Goran Mijoski
PhD, Associate Professor
University “S’s. Cyril and Methodius”
Faculty of Civil Engineering – Skopje
mijoski@gf.ukim.edu.mk

Marjana Topalovska Angjelevska
Head of asphalt department
GD GRANIT AD Skopje, OU Laboratory
marjana.topalovska@granit.mk

Lazar Nikolic
Manager
GD GRANIT AD Skopje, OU Laboratory
lazar.nikolic@granit.mk

Nedzat Bajrami
Manager of RAMS (Road Asset Management System) Unit
Public Enterprise for State Roads
n.bajrami@roads.org.mk

IMPACT OF DIFFERENT PAVEMENT REHABILITATION TYPES ON DRIVING SURFACE ROUGHNESS QUALITY

There are more factors from bond vehicle - road condition that have significant impact on driving comfort on the road. One of indicators in this bond is roughness of roadway surface (smoothness), and with this indicator safe and comfortable driving at designed speed on particular roadway is ensured.

One of the most important surface parameters of every roadway is longitudinal roughness which is functionally connected with maximum allowed driving speed. Longitudinal roughness, expressed through International Roughness Index (IRI) is significant parameter which have to be achieved on pavement surface.

The occurrence of excessive plastic deformation, fatigue and the appearance of cracks in the pavement structure are factors that require on-going quest for a technical solution in order to obtain high quality flexible road construction especially for highways and roads with very heavy traffic load. Applying a design solution by overlaying or one-layer upgrading of pavement structure, is usually limiting factor in achieving of the required roughness.

Keywords: longitudinal roughness, pavement structure, reconstruction, rehabilitation

1. INTRODUCTION

In this paper, main attention is paid to pavement surface longitudinal roughness expressed through the International Roughness Index (IRI), as one of the most important surface characteristics of each road. It is evident that roughness has a great impact on driving comfort and safety, but this pavement surface factor is variable during the exploitation of roads and depends on many influential factors.

To determine the impact of different types of rehabilitation in the road construction on road surface roughness quality, the International Scientific Project "Application of PmB in the base asphalt layers of the pavement construction at the roads with the heavy traffic loading and motorways " [1] determines the so-

called "Zero / initial" measurement of the roughness index (IRI) on a specific section of the Motorway A1 (E-75): "Negotino - Demir Kapija" (left motorway) from km 121 + 800 to km 115 + 224.

2. CHARACTERISTICS OF THE EXPERIMENTAL SECTION

The section subject to this measurement was constructed in accordance with the project Reparing and Rehabilitation of Motorway A1, section: "Negotino - Demir Kapija" in the period July/2018 to November/2018 by the contractor GD GRANIT AD Skopje. The installation of the final wearing course was completed with an electronically guided spreader supported by large MultiPlex skis, covering the full width of the road (approximately 11 m), an ideal technology that levels out any uneven road surface, undulations and irregularities. MultiPlex skis operate on the principle of non-contact scanning of the values in relation to the surface, with three laser sensors placed on both sides of the spreader at a height ranging from 250 mm to 650 mm.

The experimental section is divided into 3 subsections that differ in terms of type of rehabilitation performed:

Sub-section 1 – New motorway construction – (section where reconstruction was performed by replacement on capping layer, sub base (base course) and three layers of asphalt pavement): complete rehabilitation of the subgrade, sub base (base course) and asphalt pavement were performed on section from km 115+040 to km 116+990, at 195m length. Total thickness of pavement structure is 89 cm with following structure and dimensions:

- **Embankment of stone material** in depth of min 30 cm
- **Improved capping layer** in depth of 40 cm
- **Sub base (base course)** in depth of 30cm

Total asphalt pavement on this section is 19 cm, three layer asphalt pavement type:

I layer: Asphalt base type BNS 32sA, at 7cm thickness,

II layer: Asphalt base BNS 22sA at 6cm thickness,

III layer: Asphalt wearing course AB 16s with polymer modified bitumen PmB (45/80-65) at 6cm thickness.

Sub-section 2 – Rehabilitation – (section where rehabilitation was performed with a single-layer upgrade, e.g. overlaying on asphalt wearing course and local repair of asphalt base was performed): it's consist of two sections – section from km 116 + 990 to km 119 + 881, at 2.891 m length and section from km 120 + 228 to km 122 + 984, at 2.756 m length. The overlay on asphalt wearing course was performed with asphalt mixture type AB 16s polymer modified bitumen PmB (45/80-65) at 6 cm thickness. Total asphalt pavement on this subsection (new and existing asphalt pavement) is ≈17 cm;

Sub-section 3 – Existing pavement structure – (on this sub-section, no intervention was made): Due to planned construction of a Toll station on the section from km 119 + 881 to km 120 + 228, at 347 m length, construction activities weren't performed.

Concerning the total thickness of all asphalt layers in the road construction, the sections are categorized in one group.

3. IN SITU MEASUREMENT OF THE SURFACE ROUGHNESS OF THE LEFT MOTORWAY OF THE SECTION: "NEGOTINO – DEMIR KAPIJA" (LEFT MOTORWAY) FROM KM 121 + 800 TO KM 115 + 224

In order to notice the differences in the quality of driving surface roughness among different types of interventions, the roughness of approximately the entire section on which construction activities took place from km 115 + 040 to km 122 + 984 was measured. The measurement of the section was performed on 9/11/2018 on a stretch from km 121 + 800 to km 115 + 224 in the direction from Demir Kapija to Negotino, at 6,576 km length. It was conducted with Dynatest Road Surface Profilometer ® 5.051 Mark II, a high speed inertial profile measuring device owned by the PE for State Roads (Figure 1).

Figure 1. Initial chainage for measuring evenness

The criterion for expressing the longitudinal road surface roughness of the motorway is the International Roughness Index IRI - International Roughness Index [m / km], which is applied in the most European countries and worldwide.

In the interest of laser beam reflection accuracy, the roughness measurement was performed on a clean and dry surface, according to the standard EN 13036-5 *Road and Airfield Surface Characteristics - Test methods - Part 5: Determination of Longitudinal Unevenness Indices (EN 13036-5: 2019*). The measurement was performed with three laser units, each measuring one longitudinal profile, while these three profiles covered 3 positions (left, middle and right) of a traffic lane. Both the driving and the fast traffic lane, were individually measured.

4. ANALYSIS OF THE INITIAL AND EXPLOITATION ROUGHNESS OF THE DRIVING ASPHALT SURFACE ON THE LEFT MOTORWAY ON SECTION: "NEGOTINO - DEMIR KAPIJA" (LEFT CARRIAGEWAY) FROM KM 121 + 800 TO KM 115 + 224

In the Republic of Macedonia, measuring of the roughness through the International Roughness Index is not foreseen in the existing technical regulations, whereby the roughness is measured with 4 meter-long measuring laths. At the same time, no distinction is made between assessments of driving surface roughness of the exploited roads, new constructions, as well as different types of rehabilitations. For that reason, the assessment of the condition of the driving area is conducted according to Croatian regulations, taking into account the size of the traffic load, the category of the road, the type of intervention and the projected driving speed, enlisted under Table 1.

Table 1. Evaluation criteria for longitudinal evenness

Asphalt pavement category		Scope of construction works	Designed roughness index IRI_P *[m/km]*	Tolerance limit as per roughness index IRI_T *[m/km]*	Unacceptable roughness index IRI_N *[m/km]*
Motorway	New motorway construction	Newly constructed asphalt pavement within new contraction of the motorway (without structures)	$IRI_{DMN} \leq 0,90$	$IRI_{TMN} = 1,05$	$1,35 \leq IRI_{UMN}$
	Overlay	Newly constructed asphalt courses within overly of the motorway (without structures)	$IRI_{DMO} \leq 1,10$	$IRI_{TMO} = 1,30$	$1,70 \leq IRI_{UMO}$
	Structures	Newly constructed asphalt surface on structures as a part of a motorway (new construction and overlay)	$IRI_{DMS} \leq 1,65$	$IRI_{TMS} = 2,10$	$2,45 \leq IRI_{UMS}$
National road	New construction	Newly constructed asphalt pavement within new construction of the national road	$IRI_{DNN} \leq 1,15$	$IRI_{TNN} = 1,35$	$1,65 \leq IRI_{UNN}$
	Strengthening/ Reconstruction	Newly constructed asphalt courses within reconstruction of the national road	$IRI_{DNR} \leq 1,40$	$IRI_{TNR} = 1,70$	$2,30 \leq IRI_{UNR}$
	Overlay	Newly constructed asphalt courses within overlay of the national road	$IRI_{DNO} \leq 2,15$	$IRI_{TNO} = 2,55$	$3,00 \leq IRI_{UNO}$
City roads		Newly constructed asphalt courses within new construction and reconstruction of the city roads	$IRI_{PC} \leq 2,00$	$IRI_{TC} = 2,45$	$2,85 \leq IRI_{UC}$

The driving and the fast lane roughness index was evaluated for the entire section, at 6,576 km length, and the evaluation criteria are taken for 2 road categories: motorway reconstruction (rehabilitation) and new construction (complete reconstruction).

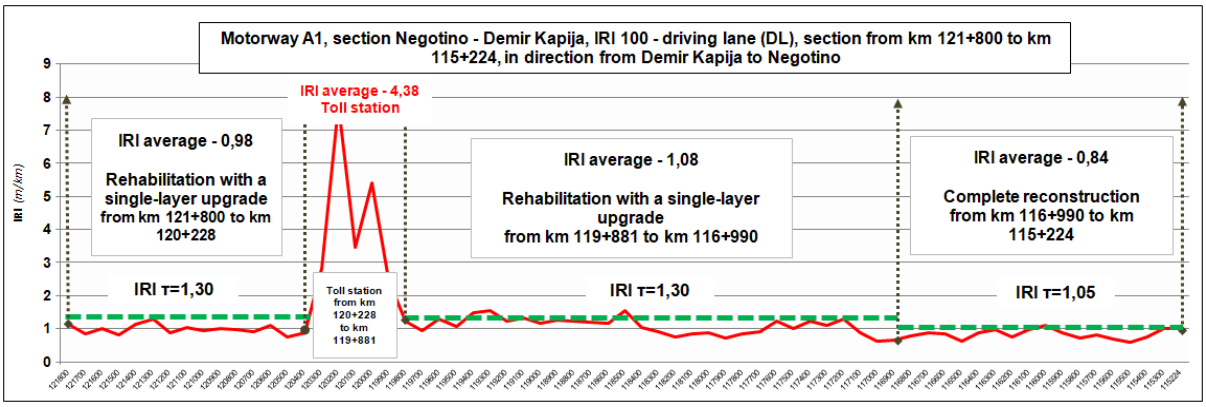

Figure 2. Measured values of IRI_{100} for the section on driving lane (DL) – section from km 121+800 to km 115+224

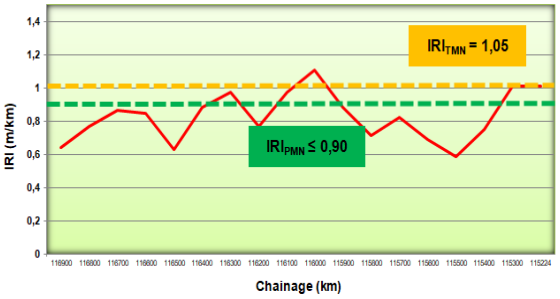

Figure 3. Measured values of IRI100 (IRI100AVG = 0,84 *(m/km);* IRI100max = 1,11 *(m/km);* IRI100min = 0,59 *(m/km))* for the section on driving lane (DL) – section where complete reconstruction has been performed – from km 116+990 to km 115+224

Figure 2 and Figure 5 show the IRI_{100} exploitational roughness of the entire measured section of the driving lane and the fast lane from km 121 + 800 to km 115 + 224, according to the criteria for tolerance limits as per roughness index enlisted under Table 1, for a new asphalt construction as part of new motorway construction (IRI_T = 1.05) for the section where complete reconstruction was performed (from km 116 + 990 to km 115 + 224) and in accordance with the criteria for tolerance limit as per roughness index for newly constructed asphalt courses within reconstruction of the motorway (IRI_T = 1.30) for the section where rehabilitation was performed with a single-layer upgrade (from km 121 + 800 to km 120 + 228 and from km 119 + 881 to km 116 + 990).

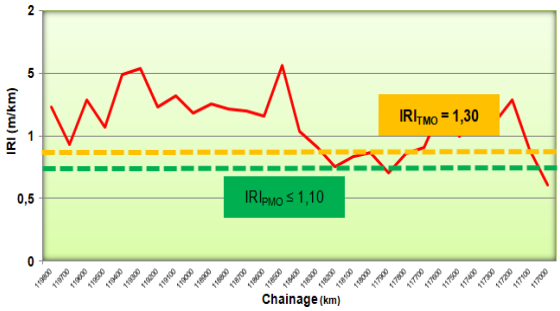

Figure 4. Measured values of IRI_{100} (IRI_{100AVG} = 1,08 *(m/km);* IRI_{100max} = 1,56 *(m/km);* IRI_{100min} = 0,61 *(m/km))* for the section on driving lane (DL) - section where rehabilitation was performed with a single-layer upgrade – from km 119+881 to km 116+990

The statistical calculation was performed on all measured values of IRI_{100} on both lanes, in terms of the type of rehabilitation, separately by subsections and for the entire section, and the characteristic statistical data are presented in Table 2 and Table 3.

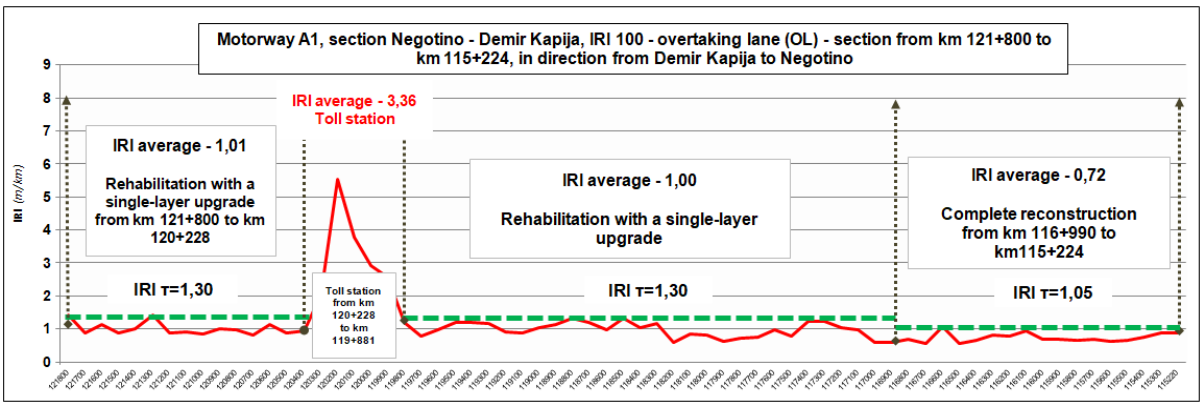

Figure 5. Measured values of IRI100 for the section on fast lane (OL) – section from km 121+800 to km 115+224

Table 2. Statistical data for IRI_{100} for the entire section and separately by subsections – DL

IRI_{100} for sub-section:	**min.**	**max.**	**Average IRI_{100AVG} *[m/km]***	**St. Dev.**	**Criteria**
Complete reconstruction Section km 115+224 to km 116+990	0.59	1.11	**0.84**	0.14	$IRI_{PMN} \leq 0,90$ $IRI_{TMN} = 1,05$ (motorway – new construction)
Rehabilitation with a single-layer upgrade Section km 116+990 to km 119+881	0.61	1.56	**1.08**	0.25	$IRI_{PMO} \leq 1,10$ $IRI_{TMO} = 1,30$ (rehabilitation of a motorway)
Rehabilitation with a single-layer upgrade Section km 120+228 to km 121+800	0.77	1.30	**0.98**	0.14	$IRI_{PMO} \leq 1,10$ $IRI_{TMO} = 1,30$ (rehabilitation of a motorway)
Existing asphalt pavement – part for Toll station km 119+881 to km 120+228	2.46	7.76	**4.38**	2.20	/
Entire section Section km 121+800 to km 115+224	0,59	7,76	1,25	1,08	$IRI_{PMO} \leq 1,10$ $IRI_{TMO} = 1,30$ (rehabilitation of a motorway)

Table 3. Statistical data for IRI_{100} for the entire section and separately by subsections – OL

IRI_{100} for sub-section:	**min.**	**max.**	**Average IRI_{100AVG} *[m/km]***	**St. Dev.**	**Criteria**
Complete reconstruction Section km 115+224 to km 116+990	0.54	1.07	**0.72**	0.14	$IRI_{PMN} \leq 0,90$ $IRI_{TMN} = 1,05$ (motorway – new construction)
Rehabilitation with a single-layer upgrade Section km 116+990 to km 119+881	0.60	1.34	**1.00**	0.21	$IRI_{PMO} \leq 1,10$ $IRI_{TMO} = 1,30$ (rehabilitation of a motorway)
Rehabilitation with a single-layer upgrade Section km 120+228 to km 121+800	0.81	1.43	**1.01**	0.19	$IRI_{PMO} \leq 1,10$ $IRI_{TMO} = 1,30$ (rehabilitation of a motorway)
Existing asphalt pavement – part for Toll station km 119+881 to km120+228	2.01	5.54	**3.36**	1.37	/
Entire section Section km 121+800 to km 115+224	0.54	5.54	1.10	0.76	$IRI_{PMO} \leq 1,10$ $IRI_{TMO} = 1,30$ (rehabilitation of a motorway)

Based on driving and fast lanes roughness assessment for the entire section, including all subsections, it can be concluded that only the tolerable limit as per index of roughness for the criterion of road reconstruction - rehabilitation is met. If the assessment excludes the section on which no intervention was made and each sub-section is analyzed separately in terms of rehabilitation type, then the results change/improve drastically, whereby all criteria are met. Notably, the section Complete Reconstruction meets the criteria for Motorway – New Construction (new motorway construction), while for section Rehabilitation meets the criteria for Motorway - Reconstruction.

The average value for IRI_{100AVG} for the section where complete rehabilitation has been performed is 0.84 *[m/km]* for the driving lane and 0.72 *[m/km]* for the fast lane, which according to the evaluation criterion for Motorway - New Construction, classifies within the projected roughness index **$IRI_{PMN} \leq 0,90$** which is the highest roughness level.

In addition to this, the average value for **IRI_{100AVG}** for the section where rehabilitation was performed with a single-layer upgrade falls within the framework of 0.98 to 1.08 *[m/km]* for the driving lane and 1.01 *[m/km*] for the fast lane, which according to the evaluation criterion for Motorway - Reconstruction, can be classified within the projected roughness index **$IRI_{PMN} \leq 1,10$,** the highest roughness level.

This statement imposes the need to draft regulations with gradation of the road (traffic load) and the type of intervention on the road.

5. CONCLUSION

The roughness of the road is one of its main features and one of the first features that users notice during driving.

It is important to note that roughness - or unevenness of the roads has an impact on travel comfort and on road safety also.

Based on the results of driving surface longitudinal roughness measurements expressed through the IRI, the following can be concluded:

- The analysis of the measured results indicates the conclusion that there is a significant difference in the value of the evaluated roughness, between the measured average value for **IRI_{100AVG}** for the whole section and by sections, visible from fig. 2 and 5.
- The results of the examination showed that there is a difference in the achieved level of roughness depending on the type of intervention of the pavement construction. It is concluded that the highest level of roughness was achieved during new pavement construction (**IRI_{100AVG}** for the part where complete rehabilitation was performed is **0.84** *[m/km]* for the driving lane and **0.72** *[m/km]* for the fast lane), and then at single-layer rehabilitation (**IRI_{100AVG}** ranges from **0.98** to **1.08** *[m/km*] for the driving lane and **1.01** *[m/km]* for the fast lane), while on the

section of the existing pavement construction, we have the lowest roughness level (**IRI_{100AVG} = 3.36** *[m/km]).* (Tab.2 & Tab. 3)

- Measurements were made on the two driving lanes of the motorway (driving and fast lane), in order to monitor the further condition of the roughness of the pavement surface in relation to the impact of traffic load, in the phase of exploitation.
- The evaluation of the longitudinal roughness in the absence of domestic, is made according to foreign regulations. Although Republic of Macedonia has modern equipment for this purpose, has not yet adopted its own regulations in this area. The need for preparation of appropriate Macedonian regulations for roughness is imposed to the authorities, respecting all influential factors and specifics such as: road class, traffic load, the type of road intervention (rehabilitation, reconstruction, new construction), road in operation or new construction, etc

REFERENCES

[1] Application of PmB in the base asphalt layers of the pavement construction at the roads with the heavy traffic loading and motorways.

[2] Dr. W. James Wilde, P.E., Department of Mechanical and Civil Engineering, Minnesota State University, Mankato, Implementation of an International Roughness Index for Mn/DOT Pavement Construction and Rehabilitation, Final Report, Published by: Minnesota Department of Transportation, Research Services Section, 395 John Ireland Boulevard, MS 330, St. Paul, Minnesota 55155-1899.

[3] Ufuk Kırba¸, Department of Civil Engineering, Ondokuz Mayis University, IRI Sensitivity to the Influence of Surface Distress on Flexible Pavements.

[4] Miroslav Šimun, Mate Sršen, Ravnost kolničkih zastora na gradevinama cestovne infrastructure. Miroslav Šimun, Mate Sršen, Kriteriji uzdužne ravnosti vozne površine asfaltnih kolnika.

[5] Kelly L. Smith, Leslie Titus-Glover, Lynn D. Evans, Pavement Smoothness Index Relationships: Final Report, PUBLICATION NO. FHWA-RD-02-057

[6] EN 13036-5 Road and airfield surface characteristics — Test methods — Part 5: Determination of longitudinal unevenness indices.

[7] ASTM, “Computing International Roughness Index of Roads from Longitudinal Profile measurements”, E1926-98, ASTM Standards.

[8] Karamihas S.M., and T.D. Gillespie et al. “Guidelines for Longitudinal Pavement, Profile Measurement”, TRB - NCHRP Report 434, Washington D.C., 1999.

[9] Perera, R.W., Byrum, C., and Kohn, S.D. (1998). Investigation of Development of Pavement Roughness, *FHWA-RD-97-147,* McLean, VA, USA.