Mechanistic-empirical design of flexible pavement structures with HiMA binder using the similarity method (SiM)

Abstract

This dissertation concerns the structural design of flexible pavements, consisting of asphalt mixtures with highly modified asphalt binder (HiMA), using the mechanistic-empirical method.

After a brief introduction in chapter 1, chapter 2 presents a literature review of the three key elements in the design of structures using the mechanistic-empirical method. The first element is the analysis of pavement material properties, particularly of asphalt mixtures. The second element is the mechanistic analysis of the structure under a load - this consists of modeling the structure, including its materials, and determining the deformation, stress and strain states in the structure. The third element is the selection of appropriate fatigue criteria – the methods and criteria used in various countries are reviewed. The literature review also includes an overview of the research on HiMA mixtures and the fatigue life of pavements composed of them.

In chapter 3, the author's method of predicting the design life based on the fatigue cracking - referred to as the similarity method (SiM) - is formulated for structures containing asphalt mixtures with highly modified asphalt binder. The method involves determining the fatigue life equation coefficients for a reference pavement structure with road binder (unmodified), based on any fatigue cracking criterion which has the form of the Wöhler equation (the AASHTO 2004 criterion was chosen in this paper). The coefficients for a structure with HiMA binder can then be calculated by correcting the reference structure coefficients according to the proposed relationships derived from the fatigue characteristics of the asphalt mixtures in the asphalt base courses of the structures (both the structure with highly modified asphalt binder and the reference structure with unmodified binder).

It was shown that it is possible to predict the fatigue life of road pavement structures with HiMA binder using the SiM method, which is the subject of the first thesis of the dissertation. Fatigue life calculations were performed for structures based on a typical pavement structure of a flexible pavement of a road with traffic category KR5 (in Poland - between 7.3 and 22.0 million of 100 kN ESAL), but with highly modified asphalt binder and varying thicknesses of the asphalt base layer. Durability was calculated based on two criteria: fatigue cracking (according to the SiM method) and structural deformation (according to the Asphalt Institute method). Structures with highly modified asphalt binder resulted in significantly

higher durability values for fatigue cracking than standard structures, but lower durability values for structural deformation relative to standard structures. The former is due to the exceptional resistance to fatigue cracking exhibited by asphalt mixtures containing HiMA binder, the latter to their lower stiffnesses relative to asphalt mixtures with road binder. The criterion of structural deformation resulting from permanent deformation of the subgrade becomes decisive for the fatigue life of the structure.

In this chapter, the sensitivity of the SiM method to deviations in the fatigue test results of asphalt mixtures was verified. The method is highly sensitive to these deviations, so it is important that the fatigue characteristics of the asphalt mixtures are determined accurately. The influence of the material model used in the mechanistic analysis on the calculated fatigue life of the primary structures was also examined, as well as the assumed value of equivalent temperature. The application of the elastic model leads to overestimation of the fatigue life of the structure. Similarly, the assumed value of equivalent temperature has a significant effect on the calculated fatigue life of the structure.

An approach was undertaken to verify the SiM method by comparing the design of a structure with a highly modified asphalt binder suitable for traffic category KR5, as proposed by other Polish researchers. The results were promising but further investigation is recommended for an accurate comparison.

Chapter 4 provides examples of the application of the SiM method. As well as standard layer systems, several other layer systems using HiMA mixtures in one or more layers for roads of traffic categories KR5, KR6 and KR7 are proposed. The aim of the calculation was to optimise the structure by equalizing the design durability according to the two adopted criteria introduced in chapter 3. The use of highly modified asphalt mixtures enables the construction of pavements with thinner asphalt layers but requires the strengthening of the lower layers of the structure or subgrade.

The work concludes that the proposed SiM method is a useful and relatively easy-to-apply tool for the mechanistic-empirical design of road pavement structures with highly modified asphalt binder and points to several related research topics worth considering.

Keywords: fatigue life, flexible pavement structure, highly modified asphalt binder, HiMA, mechanistic analysis, mechanistic-empirical pavement design method, SiM method, structural design