INVESTIGATION OF THE SHORT-TERM AGING BEHAVIOR OF BITUMEN MODIFIED WITH HYDRATED LIME

I.S. Sadikov

Professor, Doctor of Technical Sciences

B.Kh. Tovboyev

Independent Researcher Tashkent State Transport University

Abstract. *This study examines the influence of hydrated lime on the short-term aging characteristics of 50/70 penetration grade paving bitumen. Modified binders containing 1.0%, 1.5%, and 2.0% hydrated lime by weight were prepared and subjected to laboratory aging procedures. The rheological and physical-mechanical properties of the binders after short-term aging were evaluated and compared with those of the conventional binder. The results provide insight into the effectiveness of hydrated lime in enhancing the aging resistance and performance stability of bituminous binders used in pavement applications.*

Keywords: *bitumen, hydrated lime, modified bitumen, short-term aging, binder performance.*

Introduction

Bitumen is the primary binding material used in asphalt pavements and plays a decisive role in determining the mechanical performance, durability, and service life of asphalt mixtures. During production and field service, however, bituminous binders are exposed to various environmental and operational factors, including elevated temperatures, moisture, oxygen, and ultraviolet radiation. These influences gradually alter the chemical composition and structural characteristics of the binder, leading to deterioration of its original engineering properties.

The degradation of bituminous materials is generally classified into two stages:

- Short-term aging;

- Long-term aging.

Short-term aging occurs during asphalt mixture production, transportation, placement, and compaction. At this stage, the binder is subjected to elevated temperatures and intensive contact with atmospheric oxygen, which initiates oxidation processes. Simultaneously, lighter volatile components evaporate from the binder, resulting in increased viscosity and progressive hardening of the material structure.

Long-term aging takes place throughout the service life of the pavement. Continuous exposure to environmental conditions promotes further oxidation and chemical transformations within the binder matrix. These changes reduce elasticity, increase brittleness, and contribute to the initiation and propagation of pavement cracking, ultimately compromising structural integrity and pavement performance.

A comprehensive understanding of aging mechanisms and the development of effective methods to mitigate their adverse effects are essential for improving the durability, reliability, and long-term performance of road pavements.

The susceptibility of bituminous binders to short-term aging is commonly evaluated using the Rolling Thin Film Oven Test (RTFOT). This internationally recognized laboratory procedure simulates the thermal and oxidative conditions encountered during asphalt mixture production and paving operations. The test enables researchers to predict changes in the rheological and physicochemical properties of binders before their application in pavement construction.

Materials and Methods

The short-term aging behavior of conventional BND 50/70 paving bitumen and hydrated lime-modified composite binders was investigated in accordance with the requirements of GOST 33140-2014. Aging simulations were performed using the Rolling Thin Film Oven Test (RTFOT) apparatus at a temperature of 163 ± 1°C for a duration of 85 minutes [1].

This standardized laboratory procedure reproduces the thermal-oxidative conditions experienced by bituminous binders during asphalt mixture production and placement, thereby allowing prediction of technological changes occurring within the material.

The experimental procedure consisted of the following stages:

- Bitumen samples were initially heated to 105 ± 5°C and continuously stirred until all moisture had evaporated and foaming ceased. Subsequently, the temperature was increased to 160 ± 5°C to ensure adequate fluidity of the binder.

- Special cylindrical glass containers designated for the RTFOT procedure were labeled and weighed using a laboratory balance with an accuracy of 1 mg. Approximately 35 ± 0.5 g of heated binder was poured into each container.

- Immediately after filling, the containers were rotated horizontally to distribute the binder evenly along the inner wall, forming a uniform thin film. The samples were then conditioned at a room temperature of 21 ± 4°C for one hour. The number of containers prepared depended on the quantity of aged binder required for subsequent laboratory testing.

- The prepared containers were placed in the rotating carriage of the RTFOT apparatus maintained at 163 ± 1°C. During rotation, heated air was introduced into each container at a flow rate of 4 ± 0.2 L/min. The thermo-oxidative aging process was continued for 85 ± 1 minutes, while the temperature regime was monitored at regular intervals.

- Upon completion of the aging cycle, two containers were selected to determine the mass change of the binder resulting from aging. After cooling at room temperature for one hour, the containers were reweighed with an accuracy of 0.01 g, and the percentage mass loss was calculated.

- The remaining aged binders were collected into a common container and used for further evaluation of rheological and physical-mechanical properties. The investigated parameters included softening point, penetration value, ductility, and mass change, allowing comparison between conventional and hydrated lime-modified binders after short-term aging.

Figure 1. Short-term aging process of conventional 50/70 penetration grade bitumen and hydrated lime-modified bitumen using the RTFOT apparatus

Thermal aging of hydrated lime-modified binders was simulated using the Rolling Thin Film Oven Test (RTFOT). This procedure makes it possible to reproduce the thermal and oxidative conditions encountered during asphalt mixture production and placement. The test provides valuable information regarding the kinetics of binder aging, thermal degradation mechanisms, and the evolution of material properties during the short-term aging stage.

Results and Discussion

To evaluate the resistance of the binders to aging under laboratory conditions, key physical and rheological characteristics, including softening point, penetration, ductility, and mass change, were assessed. The evaluation was carried out in accordance with the requirements specified in GOST 33133-2014 [2] and GOST 22245-90 [3], while the physical and mechanical properties of both conventional and hydrated lime-modified bitumen samples were determined according to GOST 11506 [4], GOST 11501 [5], and GOST 11505 [6].

The experimental results revealed that thermal aging caused an increase in the softening point of all investigated binders. This behavior indicates progressive oxidation and the associated hardening of the bitumen structure. However, the modified binders exhibited a more pronounced improvement in thermal stability compared with the unmodified binder.

Among the investigated compositions, the sample containing 2% hydrated lime demonstrated the highest increase in softening temperature, reaching an increment of approximately 6.3°C after the aging procedure. This result suggests that hydrated lime contributes to the formation of a more stable internal structure within the binder, reducing its susceptibility to thermal degradation and enhancing its resistance to aging-related changes.

The observed improvement may be attributed to the interaction between hydrated lime particles and the bituminous matrix, which promotes the development of a reinforced microstructural framework. Such a structure improves the stability of the binder under elevated temperatures and helps maintain its performance characteristics during short-term aging.

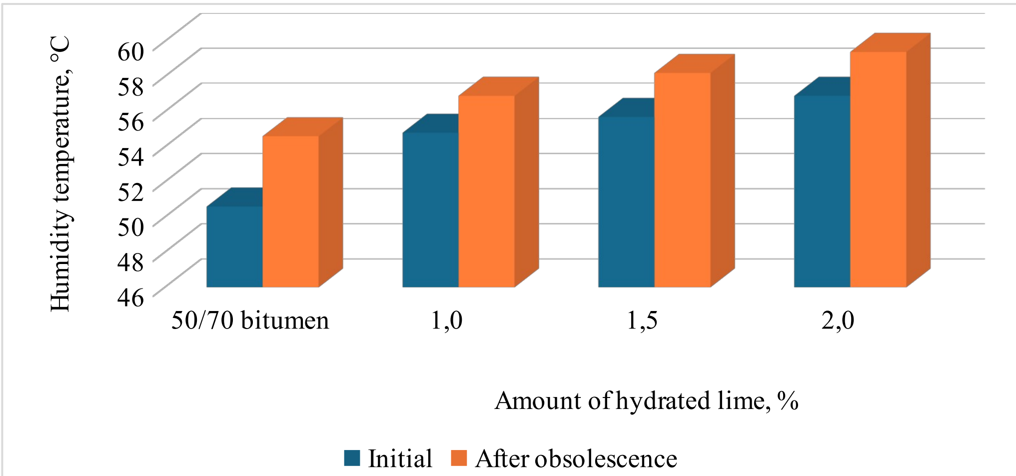

Figure 2. **Softening point values of the binders before and after the aging process**

The penetration test results demonstrated that short-term aging influenced the consistency and viscoelastic behavior of both conventional and hydrated lime-modified binders. A reduction in penetration values was observed for all aged samples, indicating an increase in binder stiffness as a consequence of thermo-oxidative aging.

For the binder modified with 1.0% hydrated lime, the penetration value decreased from 62.6 to 52.8 (0.1 mm) after aging, corresponding to a reduction of approximately 15.7%. Similarly, the specimen containing 1.5% hydrated lime exhibited a decrease from 59.5 to 49.2 (0.1 mm), representing a reduction of about 17.5%.

These findings indicate that the incorporation of hydrated lime does not prevent the natural hardening process associated with aging; however, it contributes to maintaining the binder within an acceptable performance range. Although the modified binders became stiffer after exposure to thermal aging, their penetration values remained within limits considered suitable for pavement applications. This suggests that hydrated lime enhances aging resistance while preserving the balance between stiffness and flexibility required for long-term pavement performance.

The observed changes further confirm that hydrated lime can improve the structural stability of the bituminous matrix, reducing excessive softening at high temperatures while preventing the binder from becoming excessively brittle after aging.

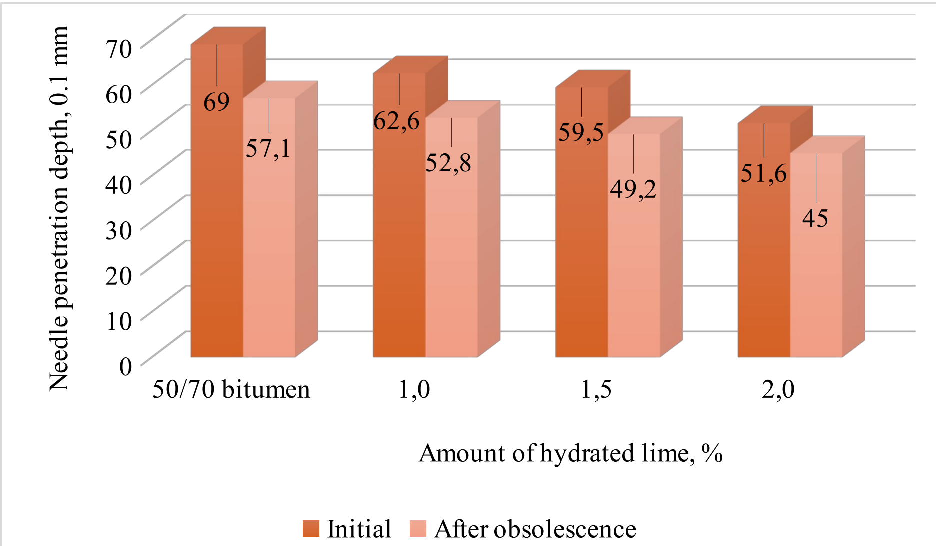

Figure 3. Ductility values of the binders before and after the aging process

A significant reduction in ductility was observed for the conventional BND 50/70 bitumen after short-term aging. The elongation at failure decreased from 105 cm to 68.5 cm, indicating a considerable loss of flexibility and an increase in brittleness as a result of thermo-oxidative aging.

In contrast, the hydrated lime-modified binders exhibited different behavior. Although the initial ductility values of the modified samples were relatively lower than those of the conventional binder, they demonstrated improved stability after the aging process compared with the unmodified bitumen.

For the binder containing 1.0% hydrated lime, ductility decreased from 69.5 cm to 36.5 cm, while the sample with 1.5% hydrated lime showed a reduction from 56.5 cm to 32.1 cm after aging.

These results indicate that although all binders experience a decline in ductility due to aging, the modified binders retain a more stable structural performance. The presence of hydrated lime appears to enhance resistance to excessive embrittlement, contributing to improved elastic behavior and better preservation of deformation capacity under thermal-oxidative conditions.

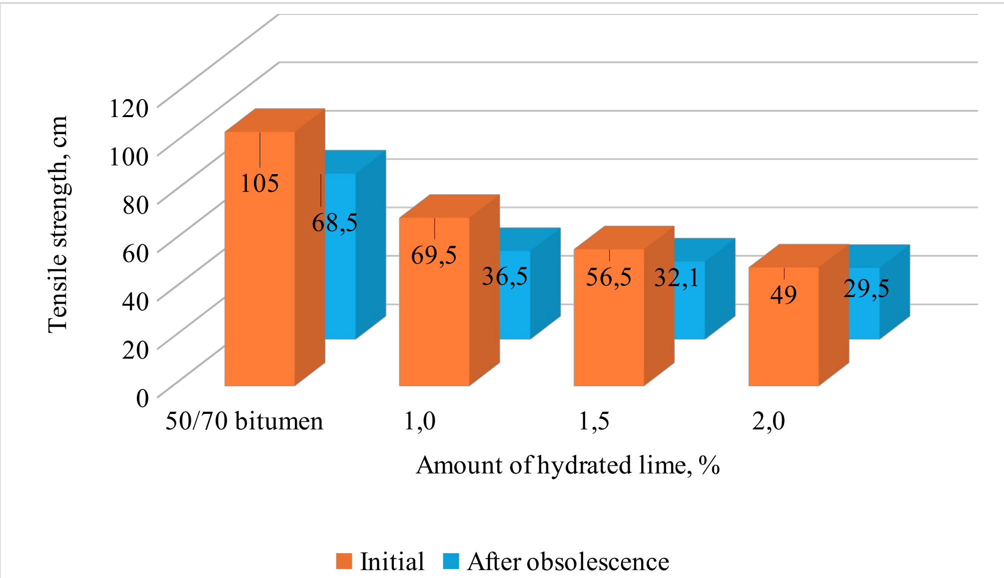

Figure 4. Ductility of the binders before and after the aging process

Based on the experimental results, it was established that bitumen modified with hydrated lime demonstrates a comparatively stable performance in terms of physical and mechanical properties during the short-term aging process. In particular, conclusions were drawn regarding changes in softening point, ductility, penetration, and mass variation, which were analyzed from a scientific perspective.

After aging, an increase in the softening point of the hydrated lime-modified bitumen was observed. This behavior indicates an improved resistance to thermal hardening and suggests enhanced thermal stability of the material under high-temperature conditions.

Although the modified binders initially exhibited lower ductility values compared to conventional bitumen, their elastic behavior remained relatively more stable during the aging process. This indicates the formation of a mechanically stable internal structure within the modified binder system, which helps preserve deformation capacity under thermo-oxidative conditions.

It was also found that the mass loss of hydrated lime-modified binders during aging was slightly higher than that of the conventional binder. This may be associated with the participation of active components of hydrated lime in oxidation-related reactions. However, this effect did not lead to any significant deterioration of the overall physical and mechanical performance of the binder.

Conclusion

The obtained results demonstrate that hydrated lime-modified bitumen exhibits higher resistance to short-term aging compared with conventional paving bitumen. The modified binder maintains structural integrity, shows improved resistance to deformation at elevated temperatures, and does not experience a significant loss of elastic properties.

Therefore, hydrated lime-modified binders can be effectively used in asphalt concrete pavements, particularly in regions with hot climatic conditions, where enhanced thermal stability and long-term performance are required.

References:

1. GOST 33140-2014 (2019). Petroleum road viscous bitum. Method for determining aging under the influence of high temperature and air (RTFOT method). Moscow, Russia.

2. GOST 33133-2014 (2015). Petroleum road viscous bitum. Technical requirements. Moscow, Russia.

3. GOST 22245-90 (1991). Petroleum road viscous bitumen. Technical specifications. Moscow, Russia.

4. GOST 11506-73 (2008). Petroleum bitumen. Method for determining softening point by ring-and-ball method. Moscow, Russia.

5. GOST 11501-78 (2008). Petroleum bitumen. Method for determining needle penetration depth. Moscow, Russia.

6. GOST 11505-75 (2008). Petroleum bitumen. Method for determining ductility. Moscow, Russia.

7. Airey, G. D. (2003). State of the art report on ageing test methods for bituminous pavement materials. *International Journal of Pavement Engineering, 4*(3), 165–176.

8. Petersen, J. C. (2009). A review of the fundamentals of asphalt oxidation. *Transportation Research Circular E-C140*, Transportation Research Board, Washington, DC.

9. Lu, X., & Isacsson, U. (2002). Effect of ageing on bitumen chemistry and rheology. *Construction and Building Materials, 16*(1), 15–22.

10. Yildirim, Y. (2007). Polymer modified asphalt binders. *Construction and Building Materials, 21*(1), 66–72.

11. Lesueur, D. (2009). The colloidal structure of bitumen: Consequences on the rheology and ageing. *Advances in Colloid and Interface Science, 145*(1–2), 42–82.

12. Read, J., & Whiteoak, D. (2015). *The Shell Bitumen Handbook* (6th ed.). ICE Publishing.

13. Bahia, H. U., Hanson, D. I., Zeng, M., Zhai, H., Khatri, M. A., & Anderson, R. M. (2001). *Characterization of Modified Asphalt Binders in Superpave Mix Design*. National Cooperative Highway Research Program (NCHRP Report 459).