers submitted to the tensile stress, has got the most advantageous influence on reducing the propagation of crack, reflected from the discontinuity in lower layer. Testing of the above interlayers on real road sections [2] confirmed the best performance in delaying reflective cracking by glass fibre grid and steel mesh track, other types of intermediate layers have proved less effective. Similar results were achieved in Por-
tuguese research [3], where steel mesh with slurry seal had the best performance, and the bitumen impregnated geotextile sections were second best.

![Graph showing crack length in the overlay (cm)](image)

**Figure 1** The early comparative tests on the efficiency of the stress relieving interlayer, delaying the reflective cracking propagation in the semirigid asphalt pavements [1]Styles dialogue in Microsoft Word 97-2003.

In all cases de-bonding has to be avoided, otherwise fatigue cracking may appear after finishing these works very quickly. The problem of the conditions required to ensure the effectiveness of geotextile interlayers in the system of asphalt layers was tested in works [4, 5]. In the last years some new research works were taken up, focussed on using the steel grid or glass-carbon grid in asphalt layers as the real reinforcement, diminishing the pavement deflection values, in this way increasing the pavement bearing capacity. Due to which, the fatigue life of the asphalt pavement can be prolonged, or the thickness of the asphalt layers decreased. As the research examples, it can be referred to the research in Belgian Road Research Centre [6], and in Cracow University of Technology [7, 8].

The present paper is devoted to the practical effects (diminishing of deflections) of applying the steel mesh track (the steel net), measured and estimated for the site condition on the asphalt pavement, constructed in the South region of Poland on national roads sections. FWD test results, before and after the reconstruction, have been provided by General Directorate for National Roads and Motorways (GDDKiA), Branch Krakow.

## 2 Selection of testing sections

The road sections selected for the reinforcement and tests did not have proper bearing capacity and were seriously damaged: many longitudinal, transversal (reflective crackings), single and alligator cracks were observed, as well as uneven areas, viscoplastic/structural ruts and patches. The example of the previous pavement condition is done at Figure 2.

All selected sections before reinforcement were submitted to the diagnostic tests of their conditions, according to the Polish System of Pavements Condition Evaluation with the measurement of the deflection bowl and using the Falling Weight Deflection apparatus.
Figure 2  View of damaged pavement on national road 44

Besides, test holes were made to identify the existing pavements structure and subgrade conditions as well as some laboratory tests on drilled cores were carried out. Those were as follows: the creep test of asphalt samples, the gradation and sand equivalent of aggregates from the base, and soils plasticity test. The list of the analysed road sections together with layers thicknesses measured on pavement cores and layers modulus determined from the back analysis are given in Table 1.

Table 1  Summary of the analyzed road sections.

<table>
<thead>
<tr>
<th>Road number</th>
<th>Localization (km)</th>
<th>Asphalt layers</th>
<th>Aggregate subbase</th>
<th>Subgrade</th>
</tr>
</thead>
</table>
| 94 – roadway right (Section 1) | 285+488 ÷ 286+300 | H = 28 cm  
E = 4111 MPa | H = 17 cm  
E = 165 MPa | H = infinity  
E = 92 MPa |
|                 | 286+300 ÷ 287+450 | H = 28 cm  
E = 3855 MPa | H = 31 cm  
E = 370 MPa | H = infinity  
E = 71 MPa |
|                 | 287+450 ÷ 288+320 | H = 26 cm  
E = 3349 MPa | H = 51 cm  
E = 159 MPa | H = infinity  
E = 73 MPa |
| 94 – roadway left (Section 2) | 285+488 ÷ 286+650 | H = 22 cm  
E = 3580 MPa | H = 40 cm  
E = 308 MPa | H = infinity  
E = 84 MPa |
|                 | 286+650 ÷ 287+870 | H = 22 cm  
E = 2726 MPa | H = 47 cm  
E = 249 MPa | H = infinity  
E = 76 MPa |
|                 | 287+870 ÷ 288+320 | H = 25 cm  
E = 6594 MPa | H = 47 cm  
E = 240 MPa | H = infinity  
E = 132 MPa |
| 94 (Section 3)  | 305+100 ÷ 307+100 | H = 21 cm  
E = 2661 MPa | H = 29 cm  
E = 281 MPa | H = infinity  
E = 57 MPa |
| 7 (Section 4)   | 632+200 ÷ 634+200 | H = 19 cm  
E = 1903 MPa | H = 66 cm  
E = 295 MPa | H = infinity  
E = 66 MPa |
| 44 (Section 5)  | 101+900 ÷ 102+900 | H = 17 cm  
E = 1500 MPa | H = 40 cm  
E = 200 MPa | H = infinity  
E = 50 MPa |
3 Designed reinforcing structures and their field evaluation

Design activities of the reinforcement included the surface milling to profile the existing structure, laying the steel net and fitting it to the lower layer with slurry seal, next placing the new binding and wearing bituminous layers of total thickness 12 ÷ 14 cm. Details of the designed structures on each road section are given in Table 2.

Table 2  Designed structures of pavement reinforcement for the analysed sections of roads.

<table>
<thead>
<tr>
<th>Road number</th>
<th>Localization (km)</th>
<th>Milling depth</th>
<th>Interlayer</th>
<th>New asphalt layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 – roadway right (section 1)</td>
<td>285+488 ÷ 288+320</td>
<td>2 ÷ 5 cm</td>
<td>Steel mesh track with 1 cm of slurry seal</td>
<td>8 ÷ 9 cm HM AC + 4 cm SMA</td>
</tr>
<tr>
<td>94 – roadway left (section 2)</td>
<td>285+488 ÷ 288+320</td>
<td>3 ÷ 5 cm</td>
<td>Steel mesh track with 1 cm of slurry seal</td>
<td>8 cm HM AC + 4 cm SMA</td>
</tr>
<tr>
<td>94 (section 3)</td>
<td>305+100 ÷ 307+100</td>
<td>4 cm</td>
<td>Steel mesh track with 1 cm of slurry seal</td>
<td>8 cm HM AC + 4 cm SMA</td>
</tr>
<tr>
<td>7 (section 4)</td>
<td>632+200 ÷ 634+200</td>
<td>6 cm</td>
<td>Steel mesh track with 1 cm of slurry seal</td>
<td>10 cm AC + 4 cm SMA</td>
</tr>
<tr>
<td>44 (section 5)</td>
<td>101+900 ÷ 102+900</td>
<td>5 cm</td>
<td>Steel mesh track with 1 cm of slurry seal</td>
<td>8 cm HM AC + 4 cm SMA</td>
</tr>
</tbody>
</table>

Designed reinforcing structures were verified with mechanical-empirical method, using the Asphalt Institute USA fatigue criteria [9]. Material parameters were assumed acc. to the Polish recommendations [10], stress and strain states were calculated with the computer program BISAR 3.0, results are given in Table 3. Obtained results have satisfied the requirements for the designed traffic category (that is >14.6 M cycles of standard axle 100 kN during the whole period of pavement exploitation, equal to 20 years).

Table 3  Results of the fatigue durability of pavement for the analyzed sections of roads.

<table>
<thead>
<tr>
<th>Road number</th>
<th>Localization [km]</th>
<th>Horizontal strain in asphalt layers</th>
<th>Vertical strain on subgrade</th>
<th>Fatigue durability of pavement [M 100 kN/axle]</th>
</tr>
</thead>
<tbody>
<tr>
<td>94 – roadway right (section 1)</td>
<td>285+488 ÷ 286+300</td>
<td>52.8 x 10^{-6}</td>
<td>-132 x 10^{-6}</td>
<td>52.8</td>
</tr>
<tr>
<td></td>
<td>286+300 ÷ 287+450</td>
<td>47.8 x 10^{-6}</td>
<td>-124 x 10^{-6}</td>
<td>78.8</td>
</tr>
<tr>
<td></td>
<td>287+450 ÷ 288+320</td>
<td>64.3 x 10^{-6}</td>
<td>-127 x 10^{-6}</td>
<td>33.5</td>
</tr>
<tr>
<td>94 – roadway left (section 2)</td>
<td>285+488 ÷ 286+650</td>
<td>59.4 x 10^{-6}</td>
<td>-122 x 10^{-6}</td>
<td>46.0</td>
</tr>
<tr>
<td></td>
<td>286+650 ÷ 287+870</td>
<td>74.3 x 10^{-6}</td>
<td>-131 x 10^{-6}</td>
<td>28.1</td>
</tr>
<tr>
<td></td>
<td>287+870 ÷ 288+320</td>
<td>39.2 x 10^{-6}</td>
<td>-118 x 10^{-6}</td>
<td>95.8</td>
</tr>
<tr>
<td>94 (section 3)</td>
<td>305+100 ÷ 307+100</td>
<td>86.3 x 10^{-6}</td>
<td>-218 x 10^{-6}</td>
<td>17.6</td>
</tr>
<tr>
<td>7 (section 4)</td>
<td>632+200 ÷ 634+200</td>
<td>79.2 x 10^{-6}</td>
<td>-117 x 10^{-6}</td>
<td>18.1</td>
</tr>
<tr>
<td>44 (section 5)</td>
<td>101+900 ÷ 102+900</td>
<td>71.7 x 10^{-6}</td>
<td>-233 x 10^{-6}</td>
<td>16.5</td>
</tr>
</tbody>
</table>

During 3-5 years after reinforcement, any damage on the renewed pavements evaluated visually was not seen. In the same time, the tests of elastic deflections with FWD apparatus were carried out on all sections, what allowed to compare the bearing capacity of pavements before and after reinforcement (all values were converted to the equivalent temperature 20°C acc. to [11]). Example of obtained results are presented in Figure 3. To evaluate the significance level of the changes, the statistical tests were conducted with using the method of multiple comparisons and LSD procedures in the Statgraphics program (95% confidence level); the results are presented in Table 4. For all analysed road sections, deflection values after reinforcement are substantially lower than before that treatment, the highest differences were observed for the section of previously the lowest bearing capacity and the thinnest thickness of the structure.
Figure 3  Comparison of the pavement deflections before and after reinforcement for the road section DK 7 – km 632+200 – 634+200.

Table 4  Analysis of significance of FWD deflection [µm] differences before and after reconstruction, with using the steel net.

<table>
<thead>
<tr>
<th>Time of measuring</th>
<th>average</th>
<th>standard deviation</th>
<th>coefficient of variation [%]</th>
<th>difference</th>
<th>+/- limits (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DK 94, km 285+488 – 288+320, roadway right (section 1)</td>
<td>Before reconstruction 188 77 40,6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After reconstruction</td>
<td>118 37 31,6</td>
<td>70</td>
<td>38*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DK 94, km 285+488 – 288+320, roadway left (section 2)</td>
<td>Before reconstruction 177 52 29,4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After reconstruction</td>
<td>110 29 26,9</td>
<td>67</td>
<td>38*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DK 94, km 305+100 – 307+100 (section 3)</td>
<td>Before reconstruction 306 83 27,0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After reconstruction</td>
<td>084 22 25,7</td>
<td>222</td>
<td>31*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DK 7, km 632+200 – 634+200 (section 4)</td>
<td>Before reconstruction 306 98 32,1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After reconstruction</td>
<td>163 41 25,5</td>
<td>144</td>
<td>40*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DK 44, km 101+900 – 102+900 (section 5)</td>
<td>Before reconstruction 639 165 25,8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After reconstruction</td>
<td>230 65 28,1</td>
<td>409</td>
<td>45*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*denotes a statistically significant difference

The comparison of obtained deflection measurement results with the Polish required values according to the pavement condition evaluation system, i.e. DSN [12], classifies all road tested sections in the class A, what means that the remaining fatigue life is equal to minimum 20 years (the results are given in Figure 4).

To separate and evaluate the influence of the steel net on the rebuilt structure bearing capacity, the next step of analysis was done. It was the comparison of the deflection bowl from FWD test and converted to the static deflection bowl for the structure acc. to [13] with the steel net, with the results for the structure without the steel net, which were calculated using mechanical-empirical calculations in the programme BISAR (the temperature in both
cases was brought to 20°C [11]). Next, for both cases, significance tests for differences in the deflection values were carried out.

![Figure 4](image)

**Figure 4** Evaluation of pavement FWD deflection acc. to DSN [12].

Results of the presented analyses given in Table 5 reveal, that the deflection values measured on the sections with the FWD method (steel net reinforced sections), are lower than deflections calculated for reinforcement structures without steel net, what proves the positive effect of the steel net applied to reinforced sections. The most profitable effect was obtained for sections where, before rebuilding, the biggest deflections were obtained, what can explain better mobilization of the steel net in the pavement structure.

**Table 5** Significance tests for deflection differences on the sections reinforced with (deflections measured) and without steel net (deflections calculated).

<table>
<thead>
<tr>
<th>Deflections [µm] (T=20°C)</th>
<th>average</th>
<th>standard deviation</th>
<th>coefficient of variation [%]</th>
<th>difference +/– limits 95% 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DK 94, km 285+488 – 288+320, roadway right (section 1)</strong></td>
<td>199</td>
<td>64</td>
<td>32,2</td>
<td>8</td>
</tr>
<tr>
<td>Calculated</td>
<td>207</td>
<td>54</td>
<td>26,1</td>
<td></td>
</tr>
<tr>
<td>Measured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DK 94, km 285+488 – 288+320, roadway left (section 2)</strong></td>
<td>173</td>
<td>46</td>
<td>26,9</td>
<td>10</td>
</tr>
<tr>
<td>Calculated</td>
<td>183</td>
<td>55</td>
<td>30,1</td>
<td></td>
</tr>
<tr>
<td>Measured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DK 94, km 305+100 – 307+100 (section 3)</strong></td>
<td>112</td>
<td>29</td>
<td>25,7</td>
<td>146</td>
</tr>
<tr>
<td>Calculated</td>
<td>258</td>
<td>65</td>
<td>25,3</td>
<td></td>
</tr>
<tr>
<td>Measured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DK 7, km 632+200 – 634+200 (section 4)</strong></td>
<td>196</td>
<td>52</td>
<td>26,7</td>
<td>30</td>
</tr>
<tr>
<td>Calculated</td>
<td>226</td>
<td>62</td>
<td>27,5</td>
<td></td>
</tr>
<tr>
<td>Measured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DK 44, km 101+900 – 102+900 (section 5)</strong></td>
<td>304</td>
<td>85</td>
<td>28,1</td>
<td>68</td>
</tr>
<tr>
<td>Calculated</td>
<td>372</td>
<td>83</td>
<td>22,3</td>
<td></td>
</tr>
<tr>
<td>Measured</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*denotes a statistically significant difference
4 Conclusions

Presented in this paper tests of the road sections and analyses of the results allowed to draw the following conclusions:

1) Condition of pavements of all analysed road sections reinforced with the steel net and 12 ÷ 14 bituminous overlay after several years of exploitation is very good. No damages were observed, what confirms the effectiveness of applied solution. Bearing capacity of the tested sections evaluated according to the pavement condition evaluation system, i.e. DSN [12], classifies all road tested sections in the class A, what means that the remaining fatigue life is equal to minimum 20 years.

2) Increase of the bearing capacity of reinforced pavements evaluated with the FWD method for all sections is very substantial.

3) Deflection values measured on the pavements reinforced with the steel net are lower than deflections calculated with BISAR program for the pavement structure without the steel net. The differences are substantial for 2-3 tested sections, depending on the assumed significance level 95% or 90 %.

4) The best effectiveness of the steel net applied is observed for the sections where the bearing capacity before rebuilding was the lowest, and where the steel net is placed in the tension zone.

5) Analysed road sections require longer periods of time to observe their condition, and in this way to better evaluate the steel net efficiency in reducing the possible reflective crackings as well as in prolonging the fatigue life.

References


