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ABSTRACT OF THE DISSERTATION

„Cohesion-based evaluation of viscoelasticity in Bitumen Stabilised Materials”

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The subject of this doctoral dissertation concerns Bitumen Stabilised Materials with bitumen emulsion (BSM-E) used for the construction of road base courses in cold recycling technology. The aim of the dissertation was to assess the cohesion development in these materials, focusing on the influence of the material-related factors and external conditions on changes in the material's performance over time. The findings enabled the identification and analysis of the viscoelastic behaviour of BSM-E mixtures.

The dissertation consists of seven chapters: three comprising the introduction to the research topic and the theoretical background, and four constituting the research part.

The introductory part of the dissertation includes the formulation of the thesis, central and detailed objectives, research scope and limitations. The theoretical part consists of a literature review on cold recycling technology, covering its historical development, current techniques, and global applications. It discusses the classification principles of cold recycling mixtures (CRM) and provides a general characterisation of Bitumen Stabilised Materials (BSM), highlighting their advantages, challenges, and the role of material components in developing their properties. Moreover, an extensive overview of the BSMs' mechanical performance is presented, discussing failure mechanisms, evolutive behaviour, and their implications for pavement design. Particular emphasis is placed on the assessment of viscoelasticity and cohesion, with a summary of current research findings, testing methodologies, and modelling approaches for permanent deformation and mechanical behaviour.

The research part of the dissertation presents the principles of the experimental program and is divided into three sections: research program, cohesion and permanent deformation response assessment, and viscoelasticity assessment. The dissertation concludes with a chapter presenting the final findings of the research and indicating the directions of the future research. In the *research program* section, the BSM-E component materials are characterised, and the procedures of mix design, sample preparation, and curing are described. Moreover, the author's original method for long-term conditioning of BSM-E specimens, which simulates the confinement conditions within an asphalt pavement base layer, is presented in detail.

The results of the comprehensive assessment of BSM-E mixtures' cohesion, both in terms of initial cohesion and its long-term evolution, are presented in the *cohesion and permanent deformation response assessment* section. As a novel approach, the Flow Number method

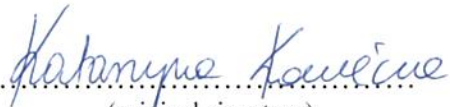
(AASHTO T378-22) was implemented for the performance evaluation of ten cold recycling mixtures differentiated by RAP content (0%–90%) and BE content (4%–7.4%), with conditioning periods ranging from 0 to 120 days. The Flow Number method proved effective in quantifying the cohesion development of BSM-E mixtures over time, using the FN, $\epsilon(\text{FN})$, and FN index parameters, which served as measures of permanent deformation response.

It was concluded that the material factors – specifically, the contents of RAP and BE – have a significant impact on the cohesive performance of BSM-E mixtures, with mixtures of higher RAP levels and intermediate BE addition showing the most favourable long-term performance. The decision tree method developed in this dissertation, which considers RAP content, presence of the cohesion development over time, and BE content, enabled both the estimation of the viscoelastic response of the material and the selection of BSM-E mixtures subjected to Dynamic Modulus (AASHTO T378-22) testing, the results of which are presented in the *viscoelasticity assessment* section.

The changes in the dynamic modulus and phase angle values of BSM-E mixtures were analysed across a wide range of test temperatures and loading frequencies. The applicability of modelling the viscoelastic performance of BSM-E mixtures using the approach traditionally employed for hot mix asphalt, taken as the reference, was positively verified. The qualitative and quantitative statistical analysis of the constructed Black curves, Cole–Cole diagrams and master curves allowed for the characterisation of the viscoelastic response of BSM-Es and supported the evaluation of the relationship between cohesive properties and viscoelastic behaviour. Based on the analysis of the test results of the 1%-cement BSM-E mixtures designed in this study, a RAP content threshold of $\geq 70\%$ and a BE content range of 4%–5% are proposed as supporting the viscoelastic behaviour.

On the basis of the findings and analyses carried out within the presented research program, it can be concluded that the main objective of the dissertation – namely, the assessment of cohesion and its development over time together with the evaluation of the viscoelasticity of BSM-E mixtures – has been achieved. This was made possible by fulfilling the partial objectives: identifying and verifying the applicability of specific testing methods and conditioning procedures for the quantitative evaluation of changes in mixture properties; assessing the time-dependent cohesion development in BSM-E mixtures considering material-related variables; and application of the time–temperature superposition for evaluation of the viscoelastic response of BSM-E mixtures. The final findings of the research demonstrate that the implemented experimental program enabled the substantiation of the dissertation thesis.

Keywords: *Bitumen Stabilised Materials, cohesion, viscoelasticity, bitumen emulsion, RAP, cold recycling.*


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