УДК 625.855.3 DOI 10.31649/2311-1429-2023-2-70-74

O. Borziak
V. Zhuravel

AN INVESTIGATION INTO THE INFLUENCE OF VARIOUS ANTI-STRIPPING AGENTS ON THE WATER STABILITY OF ASPHALT CONCRETE

Ukrainian State University of Railway Transport

Asphalt concrete, being a pivotal material in road construction, has its water stability intricately tied to the road's service life and safety. In engineering practice, an ASA is commonly employed to enhance the water stability of asphalt concrete. This investigation aims to scrutinize the impact of various ASAs on the water stability of asphalt concrete by selecting three frequently used ones. The investigation is conducted through the Marshall water immersion test. Experimental outcomes indicate that cement, AASA, and NASA effectively bolster the water stability of asphalt concrete, with NASA demonstrating the most superior performance.

Key words: *asphalt concrete, water stability, residual stability, anti-stripping agent, asphalt, pavement performance, asphalt concrete stability, Marshall method.*

Introduction

Asphalt concrete, being a frequently utilized material in road construction, exhibits a direct correlation between its water stability and the road's service life and maintenance costs[1][2][3]. During road operation, particularly in humid or rainy climates, asphalt concrete is prone to water-induced damage, including spalling, cracking, and deformation[4][5]. To enhance the water stability of asphalt concrete, anti-stripping agents (ASA) find extensive application in engineering practices, aiming to augment the bond between asphalt and aggregate while preventing water intrusion[6][7].

Research indicates that the incorporation of cement, slaked lime, amine anti-stripping agents (AASA), novel nano anti-stripping agents (NASA), and other chemical modifiers can enhance the bonding between aggregate and bitumen[8][9]. The United States has a relatively early history of ASA research, dating back to the 1920s when lime was introduced to augment the bonding of bitumen and aggregate[10]. Under the SHRP program in the U.S., a systematic study was conducted on the bonding between bitumen and aggregate, summarizing the utilization of various ASAs and their efficacy in preventing stripping. Despite numerous studies, the practical application of ASA still necessitates validation due to the continual evolution of asphalt and ASA formulations.

Raw materials

The asphalt utilized in this experiment is ZH-90 petroleum asphalt, and the pertinent technical parameters are delineated in Table 1.

The test was carried out with ordinary silicate cement of strength grade 42.5, and the main testing indexes are delineated in Table 2.

The aggregates used in the test are divided into three grades: 0-5mm, 5mm-10mm, 10mm-20mm, and the aggregates are all acidic rock granite, and the main technical indexes of the raw materials are tested in accordance with the specifications, and the specific test results are delineated in Tables 3-5.

Table 1

Technical specifications of ZH-90

Index	Experimental results	Requirement
Penetration (25 °C, 100 g.5s), 0.1 mm	87	80~100
Softening Point, °C	49.2	≥45
Flash Point, °C	395	≥245
Dynamic viscosity (60°C), Pa•s	156	≥140
Solubility, %	99.8	≥99.5
Penetration Index	-0.9	-1.5~+1.0
Density (15 °C), (g·cm-3)	1.029	—
Extensibility (15 °C), cm	127	≥100

© O. Borziak, V. Zhuravel, 2023

Table 2

Technical indexes of cement

Index	Experimental results	Requirement
IST (Initial setting time), min	125	≥45
FST (Final setting time), h	5.2	≤10
FS-3d (Flexural strength for 3d), MPa	4.8	≥4.8
FS-28d (Flexural strength for 28d), MPa	7.6	≥6.5
CS-3d (Compressive strength for 3d), MPa	24.5	≥24.5
CS-28d (Compressive strength for 28d), MPa	45.7	≥45.7

Table 3

Technical indicators of coarse aggregate(10-20mm)

Index	Experimental results	Requirement
CSV (Crushed Stone Value), %	11.7	≤28
Solmdness, %	5.3	≤12
APD (Apparent Particle Density)	2.80	≥2.5
WA (Water Absorption), %	1.2	≤3
LAAL (Los Angeles Abrasion Loss), %	11.2	≤30

Table 4

Technical indicators of coarse aggregate(5-10mm)

Index	Experimental results	Requirement
Solmdness/%	6.1	≤12
APD	2.81	≥2.5
LAAL, %	10.3	≤30
WA, %	1.5	≤3

Experimental methods

AC-20 asphalt concrete was selected for this investigation, and three varieties of ASA—cement, AASA, and NASA—were chosen based on prevalent usage and existing research. To assess the impact of ASA on asphalt concrete's resistance to water damage, these agents were introduced into the asphalt concrete, and their effects were comparatively analyzed. Cement, serving as a substitute for mineral powder, was incorporated into the asphalt concrete at dosages equivalent to 50 % and 80 % of the mineral powder replacement. The dosages of AASA and NASA were set at 0.1 %, 0.2 %, and 0.3 % of the asphalt content.

Analysis of test results

In accordance with specification requirements, the asphalt concrete treated with various ASAs underwent the Marshall water immersion test. The results of the test are presented in Table 6 and Figures 1 and 2.

Table 5

Technical indicators of fine aggregate(0-5mm)

Index	Experimental results	Requirement
Solmdness, %	9.2	≤12
SE (Sand Equivalent), %	77	≥60
APD	2.73	≥2.50
MC (Mud Content), %	2.1	≤3

Table 6

Results of Marshall water immersion test

Type of ASA	Dosage	Stability, kN	Water immersion stability, kN	Residual stability, %
Unadded	0	9.46	7.07	74.8
Cement	50%	10.8	9.5	87.3
	80%	10.3	8.97	88.2
AASA	0.1%	9.54	8.23	86.3
	0.2%	9.32	8.03	86.6
	0.3%	9.25	8.17	88.7
NASA	0.1%	10.4	9.42	89.5
	0.2%	10.23	9.72	95.1
	0.3%	10.89	10.23	94.3

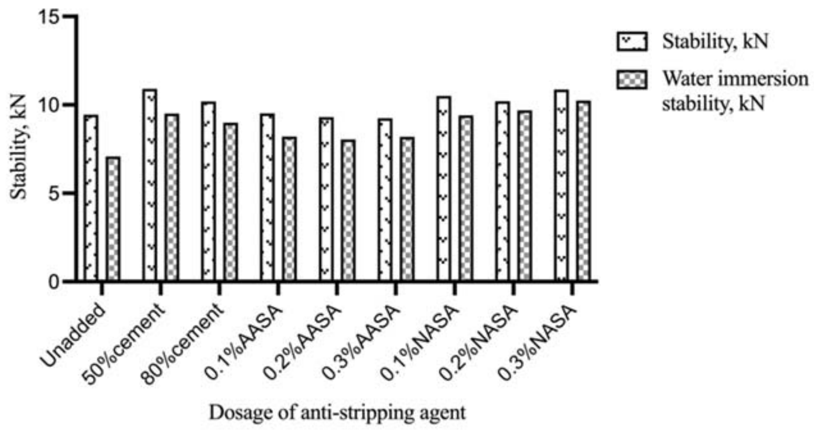

Fig. 1 − Variation in stability

Upon the addition of cement, the water immersion stability of asphalt concrete experiences a 34% increment, accompanied by a significant improvement in residual stability. This implies that cement effectively bolsters the water damage resistance of asphalt concrete. The impact of cement dosage on the mixture's stability is not substantial—whether at 50% or 80% dosage, there is no significant increase in the residual stability of asphalt concrete. Conversely, there is a certain reduction in the stability of asphalt concrete, indicating an optimal cement dosage. Below the optimum dosage, the addition of cement results in a reaction with asphalt, enhancing the stability of asphalt concrete. Beyond the optimal dosage, the extensive specific surface area of cement leads to reduced free asphalt in the mixture, resulting in a drier mixture that adversely affects stability. With the introduction of AASA and NASA, there is a noticeable enhancement in the stability, water immersion stability, and residual stability of the mixture. Notably, the NASA exhibits the most substantial improvement in the mixture's performance.

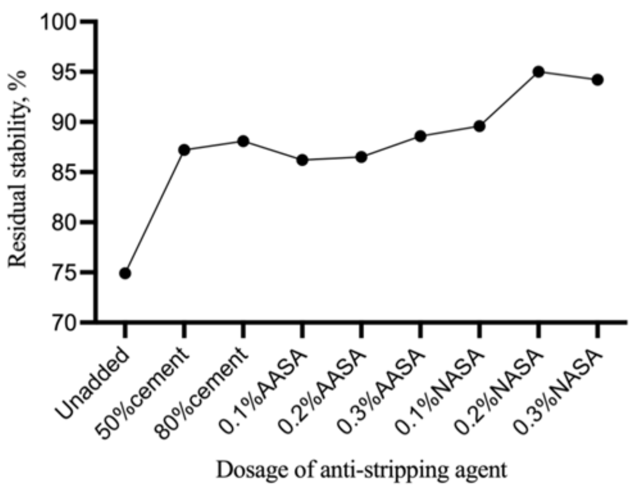

Fig. 2 − Variation in residual stability

Analysis of long-term water damage resistance

In order to further reflect the improvement of ASA, the mixture was subjected to extended time immersion test, put into 60°C constant temperature water bath, respectively, 5 days and 10 days of continuous immersion, and then all the specimens were taken out and tested for the stability of immersion, and the results of the test are shown in Fig. 3 and Fig. 4.

Through the examination of Figure 3 and Figure 4, it becomes evident that, as the water immersion time increases, the stability of the mixture incorporating three ASAs undergoes varying degrees of reduction. Following a 2-day water immersion of Marshall specimens in comparison to a 30-minute water immersion, both stability and water immersion stability witness a notable decrease. In contrast, the Marshall stability and water immersion stability exhibit marginal changes between 5-day and 10-day water immersions compared to a 2-day water immersion. The primary occurrence of test water damage takes place within the initial 48 hours of immersion, signifying that the Marshall water immersion test serves as an evaluative indicator for the water damage resistance of asphalt concrete.

The stability of specimens immersed in water for 10 days is lower than that of specimens immersed for 5 days, with the most apparent decrease in stability observed in specimens with added AASA. Conversely, the stability of specimens with added cement and NASA undergoes relatively minor changes, indicating that the long-term resistance to water damage varies among different types of ASAs. Specifically, the stability loss in mixtures with added AASA increases after prolonged water immersion, suggesting a deterioration in the effectiveness of AASA over time. In contrast, cement and NASA exhibit greater stability and durability.

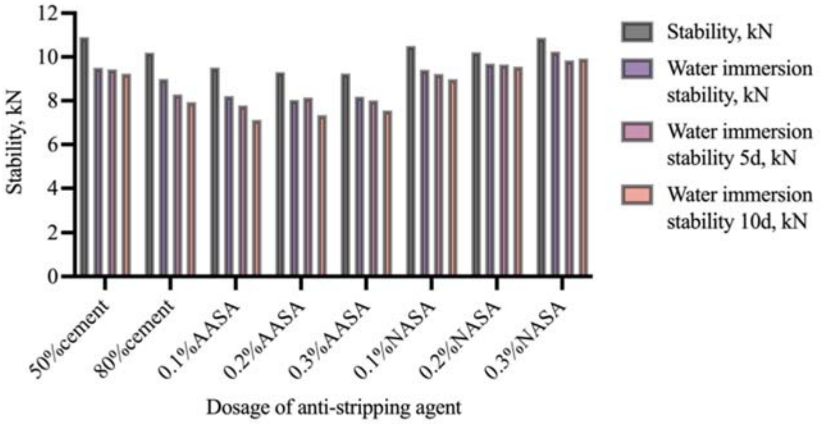

Fig. 3 − Variation of stability under different conditions

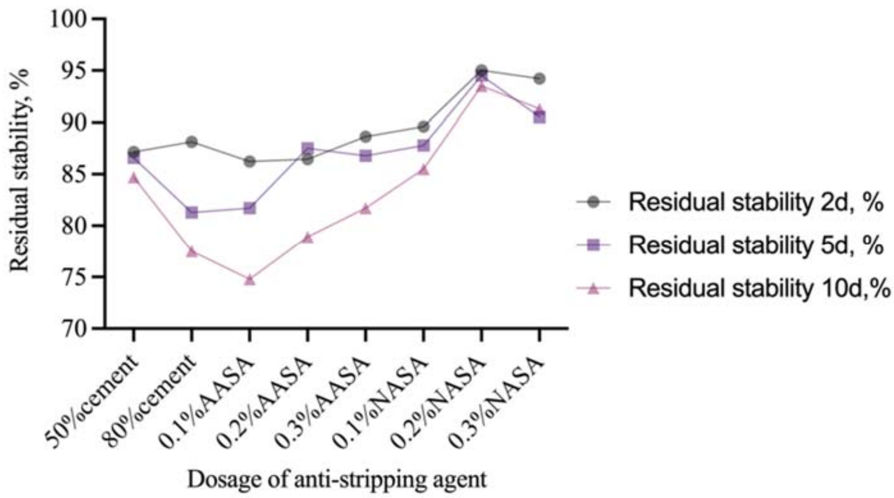

Fig. 4 − Variation of residual stability under different conditions

Upon analyzing the residual stability of different ASAs, NASA demonstrate the highest residual stability, AASA exhibit the lowest, and cement falls in between. The examination of the decreasing trend of residual stability at 5 days and 10 days reveals that AASA experience the most substantial decrease, nano agents exhibit the smallest, and cement falls in the middle.

Conclusion

Immersion tests, including Normal Immersion Marshall, 5-day Immersion Marshall, and 10-day Immersion Marshall, were conducted on granite asphalt concrete with the addition of cement, AASA, and NASA. Analysis of the test outcomes leads to the following conclusions:

1. Granite asphalt concrete does not meet the water stability requirements specified, necessitating the addition of an ASA to enhance its water stability.
2. Cement, AASA, and NASA contribute to the improvement of water stability in asphalt concrete. Notably, NASA demonstrates the most pronounced effect on water stability enhancement and optimal performance.
3. Examination of the 5-day Immersion Marshall and 10-day Immersion Marshall tests reveals a decrease in the stability of asphalt concrete with prolonged immersion time. The decline in stability is primarily concentrated within the initial 48 hours, and the reduction in stability after 2 days is relatively smaller. Additionally, a continuous deterioration in water stability is observed with extended immersion time, with AASA displaying the most significant decay in water stability and NASA exhibiting the least decay. In a comprehensive assessment, NASA exhibits the most superior performance.

REFERENCES

1. D.-W. Park, W.-J. Seo, J. Kim, and H. V. Vo, “Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents,” Constr. Build. Mater., vol. 144, pp. 399–405, 2017.
2. Ping Li, Xiying Wei, Tengfei Nian, Yang liu, and Yu Mao, “Freezing Point Test of Deicers on Asphalt Pavement in Seasonal Frozen Region Bulletin of the Chinese Ceramic Society,” Bulletin of the Chinese Ceramic Society, vol. 38, no. 05. pp. 1561–1567, 2019.
3. A. K. Andersson and L. Chapman, “The impact of climate change on winter road maintenance and traffic accidents in West Midlands, UK,” Accid. Anal. Prev., vol. 43, no. 1, pp. 284–289, Jan. 2011, doi: 10.1016/j.aap.2010.08.025.
4. G. Blomqvist and E.-L. Johansson, “Airborne spreading and deposition of de-icing salt — a case study,” Sci. Total Environ., vol. 235, no. 1, pp. 161–168, Sep. 1999, doi: 10.1016/S0048-9697(99)00209-0.
5. C. Cao, X. Chen, and X. Cao, “Study on the effect of chlorine salt snowmelt on the mechanical properties of aggregates and the adhesion of asphalt,” North. Commun., no. 8, pp. 61–63, 2017.
6. C. Zhu, G. Xu, H. Zhang, F. Xiao, S. Amirkhanian, and C. Wu, “Influence of different anti-stripping agents on the rheological properties of asphalt binder at high temperature,” Constr. Build. Mater., vol. 164, pp. 317–325, 2018.
7. Yang liu and Ping Li, “Study on Temperature Field Prediction Model and Anti Icing Technology of Asphalt Pavement in Winter of Gansu Province,” Master, Lanzhou University of Technology, 2018.
8. M. Nazirizad, A. Kavussi, and A. Abdi, “Evaluation of the effects of anti-stripping agents on the performance of asphalt mixtures,” Constr. Build. Mater., vol. 84, pp. 348–353, 2015.
9. M. Guo, V. P. Kovalskiy, T. Nian, and P. Li, “Influence of Deicer on Water Stability of Asphalt Mixture under Freeze–Thaw Cycle,” Sustainability, vol. 15, no. 18, p. 13707, 2023.
10. H. Wu, P. Li, T. Nian, G. Zhang, T. He, and X. Wei, “Evaluation of asphalt and asphalt mixtures’ water stability method under multiple freeze-thaw cycles,” Constr. Build. Mater., vol. 228, p. 117089, Dec. 2019, doi: 10.1016/j.conbuildmat.2019.117089.

Borziak Olha. − Doctor of Technical Sciences, Associate Professor of the Department of Building Materials, Structures and Facilities, Ukrainian State University of Railway Transport. E-mail: borziak.olga@gmail.com. ORCID ID: 0000-0002-8815-6936.

Zhuravel Vitalii − postgraduate student of the Department of Building Materials and Structures, Ukrainian State University of Railway Transport. E-mail: 1987robota@gmail.com. ORCID iD: 0000-0002-1348-6631.

О. С. Борзяк

В. В.Журавель

ДОСЛІДЖЕННЯ ВПЛИВУ АДГЕЗІЙНИХ ДОБАВОК НА ВОДОСТІЙКІСТЬ АСФАЛЬТОБЕТОНУ

Український державний університет залізничного транспорту

Асфальтобетон, як один з основних матеріалів, який широко використовується в дорожньому будівництві, відрізняється високою водонепроникністю, що безпосередньо впливає на термін експлуатації дорожнього покриття. В процесі експлуатації доріг асфальтобетон часто піддається різноманітним впливам, включаючи транспортні навантаження, перепади температур, атмосферні опади та інші природні впливи навколишнього середовища. Одним з ключових факторів, що впливає на водонепроникність асфальтобетону, є адгеійні властивості, які безпосередньо пов'язані зі стабільністю та стійкістю до старіння поверхневого шару асфальтобетону. Для того, щоб покращити адгезійні властивості асфальтобетону, в практиці проектування, зазвичай, використовують спеціальні адгезійні добавки.

Відбір і застосування адгезійних добавок має значний вплив на показники водонепроникності асфальтобетону. Однак механізм їх впливу на водостійкість асфальтобетону недостатньо досліджений, особливо в практичному застосуванні, оскільки їхній ефект може мати деякі відмінності. Щоб дослідити вплив на водостійкість асфальтобетону, було обрано три найпоширеніші адгезійні добавки - на основі амінів, нано адгезійну добавку та цемент. Відповідні експериментальні дослідження виконані за допомогою методу Маршалла.

Дані результати випробувань показують, що добавка на основі амінів, наноадгезійна добавка та цемент позитивно впливають на водостійкість асфальтобетону, однак найкращі показники має наноадгезійна добавка. Аналізуючи результати досліджень при зануренні на 5 та 10 діб, можна побачити, що стійкість асфальтобетону за Маршаллом знижується зі збільшенням часу занурення, причому її зниження в основному спостерігається протягом перших 48 годин, а через 2 доби зниження стає менш вираженим.

Ключові слова: асфальтобетон, водостійкість, залишкова стабільність, адгезійні добавки до бітумів, бітум, експлуатаційні характеристики покриття, стійкість асфальтобетону, метод Маршалла.

Борзяк Ольга Сергіївна – д.т.н, доцент кафедри будівельних матеріалів, конструкцій та споруд, Український державний університет залізничного транспорту. E-mail: borziak.olga@gmail.com. ORCID iD: 0000-0002-8815-6936.

Журавель Віталій Вікторович - аспірант кафедри будівельних матеріалів, конструкцій та споруд, Український державний університет залізничного транспорту. E-mail: 1987robota@gmail.com. ORCID iD: 0000-0002-1348-6631.