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Comparative evaluation and modification of laboratory compaction methods of road base mixtures manufactured in low-emission CIR technology with foamed bitumen and bitumen emulsion

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Abstract

The paper evaluates the influence of laboratory compaction methods on the properties of recycled mixtures with foamed bitumen (Foam-Mix) and bitumen emulsion (Emulsion-Mix). In Poland, the requirements concerning the design of recycled mixtures and quality control of the cold in-place recycled base course layers specify two laboratory methods of sample preparation: static compaction in a hydraulic press and impact compaction with the use of Marshall hammer. The statistical analysis (Student *t*-test) indicates that the compaction method has a significant effect on physical and mechanical characteristics of the recycled mixtures. The method of sample preparation has been found to affect the arrangement of aggregate grains in the compacted material. The hydraulic press method over-compacted the samples from both mixtures, crushing the grains. The samples compacted in the hydraulic press had better strength parameters and resistance to water, which was undoubtedly related to the lower air void content, regardless of the asphalt binder used. Static compaction, which according to the Polish guidelines is conducted under pressure of 100kN maintained for 5 minutes, in many cases (depending on the grading of the recycled mixture or amount of binding materials) produces mixtures with excessive bulk density being inadequate to real conditions and difficult to attain in the field. This paper proposes the technique for the calibration of compaction methodology for foamed and emulsion mixture samples in the hydraulic press against the Marshall method.

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Keywords: Marshall compactor; hydraulic press; road base; cold in-place recycling (CIR) technology; Foam-Mix; Emulsion-Mix.

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1. Introduction

Observed deterioration of Poland's road networks stems from the increasing traffic loads and is not without consequences for traffic safety. Poor condition of the road surface requires that appropriate measures be undertaken to improve the safety level of road users and to minimize the impact of road projects on the environment. These are the key aspects taken into account during the road infrastructure design, construction and maintenance stages. A lot of attention has been recently paid to the development of new materials and technologies allowing for environmental issues, climatic changes and sustainability [19-22]. Cold in-place recycling responds to these trends offering numerous environment and cost related benefits. Increased interest in this technology in Poland results from the possibility of reusing the existing materials, reducing the quantities of new bitumen types, aggregates and limiting energy consumption of road rehabilitation works, all of which contribute to decreased road maintenance costs. Cold in-place recycling of road surfaces with the use of mineral-cement-emulsion mixtures (Emulsion-Mix) have been used in Poland for nearly 20 years, while mineral-cement mixtures with foamed bitumen (Foam-Mix) have been used since 2010. Research [1-3] shows that despite the aggressive traffic and adverse weather conditions, the binder in the form of bitumen foam incorporated into the road surface structure ensures pavement durability. Pavement cold recycling with foamed bitumen containing only about 2-3% water quickly provides the road base material with the required mechanical characteristics, thus allowing subsequent structural layers to be placed on the same day. Since the bitumen emulsion contains 40% of water, the layers from mixtures with this binder have to be cured for 7 or 28 days [5,9].

The topic of the effect of compaction methods on the resultant properties of asphalt mixtures, both hot and cold, has been addressed in numerous studies [10-14,17]. Because of the lack of standardized Polish guidelines concerning foamed recycled mixtures intended for the base course layers, the experience and procedures for sample conditioning and compaction developed in other countries [15,16] were used in this study, along with the recommendations provided in the national General Technical Specification [4] based on the same experience and procedures.

2. Tested materials and methodology

2.1. Experimental program

This study aimed at establishing the influence of the laboratory compaction methods for recycled asphalt mixtures (Foam-Mix and Emulsion-Mix) on the variability of their physical and mechanical properties and moisture resistance.

In compliance with the recommendations [4,5], two compaction methods were used: impact method I – Marshall hammer compaction and static method II – hydraulic press compaction. The recycled mixtures, varied in terms of the binder type (foamed bitumen, bitumen emulsion), were intended for the road base layer under moderate traffic load. In addition, in order to obtain a comparable compaction level, a calibration technique was proposed for static compaction against the impact method, which consisted in varying the value of force (pressure) and the time it acted on the sample in the press.

The influence of the compaction method on the variability of the mix properties was evaluated based on the following parameters of nine samples:

- air void content (V_m, %) to EN 12697-8 and [4,5,15],
- indirect tensile strength for a set of wet specimens (ITS_w, kPa) and a set of dry specimens (ITS_d, kPa) to EN 12697-12 and [4,5,15],
- tensile strength ratio ($TSR=ITS_w / ITS_d \cdot 100$, %) to [15].

The parametric analysis was conducted for the following factors:

- *compaction* method method I (impact), method II (static),
- *type of the mix*: Foam-mix, Emulsion-mix.

Statistical *t*-tests were performed to determine if those factors (*modes of compaction* and *types of mixes*) had a statistically significant influence on the measured specimen properties.