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Fatigue life comparison of recycled cold mixes with foamed bitumen and with bitumen emulsion

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Abstract

The paper presents the results from the fatigue tests of recycled bases containing foamed bitumen and bitumen emulsion. The amount of bitumen used in both cases was 3% and 5%. For the production of the bitumen emulsion and foamed bitumen, 70/100 pen bitumen was used. Portland cement I 32,5R was applied as a binder. The binder comprised 3% of the mineral composition of the recycled base layer. Fatigue tests were performed in compliance with the requirements of enclosure E of PN-EN 12697-24 at a constant normal stress of 250kPa, 375kPa and 500kPa. The results were used to compare the effects of the binder type applied to the recycled base and determine the service life in terms of the stress applied.

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Keywords: recycled cold mix; fatigue life; energy based method; bitumen emulsion; foamed bitumen; cement; lime .

1. Introduction

Deep cold recycling technology is now a solution applied worldwide to the rehabilitation of distressed pavement layers [1-3]. Limiting values for cold recycled bases (RCM – Recycled Cold Mix) are established nationally [4-8] due to a variety of factors, such as climate, subgrade structural strength, etc., which affect the performance of the recycled layer substantially. Investigations into the influence of individual components and interaction between them on the quality and service life of RCM bases in terms of, for example, frost durability [9], effect of the binding agent

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type [10,11], possibility of using recycled aggregates, bitumen types, etc., have been reported in numerous publications. But a comprehensive evaluation of the fatigue life of RCM bases with foamed bitumen and with bitumen emulsion is lacking. Parameters specified in the guidelines as boundary conditions do not allow explicit determination of base course lifespan. The fatigue life is the basic criterion characterising the materials intended for structural layers of road pavements. Known characteristics enable prediction and accurate determination of the durability of the entire structural system. The design in which RCM base quality assessment is based only on conventional parameters, i.e., elastic modulus, indirect tensile strength or resistance to the action of water, does not provide required information about the fatigue life of road pavement structure with the recycled base layer. Many researchers in the highway engineering area [12-14] evaluate the quality of the recycled layers using fatigue life testing under cyclic loads (controlled stress or strain). Dynamic loads are more destructive in cement-based structural layers than in fully flexible layers. Exceeding the limiting values of indirect tensile strength leads to cracking due to inadequate support of the layer relative to the load applied or, in extreme cases, to the overload. Cyclic loads reduce structural capacity of the pavement, which results from the drop in elastic modulus and increase in strain [15, 16]. The location of the recycled base layer [17] within the structural system is also important, as is the design number of axles 100kN per design lane. Preliminary analyses [18] show that obtaining the required physical and mechanical parameters of the emulsion-based RCM base during the designing phase does not ensure providing the pavement structure with the required fatigue life. Stress values from the computational model transferred to the laboratory simulation showed that the fatigue life criterion laid down in enclosure E of PN-EN 12697-24 was not met. With the above in mind, determining the fatigue life of a given recycled base layer with respect to type of the binder may facilitate decision-making process concerning the selection of binders for RCM bases.

2. Object of study

To study the influence of the bitumen binder on the service life of the RCM base, the designed mineral-cement mix had to meet the requirements for limit curves of base layers with foamed bitumen [7] and with bitumen emulsion [8] intended for the road under 0.50 – 2.5 million axles 100kN [19]. The combination of components allowed a simulation of the use of waste material derived from a road pavement. To evaluate the fatigue life of the recycled base layer, samples were obtained and tested in a laboratory using the indirect tensile test (ITT) in compliance with PN-EN 12697-24 Appendix E. To assess the impact of loading on the recycled base layer, the test was performed at constant stress levels. The normal stress levels used in the tests were selected based on the literature data [18, 19] and preliminary calculations of computational models for typical layer systems in the road pavement structure laid on elastic subgrade. Three levels were selected to vary the load effect: 250kPa, 375 kPa and 500kPa. The end of the test was tantamount to the failure of the specimen or to the completion of 30 000 strain cycles at the constant stress value. These assumptions comply with the regulations as given in enclosure E to the PN-EN 12697-24 reference standard.

3. Research plan

3.1. Mix design

The mineral-cement mix design was prepared based on the technical guidelines and limit curves specified therein for the mix with foamed bitumen [7] and with bitumen emulsion [8]. Density of the recycled mix was determined to PN-EN 12697-5 method C and the optimum skeleton moisture content according to the Proctor method to PN-EN 13286-2. The results allowed preparing Marshall samples and evaluating the strength of the recycled base layer by determining void space content, indirect tensile strength (ITS) and resistance to the action of water (TSR).

The following components were used to produce the mineral-cement mix intended for the recycled base layer with foamed bitumen (FB-RCM) and bitumen emulsion (BE-RCM): recycled asphalt pavement (RAP), crushed-stone aggregate from the existing base layer and continuously graded aggregate 0/4 mm. The design of the grading curve had to meet the criterion of good grading both for FB-RCM [7] and for BE-RCM [8]. This would allow the comparison of the influence the type of binder has on the fatigue life of the base. To provide the required aggregate