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FEASIBILITY ASSESSMENT OF POLYMER AND GEOSYNTHETIC TECHNOLOGIES FOR ROAD CONSTRUCTION IN MOLDOVA

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Abstract. This article examines the factors that determine the need for introducing modern technologies in the road construction sector of the Republic of Moldova. It proposes a broader application of polymer and geosynthetic technologies to increase the durability and stability of road pavements. The geological and climatic characteristics of the Moldovan territory that affect the operational performance of road surfaces are briefly analyzed, along with an assessment of the current state of transport infrastructure. Particular attention is given to the comparison between traditional soil stabilization methods and modern polymer technologies. The study also reviews international experience in implementing similar technological solutions. The economic efficiency of using geosynthetic materials is substantiated, and their positive environmental impact is emphasized. Potential risks are identified, and corresponding mitigation measures are proposed. The paper outlines the main stages of the project for introducing polymer technologies into the road construction sector of the Republic of Moldova.

Key words: *polymer technologies, geosynthetics, road construction, infrastructure sustainability, soil stabilization, economic efficiency.*

JEL code: *L74, O32, R42; Q01*

Introduction

The geomorphological, geological, and climatic characteristics of Moldova largely determine the durability and reliability of road surfaces, as well as the stability of highway sections. The country’s diverse relief requires site-specific design and construction approaches.

Key territorial features include:

- widespread landslide processes,
- the presence of ravines,
- collapsible and swelling soils,
- areas with high groundwater levels (up to marsh formation),
- seismic activity,
- sharp temperature fluctuations typical of a temperate-continental climate.

Insufficient consideration of these factors during road design, construction, and operation can lead to premature pavement deterioration [1-4].

An assessment of the current road network shows many rural roads with gravel or dirt surfaces in poor condition; asphalted sections frequently exhibit cracking and distress, especially in geologically problematic regions (figures 1, 2).

Frequent repairs only temporarily address defects, without improving overall performance, and while straining local budgets [5-7].



Figure 1. A complex network of cracks in the asphalt pavement of a road section in Gratiesti
Photo by Alexandru Rascovoi, September 2025



Figure 2. Destruction of the slope and road surface of a section of the road in the city of Codru as a result of landslide movements
Photo by Alexandru Cîrlan, May 2025

Research Objectives

Purpose. To demonstrate the economic, technical, and environmental advantages of innovative soil stabilization methods in seismically active, ravine- and landslide-prone areas to extend pavement service life.

The study pursues the following **objectives:**

1. Examine traditional soil stabilization methods and their advantages and limitations.
2. Analyze modern polymer-based soil stabilization technologies.
3. Substantiate the feasibility of adopting international best practices in polymer technologies.

Results and Discussion

Field investigations indicate that road foundations commonly employ sand-gravel cushions and cement-bitumen mixtures; geotextiles are used only occasionally. These solutions are relatively accessible but exhibit limited service life, particularly in waterlogged areas or on slopes prone to mass movements (figure 3).



Figure 3. Slope reinforcement using geotextiles on a road section in Chisinau

Photo by: Alexandru Cîrlan, June 2025

The limited effectiveness of traditional road strengthening methods is often due to a lack of adaptation to the region's geological and hydrogeological conditions [8, 9].

It should be acknowledged that modern polymer soil stabilization technologies have not found widespread use in road construction in Moldova. However, an analysis of international experience implementing similar technologies has shown that countries such as Germany, Brazil, China, Romania, the United States, Turkey, and others have successfully implemented polymer technologies on local and highway roads. Their effectiveness has been confirmed, in particular, on road sections in the Carpathian Mountains, where geogrids and polymer stabilizers have reduced the number of emergency repairs by 65% over five years.

Research has shown that polymer additives can improve the bearing capacity and water resistance of soils. The most commonly used technological methods include injection systems, liquid polymer stabilizers, and polymer pads.

These methods have proven effective in high-humidity areas and on slopes, making them suitable for use in the Republic of Moldova. Recommended polymer technologies include:

1. Polyurethane resins (e.g., Screpa M600). High water resistance and adhesion; used to fill static joints, cracks >0.4 cm, voids and cavities for waterproofing and reinforcement; can act as binders for high-strength, non-shrink, waterproof concretes and for anchor fixation.
2. Polymer microfibers (e.g., Qfibre Makro). For reinforced concrete bases; mitigate shrinkage and microcracking, reduce permeability, and improve integrity and homogeneity.
3. Plasticizers (e.g., QBlock Plus). Enhance workability, flexibility, and strength of concrete mixtures by increasing plasticity and cohesion.
4. Deep-penetration polymer sealers. Applied for surface dust suppression and hardening to improve durability.
5. Geosynthetics (geogrids, geomembranes, drainage mats). Used for reinforcement, erosion control, drainage improvement, and layer separation; most effective in combination with polymer stabilizers.

A section of road near Ungheni serves as an example of the successful implementation of polymer technologies. In conditions characterized by gully and landslide processes, the presence of clayey rocks, and flooding, a polymer stabilizer with geogrid technology was used in a pilot project. Over two years of operation, the road required no repairs, despite heavy rains and ground movement.

As part of the analysis of the results of investment projects for the construction and operation of highways, it is advisable to conduct a qualitative and quantitative analysis of the technologies used. Table 1 presents a comparative analysis of various methods of road stabilization.

Table 1. Comparative analysis of road stabilization methods (economic aspect)

Stabilization Method	Cost (€/m²)	Service Life (years)	Comments
Crushed stone base	30	5–7	✓ requires frequent repairs
Cement-bitumen base	37	8–10	✓ prone to cracking
Polymer stabilization	42	15–20	✓ during construction: high workability; limited separation of mortar components; integrity and homogeneity of working mixtures; ✓ during operation: high water resistance, reduced formation of shrinkage cracks; frost resistance; durability.
Geogrid + polymer stabilizers	47	20+	✓ maintains the benefits of polymer stabilization; ✓ optimal solution on slopes; ✓ suitable for RM conditions.

Environmental aspects

The use of polymers in road construction will result in some positive environmental benefits, including:

1. Waste reduction: Use of recycled polymers in asphalt mixtures reduces plastic waste landfilled.
2. Reduced quarrying: Lower demand for virgin aggregates due to extended service life and stabilization.
3. Lower dust emissions: Improved surface integrity reduces dust generation.
4. Extended service life: Polymer-modified asphalt resists cracking and deformation, lowering repair frequency and resource use.
5. Lower carbon footprint: Fewer maintenance cycles reduce raw material extraction, fuel use, and life-cycle CO_2 emissions.
6. Energy efficiency: Warm-mix processing enables lower mixing temperatures, saving energy and reducing emissions.
7. Recyclability: End-of-life polymer-modified asphalt can be recycled, supporting circular economy principles.

These environmental outcomes align with international standards and guidance on life-cycle assessment and environmental management [10–14].

Risk Analysis

Alongside their advantages, polymer technologies entail environmental risks that must be proactively managed [15-18]:

1. Microplastic contamination: Pavement wear can release polymer particles into soils and aquatic ecosystems.
2. Limited biodegradability: Most polymers persist in the environment for decades.
3. Production emissions: Polymer synthesis and modification require substantial energy and may release VOCs and CO_2.
4. End-of-life management: If not recycled, landfilling polymer-modified asphalt poses hazards, including thermal degradation by-products.
5. Heterogeneous feedstocks: Use of unsorted plastics can generate toxic emissions (e.g., dioxins, styrenes) when heated.

Social risks should also be considered, particularly insufficient personnel qualifications, mistrust of new technologies, and the possibility of design errors. Risk mitigation requires training programs, product certification, and rigorous quality control at all stages – design, production, modification, construction, and operation [6, 10-11].

Project for the application of polymer technologies in road construction: Implementation stages

- development of a regulatory framework;
- training of specialists: designers, engineers, and contractors;
- implementation of a pilot project using a combined approach: polymers and geosynthetics. It is recommended that the introduction of polymer technologies begin with pilot sites in risk zones, with a gradual expansion of their application areas.
- systematic monitoring of the sites for at least two years.

Conclusion

Polymer technologies and geosynthetics should be considered a cost-effective and environmentally efficient option for Moldova to reach a new level in road infrastructure. These technologies ensure roadbed stability, resource conservation, and increased safety, especially in challenging geological and hydrological conditions.

It should be emphasized that the use of polymers in road construction can improve the environmental efficiency of infrastructure investments only if some important conditions are met:

- use of recycled and safe plastics;
- strict emission controls during production and installation;
- a road material recycling system;
- life cycle assessment (LCA) to determine the true environmental balance.

Thus, with effective planning and management, polymer-modified road pavement technology will comply with the principles of eco-efficiency and a circular economy.

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