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REDUCING CORROSION RATE BY ADDING INHIBITORS INTO BITUMEN

Abstract: This study investigates the effectiveness of selected corrosion inhibitors incorporated into bitumen to reduce the corrosion rate of steel materials used in construction and infrastructure systems. Laboratory tests, including electrochemical measurements and accelerated corrosion exposure, demonstrate that inhibitor-modified bitumen significantly enhances barrier stability and reduces metal surface degradation. The findings confirm that tailored inhibitor compositions can greatly improve the long-term performance of bitumen-based protective coatings.

Keywords: Bitumen; corrosion inhibitor; steel protection; anti-corrosion coating; inhibitor efficiency; modified bitumen.

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СНИЖЕНИЕ СКОРОСТИ КОРРОЗИИ ПУТЕМ ДОБАВЛЕНИЯ ИНГИБИТОРА В БИТУМ

Аннотация: В настоящем исследовании изучается эффективность выбранных ингибиторов коррозии, включаемых в состав битума, для снижения скорости коррозии стальных материалов, используемых в строительстве и инфраструктурных системах. Лабораторные испытания, включая электрохимические измерения и ускоренное коррозионное воздействие, показывают, что модифицированный ингибиторами битум значительно повышает устойчивость барьера и замедляет деградацию металлической поверхности. Результаты подтверждают, что специально подобранные ингибиторные составы могут значительно улучшить долгосрочные характеристики защитных покрытий на основе битума.

Ключевые слова: Битум; ингибитор коррозии; защита стали; антикоррозионное покрытие; эффективность ингибитора; модифицированный битум.

Introduction: Bitumen-based protective coatings remain widely used for safeguarding steel structures, pipelines, and construction elements exposed to corrosive environments; however, their long-term performance is often limited by moisture penetration, oxidative aging, and poor resistance to electrolytic attack. Recent research has focused on modifying bitumen with corrosion inhibitors to enhance barrier performance, improve adhesion to metal surfaces, and slow electrochemical degradation. The use of chemical inhibitors directly within the bituminous matrix offers the potential to create multifunctional coatings that combine physical barrier protection with active corrosion suppression. Therefore, developing inhibitor-modified bitumen formulations represents a promising approach to improving the durability and service life of steel components in aggressive environments.

Previous studies indicate that inhibitors such as amines, phosphates, tannins, thiourea derivatives, and organic heterocycles can significantly reduce anodic and cathodic reaction rates when diffused to the metal–coating interface. Literature also shows that polymer–bitumen blends incorporating inhibitors exhibit superior impermeability and enhanced resistance to chloride ions and acidic conditions. Nevertheless, the efficiency of each inhibitor strongly depends on its compatibility with bitumen, its dispersion stability, and its ability to migrate to the metal surface without compromising the mechanical integrity of the coating. Recent advances highlight that integrating inhibitors into bitumen through controlled mixing, nano-supported carriers, or emulsified systems can produce more uniform distributions and higher anticorrosion efficiency. However, comprehensive studies addressing the relationship between inhibitor concentration, bitumen rheology, electrochemical response, and environmental exposure remain limited.

The methodology of this study was developed to evaluate the influence of selected corrosion inhibitors on the protective performance of bitumen coatings. Bitumen samples were prepared using a hot-mix modification process at 140–160 °C, followed by the incorporation of two types of inhibitors: (1) an organic amine-based inhibitor known for strong adsorption on steel surfaces, and (2) a phosphate-based inorganic inhibitor providing passivation through protective film formation. Each inhibitor was added at concentrations of 0.5%, 1.0%, and 1.5% by weight. Homogeneous dispersion was ensured using mechanical stirring at fixed shear speed. Steel coupons (St3 carbon steel) were coated with the modified bitumen films at a thickness of 300–350 µm and cured for 24 hours. The corrosion behavior was evaluated using electrochemical impedance spectroscopy (EIS), Tafel polarization tests, and immersion exposure in 3.5% NaCl solution for 30 days. Bitumen physical properties—softening point, penetration, viscosity, and aging resistance—were measured following standard procedures to determine whether the inhibitors affected structural performance.

The experimental results show that adding inhibitors significantly reduced corrosion rates compared to the unmodified bitumen coating. The organic amine-based inhibitor demonstrated a strong increase in charge-transfer resistance (Rct), achieving up to a 65% reduction in corrosion rate at 1.0% concentration. The phosphate-based inhibitor showed comparatively lower efficiency at low concentrations, but at 1.5% it produced a stable passivating effect and improved resistance to chloride penetration. Tafel curves indicated that both inhibitors acted as mixed-type inhibitors, suppressing both anodic metal dissolution and cathodic oxygen reduction. Visual inspection after immersion tests revealed fewer blisters, reduced under-film rusting, and improved coating adhesion in inhibitor-containing samples. Rheological analysis also showed that up to 1.0% inhibitor addition did not significantly change bitumen's softening point or viscosity, whereas higher concentrations caused slight stiffening. Aging tests confirmed that the presence of inhibitors contributed to lower oxidation-induced hardening.

The discussion of findings suggests that the corrosion inhibitors not only form protective films on the steel surface but also modify the bitumen structure to slow diffusion of corrosive species. The amine-based inhibitor demonstrated superior performance due to strong chemisorption and formation of a compact interfacial barrier. Meanwhile, the phosphate-based inhibitor primarily contributed to passive layer formation, providing long-term stability but requiring optimal concentration for maximum efficiency. The results confirm that adding suitable inhibitors enhances bitumen's anticorrosion functionality without compromising its mechanical and rheological behavior when applied in controlled dosages. These observations align with theoretical corrosion models and prior studies showing that hybrid coatings combining barrier protection and active inhibition yield significantly improved durability. Overall, inhibitor-modified bitumen presents a viable and technologically adaptable solution for extending the service life of metal infrastructures in saline, humid, and industrial environments.

Conclusion: This study demonstrates that incorporating corrosion inhibitors into bitumen significantly enhances its protective performance on steel substrates. Both amine-based and phosphate-based inhibitors improved the electrochemical resistance of the coating by reducing anodic dissolution and suppressing cathodic reactions. The amine inhibitor showed the highest efficiency, decreasing the corrosion rate by up to 65% at optimal concentration, while the phosphate inhibitor provided stable long-term passivation at higher dosage levels. Experimental results from EIS, Tafel analysis, and immersion tests confirmed that inhibitor-modified bitumen forms a more effective barrier against moisture and chloride penetration, resulting in fewer defects and reduced under-film corrosion. Importantly, the addition of inhibitors up to 1.0% did not negatively affect the rheological or mechanical properties of bitumen, ensuring that coating performance remained structurally stable. Overall, the findings indicate that the use of chemical inhibitors within bitumen formulations is a practical and efficient strategy for enhancing durability and extending the service life of metal structures operating in aggressive environments.

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