Technobius, 2022, 2(1), 0013, DOI: https://doi.org/10.54355/tbus/2.1.2022.0013

Technobius
https://technobius.kz/

e-ISSN 2789-7338

Article

Practical experience with modified bitumen and bituminous binders

Zhanar Kusbergenova[1], Aizhan Zhankina[1,*], Mkilima Timoth[2]

[1]Department of Civil Engineering, L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan
[2]Ardhi University, Plot Number 3 Block L, Observation Hill, P. O. Box 35176, Dar Es Salaam, Tanzania
*Correspondence: zhankina90@mail.ru

Abstract. To date, the issue of polymer waste recycling becomes relevant, because every year the amount of plastic and polyethylene waste increases, which leads to devastating effects on flora and fauna everywhere. One of the ways to solve this problem of polymer waste recycling is to use them to modify asphalt-concrete mixture and bitumen. Thus, two problems are solved at once: reuse of plastic, polyethylene, and other polymer wastes and improvement of asphalt concrete pavement with an increase in its service life. The paper presents a discussion of the use of modified bitumen in the construction of highways and roads, the design and technological solutions, features of the technology of modified bitumen, as well as the results of laboratory tests of modified bitumen, based on which was decided on the advisability of using. The use of the combined approach of the road pavement allows increasing the service life of the road.
Keywords: bitumen, test, safety, road pavement, mixture.

1. Introduction

1.1 Bitumen modifying additives

All over the world during the last decades, the question of finding the optimal and effective composition of bitumen that meets all the requirements for its use and further operation has been actively studied. So, in particular, some types of modifiers improve the adhesive, cohesive and other properties of bitumen, but are harmful to the environment when mixed with bitumen and further use of such bitumen for road paving [1-2]. Other modifiers meet all the requirements, but the composition of the binder in such mixtures is very expensive and, therefore, such a composition is no longer profitable in economic terms.

Every year the amount of plastic and polyethylene waste increases, which leads to destructive effects on flora and fauna everywhere. One of the ways to solve the mentioned problem of polymer waste recycling is their use in the modification of asphalt-concrete mixture and bitumen [3–7]. Thus, two problems are solved at once: reuse of plastics, polyethylene, and other polymer waste and improvement of asphalt concrete pavement with an increase in its service life. All bitumen modifying additives can be divided into several groups [8–10]:

1) thermoplastic polymers, they include styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), styrene-ethylene/butylene-styrene (SE/BS);
2) Elastomers, these include rubbers and rubber-like polymers;
3) thermoplastics, these include: polypropylene, polyethylene, polystyrene, polyvinyl chloride, polyvinyl acetate;
4) thermoplastics, include epoxy, urea, polyester, and other synthetic resins.

1.2 Problems in the road sector

Bitumen is an organic binder of black or dark brown color, consisting of a mixture of high-molecular-weight hydrocarbons and their non-metallic derivatives. Bitumen is characterized by good adhesion to mineral materials, resistance to water, and acid and alkaline solutions. Bitumen reversibly converts to the viscous state when heated. Bitumen can be thinned by organic solvents and thickened by their evaporation.

Depending on their origin bitumens are divided into natural and artificial. In the construction industry are used mainly artificial petroleum bitumen is produced from the residues of oil distillation. Bitumens are divided by consistency into solid, viscous, and liquid. Bitumens are a complex mixture of high-molecular organic substances. The main chemical elements in bitumens: carbon (70-87 %), hydrogen (8-12 %), sulfur (0,5-7 %), oxygen (0,2-12 %), nitrogen (0-2 %) [1]. Most of the bitumen used in road construction is modified because the additives improve the quality of performance properties of bitumen and the result is an actual material with improved physical, mechanical and chemical properties [11]. Figure 1 shows types of pavement failures.

a) spalling, cracking, and crack netting

b) rut formation, component leakage

c) premature deterioration of asphalt pavement

d) not resistant to deformation

Figure 1 – Types of pavement failures [12]

2. Methods

The projected section of the highway is located in the city of Almaty. Non-injury roadway design presented in Figure 2 [13].

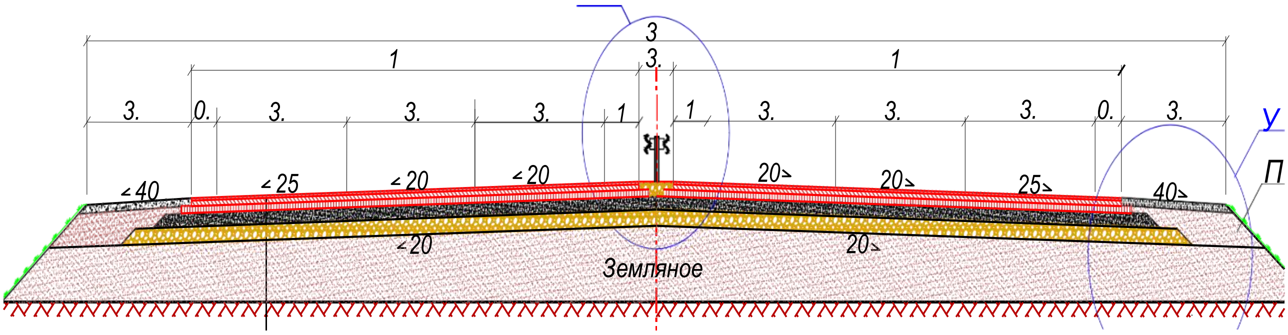

Figure 2 – Road pavement design [13]

Non-injury road pavement includes the top layer of the pavement - hot dense polymer asphalt concrete, type A, bitumen modified BMP 70/100 submark I - 5 cm; The bottom layer of the pavement - hot-laid dense asphalt concrete type A, I grade of the crushed stone mixture, grade of bitumen BND-70/100, thickness 10,0 cm; The top layer of the base - hot-laid porous asphalt concrete grade II of coarse-grained crushed stone mix, grade bitumen BND- 70/100, a thickness of 12.0 cm; The bottom layer of the basement, - crushed stone mixture C5 - 40 mm (for the foundations), a thickness of 24.0 cm; underlying layer - natural sand-gravel mixture, with a thickness of 30.0 cm. The total thickness of the pavement structure is 81 cm.

Construction of the pavement consists:

– Construction of gravel-sandy base layer and base course of crushed stone-sandy mixture
– An Additional (base) layer is made of a natural sand-gravel mixture with a thickness of 30 cm.
– The bottom layer of the base course is made of crashed stone-sandy mixture C4, with a thickness of 24 cm thickness.
– At the time of laying the mixture must have humidity close to the optimum with a deviation of not more than 10%.
– If the humidity is insufficient, moisten the mixture 20-30 minutes before the beginning of compaction.
– Distribution of the material placed in the construction layer is carried out with the help of distributors, mobile mixing plants, and motor graders.
– The layer is compacted by rollers on pneumatic tires weighing not less than 16 tons with air pressure in tires of 0.6-0.8 MPa, by trailed vibratory rollers weighing not less than Tandem vibrating rollers weighing no less than 6 tons, lattice rollers weighing no less than 15 tons, self-propelled smooth rollers weighing no less than 10 tons and combined rollers weighing more than 16 tons.
– Rolling is carried out in the longitudinal direction, with water irrigation, starting from
– The rolling is performed in the longitudinal direction, watered down from the outer edges towards the center, except for curves with curves, where except for curves and curves in which the rolling is performed from the lower edges.

Asphalt concrete pavement construction works considered:

– The top layer of the base course is made of hot porous asphalt concrete, 12 cm thick.
– The bottom pavement layer is made of hot compact coarse-grained asphalt concrete with a thickness of 10 cm.
– The top layer of the pavement is polymer asphalt concrete, 5 cm thick.

The physical and mechanical properties of the initial bitumen presented in Table 1 and of the materials are shown in Table 2.

Table 1 – Physical and mechanical properties of the initial bitumen

Indicator name	Unit of measurement	70/100	BND 70/100 Spec Limits	100/130	BND 100/130 Spec Limits	
1 – Depth of needle penetration 25°C 0°C	×0,1 мм	 75 *	 71-100 ≥ 22	 113 *	 101-130 ≥ 30	ST RK 1226 GOST 33136
2 – Softening temperature in the ring and ball	°C	45.6	≥ 45	39.5	≥ 43	ST RK 1227 GOST 33142
3 – Ductility at temperature: 25°C, 0°C	см	 96.3 *	 ≥ 75 ≥3,8	 108 *	 ≥ 90 ≥4	ST RK 1374

						GOST 33138
4 – Flash point	°C	246	≥ 230	237	≥ 230	ST RK 1804 GOST 33141
5 – Fraas temperature brittleness	°C	-16	≤ -20	-20.5	≤ -22	ST RK 1229 GOST 33143

Table 2 – The characteristics of the materials

Specifications	Porous Asphalt		Binder Course		Wearing Course		Test Standard
	Min.	Max.	Min.	Max.	Min.	Max.	
Compaction, number of blows each end of specimen	75		75		75		TS EN 12697-30
Marshall Stability kg	600	-	750	-	900	-	TS EN 12697-34
Flow, 0.25 mm (0.01 in.)	2	5	2	4	2	4	TS EN 12697-34
Percent Air Voids %	4	6	4	6	3	5	TS EN 12697-8
Percent Voids Filled With Asphalt (VFA) %	55	75	60	75	65	75	TS EN 12697-8
Percent Voids in Mineral Aggregate (VMA) %	12	14.5	13	15	14	16	TS EN 12697-8
Filler/Bitumen	-	-	-	1.4	-	1.5	
Content of Bitumen (By weight, to 100)	3.0	5.5	3.5	6.5	4.0	7.0	TS EN 12697-1
Compressed Bituminous Mixtures Resistance Against Distortion, Indirect Tensile Strength %	80		80		80		AASHTO T 283
Wheel tracking (30.000rpm at 60 °C) max. %	-		-		8		TS EN 12697-22

3. Results and Discussion

Laboratory tests of modified bitumen according to ST RK 2534-2014 [14] are presented in Table 3 [13].

The most promising is the way to improve bitumens by polymer additives. When changing the structural and mechanical properties of used bitumens focus on the indicators of high polymers capable of maintaining the ultimate deformability at low negative temperatures, while not losing strength when heated and not softening.

Table 3 – Laboratory tests of modified bitumen

Indicator name	Unit of measurement	PMB 58-28	Test Method	35/50	50/70	70/100		100/130		130/150	Test Method
						I	II	I		II	
1 – Depth of needle penetration, at a temperature 25°C	0,1 mm	90-150	TS EN 1426	35-50	51-70	71-100		101-130		131-150	ST RK 1226 GOST 33136
2 – Softening temperature in the ring and ball	°C	≥ 45	TS EN 1427	≥ 65	≥ 62	≥ 60	≥ 58	≥ 55	≥ 52	≥ 52	ST RK 1227 GOST 33142
3 – The force ductility method	J	≥ 0,5	TS EN 13589	-	-	-	-	-	-	-	-
4 – The elastic recovery of modified bitumen	%	≥ 80	TS EN 13398	≥ 60	≥ 60	≥ 60	≥ 60	≥ 60	≥ 60	≥ 60	ST RK 1374 GOST 33138
5 – Flash point	°C	≥ 220	TS EN ISO 2592	≥ 240	≥ 235	≥ 230	≥ 230	≥ 230	≥ 220	220	ST RK 1804 GOST 33141

6 – Measurement of density and specific gravity	g/cm^3	1,0-1,1	TS EN 15326	-	-	-	-	-	-	-	-
7 – Dynamic Shear Rheometer, (DSR) (G*/sinδ,1.10 kPa)	°C	≥ 58	TS EN 14770	-	-	-	-	-	-	-	-
8 – Determination of storage stability			TS EN 13399	≤ 2	≤ 2	≤ 2	ST RK 1211	≤ 2	≤ 2	≤ 2	GOST EN 13399
8.1 – Softening temperature in the ring and ball	°C	≤ 5	TS EN 1427	-	-	-	-	-	-	-	-
8.2 – Depth of needle penetration, at a temperature 25°C	0.1 mm	≤ 13	TS EN 1426	-	-	-	-	-	-	-	-

4. Conclusions

The hot polymer asphalt mixture is laid and compacted like a standard mix by conventional pavers and smooth rollers. rollers. It is recommended, if possible, that asphalt is laid across the entire width of the roadway by tracked pavers with automatic level and slope control systems. There should be no cracks or breaks in the surface of the asphalt pavement after the paver is completed. Cracks, tears, continuity defects, and other imperfections should be visible on the surface of the asphalt pavement. Detected defects can be corrected manually before the layer is compacted by adding and flattening hot mix in these areas. But the stickiness of PAS mixtures is significantly higher than conventional mixtures for dense asphalt concrete according to standards.

To obtain an even surface of the layer, it is necessary to ensure the continuity of hot polymer asphalt mixture laying is necessary to obtain a smooth surface of the layer. The recommended paving speed is at least 2-3 m/min and depends on the delivery of the asphalt mix to the pavers. For short interruptions in the delivery of the mixture, it is not recommended that it be completely discharged from the paver's hopper. The hopper should always be at least 25% full. In the case of a forced stop of the paver for 15-20 minutes, the remaining mixture from the hopper should be moved to the heated auger chamber, since hot polymer asphalt mixture mixes harden faster when cooled than standard asphalt mixtures harden faster than standard asphalt mixtures.

References

1. Polymer modified bitumen: properties and characterisation: Woodhead Publishing in materials. — Oxford: WP, Woodhead Publ, 2011. — 404 p.
2. The Shell Bitumen Handbook / R.N. Hunter, A. Self, J. Read. — London, UK: ICE Publishin, 2015. — 761 p.
3. Effect of Waste Polyethylene and Wax-Based Additives on Bitumen Performance / L. Desidery, M. Lanotte // Polymers. — 2021. — Vol. 13, No. 21. — P. 3733. https://doi.org/10.3390/polym13213733
4. Performance of porous asphalt containing modificated buton asphalt and plastic waste / D. S. Mabui, M. W. Tjaronge, S. A. Adisasmita and Mubassirang Pasra // International Journal of GEOMATE. — 2020. — Vol. 18, No. 65. — P. 118–123. https://doi.org/10.21660/2020.65.67196
5. Sustainable Practice in Pavement Engineering through Value-Added Collective Recycling of Waste Plastic and Waste Tyre Rubber / X. Xu, Z. Leng, J. Lan, W. Wang, J. Yu, Y. Bai, A. Sreeram, J. Hu // Engineering. — 2021. — Vol. 7, No. 6. — P. 857–867. https://doi.org/10.1016/j.eng.2020.08.020
6. Polymer modified asphalt binders / Y. Yildirim // Construction and Building Materials. — 2007. — Vol. 21, No. 1. — P. 66–72. https://doi.org/10.1016/j.conbuildmat.2005.07.007
7. Using Mineral Fibers to Improve Asphalt and Asphalt Mixture Behavior / L. Zhao, J. Chen, S. Wang // Traffic and Transportation Studies 2010. — Reston, VA: American Society of Civil Engineers, 2010. — P. 1352–1360. https://doi.org/10.1061/41123(383)129
8. FM analysis of aging properties of UV531/SBS modified bitumen / F. Zhengang, C. Fengjie, Y. Dongdong, L. Xinjun // IOP Conference Series: Materials Science and Engineering. — 2020. — Vol. 758, No. 1. — P. 012068. https://doi.org/10.1088/1757-899X/758/1/012068
9. Rheological behavior of recycled polyethylene modified bitumens / E.S. Okhotnikova, I.N. Frolov, Yu.M. Ganeeva, A.A. Firsin, T.N. Yusupova // Petroleum Science and Technology. — 2019. — Vol. 37, No. 10. — P. 1136–1142. https://doi.org/10.1080/10916466.2019.1578796
10. Investigation of the Effect of Adhesive Additive on the Plasticity of Road Bitumen and Physical-Mechanical Properties of the Road Concrete Mix / Mukhamatdinov I. I. // Chemistry for Sustainable Development. — 2021. — No. 1. — P. 86-97. https://doi.org/10.15372/CSD2021281

11. Development of binder specification parameters based on characterization of damage behavior / T.P. Bahia HU, Zhai H, Zeng M, Hu Y // Journal of the Association of Asphalt Paving Technologists. — 2001. — Vol. 70. — P. 442–470.
12. Institutional Support to the National Quality Center for Road Assets [Electronic resource] / ADB. — [2020]. — Mode of access: https://www.adb.org/projects/54092-001/main (accessed date: 25.02.2021).
13. Working Project «Big Almaty Ring Road Construction» Survey Materials, Geological Report // «Research and Manufacturing Company Kazdorinnovaciya» LLP, Almaty. — 2019.
14. ST RK 2534-2014 Bitumen and bituminous binders. Petroleum bitumen modified, for road surface. Specifications. — 2001. — 30 p.

Information about authors:
Zhanar Kusbergenova – Master Student, Department of Civil Engineering, L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan, zh.kusbergenova@sapaortalygy.kz
Aizhan Zhankina – PhD Student, Department of Civil Engineering, L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan, zhankina90@mail.ru
Timoth Mkilima – Research Fellow, Ardhi University, Plot Number 3 Block L, Observation Hill, P. O. Box 35176, Dar Es Salaam, Tanzania, tmkilima@gmail.com

Author Contributions:
Zhanar Kusbergenova – concept, resources, interpretation, funding acquisition.
Aizhan Zhankina – data collection, testing, visualization, drafting.
Timoth Mkilima – methodology, analysis, modeling, editing.

Received: 26.02.2022
Revised: 28.02.2022
Accepted: 01.03.2022
Published: 17.03.2022