Analysis of bus station pavement structure condition in the City of Rijeka

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Abstract: Road network condition deteriorates over time because of the climatic and meteorological conditions, traffic loading and insufficient maintenance. Bus stations on urban road network are especially exposed to premature damage appearance due to specific loading conditions. In this paper an analysis done at the chosen bus stations in Rijeka city is presented. Different parameters were measured and analysed and suggestions for maintenance of analysed pavements are defined.

Key words: pavement structure, bus stations, distress

Analiza stanja kolničkih konstrukcija na autobusnim stajalištima u Gradu Rijeci

Sažetak: Stanje prometnih površina degradira se uslijed klimatskih i meteoroloških uvjeta, prometnog opterećenja i nedovoljnog održavanja. Unutar gradske prometne mreže autobusne postaje su zbog specifičnog opterećenja osobito podložne prijevremenoj pojavi oštećenja. U radu je prikazana analiza stanja kolničkih konstrukcija autobusnih stajališta provedena u gradu Rijeci. Provedena su mjerenja i analize za više parametara što je rezultiralo preporukama za obnavljanje analiziranih kolničkih konstrukcija.

Ključne riječi: kolnička konstrukcija, autobusna postaja, oštećenja

1. INTRODUCTION

Performance of hot asphalt mixtures is affected by a number of factors, such as traffic load, material properties, temperature, moisture, freezing, aging etc. However, different studies indicate that heavy traffic load is the most important of these parameters [1]. Due to the prevailing conditions of traffic flow in urban conditions (lower speeds, congestions), pavement structure is exposed to continuous static load resulting in longer loading time and greater stresses and strains [2]. Research indicates that damage to pavement structures also increases with roughness of pavement surface and can reduce pavement serviceability up to 40% [3]. In addition, tangential stresses from breaking and moving manoeuvres of heavy vehicles at high temperatures also increase distresses in asphalt pavement surface [4].

This is especially important in pavement structures with increased traffic load, such as bus stations, which are more critical in terms of resistance to permanent deformations.

During 2015, the pavement condition was analysed on selected bus stations in Rijeka city centre, where a large number of movements and stops of urban public transport vehicles are registered. At all bus stations, pavement condition was visually assessed and evenness, macrotexture and deflection were measured. This paper presents the results of an analysis of the conducted measurements used for pavement condition evaluation on bus stations. The analysis results were used for proposal of some general maintenance/reconstruction measures.

2. MICROLOCATION OF THE ANALYSED AREA

The city of Rijeka is situated in the west of Croatia, on the northern coast of the Rijeka bay. It is a significant regional traffic node, situated on the pan-European corridor Vb (Rijeka - Zagreb - Budapest). In geographical terms the city is characterized by longitudinal extension in the east-west direction and limitation in traffic network expansion due to the narrow corridor caused by the relief [5].

The road network in the city centre is limited by the existing urban infrastructure. For the purpose of this research, bus stations in the wider city zone with highest traffic volumes are analysed. Their positions are shown in Figure 1.

Figure 1. Orthophoto view of the analysed area [6]

Analysed road network mostly consists of multi-lane roads and is only partially intended for urban public transport. Bus stations in the observed area are made as flexible pavement structures with asphalt surfacing.
In addition to maximum loads, it is important to note that bus stop pavement surfaces are also subjected to significant temperature stresses due to low positioned bus engines, which

is particularly emphasized during the summer when average pavement temperatures are already high, ranging up to 60 °C in Rijeka [7].

Traffic volumes of bus stops were determined from city bus lines timetable data, as shown in Table 1.

Table 1. Traffic volumes of bus stops (veh/day) [8]

Bus stop mark	No. of buses passing through / stopping	Bus stop mark	No. of buses passing through / stopping
1	601	10	451
2	40	11	607
3	276	12	215
4	618	13	371
5	618	14	215
6	451	15	215
7	236	16	40
8	40	17	40
9	40		

3. ANALYSIS OF THE EXISTING CONDITION OF PAVEMENT STRUCTURES

Pavement condition assessment is the process of pavement testing in order to evaluate structural and functional performance of the existing pavement structure. Pavement structural condition defines pavement structure capacity to carry the existing and planned traffic loads, while pavement functional condition relates to pavement ability to provide a surface adequate for safe and comfortable driving. The aim of pavement evaluation is the determination of current pavement structural and functional condition in order to identify critical locations and priorities for the maintenance or reconstruction plan. In addition, pavement evaluation is a valuable tool for continuous pavement monitoring and for prediction of the future pavement condition [9]. In this paper, pavement evaluation was performed using the collected data from visual inspection of pavement surface and pavement evenness, macrotexture, rut depth and deflection measurements. All measurements were performed with the equipment obtained from the project Research Infrastructure Development at the University of Rijeka campus.

3.1 Visual inspection

Pavement surface visual inspection is performed on all bus stations (shown in Figure 1.) in order to determine the type, intensity and size of distresses, but also to define reference locations further measurements. The visual inspection resulted in identification of damages in the form of cracks (longitudinal, transverse and cracks due to material fatigue), patches and potholes in almost every inspected location. The rutting and shoving damage types were observed on stops subjected to higher loads.

The reference bus stations included in further analysis were determined based on their geo-traffic position and collected data of damage types [10].

3.2 Pavement evenness

Pavement surface must be designed to ensure comfortable and safe vehicular traffic at designed speeds. One of the parameters directly influencing these requirements is pavement surface evenness (or roughness). Pavement evenness is defined as the deviation of a pavement surface from a planar surface (measuring device) in the wavelength range from 0.5 to 50 m [11]. Pavement evenness is presented by the International Roughness Index (IRI), which is calculated by the sum of vertical oscillations of the vehicle base over the road section. The roughness index represents a measure of ride comfort on a particular road section [12].

Roughness measurements were conducted using vehicle-installed laser profilometer system Hawkeye 2000 (Figure 2).

The technical parameter of roughness (IRI) was measured along the right and left wheelpath on the selected locations. For the purposes of the paper, the mean value of roughness index IRI was analysed. The measured values and condition assessment in terms of evenness are shown in Table 2.

Figure 2. A view of the measurement vehicle Hawkeye 2000

Table 2. Measured IRI values at the analysed locations

Location	Mean IRI [m/km]	Classification according to IRI_N	Classification according to index rating
1 – Fiumara	3.20	Unsatisfactory	Acceptable
7 – Manzzoni	8.29	Unsatisfactory	Very poor
8 – F.La Guardia (descent)	4.72	Unsatisfactory	Poor
9 – F.La Guardia (ascent)	4.67	Unsatisfactory	Poor
10 – Railway station	6.06	Unsatisfactory	Very poor
14 – Potok (descent)	3.85	Unsatisfactory	Poor
15 – Potok (ascent)	7.23	Unsatisfactory	Very poor
16 – Victims of Fascism	7.05	Unsatisfactory	Very poor

Based on the statistical probabilistic analysis of a sufficiently large number of IRI_{100} data values measured on representative measurement sections of constructed asphalt pavement surfaces of public roads throughout the Republic of Croatia, the road class was adopted depending on the scope of construction works and the following limit roughness criteria for urban roads [12]:

- IRI_P – designed (expected) lower limit roughness index ($IRI_P \leq 2.00$)
- IRI_T – tolerant limit roughness index ($IRI_T \leq 2.45$)
- IRI_N – unacceptable upper limit roughness index ($2.85 \leq IRI_N$)

Analysis of the presented IRI roughness index measurements on the analysed bus stops shows that the average values are within the range 3.20 <IRI <8.29. By comparison with the given limit criteria for urban roads, it can be concluded that the analysed bus stops are unsatisfactory regarding the evenness criterion [12]. By comparison according to index rating, it can be concluded that it is acceptable only on bus stop 1.

3.3 Pavement macrotexture

Asphalt pavement surface texture is an important factor in traffic safety since it directly affects pavement surface skid resistance. Surface texture is defined as the deviation of the pavement surface from an ideal planar surface and can be divided into four categories in terms of range of wavelengths that a particular category includes: microtexture, macrotexture, megatexture and roughness or unevenness [13, 14]. Pavement surface skid resistance results from the effects of surface microtexture and macrotexture, where macrotexture governs skid resistance at high speed and under wet pavement conditions. Pavement surface macrotexture represents irregularities in the wavelength range from 0.5 mm to 50 mm, and it is the result of asphalt mixture properties such as aggregate type, size and shape of aggregate grains, nominal maximum aggregate grain in the mixture, bitumen and air voids content, but also the asphalt pavement construction process and applied surface treatments. The hysteretic component of frictional force, caused by the energy loss due to the vehicle tire deformation while moving across the pavement surface, is the result of surface macrotexture [15].

Non-contact macrotexture measurements with laser technology on longer sections are usually performed using a vehicle-installed laser profilometer, so there is no need for special traffic regulation during the measurements [15]. The most common macrotexture measurement result obtained by non-contact methods is the technical parameter mean profile depth (MPD).

The measurements were performed with the Hawkeye 2000 measurement system described in chapter 3.2. The technical parameters of macrotexture were measured along the right and left wheelpath on the selected bus stations and the mean MPD value was analysed. The measured values are shown in Table 3.

Table 3. Measured MPD values at the analysed locations

Location	Average MPD [mm]	Classification according to COST 354 [16]
1 – Fiumara	0.45	Poor
7 – Manzzoni	0.42	Poor
8 – F.La Guardia (descent)	0.52	Unsatisfactory
9 – F.La Guardia (ascent)	0.63	Unsatisfactory
10 – Railway station	0.45	Poor
14 – Potok (descent)	0.37	Poor
15 – Potok (ascent)	0.54	Unsatisfactory
16 – Victims of Fascism	0.78	Satisfactory

Since there are no national technical requirements related to macrotexture evaluation expressed through MPD, this paper uses the limit values specified by the COST 354 project in the final report "Performance indicators for road pavements".

Analysis of the presented macrotexture measurements on the analysed bus stops shows that only location 16 satisfies the criteria prescribed for macrotexture.

3.4 Rutting

Pavement transverse evenness represents maximum deviation of the transverse profile from an imaginary pavement plane, and is manifested by the occurrence of ruts on the pavement surface. Ruts are permanent pavement surface deformations that occur along the wheelpaths, as a result of the traffic load. Ruts have a negative effect on the driving comfort and safety, but also on pavement structural condition in terms of durability [16].

Ruts can be determined using several measuring methods, where measuring result is usually expressed as the technical parameter rut depth (applied in Croatian regulation), determined as shown in Figure 3.

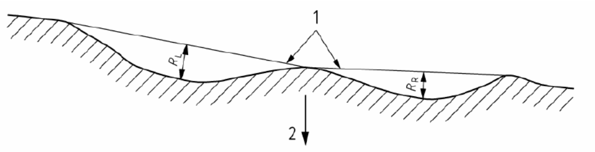

Figure 3. The method of determining rut depth [16]

The measurements were performed with the Hawkeye 2000 measurement system described in chapter 3.2. The technical parameter – rut depth was measured along the right and left wheelpath on the selected locations in conformity with HRN EN 13036-8 and the average measured value of rut depth was analysed. The measured values are shown in Table 4.

Table 4. Measured rut depth values at the analysed locations

Location	Rut depth [mm]	Classification according to COST 354
1 – Fiumara	2.03	Very good
7 – Manzzoni	6.87	Good
8 – F.La Guardia (descent)	3.21	Very good
9 – F.La Guardia (ascent)	3.20	Very good
10 – Railway station	17.88	Poor
14 – Potok (descent)	2.84	Very good
15 – Potok (ascent)	5.80	Good
16 – Victims of Fascism	2.62	Very good

Analysis of the measured rut depth values on the selected locations shows that only location 10 does not satisfy the defined criteria.

3.5 Deflection

Pavement bearing capacity is an indicator of pavement structural condition, showing the pavement ability to bear the estimated traffic load. The usage of non-destructive testing devices for the bearing capacity evaluation is increasing. Pavement deflection is a reversible elastic vertical deformation caused by the applied load. The magnitude and the duration of the load as well as the load distribution area correspond to the effect of a standard axle load on the pavement structure [17].

In this research field tests were performed with a light weight deflectometer with one geophone. The measurements were carried out in the right wheelpath, precisely on the front right wheel position. Ten measurements were performed at each location and Table 5 shows the calculated mean values.

Table 5. Measured deflection values at the analysed locations

Location	Deflection [μm]	Classification according to [17]
1 – Fiumara	80.37	Very good
7 – Manzzoni	178.03	Very good
8 – F.La Guardia (descent)	55.02	Very good
9 – F.La Guardia (ascent)	31.81	Very good
10 – Railway station	58.29	Very good
14 – Potok (descent)	163.74	Very good
15 – Potok (ascent)	17.14	Very good
16 – Victims of Fascism	67.85	Very good

Analysis of the presented deflection measurements on the analysed bus stops shows that all deflection values are below the limit value of 425 μm defined for asphalt pavements.

4. GUIDELINES FOR PAVEMENT REHABILITATION

Traffic loads on analysed locations are mostly concentrated at the vehicle stopping and braking positions, so all the measurements described in Chapter 3 were performed exactly at these specific locations. The collected and analysed measurement data can be used for the determination of the pavement rehabilitation measures.

According to the measured data, on bus stations with increased traffic volume (locations 1, 10, 14 and 15) situated in places without significant longitudinal slope, recorded structural damages are associated with increased traffic load, effects of surface temperature and inadequate maintenance measures. Two basic types of damage - cracks and ruts, were identified by visual inspection and data analysis. The cause of cracks and ruts is shrinking of asphalt layers due to temperature differences influenced by air temperatures, but also additional heating of the surfaces due to low positioned bus engines. Since the measured deflection values at these locations are within the acceptable limit values, the proposed repair measures include the usage of more resistant materials in terms of temperature stresses (whitetopping and asphalt mixtures more resistant to high temperatures).

According to measured data, bus stations with lower traffic volume (locations 7, 8, 9 and 16) and without significant longitudinal slope have structural damages associated to the effects of surface temperature and poor maintenance and repair strategies. The basic types of damages identified by visual inspection and data analysis are cracks (temperature cracks and cracks caused by material fatigue), raveling and shoving. The cause of temperature cracks was described for the locations with increased traffic volume. The cause of cracks due to material fatigue is inadequate maintenance measures. Since the measured deflection values at these locations are within acceptable limits, the proposed repair measures include the use of more resistant asphalt mixtures in terms of resistance to temperature stresses.

5. CONCLUSION

The pavement condition deteriorates over time due to the traffic and environmental effects. Maintenance measures are used to delay the deterioration processes and extend the pavement service lifetime. Pavement condition data is used for the determination of adequate maintenance strategy. In the absence of national technical requirements for pavement condition evaluation, it is possible to use the recommended criteria developed within the COST 354 program. By quantifying the key parameters necessary for proper management of maintenance and rehabilitation activities, it is possible to develop guidelines for maintenance activities that will provide useful information on suitability of particular procedures for good pavement management practice.

This paper presents the results of the performed analysis of several technical parameters – longitudinal evenness, macrotexture, rut depth and deflection, analysed in selected bus stations in Rijeka city centre. This research is an simple example of pavement condition analysis and usage of the analysed data for quality planning and optimization of pavement maintenance and rehabilitation measures. From the analysed data, it can be observed that the technical parameters of longitudinal evenness and macrotexture are not satisfactory at most locations. Unfavourable values of the rut depth parameter occur on bus stop pavements subjected to higher traffic loads. At all locations, the deflection values are within allowable values, which indicates that all registered defects are surface type and do not affect the pavement structure. From the data on structural bearing capacity of the pavements and functional properties, it is possible to determine rehabilitation methods more easily and thus optimize the pavement maintenance practice.

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