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INITIAL ASSESSMENT OF THE QUALITY OF ROAD SURFACES

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Purpose: The aim of the article is to check the quality of the road and classify the selected road on a four-level scale.
Design/methodology/approach: The paper outlines the impact of comprehensive road surface quality management on the safety of vehicles and road users. The basic types of road damage were presented, as well as preliminary diagnostics of a randomly selected national road was carried out. Visual tests were carried out to determine: the type and geometry of the pavement damage, the number of damage, the area covered by the damage. In the article the damage indicators were calculated. The results allowed for the assessment of the quality of the tested pavement and its classification on a four-point scale.
Findings: The quality of the road surface was assessed and classified as level C.
Research limitations/implications: In the future, it can be suggested to change the methodology of investigate the road. It is proposal to using drone with the application.
Practical implications: The research indicates the need to plan the renovation of the road surface and suggests changing the surface material from construction asphalt to the new modified asphalt.
Originality/value: The article indicates the need to amend the documents and the current methodology of the procedure.

Keywords: surface quality, road transport, road safety.

Category of the paper: Case study.

1. Introduction

Comprehensive management of the technical condition of road surfaces is a key factor influencing the safety of maneuvers by motor vehicles. The pavement condition assessment enables rational planning of repairs and renovations (Piłat et al., 2017). In order to develop appropriate solutions in the scope of proposing the replacement of the road surface, it is first necessary to obtain detailed and up-to-date information on the technical condition of the surface (Staniek, 2013). Most of the costs incurred in the road operation process can be avoided by diagnosing the problem before the condition of the pavement deteriorates in a way that threatens the safety of travelers. Initial tests of the road surface condition are very important as they enable diagnosis and making the right decisions regarding repairs, further tests, modernization or even exclusion of a given road from use (Graczyk, and Harasim, 2008). Properly made decisions often allow to avoid potentially dangerous situations leading to accidents, material losses, and in extreme cases to the loss of life of road users (Wesołowski, 2020). The inadequate condition of roads may be caused by both an incorrect selection of materials and surface technology, as well as the constantly changing conditions of their operation (Błażejowski et al., 2004). Changes in the conditions of road surface use are caused, among others, by environmental changes (climate, earth movements, shocks, vibrations, temperature, precipitation), changes in the intensity of vehicle traffic (increase in the number of vehicles traveling on roads, including heavy goods vehicles), changes in the structure of vehicles traveling on roads, resulting in the transport of loads of greater mass, etc. (Graczyk, 2010).

The loads acting on the road surface are usually loads that change with time. It is possible to register both repeatedly repetitive, short-term and dynamic loads transmitted by motor vehicles, but also long-term static loads (Borkowski, 1973). According to the literature data, trucks and buses have the most destructive impact on the pavement. As a result of the action of mechanical loads and atmospheric influences on the road surface, five basic forms of pavement damage occur (Szpinek, 1999):

- permanent deformations, which include: impressions, waves, folds, ruts and traces,
- reflected cracks,
- fatigue cracking,
- thermally induced cracks,
- surface damages, such as: falling out of single grains of aggregate and mortar from the wearing course, losses in the asphalt mix.

Permanent deformations in road surfaces most often arise as a result of long-term loads and elevated temperature. Sometimes, to prevent the formation of ruts, rigid, rutting-resistant structural elements are introduced into road construction (Piłat et al., 2015). The solution may not be used everywhere, because as a result of repeated stresses, it leads to the appearance of road surface cracks during its operation. Another form of surface damage is fatigue cracking

(Borkowski, 1973). They arise when tensile stresses arise in the lower pavement layer and when the fatigue life of the asphalt mixture is exhausted in the outer pavement layer, which results in the formation of cracks. The fatigue destruction process is caused by repeatedly repeated stresses. Such stress is the result of repeated deflections of the pavement layers under the pressure of the wheels of passing vehicles. Thermally induced cracks arise as a result of changes in the physical properties of the pavement, i.e. expansion and contraction of materials under the influence of temperature, of which the pavement is made (Waligóra, 2022). The most common causes of surface damage are improper compaction of the asphalt mix and improperly selected materials (their quality, bonding properties, etc.). Improper selection of materials results in poor asphalt adhesion, crumbling of mortar elements or aggregate from the matrix, and easy formation of cavities in the pavement (Piłat et al., 2020).

The longitudinal evenness of the surface translates into driving comfort (vibrations, vibrations) and the safety of drivers. Unevenness of the road not only increases the wear of the vehicle's suspension components, the possibility of tire damage, but also the driving stability. Deep ruts pose a significant risk to road traffic when overtaking vehicles and changing lanes. In addition, they create a risk because they limit the drainage of rainwater, most often on sections of roads with small longitudinal slopes (Due to the accumulation of water in the ruts, a water cushion may form between the tire tread and the road surface. As a result, the vehicle's adhesion to the ground is reduced and it falls into. In extreme cases, a collective accident may occur, which is why a properly conducted inspection and preliminary visual assessment of the road surface condition is very important (Czarnecki, and Janowski, 1999).

2. Aim and investigation methods

The aim of the research undertaken in the study was to make a preliminary assessment of the technical condition of the surface of the national road located in Upper Silesia and to make a decision on its further safe operation. The object selected for the research was a road, made of the so-called asphalt road. In order to assess the initial quality of the road surface, visual tests were carried out to identify the places of non-compliance and defects, such as: cracks, longitudinal unevenness, ruts, etc. Highways pt. "SOSN Surface Condition Assessment System – Appendix A" (GDDP, 2002a) and "SOSN Surface Condition Assessment System – Appendix E" (GDDP, 2002b). The total length of the tested road section was 400 m. In addition, photographic documentation of the identified damage was made using a digital camera built into the Samsung Galaxy M12. Next, the so-called damage score for the next 100-meter road sections, using the formula (GDDP, 2002a):

$$P_{ij} = a \cdot \left(\frac{x}{b}\right)^{c} \cdot f \tag{1}$$

where:

P_{ij} – points for damage i at damage degree j,

x – the extent of damage (calculated separately at different degrees of harmfulness),

a, b, c – parameters, read from tables, depending on the degree of harmfulness, in the analyzed case the degree was defined as big,

f – coefficient taking into account the influence of traffic volume, for the analyzed road coefficient f = 0.9.

Then, using the formula (2), the harmfulness coefficient P_i was calculated:

$$P_i = 0{,}9 \cdot P_{ijmax} + 0{,}1 \cdot \Sigma P_{ij} \tag{2}$$

where: P_{ij} – points calculated for the damage and for the harmfulness j_{max}, i.e. the harmfulness with the highest number of points.

Then, for all measuring sections, the value of the crack indices nm and the surface condition were calculated according to the formula:

$$n_m = E(n) + \alpha \cdot D(n) \quad p_m = E(p) + \alpha \cdot D(p) \tag{3}$$

where:

E – the average value of the set of assessments for 100 m long sections belonging to the measuring section,

D – standard deviation of the evaluation set for 100 m long sections belonging to the measuring section,

α – a scaling factor of 0.3.

The parameters of the pavement condition determined on the basis of the visual assessment and the measurements of the non-compliance geometry were referred to the four-level classification of road conditions (Fig. 1).

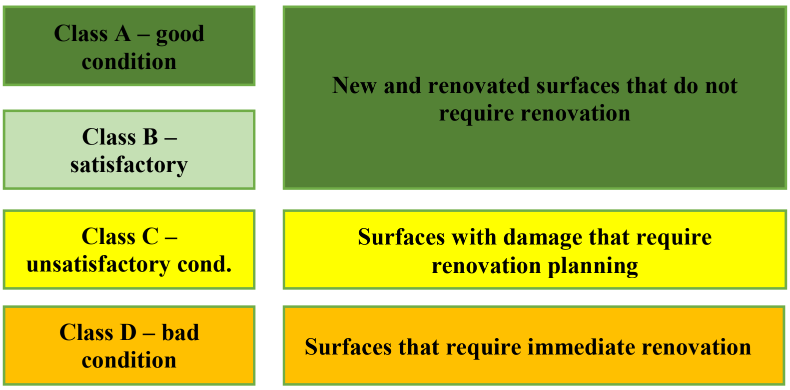


Figure 1. Scheme 1 – classification of road conditions according to SOSN Annex E (GDDP, 2002b).

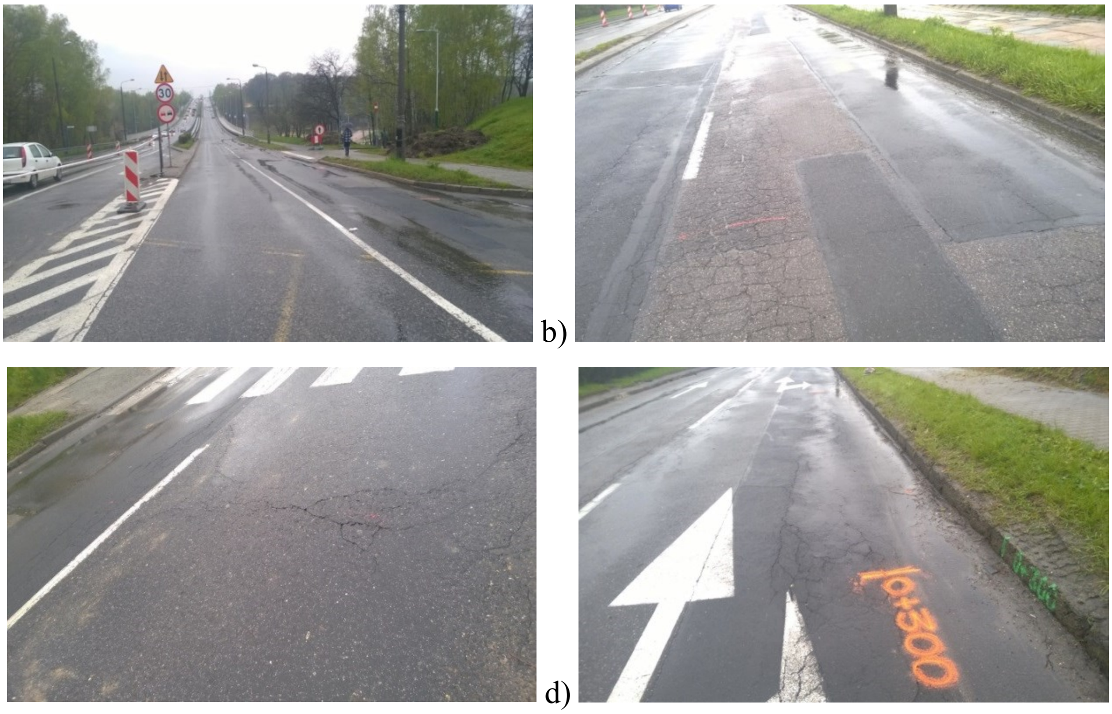
The class was selected on the basis of the nm indices calculated from the formula (3) and the comparison of the results with the tolerances assigned to the class (GDDP 2002b):

- Class A – indicators nm and pm in the range 1.00-0.90.
- Class B – indicators of nm and pm in the range of 0.56-0.90.
- Class C – indicators of nm and pm in the range of 0.41-0.55.
- Class D – indicators of nm and pm in the range of 0.40-0.00.

On this basis, it was concluded whether a given pavement is suitable for use, whether it should be modernized or renovated.

3. Results of investigation

The road has two roadways with two lanes for each direction (Figure 1a). The preliminary visual assessment of the road shows that the dynamics of pavement degradation is advanced, significant damage to the pavement is visible, including mesh cracks and patches (Fig. 1b), transverse cracks along the entire width of the road (Fig. 1c) and longitudinal cracks (Fig. 1d).



a) b) c) d)

Figure 2. Fragment of Matuszczyka Street in Wodzisław Śląski a) general view, b) mesh patches and cracks in the pavement, c) transverse crack, d) longitudinal crack (own elaboration).

The identified patches on the first section of the road under study (section marked 0 + 000 - 0 + 100) were assessed as high harmfulness, cracks were found at the joints of the patches with the remaining pavement. Patches occupy more than 50% of the width of the lane. The dimensions of the battens shown in Figure 1b were determined using the STANLEY

0-35-458 wooden measure. The batten shown in Fig.1b on the right side has dimensions of 0.3 m × 0.6 m, and the batten on the left – 1.2 m × 6 m. The remaining battens on the tested road section were measured similarly. The total area of battens on the 100 m road section is 36.90 m^2.

In the next stage of the research, mesh cracks were assessed, which were also classified as high harmfulness. The examination of the pavement revealed the presence of loose pavement pieces in the area of mesh cracks. Registered changes amounted to less than 50% of the width of the assessed lane. The pavement area with all identified mesh fractures on the tested road section was 22.5 m^2. Next, the damage was scored using the formula (1). After substituting the obtained measurement values and coefficients for the degree of harmfulness defined as high, the following results were obtained: for pavement damage in the case of patches $P_{ij} = 49.85$ and for a mesh crack $P_{ij} = 47.1$.

Then, using the formula (2), the coefficient Pi was calculated:

$P_i = 0.9 \cdot 49.85 + 0.1 \cdot (49.85 + 47.10) = 54.56$

Successive road sections were analyzed in a similar way. 16 transverse cracks were found in the marked section (0 + 100 - 0 + 200). For the P_{ij} calculations, the damage of the cracks was assumed to be high, the cracks were characterized by the lack of tightness and flooding of the crack. Their width is defined as large, as the cracks cover the entire width of the lane. Then, the length of the cracks was measured (for example, the crack shown in Figure 1c was 2.95 m long). The sum of the lengths of all cracks occurring over the distance of 100 m was 47.20 m. According to the formula (2), $P_{ij} = 40.77$ was calculated.

Visual tests on the section of the road marked (0 + 200 - 0 + 300) allowed to identify 13 damages in the form of longitudinal and mesh cracks. The identified cracks are harmful. Cracks are not tight and have chipping at the edges. Their total length is 52 m. The width for longitudinal cracks is not specified. The calculated damage score according to formula (2) is $P_{ij} = 41.77$.

Figure 3. Patches and cracks on the section (0 + 300 - 0 + 400) of the tested road (own elaboration).

In the last section of the road marked (0 + 300 - 0 + 400) there are patches, mesh cracks and longitudinal cracks (Fig. 3). All the damage due to its nature and the area occupied was classified as damage of high harmfulness. The number of patches on the tested road section was 5 with a total area of 31 m^2. Cracks were found between the patches and the surface. The calculated damage score, in accordance with the formula (1), was P_{ij} = 47.07. The length of longitudinal cracks was measured on the tested section of the road, the length was 24 m. The score for these damage was P_{ij} = 34.43. In addition, mesh cracks with a total area of 41 m^2 and a width exceeding 50% of the lane width were identified. For mesh cracks, the calculated damage score was P_{ij} = 54.72.

Then, using the formula (2), the harmfulness index Pi was calculated:

$Pi = 0.9 \cdot 54.72 + 0.1 \cdot (47.07 + 34.43 + 54.72) = 62.87.$

Based on the formula (3), the nm index was determined for individual measurement sections and for the entire length of the section of the tested road (0 + 000 - 0 + 400). The calculation results are presented in Table 1.

Table 1.
A fragmentary overview of the indicators n_m

Measurment distance:	**0+000 – 0+100**	**0+100 – 0+200**	**0+200 – 0+300**	**0+300 – 0+400**	**0+000 – 0+400**	**Klasa**
Indicator n_m	0,45	0,59	0,52	0,37	0,55	C

For the calculation of nm, the arithmetic mean E and the standard deviation D were calculated:

$$E = \frac{0.45+0.59+0.25+0.37}{4} = 0.48$$

$$D = \sqrt{\frac{(0.45-0.48)^2+(0.59-0.48)^2+(0.52-0.48)^2+(0.37-0.48)^2}{0.48}} = 0.24$$

$nm = 0.48 + 0.3 \cdot 0.24 = 0.55.$

The obtained result was compared with the tolerances assigned to a given road quality class. The quality class C was obtained for the entire measuring section. This means that the tested pavement can be used in accordance with Polish law, but requires renovation planning. Its condition is described as unsatisfactory.

4. Summary and conclusions

The conducted research shows that the road condition is unsatisfactory. The quality of the road in the four-stage classification was determined at the C level, the calculated factor n_m was 0.55. According to the authors, preliminary diagnostics indicate a significantly progressive process of road degradation. The pavement life cycle is in the stage of accelerated degradation, which may turn out to be dangerous for road traffic. It is recommended to conduct a more extensive diagnosis of the road, including tests from the scope of the entire document of the "SOSN Surface Condition Assessment System". In this case, the diagnostics should enable the prognosis of failure-free operation of the pavement in the existing working conditions and with loads resulting from traffic intensity.

Initial tests carried out in accordance with the applicable document (GDDP 2002a; 2002b) are very time-consuming. Considering that every road allowed for traffic should be monitored, according to the authors, it would be advisable to amend the regulations so as to allow for the possibility of using drones equipped with specialized research programs to perform measurements. Certainly, such a solution would facilitate diagnostics and comprehensive management of the technical condition of road surfaces.

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