Studies on the replacement ability of bitumen with bio-materials based on multi-performance compatibility analysis

Abstract for the general public

Modern road infrastructure and automobile transportation serve as hallmarks of societal progress, significantly impacting the economic development of nations and countries. For decades, bitumen derived from petroleum has been the basic material for road construction. However, driven by principles of sustainable development, global climate aims, and the imperative to decarbonize industry, the exploration of alternatives to petroleum-based materials, such as bio-based substitutes or by-products of natural origin from industrial processes, has become crucial. Due to the very high demand for road construction materials, in recent years attempts have been made to modify or replace bituminous materials with industrial waste or materials of plant origin. However, many of these actions postpone the problem and future generations will have to face these problems. Previous research on this topic mainly focuses on the use of bio-additives without a prior understanding of its fundamentals, mainly considering the direct modification effect without in-depth analysis of chemical, structural changes, durability and environmental impact.

The aim of the project is to develop the maximum acceptable level of replacing petroleum-based bitumen with bio-materials of plant origin and to determine their mutual interactions and compatibility. The research undertakes a thorough analysis of a diverse array of bio-origin, identifying two highly promising groups capable of partially replacing traditional bituminous materials, thereby curtailing the consumption of petroleum. The project encompasses materials like bio-oils, recycled oils, and industrial biomass by-products, notably lignin, a biopolymer primarily derived from the paper industry, which is currently being burnt due to difficulty in reusing.

The large variety of plant-derived materials and, thus, the wide spectrum of their activity means that a wide variability in the final properties of bitumens modified with bio-materials can be expected. The project will include comprehensive research on the interaction between bio-materials and bitumen. Physical, mechanical and chemical tests will be carried out, considering durability and resistance to aging. Comprehensive testing and assessment of compatibility development are key to ensuring that the resulting bio-modified bitumen products maintain their integrity during production processes and future use in road pavement. The scientific novelty of the project is not only the modification of bitumen with bio-materials but above all the attempt to significantly replace bitumen with plant-based bio-materials. In addition, a pioneering attempt will be made to define and describe the principles of compatibility of bio-materials and bitumen, because the best practices so far have not been fully established and have been treated selectively.

The expected outcomes of the project will be bitumen compositions with a significant level of bio-material replacement with ensured compatibility. At each stage of the project implementation, environmental impact analyses will be performed in terms of ecotoxicity and the potential of new materials for recycling in the future will be determined. A practical aspect of the project will be to determine how to avoid mistakes in the future in the search for replacements for bituminous binders. The project will also contribute to reducing the exploitation of non-renewable raw materials, i.e. crude oil, shaping the trajectory of future road construction towards a more ecologically conscious and resource-efficient paradigm.