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Evaluating the impact of elevations between concrete pavement slabs on road surface smoothness

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Abstract: This article investigates the formation of elevations between cement-concrete pavement slabs on the 228-581 km section of the A-380 "Guzar-Bukhara-Nukus-Beyneu" highway and the reasons for their impact on road surface smoothness. Experimental studies were conducted using the "TRASSA" mobile road laboratory. Based on the obtained results, the elevations in the expansion joints between concrete pavement slabs and their negative impact on road surface smoothness were evaluated. The study also considered the operating conditions of cement-concrete pavements and the influence of moving loads on the expansion joints between the slabs. The article analyzes how these elevations between slabs negatively affect road safety and the long-term performance of the road for vehicular traffic.
The obtained results serve to identify problems that arise in the production and operation of cement-concrete pavements and to develop practical recommendations for their elimination. The study also demonstrates the necessity of applying advanced technologies in road construction to enhance the quality of roads and improve their effective management.
Keywords: Evenness, protrusions, joints, IRI, dowel, anchor, cracks, structure, deformation, expansion joint, slab

1. Introduction

The formation of elevations between slabs on cement-concrete paved roads significantly affects the smoothness of the road surface. These elevations cause deformations on the road surface, which complicates vehicle movement and reduces safety. The elevations create unsmoothness of varying degrees (cracks and rises) on the road surface. This situation complicates the movement of vehicles, especially at high speeds, potentially leading to dangerous situations for drivers due to the elevations on the road surface. The irregularities and deformations deteriorate the road's smoothness, which leads to vehicles slowing down and, consequently, decreases the overall operational efficiency of the road [1,4].

If the smoothness of the road deteriorates due to uplifts and deformations, this, in turn, increases repair and maintenance costs. Deformed sections of concrete require repair or replacement, which shortens the road's service life and leads to additional expenses.

If elevations and deformations occur frequently, the road requires regular maintenance and renovation. This affects the continuous and safe movement of vehicles.

The key quality indicators of road surfaces are their durability and smoothness, which significantly influence traffic flow speed, ease of movement, transport safety, and load-bearing capacity. When certain road sections have low durability and smoothness, it necessitates the allocation of additional resources for their repair, leads to deterioration of vehicle traffic conditions, reduces the efficiency of automobile transport, and increases transportation costs (including fuel consumption and wear of spare parts and tires).

The importance of the highway, the conditions for ensuring convenient movement, and the calculated speed requirements are presented in QR 06.03-23 (Table 1) according to the international IRI (International Roughness Index) indicator and the established standards [3,6,8].

1-table

Requirements for the International Roughness Index (IRI)

№	The Significance of the Path	Road Classification	Types of coatings	Based on various assessments of road smoothness, its values according to the international IRI (International Roughness Index), (m/km)				
				Excellent	Very good	Good	Satisfactory	Unsatisfactory
1	International	I (Ia and Ib)	Hot asphalt concrete Cement concrete	up to 2,1	2,1-2,5	2,5-3,1	3,1-3,9	greater than 3,9
2	State	II	Hot asphalt concrete Sementbeton	up to 2,8	2,8-3,3	3,3-4,0	4,0-4,9	greater than 4,9
		III	Hot asphalt concrete	up to 3,2	3,2-3,8	3,8-4,7	4,7-5,8	greater than 5,8
			Cold asphalt concrete	up to 3,5	3,5-4,2	4,2-5,1	5,1-6,2	greater than 6,2
			Cold asphalt concrete	up to 4,4	4,4-4,9	4,9-5,6	5,6-6,5	greater than 6,5

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		IV	Black crushed stone	up to 4,7	4,7-5,3	5,3-6,1	6,1-7,2	greater than 7,2
			Stone materials processed with binders					
		V	Black crushed stone	up to 6,1	6,1-7,1	7,1-8,5	8,5-10,1	greater than 10,1
			Stone materials processed with binders					
3	Local		Crushed stone or stone aggregates	up to 6,5	6,5-7,6	7,6-8,9	8,9-10,6	greater than 10,6

As evident from the experience of developed countries, the smoothness of road surfaces is evaluated using the International Roughness Index (IRI). It is known that the formation of bumps on cement-concrete paved roads significantly deteriorates the smoothness of the road surface.

2. Research methodology

The Guide for Mechanistic-Empirical Design of New and Reconstructed Pavements - GMED-2003 (USA) contains a model for predicting pavement smoothness. Using this model, calculations are performed to evaluate the impact of elevation on pavement smoothness [2,9,10]:

$$\mathrm{IRI} = \mathrm{IRI}_0 + 0{,}013 \cdot C + 0{,}007 \cdot J + 0{,}0015 \cdot H + 0{,}4 \cdot S \qquad (1)$$

Here:

IRI_0 – initial roughness index, m/km;

C– Number of plates with transverse and angled cracks, %;

J – percentage of deteriorated (damaged) seams, %;

N- final value of the rise per 1 km of road, in mm;

S- The construction factor is calculated as follows:

$$\mathrm{S} = (\mathrm{T} \cdot (1 + \mathrm{I}) \cdot (1 + P_{0{,}075})) \cdot 10^{-6} \qquad (2)$$

Here:

T – age of the surface layer, in years;

I– cold hardiness index, °C days;

$R_{0{,}075}$- the percentage of particles smaller than 0.075 mm in the road subgrade soil.

3. Analysis and Results

We calculate the international roughness index for the studied sections of the road and adopt it as the initial smoothness measurement. In recent years, requirements for road surface smoothness have become more stringent. In this context, in foreign countries, the issue of ensuring the required pavement smoothness throughout its entire design life is addressed at the stage of determining and calculating the pavement structure. When calculating road surfaces, particularly rigid pavements, using modern methods, in addition to determining the main parameters of the structure, the probability of crack formation is assessed, taking into account the potential changes in road and environmental conditions.

We determined the longitudinal smoothness values for sections 228-581 km of the A-380 "Guzar-Bukhara-Nukus-Beyneu" highway using the "TRASSA" mobile road laboratory (Figure 1). The results obtained from measuring the longitudinal smoothness were processed and converted into graphical representations (Figures 2-6).

Fig. 1. "TRASSA" mobile road laboratory vehicle

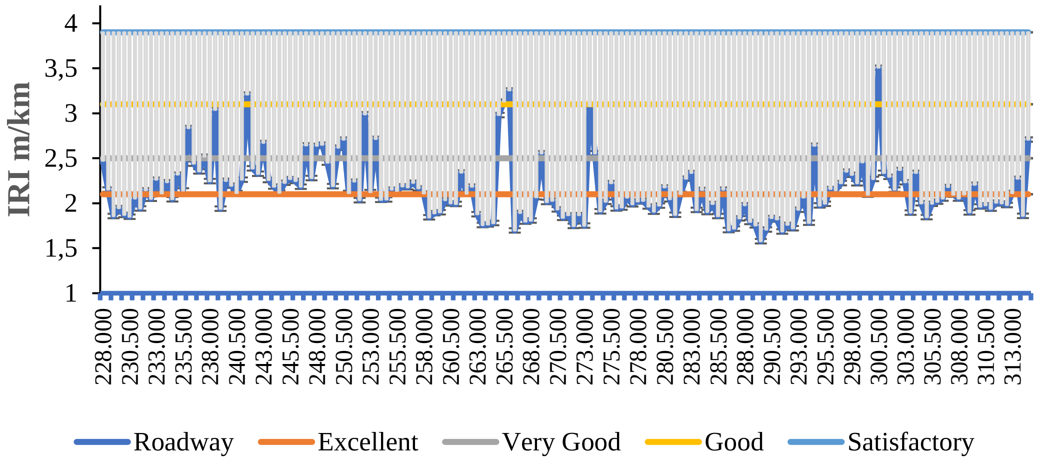

Fig. 2. Smoothness indicators of the cement-concrete pavement on the 228-315 km section of the A 380 highway

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Fig. 3. Smoothness indicators of the cement-concrete pavement on the 315-355 km section of the A 380 highway

Fig. 4. Smoothness indicators of the cement-concrete pavement on the 355-440 km section of the A 380 highway

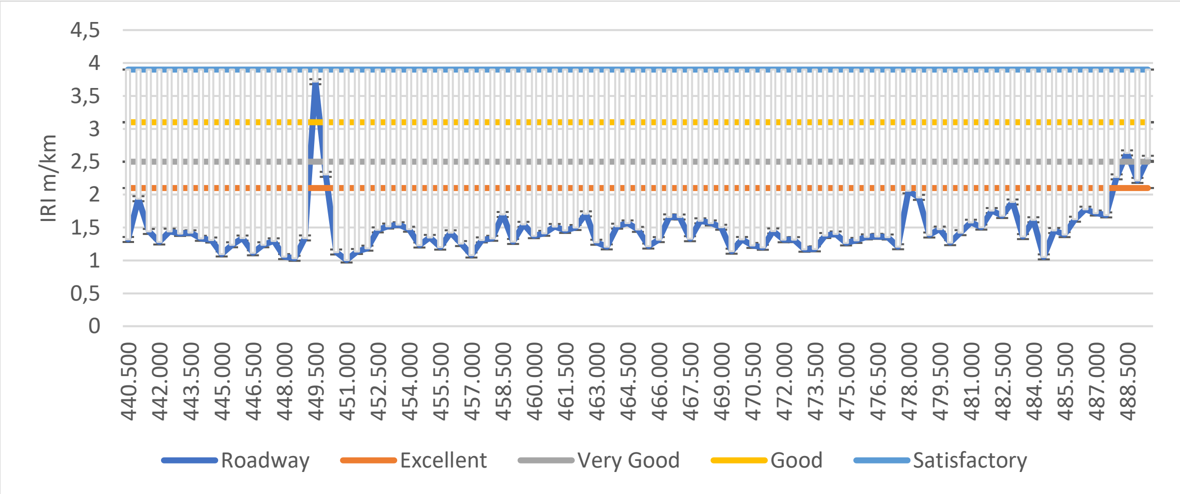


Fig. 5. Smoothness indicators of the cement-concrete pavement on the 440-490 km section of highway A 380

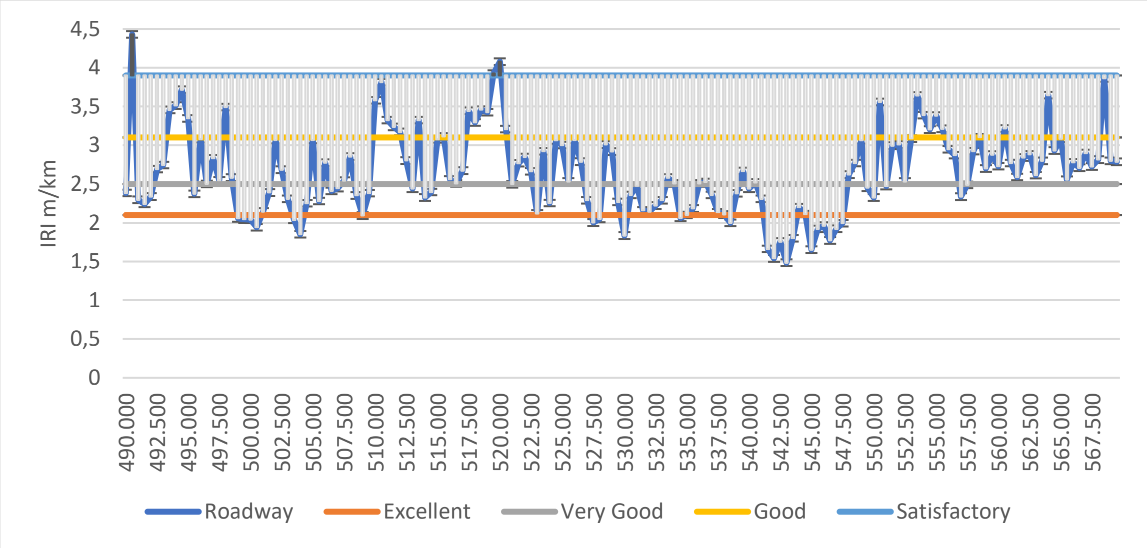
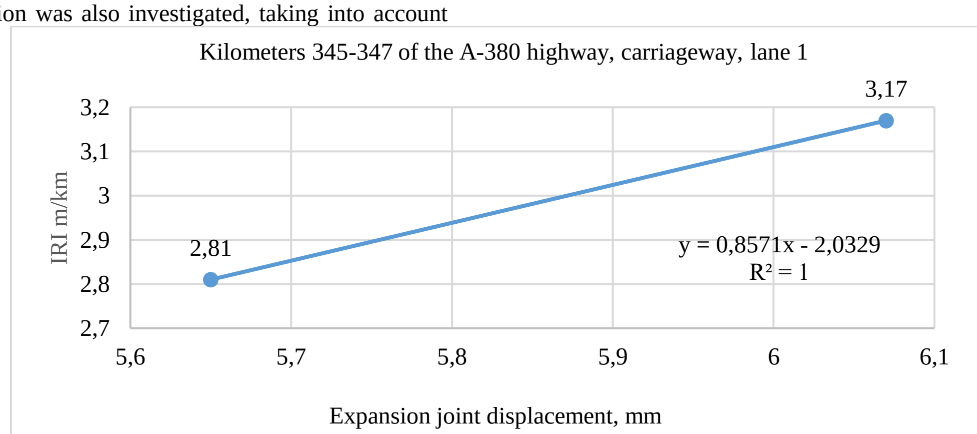


Fig. 6. Smoothness indicators of the cement-concrete pavement on the 490-581 km section of A 380 highway

In recent years, requirements for road surface smoothness have become more stringent. Consequently, in other countries, the issue of ensuring the required pavement smoothness throughout its entire design life has been addressed at the stage of determining and calculating the road surface structure [5,7,8].

In modern methods of calculating road pavements, particularly rigid pavements, not only were the main parameters of the structure determined, but the probability of crack formation was also investigated, taking into account the likelihood of changes in road and natural pavement conditions.

The calculation of the road surface concludes with determining the predicted condition of the pavement during road operation. Graphs and tables showing the relationship between changes in roadway smoothness and the spaces between concrete slabs for sections 345-347 km, 370-373 km, and 425-430 km of the A-380 "Guzar-Bukhara-Nukus-Beyneu" highway are presented below.

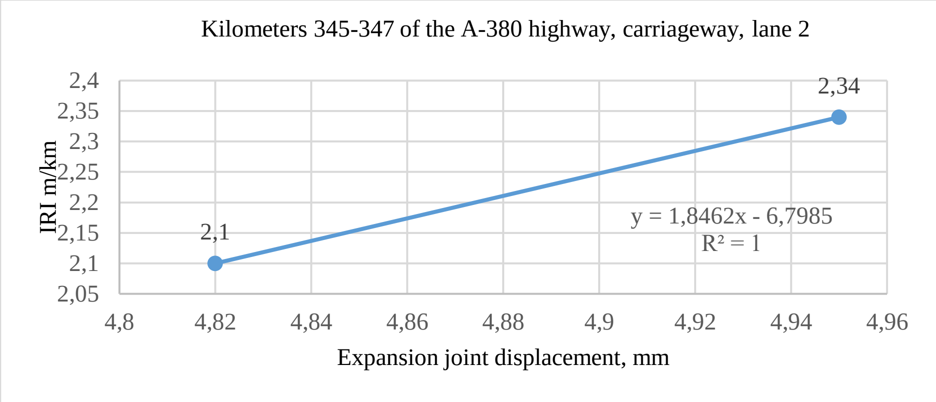


Graph 1. Relationship between IRI and elevation differences between slabs

Table 2

Dependence of pavement smoothness on changes between plates

№	Highway A-380, second lane of the roadway, km	Change in spacing between plates, mm	IRI, m/km
1	345-346	5.65	2.81
2	346-347	6.07	3.17

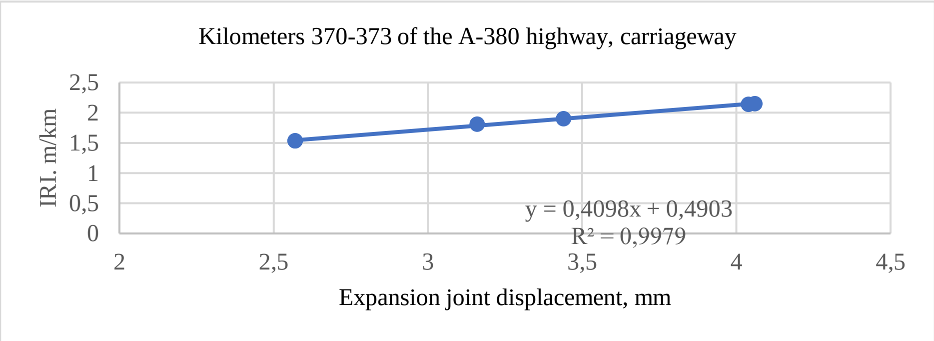


Graph 2. Relationship between IRI and elevation differences between slabs

Table 3

Dependence of pavement smoothness on changes between plates

№	Highway A-380, second lane of the roadway, km	Change in spacing between plates, mm	IRI, m/km
1	345-346	4.82	2.1
2	346-347	4.95	2.34

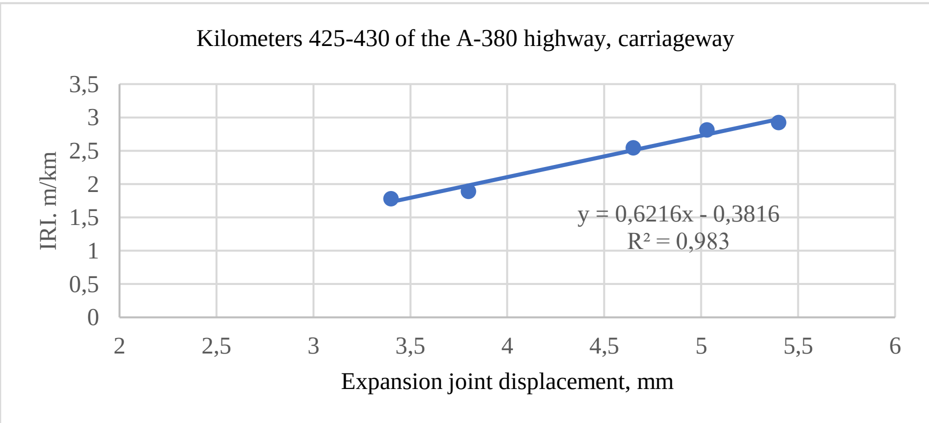


Graph 3. Relationship between IRI and elevations between slabs

Table 4

Dependence of pavement smoothness on changes between plates

№	Highway A-380, second lane of the roadway, km	Change in spacing between plates, mm	IRI, m/km
1	370,0-370,5	2.57	1.53
2	370,5-371,0	2.57	1.53
3	371,0-371,5	3.16	1.81
4	371,5-372,0	3.44	1,90
5	372,0-372,5	4.06	2.15
6	372,5-373,0	4.04	2.14



Graph 4. Relationship between IRI and elevations between slabs

Table 5

Dependence of pavement smoothness on changes between plates

№	Highway A-380, second lane of the roadway, km	Change in spacing between plates, mm	IRI, m/km
1	425-426	3.4	1.78
2	426-427	5.03	2.81
3	427-428	4.65	2.54
4	428-429	5.4	2.92
5	429-430	3.8	1.89

4. Conclusion

It is expected that the smoothness of roads with cement-concrete pavement complies with the requirements of QR 06.03-23.. In the conducted research work, negative elevations between the slabs were identified on the A-380 "Guzar-Bukhara-Nukus-Beyneu" highway at sections 345-347 km, 370-373 km, and 425-430 km. As a result of testing the pavement smoothness using the "TRASSA" mobile road laboratory equipment, indicators in the range of 1.53-3.17 m/km were determined. Through a graph showing the relationship between the state of elevations in the transverse expansion joints and the pavement smoothness, it was established that the elevations on the slabs directly affect the smoothness.

After the construction of roads with cement-concrete pavement, transverse expansion joints, vertical and horizontal displacements of cement-concrete slabs, impacts from vehicle wheels, and slab tilting result in the normalization of transverse and longitudinal joints. Their regulatory and legal activities in the field of road construction ensure.

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