

MODERN METHODS FOR EXTENDING THE SERVICE LIFE OF ASPHALT ROAD PAVEMENTS

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ABSTRACT

Georgia's specific geographical location, its geopolitical significance in the Caucasus region, and the high-volume transit flows through the country highlight the urgent need for the rapid and efficient development of its road network. Improved road conditions enhance safety and driving comfort, making international routes more suitable for cargo transportation. This, in turn, attracts more tourists and stimulates economic growth, resulting in increased national income. Combining traditional methods and local materials with newly developed techniques and modern materials can yield greater results—producing high-quality roads with longer service life and lower maintenance costs.

Keywords: Georgia, Roads, Pavement, Asphalt, Construction.

Introduction

Georgia's geographical location and geopolitical significance are of great importance. The country lies along the axis of the ancient Silk Road (The Great Silk Road), and even today, large volumes of cargo move between East and West through its territory. Georgia borders several key countries—Turkey, Russia, Azerbaijan, and Armenia—further enhancing its strategic position. Considering these factors and the current regional dynamics, it can be argued that Georgia represents the only safe and reliable land corridor for transporting goods between Europe and Asia.

It is important to emphasize that Georgia's land corridor is not only a route for fast and cost-effective transit, but also a hub for pipelines, air routes, and subsoil communication networks. The growth in cargo turnover has a direct positive impact on the country's economic development—foreign investment increases, new jobs are created, and the standard of living for the Georgian population rises. Additionally, Georgia has assumed an increasingly significant political role in the region.

Considering all the points mentioned above, it is crucial to have a high-quality, safe, and durable road infrastructure. However, numerous disruptive factors make achieving this goal particularly challenging.

Main Text

Georgia's diverse and often harsh climatic conditions pose significant challenges to the durability and maintenance of its road infrastructure. The country features a complex topography, ranging from coastal lowlands to high mountain regions, and experiences a wide range of weather conditions throughout the year. These climatic variations—especially the

extreme temperature fluctuations, heavy precipitation, and seasonal freeze-thaw cycles—have a direct impact on road pavement integrity and longevity.

One of the most critical factors affecting pavement performance in Georgia is the freeze-thaw cycle, particularly in mountainous and highland regions. During winter, water infiltrates cracks and pores in the pavement structure. As temperatures drop, the water freezes and expands, exerting pressure on the surrounding materials. Repeated cycles of freezing and thawing cause the pavement to weaken, crack, and eventually break apart, a phenomenon commonly referred to as frost heave.

Heavy rainfall, which is prevalent in western and central Georgia, also contributes significantly to pavement deterioration. Prolonged or intense precipitation leads to water penetration beneath the pavement layers, weakening the subgrade and base materials. This results in rutting, potholes, and surface deformation. Poor drainage systems exacerbate this issue by allowing water to accumulate on or under the road surface.

In the summer months, high temperatures—particularly in the eastern regions—can soften asphalt surfaces, making them more susceptible to rutting under heavy traffic loads. Thermal expansion can also lead to longitudinal cracking and joint displacements in rigid (concrete) pavements.

Wind-driven dust and sand, common in some arid areas, contribute to the abrasion of surface layers, while landslides and soil erosion in mountainous areas can lead to structural failures of entire road sections.

Typical types of pavement damage observed in Georgia due to these climatic stresses include:

Grid Cracking: A network of interconnecting cracks caused by fatigue and water infiltration;

Potholes: Depressions or holes resulting from the loss of pavement material, often caused by water damage and traffic stress;

Rutting: Depressions in wheel paths due to deformation of pavement layers under repeated loads;

Edge Cracking: Cracks along the pavement edge caused by insufficient support or drainage;

Block Cracking: Large rectangular cracks caused by temperature changes and shrinkage.

To address these challenges, it is essential to implement climate-resilient road construction practices, use high-quality materials, and ensure regular maintenance. Incorporating advanced drainage systems and designing pavement structures specifically for local climate conditions can significantly extend the service life of roads in Georgia.

Over the past few decades, the cost of road pavement construction has steadily increased due to a range of economic, industrial, and environmental factors. One of the primary reasons is the rising price and declining quality of key raw materials—particularly bitumen, the binder used in asphalt. Bitumen is a byproduct of crude oil refining. As global energy markets shift toward cleaner fuels and more efficient refining processes, the yield of heavy residues like bitumen has decreased. Modern refineries are optimized to extract lighter, more valuable fuels, which reduces the availability of high-quality bitumen for the construction industry.

This has led to a regression in bitumen quality. The bitumen produced today often lacks the natural strength and durability of earlier decades. It tends to be more brittle, less elastic, and more susceptible to oxidation and temperature extremes. As a result, pavements built with this lower-grade material are more prone to cracking, rutting, and general wear, especially under high traffic loads and harsh climate conditions. To compensate for the shortcomings of modern

bitumen, additional additives and modifiers are now required, which increases both the complexity and the cost of asphalt production.

Additives such as polymers, rubber, fibers, and chemical stabilizers are widely used to enhance the performance of asphalt mixtures. These materials improve elasticity, temperature resistance, and load-bearing capacity. However, they come at a premium, both in terms of raw material cost and the specialized mixing processes they require. Moreover, their transportation and storage demand more careful handling, contributing further to rising expenses.

The growing focus on environmental sustainability also influences material pricing. Regulatory pressures often require the use of low-emission technologies, recycled content, and eco-friendly binders, which can be more expensive or require investment in new production facilities. Warm mix asphalt, for example, reduces energy use but involves the use of specialized additives or foaming equipment, increasing initial costs despite long-term savings.

Global supply chain disruptions, driven by geopolitical instability, pandemics, and fluctuating oil prices, have also impacted the availability and pricing of construction materials. Raw materials for asphalt and concrete must often be imported or transported over long distances, and transportation costs have increased substantially in recent years. Additionally, natural aggregates, such as crushed stone and gravel, are becoming scarcer in some regions, leading to higher extraction and haulage costs.

Labor and equipment costs are another factor. Skilled labor is needed to handle modern paving technologies and additives correctly. The machinery used in asphalt mixing and paving must also be calibrated to ensure proper blending and distribution of these complex mixtures. This need for technical expertise and advanced equipment raises capital investment requirements and operational costs.

Furthermore, road construction projects are increasingly held to higher quality and performance standards, especially for highways, international transit corridors, and urban networks. Governments and private sector stakeholders demand pavements with longer service lives and fewer maintenance needs. Meeting these expectations with declining base material quality necessitates more sophisticated engineering solutions and costlier materials.

Georgia is rich in various local materials that are essential for road construction, including crushed stone, gravel, sand, and basalt. These materials are found in different regions across the country, particularly in mountainous and river valley areas, providing a reliable and cost-effective supply for infrastructure projects. Using local materials significantly reduces transportation costs, which is especially important in a country with challenging terrain and a limited logistics network. It also shortens construction timelines and lowers the carbon footprint of projects by minimizing long-distance hauling.

In addition to economic and environmental benefits, local materials are naturally suited to Georgia's climate and geotechnical conditions. For example, basalt and other volcanic rocks from western Georgia are known for their durability and resistance to weathering, making them ideal for high-stress pavement layers. The use of locally sourced aggregates helps create stronger, more resilient road bases and sub-bases, which are critical under the country's heavy freight traffic and variable weather patterns.

Promoting the use of domestic resources also stimulates local industries, creates jobs, and supports regional development. Moreover, relying on local materials helps Georgia reduce its dependence on imported construction products, which are subject to global price fluctuations and supply chain disruptions. In a context where the quality of bituminous binders is declining and costs are rising, the effective use of high-quality local aggregates becomes even more important to ensure durable and cost-efficient roads. Encouraging the integration of these

materials with modern technologies and binders can lead to more sustainable and long-lasting pavement solutions tailored to Georgia's unique needs.

In addition to using local materials, incorporating various additives into bitumen can be considered a practical and effective approach to improving road pavement quality.

Additives play a crucial role in enhancing the performance of bitumen used in road pavements. As the quality of natural and refined bitumen has declined over the years—due to changes in crude oil processing and refinery outputs—additives have become essential to meet modern road performance standards.

One of the most common additives is polymer modifiers, such as styrene-butadiene-styrene (SBS) or ethylene-vinyl acetate (EVA). These polymers improve elasticity, enhance fatigue resistance, and allow pavements to better withstand freeze-thaw cycles and temperature fluctuations. Rubber powder, often recycled from used tires, is also used to increase elasticity and resilience. These rubber-modified binders help reduce cracking and extend pavement life.

Anti-stripping agents are another type of additive that improve the bond between bitumen and aggregates, preventing moisture damage—a common issue in regions with heavy rainfall or poor drainage. Without these agents, water can infiltrate the asphalt and weaken the structure, leading to potholes and early deterioration. Filler additives such as hydrated lime also improve the chemical stability of the asphalt mixture and reduce oxidation, further increasing pavement lifespan.

In hot climates or areas with heavy traffic, viscosity-modifying additives are used to prevent bitumen from softening and deforming under pressure. Conversely, in colder climates, low-temperature additives enhance flexibility and help the pavement resist thermal cracking. Warm mix asphalt (WMA) additives allow asphalt to be produced and laid at lower temperatures, reducing energy consumption and emissions while still maintaining workability and performance.

Fibers, such as cellulose, glass, or synthetic types, are sometimes added to the asphalt mix to improve structural integrity and reduce the likelihood of rutting and cracking. These fibers create a reinforcing network within the pavement that helps distribute loads more evenly. Nano-additives, though still in experimental and early commercial use, are emerging as powerful tools to improve binder performance at the molecular level, offering superior durability and resistance to aging.

Incorporating additives not only improves road quality but also supports sustainability. For example, additives allow for greater use of Reclaimed Asphalt Pavement (RAP) by restoring the performance of aged bitumen, reducing the need for virgin materials. This contributes to both environmental protection and cost savings.

However, using additives also presents challenges. They can increase initial material costs and require precise dosing, specialized equipment, and trained personnel to ensure effectiveness. Improper use can lead to inconsistent pavement performance or premature failure. Still, when properly selected and applied, additives offer significant long-term benefits by improving pavement lifespan, reducing maintenance frequency, and enhancing safety.

Conclusion

In summary, the effective use of high-quality local materials combined with modern additives offers a practical and sustainable solution for improving road pavements in Georgia. Locally sourced aggregates, such as basalt and gravel, are well-suited to the country's terrain and

climate, reducing transportation costs and ensuring structural compatibility. When enhanced with carefully selected bitumen additives, these materials contribute to stronger, more resilient pavements that can withstand extreme weather and heavy traffic loads. This approach significantly extends the service life of roads, minimizing the frequency and cost of maintenance interventions.

Long-lasting pavements not only provide economic benefits but also improve driving comfort and safety for road users by reducing surface damage, deformation, and hazards such as potholes. Additives further enhance pavement performance by improving resistance to cracking, water damage, and temperature-related stress. Together, local materials and modern modification techniques create cost-efficient, durable roads that meet the demands of both transit and domestic travel. Investing in these strategies ensures a smoother, safer, and more reliable road network—supporting Georgia's economic development and strengthening its role as a vital regional transport hub.

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