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Evaluation of a Newly Constructed Freeway Asphalt Pavement Surface Unevenness: Case Study

Evaluación de las irregularidades de la superficie del pavimento asfáltico de una autopista de nueva construcción: Estudio de caso

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Abstract

It is not rare for newly constructed asphalt pavement to have an uneven surface; consequently, conducting regularity tests of asphalt pavement surface evaluates rider comfort and a level of construction. The irregularity of the asphalt pavement surface generates vibration and noise in vehicles, confuses drivers, and limits speed and maneuverability; also, the highway does not complete its operational duty, which requires early maintenance work. Hence, many transportation officials worldwide view having a smooth pavement as essential. Meeting the standards for surface regularity is crucial to constructing an asphalt road with a smooth surface. This study included irregularities tests before and two years after traffic opened and investigated longitudinal surface variations in the newly laid asphalt pavement. It found a difference in the longitudinal road surface irregularity that was not statistically significant, and the densification of the pavement layer is the cause of this difference due to traffic load.

Keywords: Irregularity test; asphalt pavement; rider comfort; surface unevenness; freeway.

Resumen

No es raro que el pavimento asfáltico recién construido tenga una superficie irregular; En consecuencia, la realización de pruebas de regularidad de la superficie del pavimento asfáltico evalúa la comodidad del conductor y un alto nivel de construcción. La irregularidad de la superficie del pavimento asfáltico genera vibraciones y ruido en los vehículos, confunde a los conductores y limita la velocidad y la maniobrabilidad; Además, la carretera no cumple con su deber operativo, lo que requiere trabajos de mantenimiento tempranos. Por lo tanto, muchos funcionarios de transporte de todo el mundo consideran que tener un pavimento liso es esencial. Cumplir con los estándares de regularidad de la superficie es crucial para construir una carretera de asfalto con una superficie lisa. Este estudio incluyó pruebas de irregularidades antes y dos años después de la apertura del tráfico e investigó las variaciones longitudinales de la superficie en el pavimento asfáltico recién colocado. Encontró una diferencia en la irregularidad longitudinal de la superficie de la carretera que no fue estadísticamente significativa, y la densificación de la capa de pavimento es la causa de esta diferencia debido a la carga de tráfico.

Keywords: Ensayo de irregularidad; pavimento asfáltico; confort del conductor; desnivel superficial; autopista.

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Vol. 40
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1. Introduction

Since the turn of the 20th century, as vehicles such as cars and trucks have allowed people to travel farther and faster, the population's average number of automobiles owned has climbed. Undoubtedly, this aspect results in heightened mobility and travel between the urban area and its surrounding suburbs, resulting in form traffic congestion. As a result, modern roadway construction is always necessary to accommodate the demands of growing traffic numbers. To this end, it must prioritize factors such as the quantity, classification, speed, and weight of individual vehicles and the safety, comfort, and passenger satisfaction.

Ensuring appropriate travel circumstances leads to improved quality of transportation services (Wawryszczuk et al., 2023). Ensuring passenger comfort is paramount in transportation and is directly related to the vehicle and road surface condition (Oborne, 1978). Pavements deteriorate with time and heavy traffic. A safe and comfortable journey is needed to repair deteriorating pavements (Leitner et al., 2019). Uneven pavement might render motorists less safe and increase the likelihood of accidents (Loprencipe et al., 2023). A smooth pavement surface provides riders with an enjoyable, safe, and cost-effective driving experience while extending the pavement's life with less maintenance (Hettiarachchi et al., 2023). Asphalt pavement distress, such as rutting, shoving, corrugation, local depression, and potholes, decreases highway performance (Albayati and Qader-Ismael, 2024). The performance of the pavement in terms of vehicle safety and comfort is affected by pavement surface smoothness (Albayati and Ismael, 2024). Furthermore, enough friction resistance between the vehicle tires and the pavement surface is required (Mohammad and Ismael, 2021). Longitudinal evenness (smoothness), skid resistance, rutting, cracking, and any other surface distress are pavement surface characteristics related to the functional evaluation of pavement surfaces. Essentially, the type and intervention requirement through functional evaluation determines whether the pavement needs to be maintained, rehabilitated, or reconstructed. Therefore, it is vital to take care and conform to requirements and norms when developing and constructing roadways. One of the most dedicated and norm-restricting types of roads is freeways. It is built with stringent specifications to maintain its primary purpose of reaching a high level of mobility through movement.

The main problem of the study's topic is the following:
Since the construction and operation of the road in 2022, little noise (vehicle vibration) or discomfort was detected when passing certain road sections, as observed by road surveillance patrols. At that time, there were two prevailing beliefs. The first was that many corrugations were likely due to problems with road soil layers that had worsened, and the other was likely poor construction. The first belief was more likely because the regularity test of the pavement surface after implementation and before traffic opening was within the limits of the standard.

The study's hypothesis was to retain traffic movements as they are. Irregularity tests after 2-3 years of traffic opening are conducted. During this time periodic monitoring of the road continues in anticipation of sudden huge deformation. The test findings of the initial (pre-traffic opening) irregularities with the final are compared, and the difference is evaluated to conclude.

The study aims to employ a travel beam device to do an on-site analysis of the Daurah-Yusufiyah freeway's asphalt pavement surface's regularity to identify any irregularities and perform an evaluation.

2. Project and study area description

The Daurah neighborhood of Baghdad-Iraq's capital is the site study area. The project is a 14-kilometer-long freeway connecting the Daurah-Approach highway from the north and the expressway from the south. There are four lanes on each of the symmetrical two sides of the road (the right lane is the standing lane). The lane width is 3.75 m, while the standing lane width is 2.5 m. The guide strip is 0.75m on the left and 0.5 m on the right of both sides. The medium width is 10 m, and each side has a granular materials shoulder width of 1.5 m. The total carriageway width is 15 m. The asphalt pavement has a 40 cm of granular materials course subbase, an asphalt base course thickness of 20 cm, an asphalt binder course thickness of 8 cm, and an asphalt wearing course thickness of 5 cm using bitumen modified with Styrene-Butadiene-Styrene (SBS) polymer. (Figure 1) shows the study area. (Figure 2) shows the typical cross-section of the freeway.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00144.21

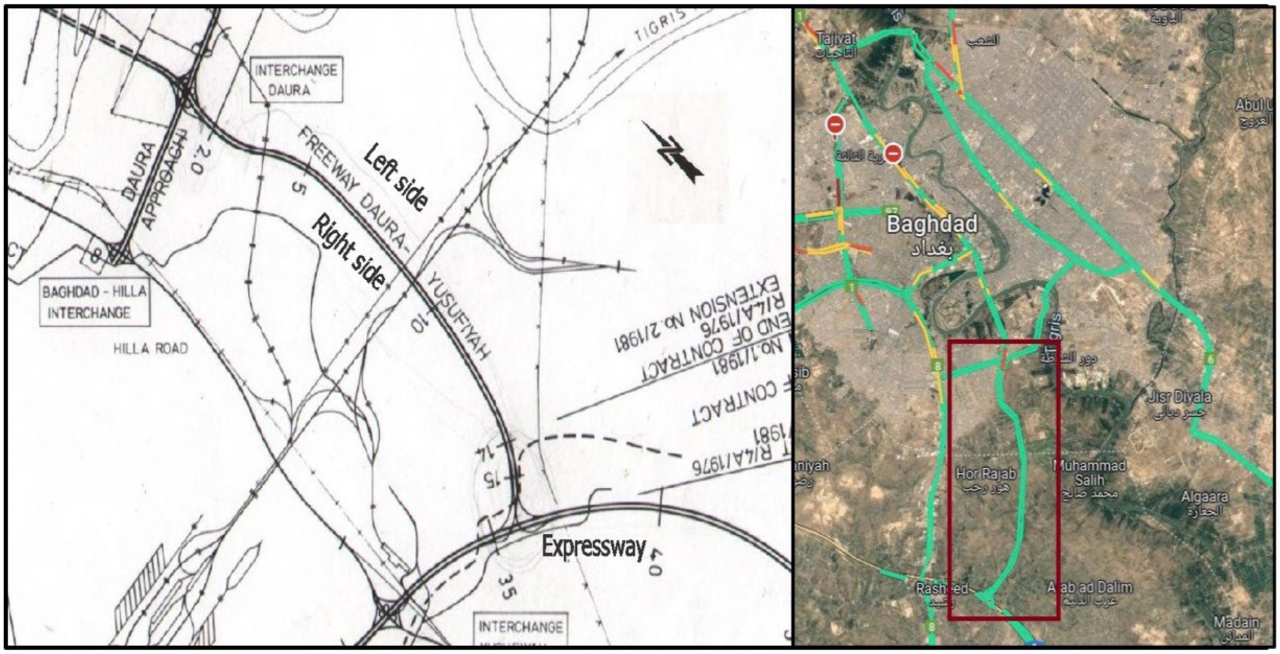

Figure 1. The study area of the freeway.

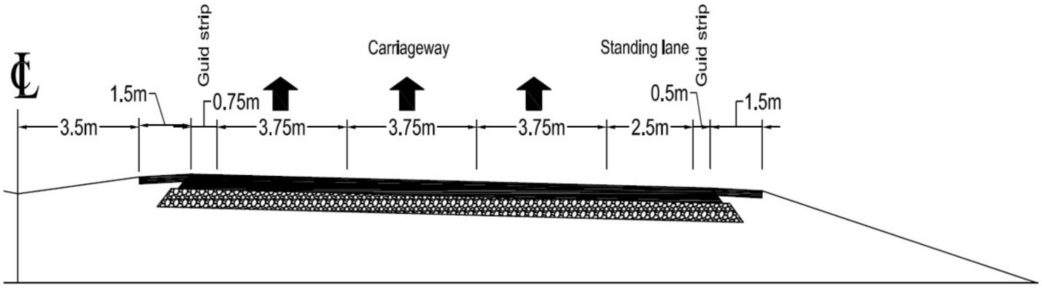

Figure 2. Typical cross-section of the freeway.

Statistical samples are supposed to be selected randomly (Singh et al., 2022). Since not all road segments in the study area showed issues, it would not be financially feasible to assess the road's regularity for 14 km (or 28 km in each direction); furthermore, it is possible to choose sections where no problems have appeared. As a result, there are issues in this investigation in three regions on each side of the road. Each of the six has a length of 300 m. The evaluation procedure entailed determining a 300-meter length for each test region according to Iraqi standards for roads and bridges (SCRB, 2003), which outlined the maximum number of irregularities within this distance. The six were purposely selected. The three segments (stations) on the right side that showed issues are 00+700 - 1+000, 6+600 - 6+900, and 13+500 - 13+800. The three segments (stations) on the left side that showed issues are 2+200- 2+500, 7+600- 7+900, and 13+700- 14+00.

3. Methods

Because the rolling straight-edge device is affordable and readily available, it is selected to perform the regularity test for the selected portions. The device is a trolley with a length of 3 m and consists of three segments with a length of 1m fixed by screws. It contains an analog dial indicator in the middle to read the deflections—an odometer to measure the testing distance. It is moved by a human. (Figure 3) shows the rolling straight-edge device.

ISSN: 0718-5073

Vol. 40
Nº1 2025
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For each of the six selected regions which were each one 300 m length. For the three lanes of the carriageway, the longitudinal irregularities measurements or variation in the profile of the road surface were read according to the requirements range (4-10mm) of Iraqi standards for roads and bridges (SCRB, 2003) irregularities are shown in (Table 1).

The regularity test of the road was conducted immediately before the traffic opening in 2022, and the second for sections in which issues were suspected was carried out in mid-2024.

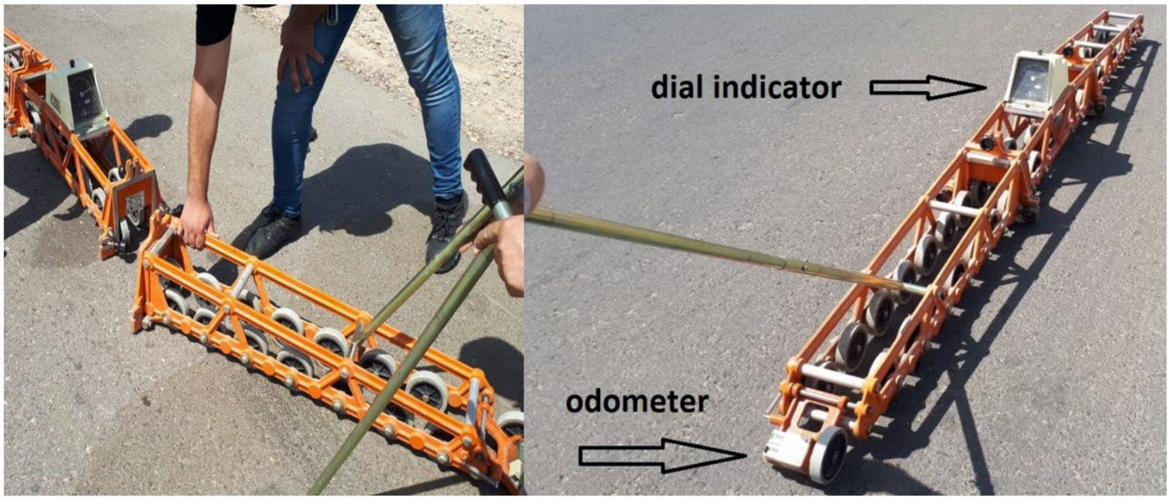

Figure 3. The rolling straight-edge device.

Table 1. Maximum permitted number of surface longitudinal irregularities (SCRB, 2003) .Course Irregularities.

Course	Irregularities	
	4-5.9 mm	6-10 mm
Surface	20	2

4. Results and discussion

The initial irregularity tested followed the construction of the wearing course but before the traffic opening. The number of irregularities permitted, according to SCRB, 2003, ranged from 4 to 10 mm, as shown in (Table 2).

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00144.21

Table 2. Initial regularity test results.

Side	Station	Symbol	Lane	Irregularities			
				4 – 5.9 mm	No.	6-10 mm	No.
Right	00+700 - 1+000	IR1L	Left	4-4-4.3-4.5-5-4.9-5-5.3-5.6-4.6-4.7-5.4	12	-	-
		IR1M	Middle	4-4.5-5-5.3-4.7-4.8-5-5-5.3-5.7	10	-	-
		IR1R	Right	4.8-5-5.3-5.4-4.9-4.6-4.8-5-5.3-4-4.6-4.7	12	-	-
Right	6+600 - 6+900	IR2L	Left	5.8-5.7-5.2-5.6-4.9-4-4.6-4.7-4.5-4-4-4.7-5	13	-	-
		IR2M	Middle	4-4.3-4.6-4.8-4-4.3-5-5.1-5.3-5.6-4-4.6-5	13	-	-
		IR2R	Right	4.6-4.3-4.7-5-5-5.6-5.4-4.9-5.1-4.3-4	11	-	-
Right	13+500 -13+800	IR3L	Left	4.3-4.6-5-4.6-4.7-5-5.3-5.1-5.4-5	10	-	-
		IR3M	Middle	5-5-4.6-4.7-4.1-5-5.3-5.4-4.8	9	-	-
		IR3R	Right	4.3-5-4.6-4.7-4-5-5.3-5.7-4.9-4.1-5	11	-	-
Left	2+200- 2+500	IL1L	Left	4-4.3-4.6-4-5-5-4.6-4.9-5.1-5.3-5.7-4.6-4.9	13	-	-
		IL1M	Middle	4-4-4.3-4.9-4.7-4.8-4-4-5-5.2-4.9-4.7-4.8	13	-	-
		IL1R	Right	5-5.3-4-4-5.3-5.4-5.5-5.6-4.5-5.4-4.7-4.7	12	-	-
Left	7+600- 7+900	IL2L	Left	4.6-4.7-4.8-4.1-4.3-5.1-5.3-5.5-5.4-4.5-4.8-4.7	12	-	-
		IL2M	Middle	4-5-5.3-5.4-4.3-4.7-4.9-4.5-5.1-5.6-5.4-4.9	12	-	-
		IL2R	Right	4.3-4.6-5.1-4.6-5.5-5.3-4.8-4.6-4.1-5.6-5.4-5.7	12	-	-
Left	13+700- 14+00	IL3L	Left	5-5-4.7-5.1-5.3-4.7-5.6-5.7-4.6-4.7-4.5-4.6-4.8-4	14	-	-
		IL3M	Middle	4-5-4-5.6-5.7-4.6-4.8-4.1-4.6-5-4.6-4.7-4.5	13	-	-
		IL3R	Right	5-4-5.3-5.7-5.8-5.1-5.3-5.2-5.7-4.8-4.9-4.1	12	-	-

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00144.21

The deviation of the final regularity test was registered, as shown in (Table 3).

Table 3. Final regularity test results.

Side	Station	Symbol	Lane	Irregularities			
				4 – 5.9 mm	No.	6-10 mm	No.
Right	00+700 -1+000	FR1L	Left	5-5.3-5.4-5.4-5-4.8-4.7-4.9-4.2-5.6-5.4-5.3-4.6-5.2	14	6	1
		FR1M	Middle	4.2-4.9-4-5.2-5-5-5.3-5.7-4.8-4.5-5.5-5.5-4.5	13	6	1
		FR1R	Right	5.3-5.6-5.4-5-5.2-5-5.6-5.3-5.4-4.8-4.6-5-4-4-5	15	6	1
Right	6+600 - 6+900	FR2L	Left	5.3-5.7-5.1-5.5-4.6-4.7-5.1-5.3-5.5-5.5-5-5-4-4-5.3-5.1	16	-	-
		FR2M	Middle	5.4-5.6-4.9-5-5-5-5.8-5.4-5.5-5.4-4.6-4.3-4.7-4.9-5	15	-	-
		FR2R	Right	5.6-5.4-5.9-5.7-5.8-5.1-5.3-5-5.3-5.8-4.7-4.6-4.3-4	14	6	1
Right	13+500 -13+800	FR3L	Left	5.3-5.4-5.7-5-5.3-5.7-5.8-5.9-5.4-4-4-4-5-4.8-4.5-4.5	16	-	-
		FR3M	Middle	4.8-4.7-5-5.3-5.4-5-5.6-5.5-5.5-4.8-4.9-5.1-4-5-4.7-5.3	16	-	-
		FR3R	Right	5.7-5.6-5.4-5.3-5.8-5.2-5.8-5.6-5.4-4.5-4.1-4-4.3-4.8-4.9-4	16	6.5	1
Left	2+200- 2+500	FL1L	Left	5.3-5.4-5.5-5.4-5.1-5.8-5.3-5.8-5.7-5.1-4-4.3-4.6-4.5-4.8-4.9-5	17	-	-
		FL1M	Middle	4-4.6-4-5.3-5.8-5.7-5.4-5.6-4.2-5.6-5.1-4.5-5-5.7-5-5.3-4.9	17	-	-

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00144.21

Table 3. Final regularity test results (continued)

Side	Station	Symbol	Lane	Irregularities			
				4 – 5.9 mm	No.	6-10 mm	No.
Left	7+600- 7+900	IL2L	Left	5.3-5.4-5.3-4-4-4.5-4.5-4.6-4.9-4.8-5.3-5.6-5.8-5.7-5.4	15	-	-
		FL2M	Middle	5.6-5.1-5.8-4.6-4.8-5-5.6-5.5-4.5-4.9-4.3-4.8-5.3-5.4-5-4	16	-	-
		FL2R	Right	5-4-4-5-5-5.6-5.8-5.9-5.4-5.5-5.5-4.5-4.9-4.9-4.8-4.8-5	17	6-7	2
Left	13+700- 14+00	FL3L	Left	5.2-5.6-5.4-5.9-4.6-4.8-4.7-4.2-4.8-5.3-5.2-5.5-5.5-5-4-5.7	16	-	-
		FL3M	Middle	5.5-5.1-5.8-5.7-5.6-5.5-4.9-4.8-4.2-4.3-5-4-5.6-5.5-4.5-4-5	17	-	-
		FL3R	Right	5.6-5.3-5.9-5.7-5.3-5.7-4.8-4.9-5-4.7-4.3-4.5-4.5-5.5-5-4	16	-	-

By comparing the initial and final test results in (Table 2) and (Table 3) with the limits of the Iraqi standard SCRB, 2003 in (Table 1), it is clear that all of them meet the requirements of the specification limits.

As seen in (Figure 4), (Figure 5), (Figure 6); (Figure 7); (Figure 8) and (Figure 9), it is also possible to observe there are more irregularities in the final testing results than in the initial testing results across all sections. The observed differences could attributed to the compaction of asphalt pavement related to the reduction in air voids caused by traffic loads over two years.

To verify whether the difference in deviations is statistically significant for corresponding sections for the initial and final, a multiple analysis of variance (ANOVA) tests at a significance value of 0.05 has been conducted. The test findings in Table 4 reveal that the significance value of 0.235 is more than 0.05. There is no statistically significant difference between the relevant groups.

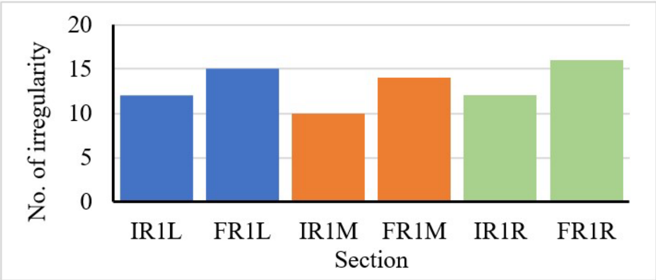

Figure 4. Number of irregularities for right side 00+700 - 1+000.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00144.21

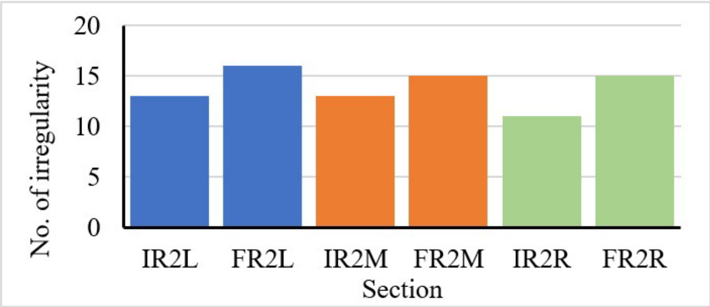

Figure 5. Number of irregularities for right side 6+600 - 6+900.

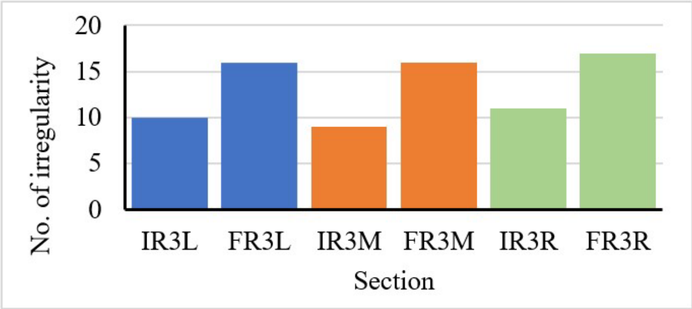

Figure 6. Number of irregularities for right side 13+500 - 13+800.

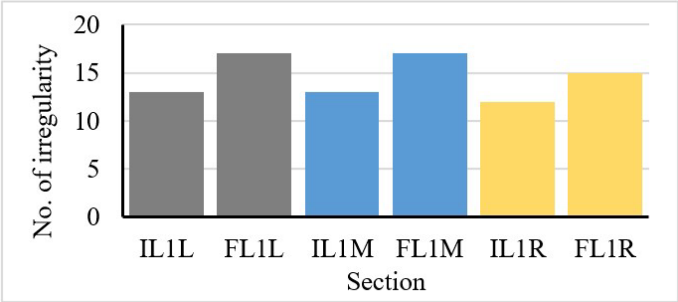

Figure 7. Number of irregularities for left side 2+200- 2+500.

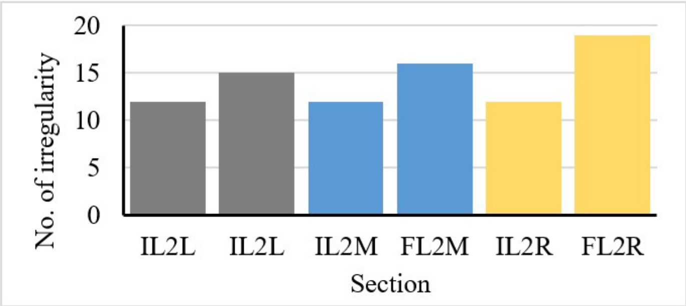

Figure 8. Number of irregularities for left side 7+600- 7+900.

ISSN: 0718-5073

Vol. 40
Nº1 2025
DOI: 10.7764/RIC.00144.21

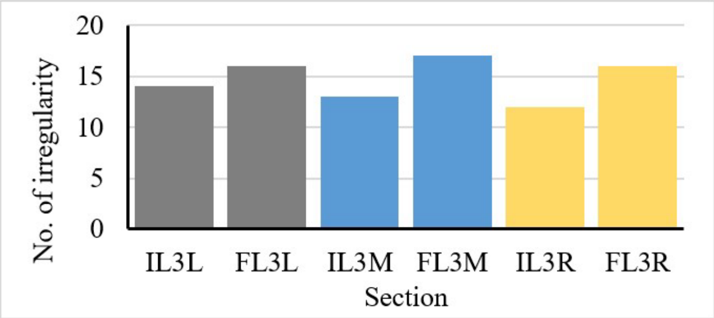

Figure 9. Number of irregularities for left side 13+700- 14+00.

Table 4. Test results of ANOVA.

	Sum of squares	df	Mean square	F	Sig. value
Between-group	11.603	35	0.332	1.156	0.235
Within group	133.695	466	0.287		
Total	145.299	501			

5. Conclusions

Based on the findings of the irregularity tests conducted both before and after the opening of traffic, as well as the available project data, it is possible to generate the following conclusions:

The presence of discomfort or noise in vehicles is possible due to the high frequency of irregularities and the proximity between them.

There is no evidence of deterioration in the formation layers of the road based on the findings of the irregularity tests performed before and after opening the traffic. The difference in pavement deviations, which was not statistically significant, confirmed it. Generally, the asphaltic concrete pavement for the surface layer is constructed with air voids of 3 to 5% (SCRB, 2003) therefore, the disparity may attributed to the traffic loads' densification of the asphalt pavement, which decreased the amount of air voids.

More importantly, the large number of irregularities may be due to poor implementation or due to the laying of the asphalt-surface layer using asphalt cement modified with polymer in the winter, where the loss of temperature of the asphalt mixture led to an increase in asphalt mixture consistency, which led to poor laying and compaction process.

6. Notes on Contributors

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Vol. 40
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