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Analysis of the impact of concrete pavement construction technology on selected operational characteristics

Abstract: Using Fieldorfa Street in Wrocław as an example, the impact of concrete pavement construction technology on selected performance characteristics was analyzed. The street in question was constructed in two sections. The first section was constructed using commercial technology without the use of dedicated concrete paving machines. The second section was constructed using specialized concrete pavers. Based on measurements of the longitudinal evenness index (IRI), the macrotexture index (MPD), and the coefficient of friction, it was found that there was variation in results between the sections, but significant variation in the evenness index.

Keywords: Texture; Roughness; Concrete Pavement, OBSI, IRI, MPD

Introduction

Concrete pavements experienced their "second" phase of development during the construction of expressways and motorways. In 1995, sections of the A4 motorway were built for higher traffic categories and high traffic volumes. Subsequently, a section of the A2 motorway was constructed in 2012, followed by the S8 expressway in 2015. Additionally, two continuously reinforced concrete pavement sections were built on the A2 motorway (2012) and the A4 motorway (2004). Older concrete pavement sections are also known, such as National Road DK50 from 2002 and the A18 motorway dating back to the 1940s. Currently, concrete pavements are being constructed outside built-up areas for national and local roads, including urban areas. One such example is Fieldorfa Street in Wrocław.

A key issue in concrete pavement construction is achieving appropriate operational characteristics related to the finishing of the concrete slab surface. The most important characteristics include longitudinal smoothness and skid resistance. Numerous research projects have analyzed the relationships between operational characteristics and pavement noise emissions [5], [7], [8], [10], [3], [2], [6].

Characteristics of the Test Section

Fieldorfa Street is located in the northern part of the city of Wrocław (Fig. **1**). It connects to Kosmonautów Street in the south via a channelized intersection and to Wojnarowska Street in the north via a roundabout. The total length of the street is approximately 1,000 m.

1. Location of measurement sections – Fieldorfa Street in Wrocław

Two measurement sections (Sections 1 and 2) were distinguished along the street, constructed in two stages. The first section, approximately 500 m long, extending from Kosmonautów Street, was built using a conventional, non-mechanized method without paving machines. Significant unevenness occurs along this section. The second section was constructed using slipform pavers and is in considerably better technical condition. Figures **2**–**4** present the pavement condition of both sections.

2. View of pavement on Section 1 from Kosmonautów Street (0+000–0+500)

3. View of pavement on Section 2 of Fieldorfa Street (0+500–1+000, roundabout)

4. Connection between Section 1 and Section 2

Section 1 (0+000–0+500) was opened to traffic in 2013. Its pavement structure consists of:

- doweled and tied concrete slabs C35/45, 25 cm thick, concrete placed manually and compacted with vibrating screeds, dowels and tie bars placed on supports,
- geotextile,
- lean concrete C8/10, 18 cm thick, placed manually,
- cement-stabilized layer, 15 cm thick,

– frost protection layer, 15 cm thick.

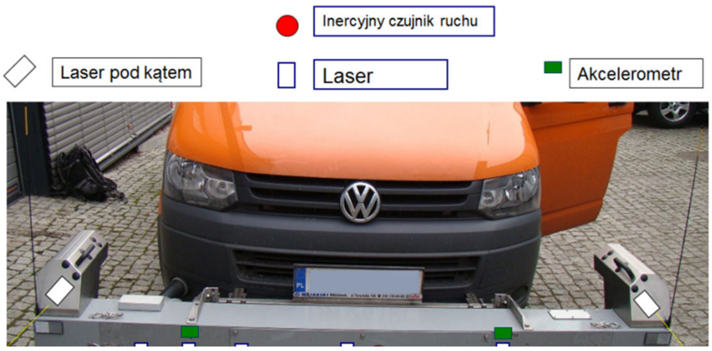
Section 2 (0+500–1+000, roundabout) was opened to traffic in 2017. Its pavement structure consists of:

– doweled and tied concrete slabs C35/45, 23 cm thick, concrete placed mechanically, dowels and tie bars vibrated into place,
– asphalt concrete layer, 8 cm thick,
– cement-stabilized layer, 18 cm thick,
– frost protection layer, 15 cm thick.

It should be noted that, in addition to the different construction technologies, the pavements differ in concrete slab thickness and the composition of underlying layers. Preliminary analysis indicates that Section 2 may exhibit greater deformation susceptibility under load. However, both structures use high-strength concrete and include doweling and tying to ensure proper load transfer between slabs. Both pavements can be classified as traffic load category KR3/KR4.

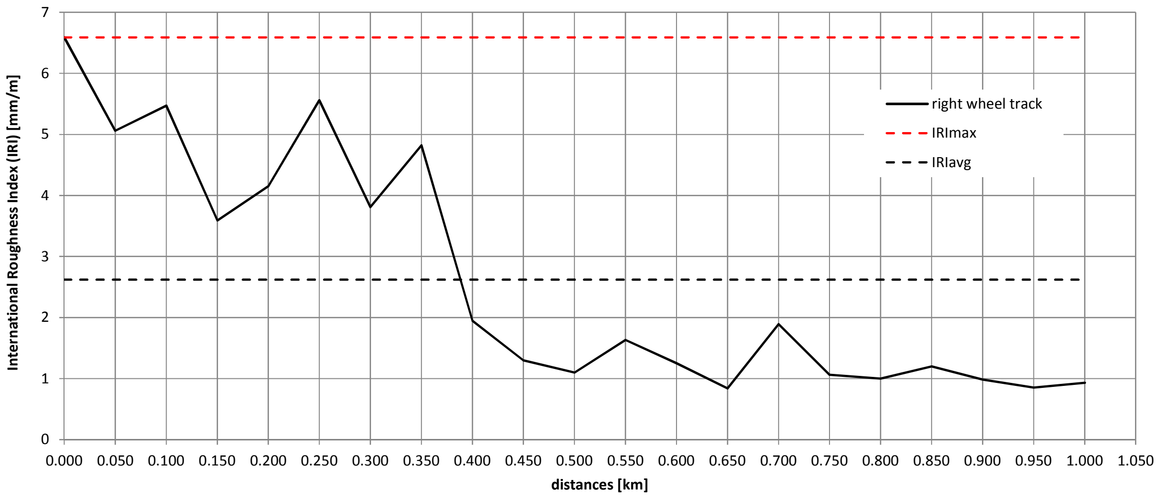
Results of Surface Characteristics Measurements

In accordance with relevant standards and guidelines [1], [9], [11], measurements were carried out using a laser profilograph (Fig. **5**). The International Roughness Index (IRI) and surface texture expressed by the Mean Profile Depth (MPD) were measured. Additionally, skid resistance was evaluated by measuring the friction coefficient. These parameters are also used within the DSN system [4] for pavement condition assessment in Poland.

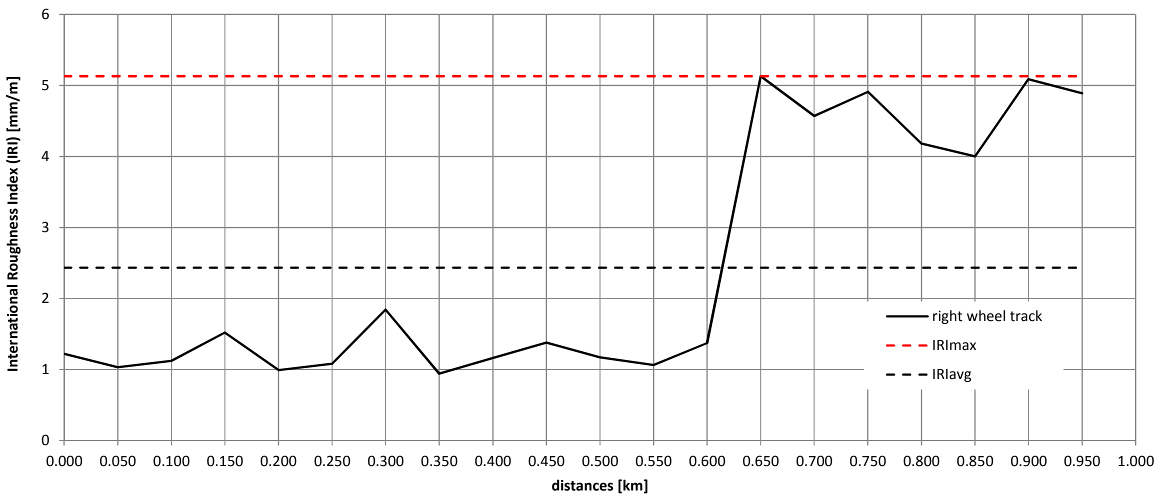


5. Laser profilograph used for measurements

Longitudinal roughness was evaluated in the right wheel path, in accordance with the designed direction of travel. IRI values were calculated at 50 m intervals. Sections with a length of 500 m were analyzed. Figures **6** and **7** present the IRI measurement results.



6. IRI measurement results for Fieldorfa Street (direction toward the roundabout)



7. IRI measurement results for Fieldorfa Street (direction toward Kosmonautów Street)

The following IRI values were obtained:

Direction toward the roundabout

Section 1:
IRImax = 6.6 mm/m
IRIavg = 3.9 mm/m

Section 2:
IRImax = 1.9 mm/m
IRIavg = 1.2 mm/m

Direction toward Kosmonautów Street

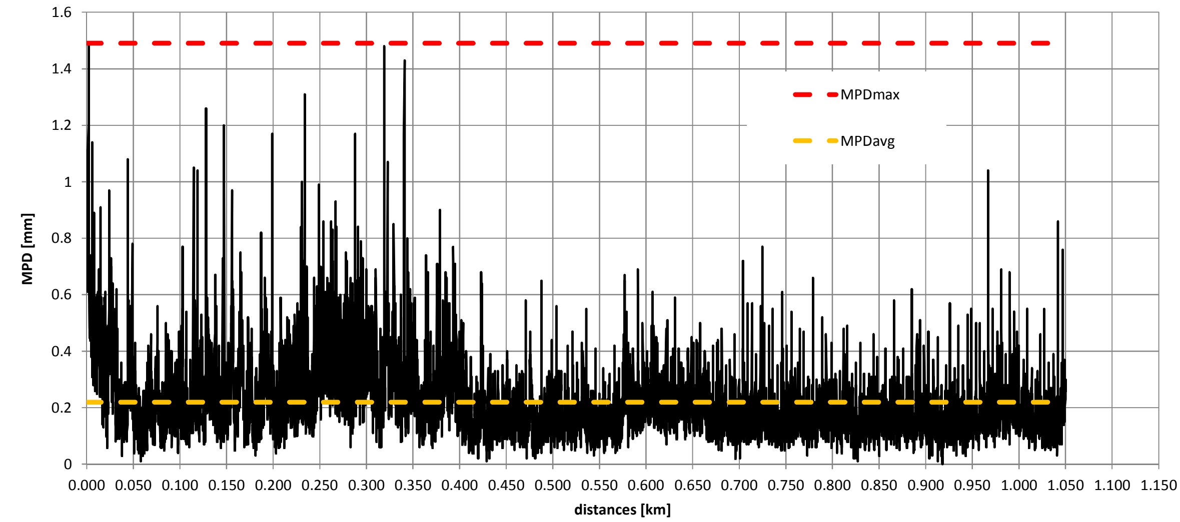
Section 1:
IRImax = 5.1 mm/m
IRIavg = 3.9 mm/m
Section 2:

IRImax = 1.8 mm/m
IRIavg = 1.2 mm/m

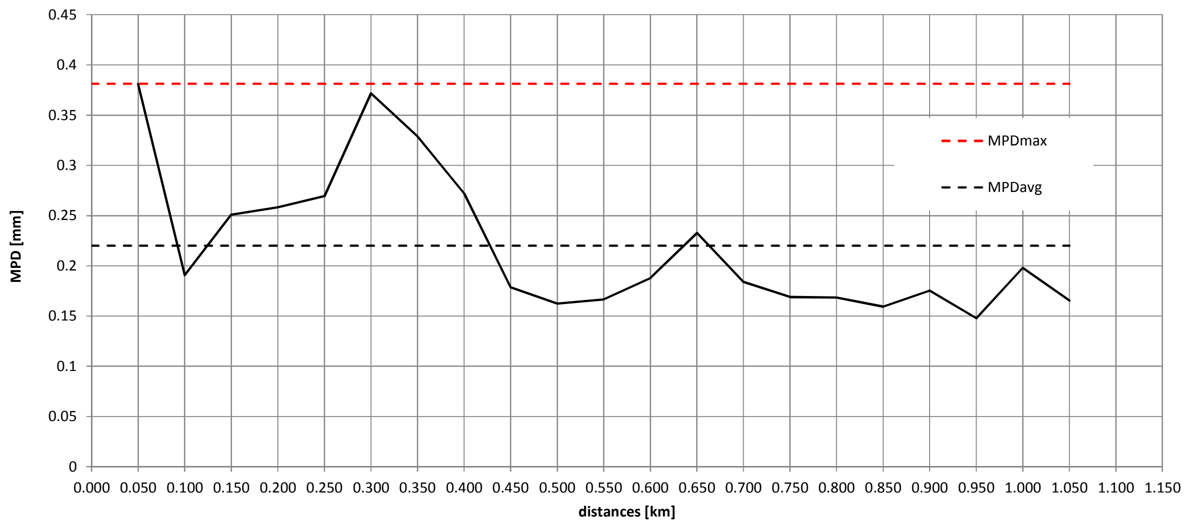
Based on the longitudinal roughness measurements, Section 1 exhibits significantly higher maximum and average IRI values than Section 2, regardless of traffic direction. The values are approximately three times higher for Section 1. Texture measurements were performed at 100 mm intervals. For selected lanes and road sections, average values were calculated for 50 m and 500 m segments. In order to classify the sections based on texture, the Mean Texture Depth (MTD) was calculated using the following relationships:

$$MPD_{60} = MPD_{pom} - 0{,}002 \cdot (60 - V_{pom})$$
$$MTD \approx ETD = 1{,}1 \cdot MPD_{60}$$

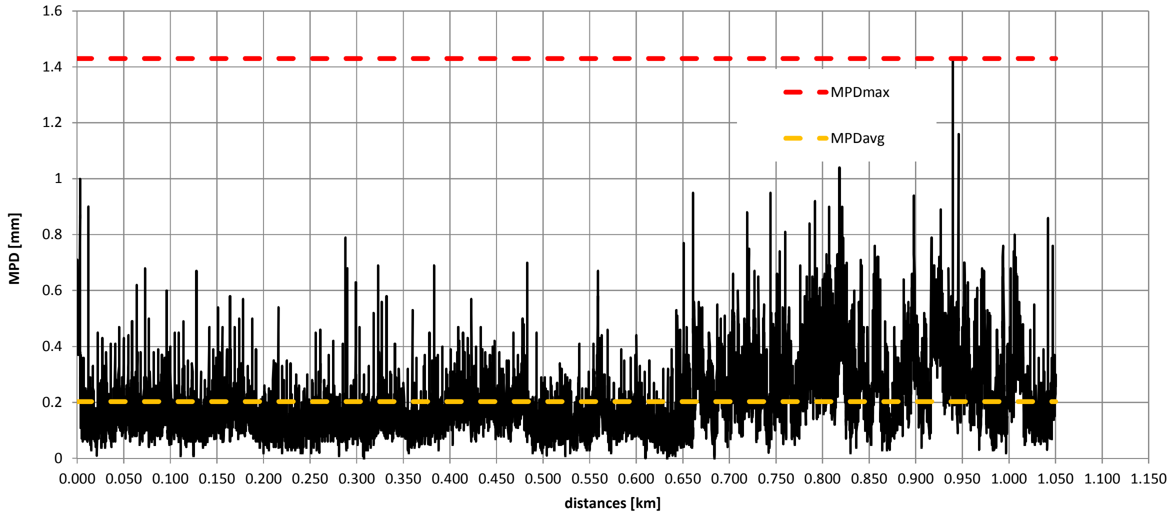
Figures **8–11** present MPD measurement results.



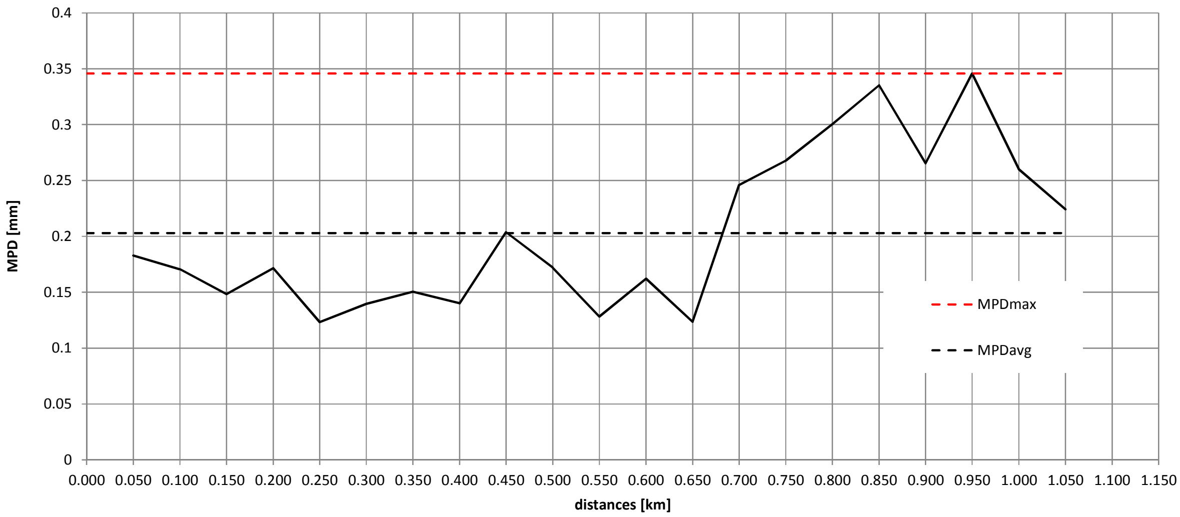
8. MPD measurement results for Fieldorfa Street in Wrocław (direction to the roundabout, results every 100 mm)



9. MPD measurement results for Fieldorfa Street in Wrocław (direction to the roundabout, results every 50 m)



10. MPD measurement results for Fieldorfa Street in Wrocław (direction to Kosmonautów Street, results every 100 mm)



11. MPD measurement results for Fieldorfa Street in Wrocław (direction to Kosmonautów Street, results every 50 m)

The following MTD values were obtained:

Direction toward the roundabout

Section 1:
MTDmax = 0.40 mm
MTDavg = 0.27 mm

Section 2:
MTDmax = 0.23 mm
MTDavg = 0.17 mm

Direction toward Kosmonautów Street

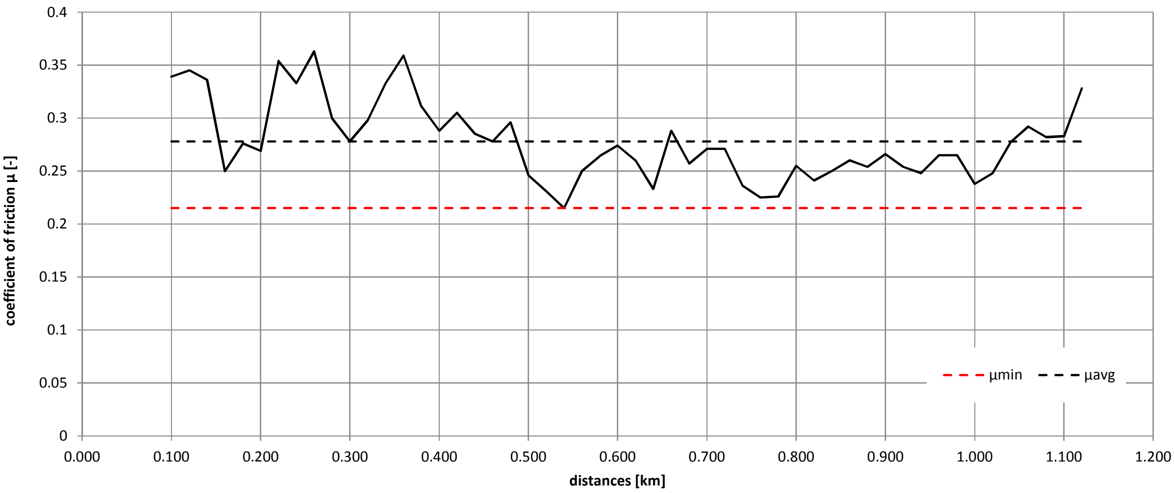
Section 1:
MTDmax = 0.36 mm
MTDavg = 0.24 mm

Section 2:
MTDmax = 0.20 mm
MTDavg = 0.15 mm

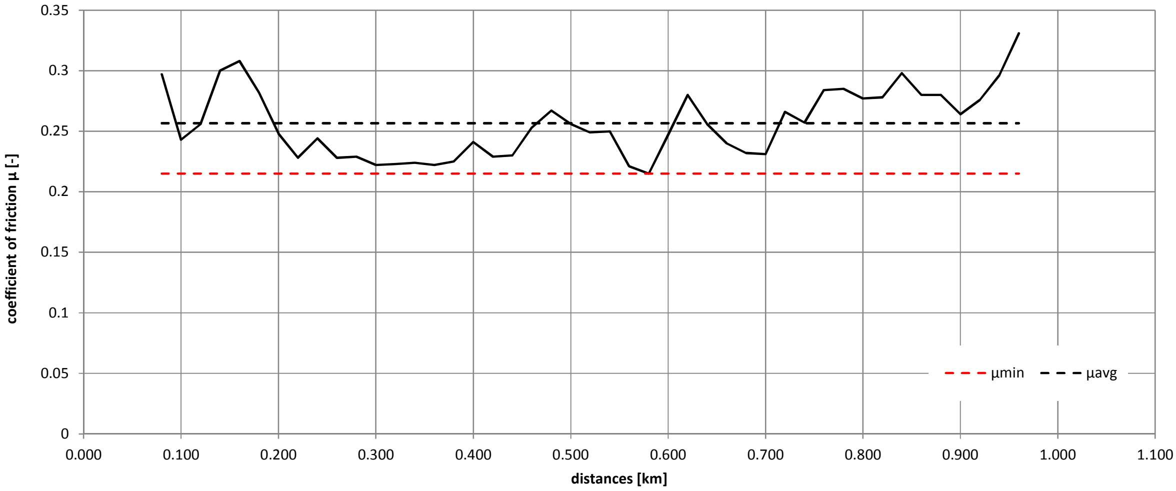
Texture measurements indicate higher maximum and average MTD values for Section 1, regardless of travel direction. These values are approximately 1.5 times higher than those for Section 2.

Skid resistance measurements were conducted at test speeds of 60 km/h and 30 km/h. Results were averaged over consecutive 20 m segments, and evaluated sections were defined every 100 m. Friction coefficients were calibrated to the DFT device (WR-D-64 project).

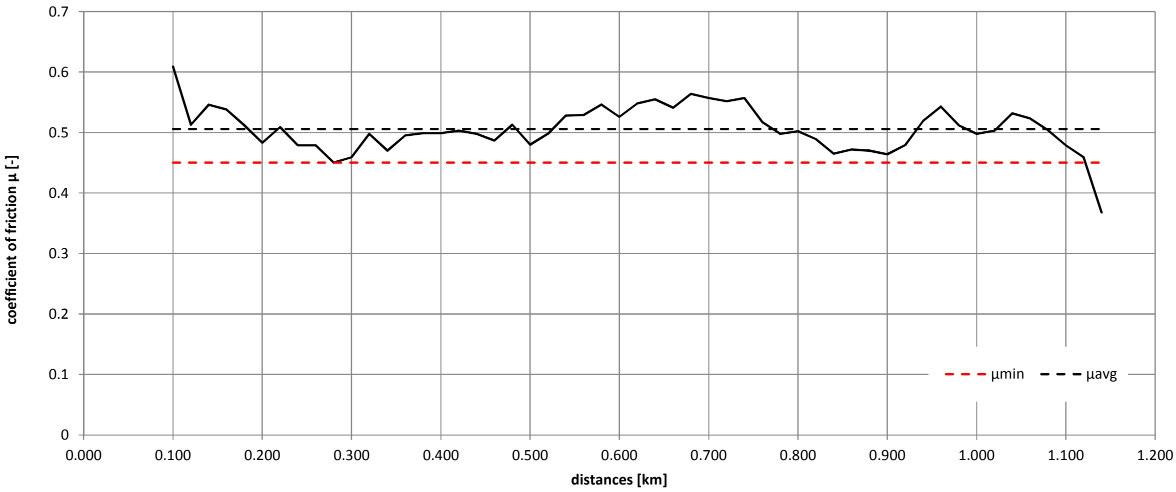
The evaluated skid resistance parameters were the average friction coefficient (µavg) and the minimum friction coefficient (µmin). Figures **12–15** present the friction measurement results.



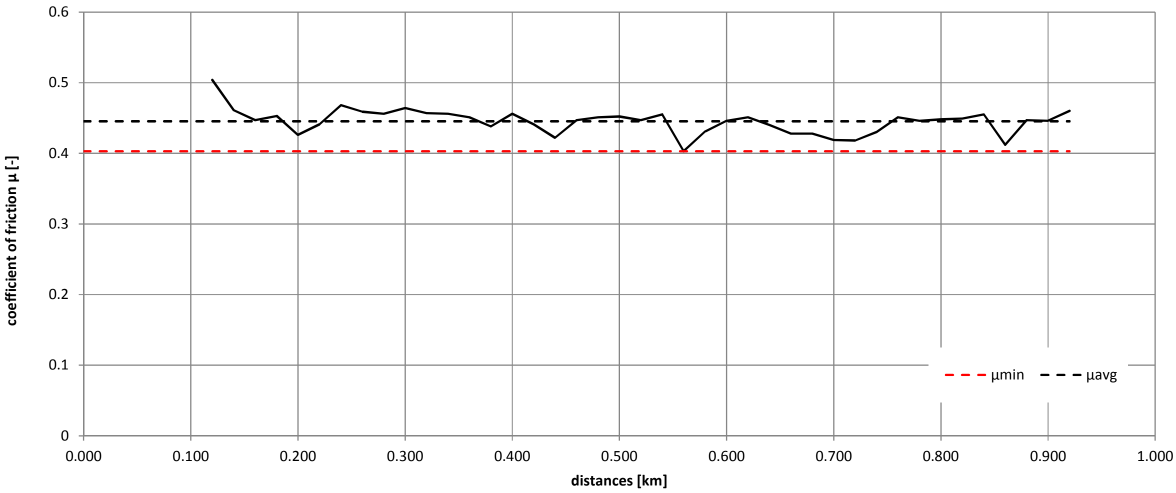
12. Friction measurement results for Fieldorfa Street in Wrocław (direction towards the roundabout, results for v = 60 km/h, every 20 m)



13. Friction measurement results for Fieldorfa Street in Wrocław
(direction towards Kosmonautów Street, results for v = 60 km/h, every 20 m)



14. Friction measurement results for Fieldorfa Street in Wrocław
(direction towards the roundabout, results for v = 30 km/h, every 20 m)



15. Friction measurement results for Fieldorfa Street in Wrocław
(direction towards Kosmonautów Street, results for v = 30 km/h, every 20 m)

The following friction coefficients (converted to DFT) were obtained:

Direction toward the roundabout

Section 1:
$\mu min = 0.25$
$\mu avg = 0.31$

Section 2:
$\mu min = 0.22$
$\mu avg = 0.26$

Direction toward Kosmonautów Street

Section 1:
$\mu min = 0.22$
$\mu avg = 0.26$

Section 2:
$\mu min = 0.22$
$\mu avg = 0.25$

Based on friction measurements, Section 1 shows slightly higher minimum and average friction values than Section 2, regardless of travel direction. The differences are relatively small, approximately 10%.

Conclusions

Analysis of the results of tests on the operational parameters of Fieldorfa Street's pavement (evenness, texture, friction) revealed that, depending on the construction technology and the period of operation (a difference of four years), there was variation in the examined pavement characteristics.

The greatest variation was observed for the longitudinal evenness index. For section 1, both the maximum and average values were three times higher (relative to the traffic lane (direction)).

Less variation was observed for texture measurements (MTD values were 1.5 times higher for section 1 compared to section 2) and for friction (friction coefficient values were 10% higher for section 1 compared to section 2).

In the case of the studied street constructed using two technologies, it should be noted that construction using the commercial method without the use of special concrete paving machines can significantly deteriorate the evenness of the pavement. Surprisingly, however, the section using this technology achieved a higher texture index and a slightly higher friction coefficient despite the surface being four years older. This may be related to increased surface degradation due to spalling and aggregate loss. It is possible that this effect will be undesirable in the long term due to increased noise emissions during the surface's operation. In a later stage of the work, the authors will conduct analyses related to the noise level of this surface.

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texturing techniques, RID II (Protection against road noise), which is co-financed by the National Centre for Research and Development and the General Directorate for National Roads and Motorways.

Source materials

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