Conducting experimental studies of cement concrete pavement joints

Khodzhiakmal Aripov*, *Kurbon* Muminov, *Yakubjon* Kochkharov, and *Jakhongir* Khushvakhtov

Tashkent State Transport University, Tashkent, Uzbekistan

Abstract. To increase the life of roads in our Republic, several reforms are being carried out to operate roads with high strength and efficiently use available materials. Experience in constructing cement concrete roads shows that, over time, elevations of several millimeters can form between the slabs. The formation of disturbances hurts the longitudinal plane of the carriageway. It increases the driving resistance, makes the movement of vehicles uncomfortable, and causes the vehicles to oscillate. This increases the load on the roadway. Therefore, the study and development of recommendations for forming a shift between cement concrete paving slabs are relevant today. A study of negative changes (formation of steps) of the cement concrete pavement from dry-hot climatic conditions and over time in longitudinal, transverse compression, transverse expansion, floating, false, and working seams is presented. The results were obtained on 315-320 km of highway A 380 "Guzor-Bukhara-Nukus-Beyneu" by measuring the heights and subsidence of the plates of transverse expansion joints with an electronic caliper and protractor. Using a mobile laboratory machine, "Ford Terrassa", the longitudinal smoothness of the coating of this object was determined, and the results were obtained. Then a correlation plot of the effect of variation between plates (steps) on the smoothness of the coating (IRI) was plotted.

1 Introduction

More than two thousand years ago, the first roads with concrete pavement based on mineral binders were built in the Roman Empire and have partially survived to this day [1]. The first pavements made of concrete on Portland cement were built in England (Edinburgh) in 1866. 25 years later, in 1891, the first paved road was built in the United States [2]. Mass construction of such roads has begun in this country. By 1912 there were 400 km of paved roads in the USA; By 1913, this number had doubled. In 1914 there were 3 thousand km, and in 1951 - 140 thousand km [3]. The first concrete sections in Russia were built in 1913 on the streets of St. Petersburg. In the pre-war period (until 1941), concrete pavements in Russia were built experimentally - on a small scale and with the help of foreign concrete pavers. Large-scale construction of concrete roads began in the 50s of the 20th century [4].

*Corresponding author: khojakmalaripov22@gmail.com

The construction of cement concrete roads in our republic began in 1962. In the 70s and 80s of the last century, some sections of M-39 "Almaota-Bishkek-Tashkent-Termez" and 4R1 "Tashkent ring road" were built with cement concrete pavements with the help of DS-110 concrete laying machine [5]. Today, cement concrete roads account for 60% of all roads in the US and 38% in Germany. It is 46% in Austria, 3% in Russia, only 2.5% in Uzbekistan, and to date, the construction of cement-concrete roads is gradually being completed [6].

To date, the length of railways in our Republic is 8,000 km, and the total length of roads is 209,496 km, of which:

- public highways – 42.869 km;
- internal roads – 141.882 km;
- departmental roads – 24.745 km.

Public roads are under the jurisdiction of a specially authorized body - the Committee of Highways, internal economic roads, under the authority of local government bodies, and departmental roads are under the authority of legal entities and individuals [7]. The network of public roads in our republic, in turn, is divided into 3.981 km of international importance, 14.105 km of national importance, and 24.609 km of local roads [8].

Therefore, today, the construction of a four-lane monolithic cement-concrete pavement on the A-380 Guzor-Bukhara-Nukus-Beyneu highway, which is part of the Uzbek National Highway, is underway at an accelerated pace, at the expense of investments programs [9].

2 Methods

The article uses a systematic approach, experiment-research, and methods of processing the study results.

In cement concrete pavements, transverse and longitudinal seams should be designed. The transverse seams include expansion (compensation), compression, waist, and working seams. If the width of the coating is more than 23 times its thickness, transverse seams are applied. These seams are built to reduce stresses caused by daily and seasonal changes in air temperature. A design feature of cement-concrete coatings is the presence of expansion joints that ensure the deformation of the structure during operation under the influence of changes in ambient temperature [10].

Longitudinal and transverse seams, as a rule, should intersect at right angles, and transverse seams should be located in one line across the width of the pavement. Expansion joints are not arranged on class IV pavements. Longitudinal and transverse seams in cement concrete pavements divide the monolithic pavement into slabs [11].

Determined by calculating the distance between the compression joints (slab length). The length of the slab depends on the distance between the compression joints, the climatic conditions of the construction site, and the thickness of the slab.

The length of the slabs without reinforcement is allowed to be determined according to Table 1, depending on the thickness of the coating. During the construction period, the length of the slab can only be changed by the design organization for technical and economic reasons [12].

Table 1. Recommended slab lengths without reinforcement.

Climatic conditions	Coating thickness		
	18	20	22-24
	Plate length		
Continental	3.5-4	4-5	4.5-6.0

The continental (dry-hot) climate is characterized by the air temperature being repeated for more than 50 days during the year, and the daily maximum and minimum temperature

 https://doi.org/10.1051/e3sconf/202340102047

difference is more than 12°C [13]. Depending on the car's speed, steps are measured at three points along the lane here (Fig. 1). Points 1 and 3 were measured at a distance of 0.5-1.0 m from the edge of the right and left lanes. At point 2, the measurement is made strictly in the middle of the tape [14].

According to the guidelines for the installation of solid pavement (instead of VSN 197-91), during the life of the pavement, the steps on the slabs should not exceed 3 mm (Fig 1) [15].

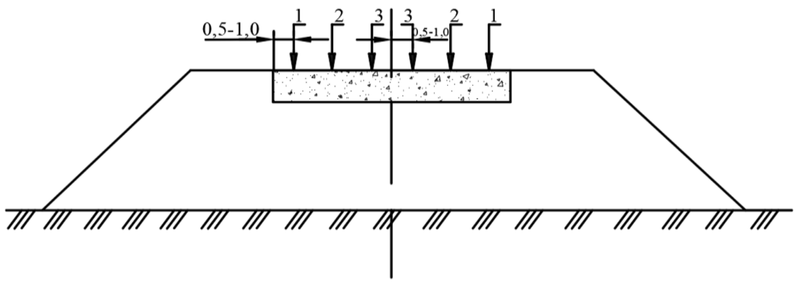

Fig. 1. Measurement points for stairs along the roadway

315-581 km of the highway A-380 "Guzor-Bukhara-Nukus-Beyneu", we measure changes between plates using an electronic caliper and protractor (Fig 2., Table 4) [16].

Fig. 2. Measuring and determining the difference between the plates using an electronic caliper and protractor.

Fig. 3. 315-320 km of route A 380. Photos from measuring the smoothness of the cement concrete pavement in the section (11/15/2022).

After determining the evenness of the road surface, we evaluate it according to Table 2 [17].

Table 2. Following the administrative significance of the highway and the condition for ensuring comfortable traffic, requirements are imposed on the assessment of consumption based on the international indicator IRI

№	Importance of the road	Road category	Types of coating	Based on a different assessment of ride comfort, its value according to the international IRI index, (m / km)				
				Excellent	Very good	Good	Satisfactor y	Unsatisfac tory
1	International	I (Ia and Ib)	Hot asphalt concrete	2.1 up to	2.1 - 2.5	2.5 - 3.1	3.1 - 3.9	3.9 more than
			Cement concrete					
2	State	II	Hot asphalt concrete	2.8 up to	2.8 - 3.3	3.3 - 4.0	4.0 - 4.9	4.9 more than
			Cement concrete					
		III	Hot asphalt concrete	3.2 up to	3.2 – 3.8	3.8 - 4.7	4.7 - 5.8	5.8 more than
			Cold asphalt concrete	3.5 up to	3.5 - 4.2	4.2 – 5.1	5.1 - 6.2	6.2 more than
3	Local	IV	Cold asphalt concrete	4.4 up to	4.4 – 4.9	4.9 – 5.6	5.6 - 6.5	6.5 more than
			Black pebble	4.7 up to	4.7 – 5.3	5.3 - 6.1	6.1 - 7.2	7.2 more than
			Stone materials treated with binders					
		V	Black pebble	6.1 up to	6.1 – 7.1	7.1 - 8.5	8.5 - 10.1	10.1 more than
			Stone materials treated with binders					
			Rubble or stone materials	6.5 up to	6.5 – 7.6	7.6 - 8.9	8.9 - 10.6	10.6 more than

3 Results and discussion

As a result of experimental studies, a change in the width of transverse expansion joints was determined in section 315-320 km of the A 380 highway (Fig. 4-5, Table 3) [18].

Fig. 4. Photographs of the change in the width of the grooves of the transverse expansion joints in section 315-320 km of the A 380 highway (2022).

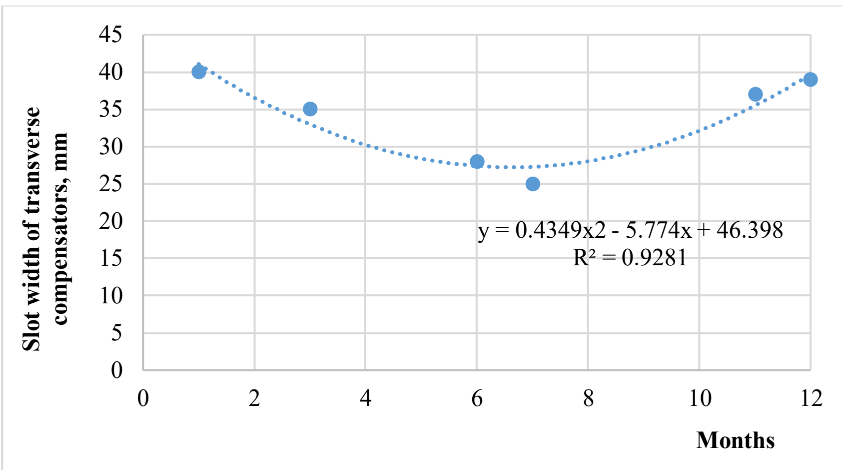

Fig. 5. Change in the width of the grooves of the transverse expansion joints in section 315-320 km of the A 380 highway (2022)

Table 3. The results of the experiment on section 315-320 km of the A-380 highway "Guzor-Bukhara-Nukus-Beyneu".

1st carriageway					2nd carriageway				
№	Kilometers covered by research	Right side part	Middle part	Left side part	№	Kilometers covered by research	Right side part	Middle part	Left side part
1	315.1	3.19	4.5	8.16	1	315.1	6.88	7.27	8.31
2	315.2	3.28	4.75	7.33	2	315.2	6.75	7.19	8.24
3	315.3	3.53	4.68	7.82	3	315.3	6.91	7.35	8.19
4	315.4	3.61	4.85	8.22	4	315.4	7.42	8.47	8.38
5	315.5	3.51	6.92	9.14	5	315.5	7.55	9.26	9.48
6	315.6	3.93	5.68	8.37	6	315.6	8.03	8.71	8.27
7	315.7	3.48	7.11	9.18	7	315.7	6.88	8.34	10.25
8	315.8	3.54	8.26	9.30	8	315.8	6.78	7.33	9.17
9	315.9	4.05	6.54	8.24	9	315.9	7.61	10.61	10.75
10	316.0	3.69	6.13	8.15	10	316.0	7.66	10.23	10.22
11	316.1	4.88	8.33	9.47	11	316.1	9.09	12.56	10.25
12	316.2	5.08	8.44	9.55	12	316.2	8.45	9.53	10.17

Continuation of table № 3

1st carriageway					2nd carriageway				
№	Kilometers covered by research	Right side part	Middle part	Left side part	№	Kilometers covered by research	Right side part	Middle part	Left side part
13	316.3	4.53	6.97	9.52	13	316.3	8.27	9.83	10.23
14	316.4	4.57	5.83	9.11	14	316.4	8.24	8.26	8.28
15	316.5	4.41	7.55	9.37	15	316.5	8.51	8.59	9.04
16	316.6	4.28	5.21	8.89	16	316.6	8.31	8.44	8.93
17	316.7	4.95	6.83	8.44	17	316.7	10.5	12.83	8.71
18	316.8	4.91	6.71	9.31	18	316.8	8.25	8.28	8.66
19	316.9	4.93	6.54	9.15	19	316.9	8.27	10.34	10.35
20	317.0	4.56	6.85	9.38	20	317.0	8.31	10.45	10.32
21	317.1	3.89	6.34	8.28	21	317.1	3.59	5.78	9.3
22	317.2	3.06	5.66	7.56	22	317.2	3.71	6.88	8.82
23	317.3	3.54	5.81	7.56	23	317.3	3.76	5.17	8.55
24	317.4	3.12	4.57	7.33	24	317.4	4.06	5.07	8.66
25	317.5	4.02	7.41	8.17	25	317.5	4.93	6.53	8.71
26	317.6	3.14	6.67	8.41	26	317.6	3.76	4.34	8.86
27	317.7	3.59	6.41	7.84	27	317.7	3.85	5.26	8.69
28	317.8	3.22	6.13	8.25	28	317.8	3.89	6.75	8.82
29	317.9	3.37	5.56	7.31	29	317.9	3.85	5.29	8.7
30	318.0	3.48	6.28	8.03	30	318.0	3.96	6.24	8.69
31	318.1	3.61	4.85	8.51	31	318.1	6.88	6.90	7.7
32	318.2	3.53	6.90	9.53	32	318.2	6.95	7.61	8.35
33	318.3	3.88	7.11	9.18	33	318.3	8.22	7.83	8
34	318.4	3.46	8.26	9.51	34	318.4	6.65	8.67	9.94
35	318.5	3.53	8.26	9.54	35	318.5	6.61	7.49	9.27
36	318.6	4.02	6.54	9.45	36	318.6	7.01	10.24	10.45
37	318.7	3.96	6.13	9.51	37	318.7	7.07	10.45	10.23
38	318.8	3.99	8.33	9.47	38	318.8	9.35	12.56	10.2
39	318.9	4.01	8.44	9.59	39	318.9	8.79	9.53	10.15
40	319.0	3.57	6.97	9.53	40	319.0	8.27	9.83	10.18
41	319.1	3.94	5.83	8.26	41	319.1	8.24	8.26	8.68
42	319.2	3.71	7.55	8.37	42	319.2	8.61	8.59	9.03
43	319.3	3.28	5.21	8.23	43	319.3	8.25	8.44	8.81
44	319.4	4.02	6.83	8.12	44	319.4	10.5	12.83	8.71
45	319.5	3.99	6.71	9.31	45	319.5	8.25	8.28	8.69
46	319.6	3.86	6.75	8.16	46	319.6	8.31	7.32	8.88
47	319.7	3.57	6.54	8.35	47	319.7	6.94	8.21	8.97
48	319.8	3.15	6.51	8.09	48	319.8	5.74	5.89	8.85
49	319.9	3.47	6.58	8.06	49	319.9	7.12	7.43	8.71
50	320.0	3.64	8.28	8.37	50	320.0	7.01	7.29	8.29

We determined the longitudinal smoothness of the cement concrete pavement using a mobile laboratory machine-mechanism "Ford Terassa", and obtained the following results (Table 4) [19].

Table 4. IRI - Longitudinal rounds

1st carriageway				2nd carriageway			
№	Start and end of the object, km	Tape 1	Tape 2	№	Start and end of the object, km	Tape 1	Tape 2
1	315.0-315.1	1.81	2.94	1	315.0-315.1	2.48	2.72
2	315.1-315.2	2.03	2.54	2	315.1-315.2	2.41	2.59
3	315.2-315.3	2.19	2.81	3	315.2-315.3	2.50	2.57
4	315.3-315.4	2.28	2.96	4	315.3-315.4	2.75	2.79
5	315.4-315.5	2.19	3.24	5	315.4-315.5	2.82	3.07
6	315.5-315.6	2.54	3.01	6	315.5-315.6	2.99	2.64
7	315.6-315.7	2.11	3.22	7	315.6-315.7	2.48	3.38
8	315.7-315.8	2.19	3.25	8	315.7-315.8	2.43	2.89
9	315.8-315.9	2.56	3.16	9	315.8-315.9	2.89	3.41
10	315.9-316.0	2.37	3.22	10	315.9-316.0	2.91	3.36
11	316.0-316.1	2.46	3.17	11	316.0-316.1	3.43	3.34
12	316.1-316.2	2.48	3.27	12	316.1-316.2	3.03	3.27
13	316.2-316.3	2.23	3.24	13	316.2-316.3	2.89	3.32
14	316.3-316.4	2.38	2.88	14	316.3-316.4	2.78	2.86
15	316.4-316.5	2.22	2.98	15	316.4-316.5	3.04	3.22
16	316.5-316.6	2.03	2.85	16	316.5-316.6	2.99	3.08
17	316.6-316.7	2.57	2.63	17	316.6-316.7	3.62	2.99
18	316.7-316.8	2.53	3.19	18	316.7-316.8	2.86	2.91
19	316.8-316.9	2.56	3.16	19	316.8-316.9	2.89	3.41
20	316.9-317.0	2.37	3.22	20	316.9-317.0	2.91	3.36
21	317.0-317.1	2.52	3.04	21	317.0-317.1	2.05	2.80
22	317.1-317.2	1.72	2.67	22	317.1-317.2	2.24	2.72
23	317.2-317.3	2.06	2.67	23	317.2-317.3	2.26	2.47
24	317.3-317.4	1.98	2.57	24	317.3-317.4	2.53	2.54
25	317.4-317.5	2.63	2.89	25	317.4-317.5	2.90	2.66
26	317.5-317.6	1.88	3.19	26	317.5-317.6	2.26	2.77
27	317.6-317.7	2.18	2.79	27	317.6-317.7	2.41	2.57
28	317.7-317.8	1.81	2.94	28	317.7-317.8	2.48	2.72
29	317.8-317.9	2.03	2.54	29	317.8-317.9	2.41	2.59
30	317.9-318.0	2.19	2.81	30	317.9-318.0	2.50	2.57
31	318.0-318.1	2.28	2.96	31	318.0-318.1	2.75	2.79
32	318.1-318.2	2.19	3.24	32	318.1-318.2	2.82	3.07
33	318.2-318.3	2.54	3.01	33	318.2-318.3	2.99	2.64
34	318.3-318.4	2.11	3.22	34	318.3-318.4	2.48	3.38
35	318.4-318.5	2.19	3.25	35	318.4-318.5	2.43	2.89
36	318.5-318.6	2.56	3.16	36	318.5-318.6	2.89	3.41
37	318.6-318.7	2.37	3.22	37	318.6-318.7	2.91	3.36
38	318.7-318.8	2.46	3.17	38	318.7-318.8	3.43	3.34
39	318.8-318.9	2.48	3.27	39	318.8-318.9	3.03	3.27
40	318.9-319.0	2.23	3.24	40	318.9-319.0	2.89	3.32
41	319.0-319.1	2.38	2.88	41	319.0-319.1	2.78	2.86
42	319.1-319.2	2.22	2.98	42	319.1-319.2	3.04	3.22
43	319.2-319.3	2.03	2.85	43	319.2-319.3	2.99	3.08
44	319.3-319.4	2.57	2.63	44	319.3-319.4	3.62	2.99
45	319.4-319.5	2.53	3.19	45	319.4-319.5	2.86	2.91
46	319.5-319.6	2.34	2.78	46	319.5-319.6	2.70	3.06
47	319.6-319.7	2.14	2.96	47	319.6-319.7	2.49	3.11
48	319.7-319.8	1.85	2.58	48	319.7-319.8	2.13	3.04
49	319.8-319.9	2.08	2.49	49	319.8-319.9	2.74	2.89
50	319.9-320.0	2.29	2.98	50	319.9-320.0	2.56	2.73

Road: A 380_315_320 1st carriageway and 2nd carriageway. Road code: 1511022 Beginning of the object, km: 315,000 End of the object, km: 320,000 Measurement date: 11/15/2022.

The results of mutual changes (stepping) of cement concrete paving slabs, depending on the smoothness of the coating, we can see in the following tables 6-9 and figures 6-9 [20].

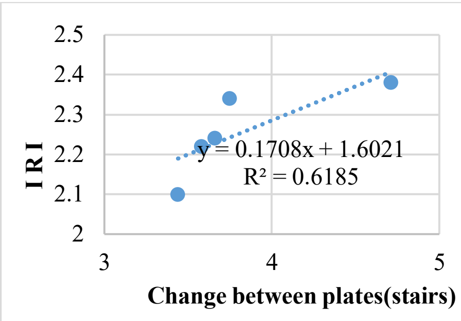

Fig. 6. 315-320 km of the A 380 highway, 1st carriageway, 1st lane, changes (stairs) between plates, depending on the IRI.

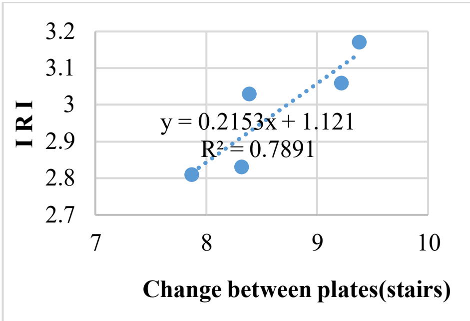

Fig. 7. 315-320 km of the A 380 highway, 1st carriageway, 2nd lane, changes (stairs) between plates, depending on the IRI.

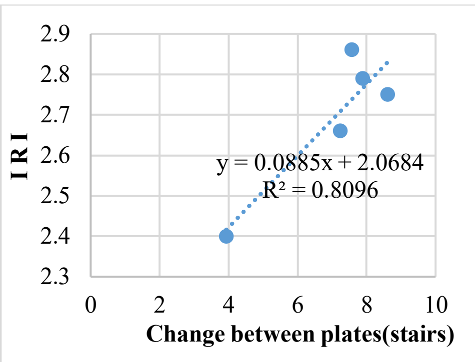

Fig. 8. 315-320 km of the A 380 highway, 2nd carriageway, 1st lane changes (stairs) between plates, depending on the IRI.

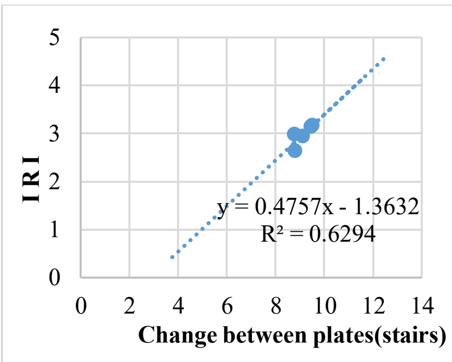

Fig. 9. 315-320 km of the A 380 highway, the 2nd carriageway, the changes (stairs) between the plates in the 2nd lane, depending on the IRI.

4 Conclusions

In short, expansion joints increase the concrete pavement's longitudinal strength in the summer heat. They should always be built at the approaches to bridges, overpasses, and at the level of intersections of concrete sidewalks. The width of the seams is 30 mm. The design documentation shows the seam laying scheme on the reconstructed 315-581 km of the A-380 highway. This drawing shows the installation of a transverse expansion joint every 80 m.

But we recommend installing transverse expansion joints every 300 m. Following paragraph 2.18 of MKN 43-08, it is allowed not to construct expansion joints if the temperature during the installation of a coating with a thickness of 22-24 cm or more using a series of sliding formwork machines is from +15 to + 25 °C and above. The following conditions must be met:

base - from soils reinforced with inorganic binders,

curb - must be made of solid materials or concrete.

All transverse seams must be sealed with mastic in time during the road operation. If the road surface is designed without expansion joints, then every 15-30 m in front of bridges and overpasses, at least 3 expansion joints should be made, filled with solid compressible material, 6 cm wide.

References

1. Amirov, T., Urakov, A., Aripov, X., Qurbonov, B., & Tuxtayev, M. (2023, March). Forecasting model of strength indicators of gravel-sand mixture treated with cement. In AIP Conference Proceedings (Vol. 2612, No. 1, p. 040028). AIP Publishing LLC.
2. Amirov, T., Aripov, X., Qurbonov, B., Tuxtayev, M., & Rakhmatov, S. (2021). Designing the composition of road concrete with chemical additives. In E3S Web of Conferences (Vol. 264, p. 02049). EDP Sciences.
3. Nuraliev, A. K., Amirov, T., & Esenbekov, A. J. (2020). On the energy efficiency of electromechanical systems with an electromagnetic vibration exciter. In E3S Web of Conferences (Vol. 216, p. 01108). EDP Sciences.
4. Urokov, A., Ubaydullayev, F., Mamatkulov, M., & Soataliyev, R. (2022, June). The use of gibberellin in the cultivation of horse chestnut seedlings (Aesculus hippocastanum L.) for the landscaping of highways. In AIP Conference Proceedings (Vol. 2432, No. 1, p. 030078). AIP Publishing LLC.
5. F. A. Aleksandrovich, Influence of the parameters of the design of the pave pad on the process of formation of ledges between cement concrete covering plates. 2009, p. 195.
6. Zhu Z., and Chen, X. Discussion and analysis on the improvement of the widening technology of cement concrete pavement of rural highway. European Journal of Remote Sensing, 1-11. (2022).
7. Urakov, A., Tashev, D., Xametov, Z., & Soataliev, R. (2022, March). Road Maintenance and Climate Zoning of the Territory of the Republic of Uzbekistan. In International Scientific Siberian Transport Forum TransSiberia-2021: Volume 1 (pp. 1213-1224). Cham: Springer International Publishing.
8. Taher S. A., Alyousify S., and Hassan H. J. A. Comparative Study of Using Flexible and Rigid Pavements for Roads: a Review Study. Journal of Duhok University, 23(2), 222-234. (2020).
9. Khasanov B., Vatin N., Mirzaev T., Suyunov A., Radjabov M. Analysis of the mode of squeezing out excess water for mixing concrete mixture in the process of peristaltic compaction, IOP Conference Series: Materials Science and Engineering, 1030(1), 01202, (2021)
10. Alaitz Linares-Unamunzaga 1,* , Heriberto Pérez-Acebo 2 , Marta Rojo 1 and Hernán Gonzalo-Orden 1. Flexural Strength Prediction Models for Soil–Cement from Unconfined Compressive Strength at Seven Days.January 2019. Materials 12(3):387. DOI:10.3390/ma12030387. License. CC BY 4.0.

11. Amiruddin Ismail[1,2,a] ,Mojtaba Shojaei Baghini[1,2,b], Mohamed Rehan Bin Karim[3,c],[1,2,d] Foad Shokri, Ramez A. Al-mansoba[1,2,e] , Ali Asghar Firoozi[2,f] , Ali Akbar Firoozi[2,g] Laboratory investigation on the strength characteristics of CementTreated Base. Applied Mechanics and Materials Vol. 507 (2014) pp 353-360 © (2014) Trans Tech Publications, Switzerland doi:10.4028/www.scientific.net/AMM.507.353.
12. Rasha. Abd Al-RedhaGhani, Dr. Mohammed A. Al-Jummaily and Dr. Ahlam K. R. Al-Zerjawi. Study of cement treated base agreagate properties for pavement structure. International Journal of Information Research and Review 2018,05, 5093-5100
13. Dauletov Madiyar Boranbaevich, Assistant, "Analysis of the factors causing the formation of breaks between cement concrete slabs," Am. J. Orthod. Dentofac. Orthop., vol. 2, no. 9, pp. 189–195, 2022, doi: 10.1016/j.ajodo.2022.07.001.
14. Montes F., Valavala S., and Haselbach L. M. A new test method for porosity measurements of Portland cement pervious concrete, Vol. 2, No. 1. ASTM International. (2005).
15. Urokov A., Soataliev R., Kasimkhodjaev B., and Mamatmuminov A. The Current State and Prospects of Development of the Network of Public Roads of Uzbekistan. Journal of applied research, 8(04), 290-293. (2022).
16. Yadgarov S. N., Amirov T. Dz., Gapporov Sh. Optimization of the design of road gondolas with cement concrete coating. Actual problems of the humanities and natural sciences. 4, pp. 15-16. (2016).
17. Adilkhodjaev A., Hasanov B., Shaumarov S., Kondrashchenko V. Aerated concrete with predetermined pore parameters for the exterior walls of energy efficient buildings, IOP Conference Series: Materials Science and Engineering, 1030(1), 012006, (2021).
18. Sh.N.Q-3.06.03-21, Automobile roads, vol. 0, no. 0. 2021.
19. AASHTO «Standard specifications for transportation materials and methods of sampling and testing». Thirtieth Edition (2010).
20. European Standard EN 206-1:2000 «Concrete - Part 1: Specification, performance, production and conformity», (2000).