SMART TECHNOLOGIES AND FLEXIBLE ROAD MAINTENANCE SYSTEMS VIA NANOMATERIALS

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Rezumat. *Această cercetare examinează integrarea sistemelor flexibile de fabricație cu tehnologii inteligente pentru a îmbunătăți produsele existente utilizând materiale bazate pe nanotehnologie. Studiul evidențiază rolul flexibilității în adaptarea proceselor tehnologice la condiții variabile de operare și urmărește optimizarea soluțiilor de întreținere a drumurilor prin integrarea nanomaterialelor în compoziția asfaltului. În același timp, sunt analizate tehnologii inteligente precum monitorizarea, automatizarea și analiza datelor. Cercetarea propune un model aplicabil pentru creșterea sustenabilității infrastructurii, bazat pe reconfigurarea sistemelor flexibile. Rezultatele evidențiază potențialul acestor tehnologii de a reduce costurile de întreținere, de a crește eficiența operațională și de a dezvolta soluții durabile în ingineria drumurilor.*

Abstract. *This research examines the integration of flexible manufacturing systems with smart technologies to improve existing products using nanotechnology-based materials. The study highlights the role of flexibility in adapting technological processes to variable operating conditions and seeks to optimize road maintenance solutions by integrating nano-materials into asphalt composition. At the same time, smart technologies such as monitoring, automation, and data analysis are being analyzed. The research proposes an applicable model for increasing infrastructure sustainability, based on the reconfiguration of flexible systems. The results highlight the potential of these technologies to reduce maintenance costs, increase operational efficiency, and develop sustainable solutions in road engineering*

Keywords: Nanomaterials, Road infrastructure maintenance, Smart Technologies

1. Introduction

Road infrastructure maintenance is undergoing a stage of structural transformation driven by traffic intensification, climate variability, the accelerated degradation of bituminous pavements, and budgetary constraints. In this context, the traditional approach based on reactive interventions is becoming insufficient, making it necessary to move toward predictive maintenance models capable of anticipating degradation, optimizing the prioritization of works, and reducing intervention times [3], [5], [10].

Within this framework, stockpiled asphalt mixtures and cold-applied bituminous materials are gaining increased operational relevance due to their ability to enable rapid interventions independent of complex thermo-energetic infrastructures. The evolution of these materials, from solutions regarded as temporary to technical

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