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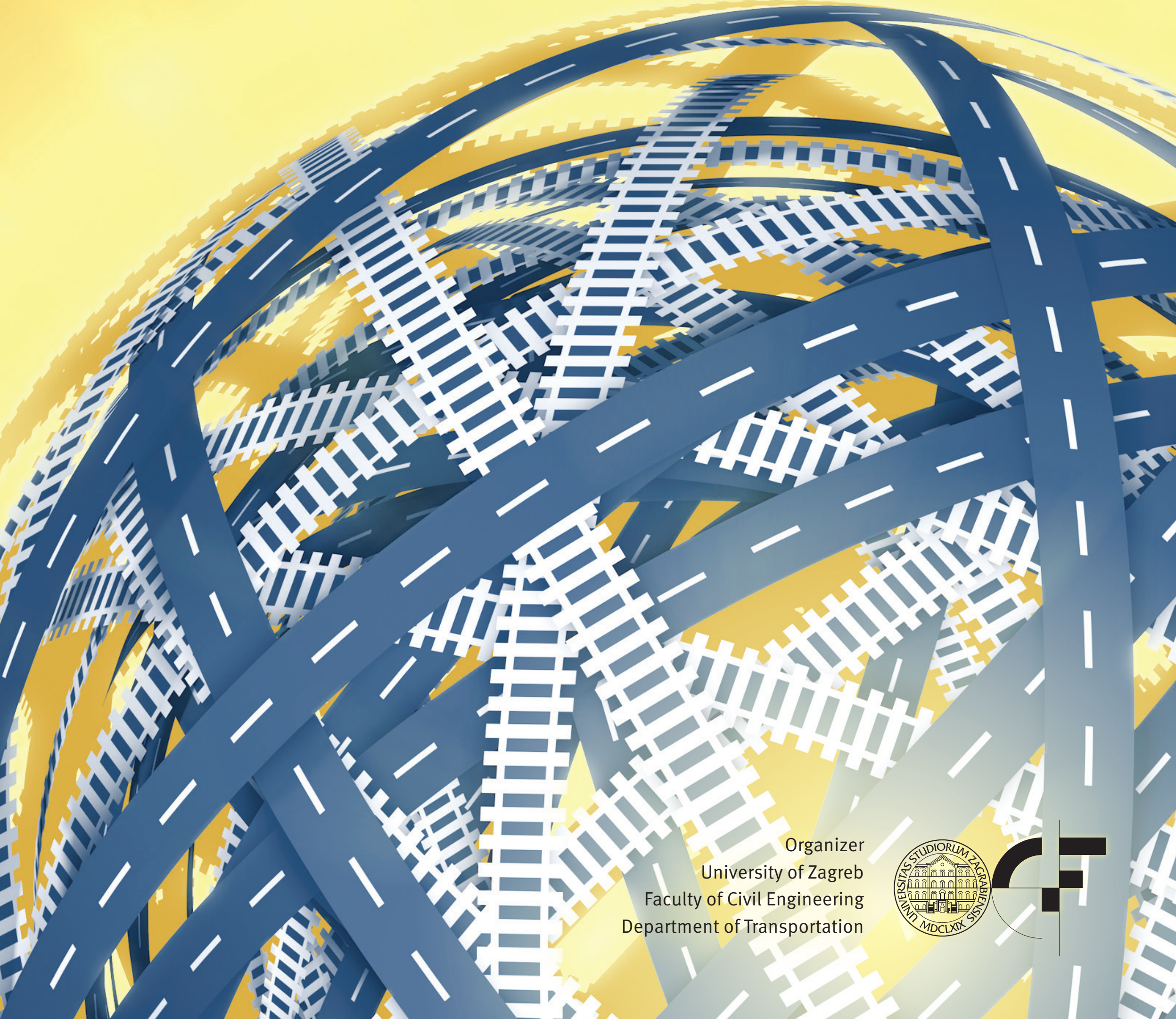
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure IV

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ACTUAL EFFICIENCY OF ROAD PAVEMENT REHABILITATION

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Abstract

Most European countries, including Hungary have already practically completed the development of highway network (excluding the construction of new motor-way sections and bypasses). Instead, the real challenge is the condition pre-servation of existing road network, among others, by properly planned, designed and executed pavement rehabilitation. This is the reason why the knowledge on the actual efficiency of various road rehabilitation techniques can be considered of utmost importance. 60 trial sections selected of Hungarian national highway network in 1991 have been yearly monitored since then. (Condition parameters systematically characterized are: bearing capacity, longitudinal and transversal unevenness, micro and macro texture, surface defects). However, the main aim of the already 25-year-old pavement monitoring is the development of ever im-proving pavement performance models for several road management purposes (done by KTI Institute for Transport Sciences Non-Profit Ltd., Budapest in a continuous research work) the condition data time series obtained can be utilized also for the evaluation of the actual road pavement rehabilitation techniques in Hungary. During such a long (25-year) monitoring period, it is obvious that almost every trial section ought to be rehabilitated (using surface dressing, thin asphalt layer, pavement strengthening) at least once. Since the monitoring of re-habilitated sections have continued after their condition improving intervention, the following information types could have been collected: actual condition level at intervention, actual condition improving effect for various condition parameters and deterioration trend in the pavement life cycle after rehabilitation compared to the previous one(s). KTI has carried out this kind of analysis, and can give information on the actual efficiency of various road pavement rehabilitation in Hungary for 14 combinations of pavement structure type (flexible, super-flexible, semi-rigid), traffic size (heavy, medium and light) and subgrade soil type (granular, intermediate, cohesive) based on the case studies performed.

Keywords: road rehabilitation, efficiency of road rehabilitation, trial section monitoring, pavement condition parameter, pavement life cycle

1 Introduction

Most European countries, including Hungary have already practically completed the development of their highway networks (excluding the construction of new expressway sections and bypasses). Instead, the real challenge is the condition preservation of existing road network, among others, by properly planned, de-signed and executed pavement rehabilitation. This is the reason why, the know-ledge on the actual efficiency of various road rehabilitation techniques can be considered of utmost importance. 60 trial sections of 500 m length selected of Hungarian national highway network in 1991 have been yearly monitored since then [1]. During such a long (25-year) monitoring period, it is obvious that almost every tri-al section ought to be rehabilitated. Since the monitoring of rehabilitated sections have continued after the condition improving intervention, the following informa-tion types could have been collected: actual condition level at intervention, actual condition improving effect for various condition parameters and deterioration trend in the pavement life cycle after rehabilitation compared to the previous one(s) [2]. The results of this research effort will be subsequently summarized, and discussed.

2 Trial section monitoring in Hungary

In Hungary, 60 sections of the public road network of “normal” traffic have been systematically monitored since 1991. The time data series of several condition parameters obtained from the test sections, made it possible to develop highway performance models for several pavement structural, traffic and environmental variants [3]. Semi rigid, flexible and super-flexible (macadam-type, unbound base) structure categories, three traffic categories (max 2,000 pcu/day, 2,001-5,000 pcu/day, min 5,001 pcu/day) and three environmental (subsoil type or bearing capacity) classes were considered. The realistic variants (combinations) of the parameters mentioned were represented by 4-6 test sections. The following con-dition parameters of the 500-m long trial sections have been evaluated, and ana- lysed:

- Longitudinal unevenness (IRI using laser RST)
- Rut depth (using laser RST)
- Macro texture (using laser RST)
- Micro texture (using laser RST)
- Bearing capacity (using KUAB falling weight deflectometer)
- Surface defects (visual evaluation aided by keyboard apparatus Road Master).

Besides, the traffic parameters of, and the major maintenance (rehabilitation) ac-tions on all sections have been collected. The major goal of trial section monitoring is the development of pavement per-formance models, the average (typical) deterioration curves in a structure-traffic-subsoil type combination. The performance models of the road categories can be attained by putting regression curves on the points representing condition para-meter levels as a function of time. (Similar curves are determined as a function of the traffic passed). The function types applied in the development of the HDM-III model organised by the World Bank [4] were selected for the condition para-meters. (Exponential functions were chosen for unevenness and rut depth, while linear functions for the other condition parameters monitored). The performance models for each road category and each condition parameter have been determined, every monitoring year, utilising also the latest condition information. Box-Whiskers test is applied to select and to exclude the outliers of the data series analysed [1].
No determined trends could be found for bearing capacity parameters (deflection value or stiffness modulus) yet as a function of time or traffic passed. The seasonal and the yearly strength fluctuations due to environmental reasons seem to be more pronounced than the fatigue of pavement structures.

3 Pavement rehabilitations on trial sections

The trial section monitoring in Hungary has been performed since 1991. During this 25-year period, a considerable share of the sections deteriorated to such an extent that some kind of rehabilitation (surface dressing, resurfacing or streng-thening) was needed. It was decided to go on with the regular condition evalua-tion since the additional survey could provide other kinds of useful information. The condition parameter levels in the years before and after the intervention can be utilised for the determination of the actual condition improving effect of various major maintenance techniques. Furthermore, the continuation of trial section monitoring for several more years can provide information about the deterioration trends after the intervention which can be compared to the tendencies during the former life cycle(s).

Between 1991 and 2015, 55 pavement sections (that is 92 % of the 60 trial sec-tions) were rehabilitated. Altogether 37 projects with pavement strengthening, 9 thin asphalt layers and 20 double bituminous emulsion surface dressings were built. (11 sections had two interventions during the period mentioned).
In group “pavement strengthening”, the overlaying above 40 mm asphalt layer thickness is taken into consideration. The effects of strengthening on surface defects, unevenness, rut depth, macro texture and micro texture were analysed.
In the group “resurfacing using thin asphalt layers”, the consequences of the same condition parameters were evaluated as in pavement strengthening group. For the surface dressed trial sections, mainly the changing in surface defects, macro and micro textures were evaluated; however, its influence to rutting and IRI-values was not disregarded, either.

4 Condition level before rehabilitation

Pavement management systems usually utilize intervention levels that are the given condition parameter values below which pavement operation is not econo-mical any more [5]. These levels are, of course, different in various road types (e.g. 2.5 m/km IRI-value on motorways). Since the actual values of intervention levels constitute a basic PMS information, their validation is of utmost importance. The long-term monitoring of trial sections offered a good opportunity for this validation.
There is here another important fact to be considered: the deterioration speeds of various pavement condition parameters are usually not identical. When the “most rapid” of them, the critical parameter reaches its intervention level – and thereby necessitates pavement rehabilitation – other parameters are still at a relatively appropriate level, at which the condition improving rehabilitation actions are not needed yet. (However, the typical rehabilitation techniques improve the actual condition of all parameters including the ones that are still at an acceptable level [4]). The analysis of trial section performance data makes it also possible to gather information on the critical condition parameters of different road types that can be considered as a basic knowledge for the further development of national pavement design theory and practice. Similarly, the actual levels of critical parameters before the condition improving actions coming from trial section monitoring are important piece of knowledge.
The ages of trial section wearing courses before strengthening were between 4 and 31 years. The most frequent pavement age happened be in the range of 11-15 years; however, 6 cases with 6-10 years, 4 cases with 16-20 years and 5 cases between 20-24 years were registered. (The pavement ages less than 6 years and above 24 years happened to be just exceptional).
The longitudinal unevenness, IRI-values of trial section pavements to be rehabili-tated were usually in the range of 1.1-2.6 m/km. (The only exception was an asphalt macadam pavement with 7.1 m/km IRI-value).
In case of thin asphalt layers, old wearing course ages and IRI-values were simil-ar to those of pavement strengthening. Rut depth range of trial sections before pavement strengthening took place bet-ween 1.5 and 14.8 mm. It is obvious that, in the cases with 1.5-5.0 mm rut depth, some other pavement condition parameter was the critical one necessitating re-habilitation. The condition data time series of trial sections have validated the pre-vious expectation according to which no thin asphalt layer can be effective if rut depth of old pavement surface exceeds 10 mm.
The initial longitudinal unevenness of trial section before surface dressing happened to be 1.8-3.6 m/km IRI-value on main roads and 4.0-6.0 m/km on secondary roads. The initial average rut depth amounted to 2.0-4.5 mm on main roads and 2.0-9.0 mm on secondary roads. The rather wide range of the macro texture of “old” pavement surface amounted to between 0.20 and 0.65. The mass of micro textures proved to be more homogeneous, with 0.13 and 0.38 extreme values.

5 Actual condition improving effect of pavement rehabilitation

Figure 1 shows the effect of pavement strengthening on the visual condition state (characterisation of surface defects). It can be seen that the originally medium-poor condition level (grades 3-5) changes into excellent (grade 1) or good (grade 2) one. The five points in Figure 1 actually represent information about 16 sec-tions, since the variant 4⇢1 occurs seven times, and 5⇢1 three times, while the variants 4⇢2, 3⇢1 and 5⇢2 twice. So, the results are close to the expected ones: 75 % grade 1 and 25 % grade 2. (The not fully perfect condition state, a single year after the construction, refers to quality problem during the execution).

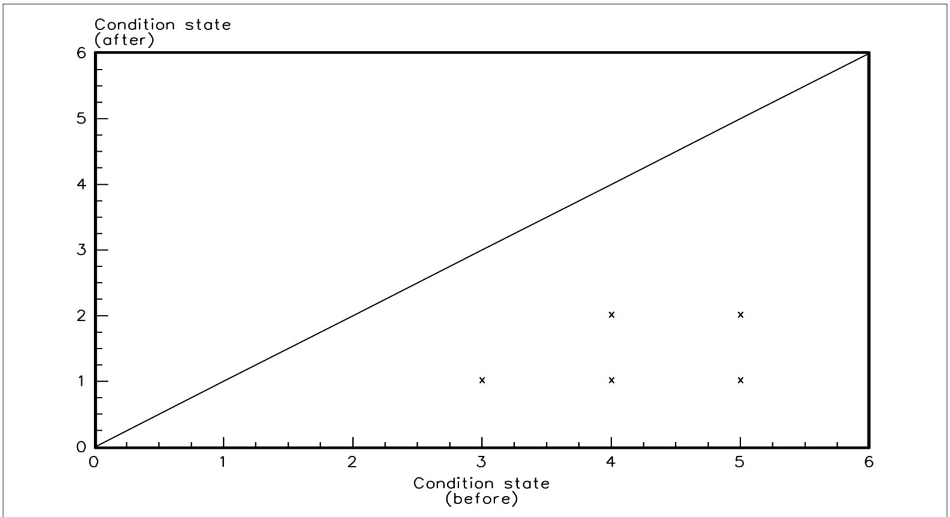

Figure 1 Effect of strengthening on surface defects (visual condition state)

Before and after surface dressing, all of the condition parameters mentioned be-fore were collected, and evaluated. The changing of texture parameters was considered of high importance [6]. The following consequences could be drawn:

- surface dressing is usually able to improve macro texture to a higher degree than surface micro texture (both parameters were characterized by dimensionless parameters measured by laser RST),
- usually an improvement by 0.10-0.20 could have been attained in macro roughness, however, in two cases, much higher (0.43-0.78) increases were reached,
- on one of the trial sections, a slight worsening of macro texture was observed, although, this case, the initial surface macro texture had been rather high (0.46),
- typically, 0.05-0.13 micro texture improvement could be detected after surface dressing; however, an increase of 0.22 and another one of 0.41 were observed (in this latter case, there has been an extreme improve-ment in macro texture, as well),
- it is worthwhile to mention that, on the trial section where macrotexture worsened after surface dressing, micro texture also decreased slightly (by 0.01).

6 Deterioration trends before and after rehabilitation

The deterioration of pavements after rehabilitation, e.g. strengthening without mill-ing old layer(s) depends on various, partly controversial factors, among others, thickness and quality of new asphalt layer(s), the quality of remaining, old pave-ment layers and the traffic progression factors. The actual deterioration (and duration of new life cycle) is originated from the combination of influencing para-meters. The deterioration features of two typical trial sections – as case studies – are compared before and after the condition improving intervention (pavement strengthening or surface dressing).

Figure 2 presents the deterioration curve of a trial section showing the trends before and after a pavement strengthening done in 2002. The trends of surface defects ("Rbal"), rut depth ("Knyom") and IRI are shown on the figure [1]. The following statements can be made when comparing the deterioration curve "parts" of various condition parameters before and after the intervention in 2002:

- surface defects characterized by Road Master aided, 5-graded visual inspection reached the worst (5) score in the "before" life cycle already at the age of 11 years (the trial section had been constructed in 1989), while the deterioration during "after" life cycle is considerably slower showing still a medium condition level (grade 3) after 12 years in 2014;
- the average rut depth of the section in 2 years before the pavement strengthening – at the age of 11-13 years – was around 8 mm, the same level was attained after 10 years in the "after" life cycle proving the similarity of the two rut depth progression trends;
- trend of IRI values is practically not influenced by the pavement rehabili-tation, since it is continuously around 2 m/km proving that longitudinal unevenness constitutes very rarely the critical condition parameter of Hungarian main roads with relatively thick pavement structure.

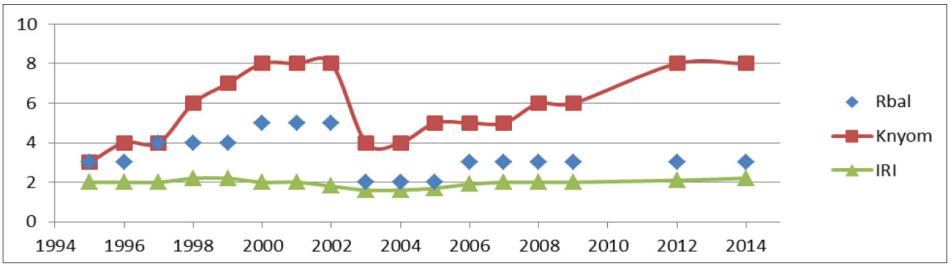

Figure 2 Deterioration curve of a trial section before and after a pavement strengthening in 2002

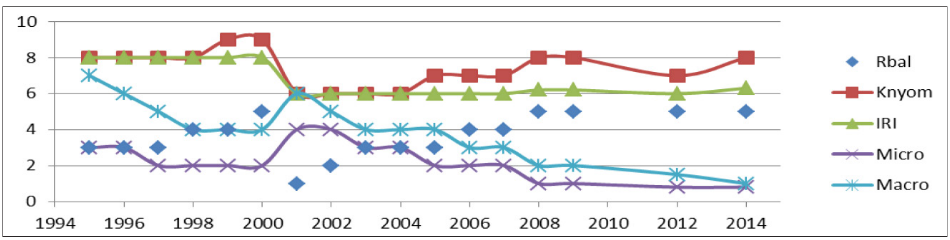

Figure 3 Deterioration curve of a trial section before and after a surface dressing in 2001

Figure 3 shows the deterioration curve of a trial section before and after a surface dressing in 2001. (A former surface dressing was carried out in 1992). The trends of surface defects ("Rbal"), rut depth ("Knyom"), IRI, micro roughness and macro roughness are shown [1]. The following statements can be made when compar-ing the deterioration curve "parts" of various condition parameters before and after the intervention in 2001:

- during the "before" life cycle, the worst (5) grade of surface defects had been reached in 2000, at the age of 8 years, while, in the "after the sur-face dressing in 2001" life cycle, the same poor condition level surface was attained at the age of 7 years (2008), that is the deterioration trends of surface defects during the two life cycles are similar to each other;
- 8-9 mm rut depth could be measured at the age of 8-9 years, at the end of the "before" life cycle, similarly, 7-8 years were needed in the "after" life cycle to attain the same level (it

should be also emphasized that the surface dressing could reach, not surprisingly, just a reduction of 3 mm in the average rut depth);
- the second period of "after" life cycle was characterized by a rather high (8 m/km) average IRI-value, the pavement rehabilitation by surface dressing can reduce IRI by 2 m/km, and, a bit surprisingly, this 6 m/km value was measured, almost unchanged, during the first 13 years of the "after" life cycle; in such a way, a significant improvement can be seen in the second life cycle (the reason can be the effective and durable waterproofing effect of the double surface dressing);
- the dimensionless micro texture parameter measured by laser RST had reached the rather poor (0.2) level at the age of 6-8 years, at the end of the "before" life cycle, surface dressing had improved its value to the level of 0.4 that have deteriorated to 0.2 in 4-5 years, and even to an extremely poor level of 0.1 in 7-8 years proving that surface dressing could not fulfil one of its main tasks, the durable improvement of surface micro texture;
- the dimensionless macro texture parameter measured by laser RST had reached the level of 0.4 at the age of 6-8 years, at the end of the "be-fore" life cycle, surface dressing had improved its value to the reason-able level of 0.6 that have deteriorated to 0.4 in 2-3 years and to a poor level of 0.2 in 7-8 years, and even to an extremely poor level of 0.1 in 12-13 years proving that surface dressing could not fulfil one of its main tasks, the durable improvement of surface macro texture.

7 Conclusion

Based on the results of the two trial section case studies (Figures 2 and 3), the following general statements can be made:
- the typical condition parameters of Hungarian asphalt pavements (the very poor levels of which necessitate rehabilitation actions) are surface defects and/or rut depth;
- the actual condition state of a critical parameter at the time of reha-bilitation is usually below the "official" intervention level specified in relevant standards or technical directives due to the typical shortage of financial means available in road sector;
- the actual condition improvement in various parameters covers a rather wide range depending mainly on the quality level of old structure, design and construction features; the "rehabilitated" condition very rarely reaches that of the original, newly built pavement;
- deterioration trends before and after pavement rehabilitation are typ-ically similar; however, local extreme traffic, design, construction, main-tenance and/or climatic conditions can induce basic differences between them.

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