Assessment of the Behavior of a Mineral-asphalt Mixture with an Increased Content of Asphalt Granules Based on Laboratory and Field Tests

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Abstract

The need to protect natural mineral deposits used in the production of road aggregates requires the reuse of materials existing in existing surfaces. A specific example of the policy of reusing materials is obtaining them from asphalt granules from existing mineral and asphalt layers and using it to produce a new mineral and asphalt mixture. The use of asphalt granules reduces the consumption of new aggregates and reduces the amount of new asphalt used in the mixture. Unfortunately, the asphalt contained in the granulate has different properties than the new asphalt added in the production of a new mixture. In order to assess the impact of asphalt granules on the properties of the new asphalt mixture, it is required to conduct both laboratory and field observations and tests. The paper presents the results of research carried out at the research site, the aim of which was to observe two sections with surfaces that differ in their asphalt layer. An asphalt mixture made of new materials (the so-called reference mixture) and a mixture containing 40% of reclaimed asphalt were observed. In research, among others: Fiber optic sensors were used to measure deformations in mineral and asphalt layers.

Keywords: *Hot mix recycling, RAP (Reclaimed Asphalt Pavement), DOFS*

1. Introduction

The need to protect natural mineral deposits and reduce the carbon footprint requires the greatest possible reuse of materials from degraded pavement layers. Reusing these materials reduces the exploitation of natural resources. An equally important advantage of recycling is the lack of need to store these materials in landfills, which pose a threat to the natural environment.

The issue of recycling is particularly important in road surfaces [1], where we are dealing with large volumes of materials to be incorporated in the case of new surfaces or dismantled and incorporated in the case of modernized surfaces [2].

One of the cases of using recycling in road construction is the use of material from the demolition of mineral and asphalt layers [1-4]. The so-called obtained in this way Reclaimed asphalt, after granulation, can be a valuable component of a new mineral and asphalt mixture, reducing the amount of new asphalt added. It is worth noting, however, that the quality of new mineral-asphalt mixtures with the addition of asphalt granules depends on the quality of the obtained asphalt granules, i.e. homogeneity and degree of asphalt aging. It is obvious that the more the new asphalt mixture contains more asphalt granules, the more the characteristics of this mixture depend on the material with worse properties and therefore its properties are less predictable [4]. The technical requirements currently in force in Poland allow the use of asphalt granules in an amount not exceeding 20% in the "cold method" and in an amount not more than 30% in the "hot method" [5]. As evidenced by experience from many studies [1], it is possible to use granules to a greater extent than 30% [5], especially if additional agents are used to improve the properties of asphalt [3]. It should be noted, however, that the impact of asphalt granules on asphalt mixtures operated in real conditions still requires experimental tests to assess the durability of this type of materials. This article presents selected results from laboratory and field tests of an asphalt mixture containing 40% of asphalt granules and a reference mixture made without the addition of asphalt granules.

2. Research Program

The scope of the research included laboratory tests and field tests on a specially prepared test track.

The subject of the research was AC22P asphalt concrete used for the upper layer of the basic foundation. The mixture was made in two variants. A reference variant using new materials and an experimental variant using new materials and asphalt granules in the amount of 40%.

Laboratory tests included basic physical and mechanical tests, including: including the content of voids, the mixture's grain size curve, intermediate tensile strength, the mixture's resistance to water and frost, and its resistance to rutting.

Field research consisted of creating a research field consisting of 2 sections. A truck simulating the traffic load of the KR2 traffic category [6] moved across the plot. In both sections, a system of pavement layers of the same thickness was made, consisting of 2 mineral and asphalt layers, aggregate base and improved subgrade. The difference between the sections concerned the type of mineral and asphalt mixture used to make the lower asphalt layer. In section B1, asphalt concrete was used, made of new materials, and in section B2+f, the asphalt concrete additionally contained asphalt granules.

3. Research Results and Result Analysis

3.1 Laboratory tests

The laboratory testing program included testing three mineral-asphalt mixtures for the base layer and traffic load KR3-4. The test results were compared to the applicable requirements for mixtures containing the permissible content of asphalt granules. The tested asphalt concrete contained: 30%, 35% and 40% of asphalt granules. The research and its results are presented in Table 1.

Tab. 1. Summary of test results for mixtures with different contents of asphalt granules [8].

Selected properties of asphalt and asphalt concrete		Requirements WT-2 KR4, AC22P	Granulate content in AC22P					
			35%		40%		45%	
			Long-Term Oxidative Aging (LTOA)		Long-Term Oxidative Aging (LTOA)		Long-Term Oxidative Aging (LTOA)	
			before	after	before	after	before	after
Asphalt penetration PN-EN 1426:2001		Type of asphalt 35/50, 50/70	47	45	48	47	49	46
Softening temperature, *°C*			52.1	52.2	52.7	52.1	52.5	52.8
Free space content, *%(v/v)* PN-EN 13108-1:2008		4 ÷ 8	5.4	5.3	6.1	6.1	6.1	6.1
Content of dissolved asphalt, *%(m/m)* PN-EN 12697-1:2012		≥ 4.0	4.1	4.0	4.1	4.1	4.4	4.7
Water and frost resistance ITSR, *%* PN-EN 12697-12:2008		≥ 70	77.1	74.6	72.1	71.8	70.1	64.2
Rutting resistance in small apparatus (method B, in air), PN-EN 12697-22	Slope of the rutting graph WTS_{AIR}, *mm/1000 cycles*	≤ 0.3	0.05	0.05	0.06	0.06	0.16	0.18
	Proportional rut depth after 1000 cycles, PRD_{AIR}, *%*	≤ 0.9	3.1	3.2	3.1	3.5	5.0	5.1

The results of laboratory tests indicate that for the materials used, the asphalt granulate content of 45% does not meet the requirements in accordance with WT-2 [5]. This was influenced by the quality of the material obtained from the demolition of the existing surface. It is worth noting that this result excludes the use of 40% asphalt granules of the quality of the asphalt granules used. The use of a more homogeneous granulate and, above all, the use of rejuvenators [3] significantly improves the properties of the asphalt granulate and, therefore, the properties of the produced mineral-asphalt mixture.

3.2 Field research

Field research was carried out on the research section, which consisted of two sections B1 and B2. Each section had a system of layers with the same thicknesses, i.e. a 4 cm AC wearing course, a 7 cm AC base layer, a 30 cm aggregate base layer, and a base made of non-cohesive layers. The thickness of the pavement layers corresponded to typical solutions [6] for KR2 traffic loads. The difference in the construction of the surface concerned the material used for the base. In section B1 it was asphalt concrete made of new materials, and in section B2 asphalt concrete with 40% of asphalt granules was used. The research plot (sections B1 and B2) was located on a circular track on which a truck moved, generating the traffic load of KR2.

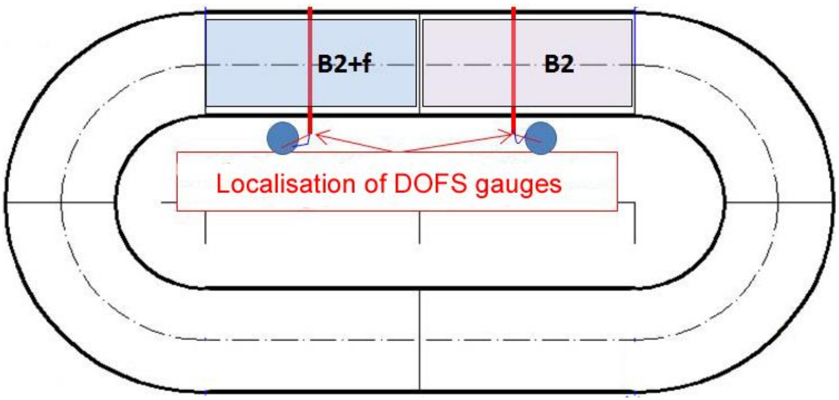

Fig. 1. Characteristics experimental sections B1, B2 and localization DOFS gauges.

DOFS (Distributed Optical Fiber Sensors) [7] were used to measure strains. The sensors were installed on the bottom of the mineral and asphalt package and on the bottom of the aggregate base. Horizontal deformation measurements using DOFS were performed before and after the truck's journeys. The values of the measured deformations before loading cycles with a truck are shown in Figure 2, and the deformations after loading cycles are shown in Figure 3.

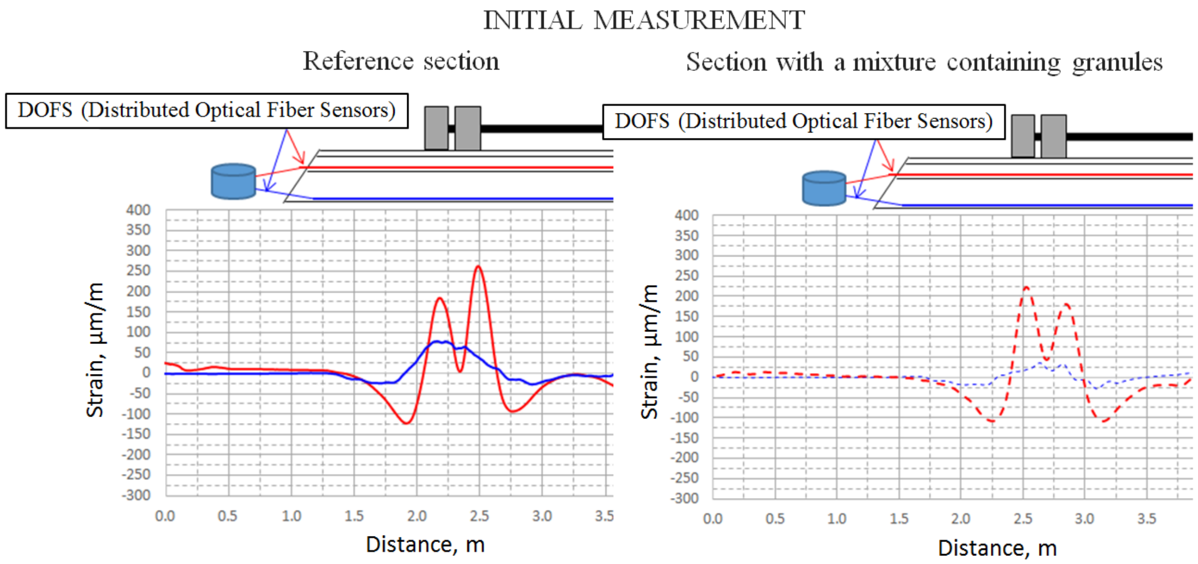

Fig. 2. Distribution of measured strains on the bottom of asphalt layers (red graph) and on the bottom of the unbound mixture base (blue) - initial measurement.

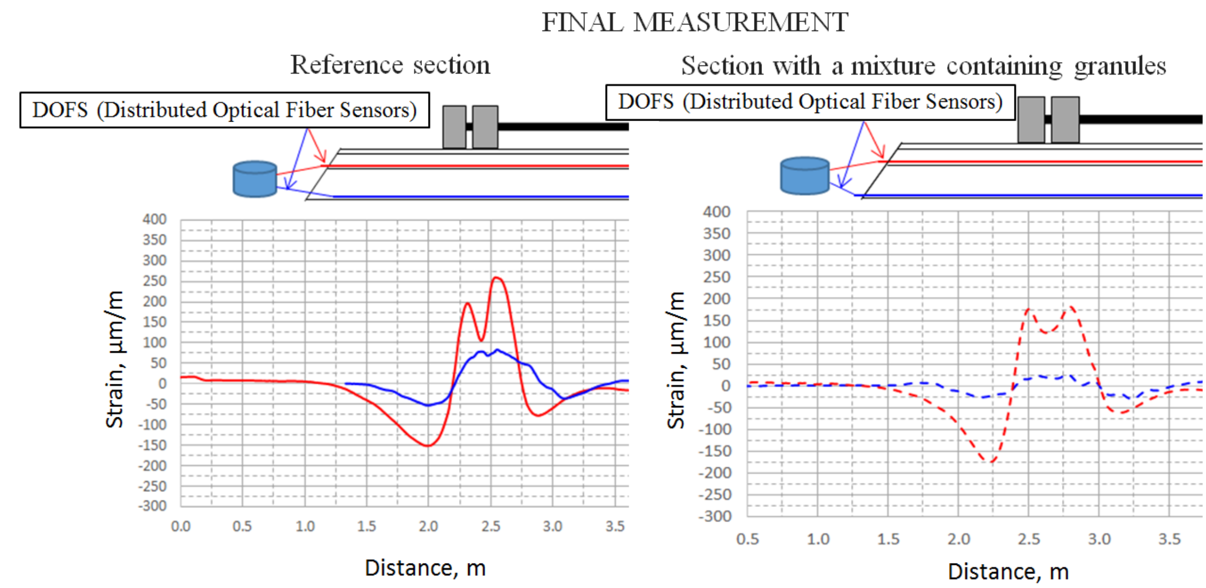

Fig. 3. Distribution of measured strains on the bottom of the asphalt layers (red graph) and on the bottom of the unbound mixture base (blue) - final measurement.

4. Results analysis

The results of laboratory tests indicated that the mineral-asphalt mixture with the highest content of asphalt granules, and at the same time meeting the requirements of Polish regulations, is a mixture with 40% of asphalt granules. In the second stage of the research, this mixture was subjected to real-scale observations on a field training ground. The results of the strain measurements made it possible to formulate several important observations.

- Horizontal deformations in the mineral and asphalt package are characterized by relatively high values (>175µm/m), compared to the deformations that occur in the layers of a typical full pavement structure. This effect was achieved by applying a greater vehicle load, exceeding the nominal load capacity of the vehicle, i.e. the rear axle load was 11.5 t. instead of 8 t.
- Measured deformations using optical fibers enabled the observation of the distribution of highly variable deformations in the contact zone: twin wheels - road surface. The lower deformation values can clearly be associated with the space between the twin wheels (Figures 2 - 3). This effect is probably also visible because the thickness of the mineral and asphalt package is relatively small, i.e. in the presented case it is approximately 11 cm, and the optical fiber is located close to the surface.
- The maximum deformation values from both measurements (Fig. 4) allow us to conclude that the mixture containing 40% of asphalt granules is characterized by at least the same properties as the reference mixture made in accordance with the applicable technical recommendations [5].

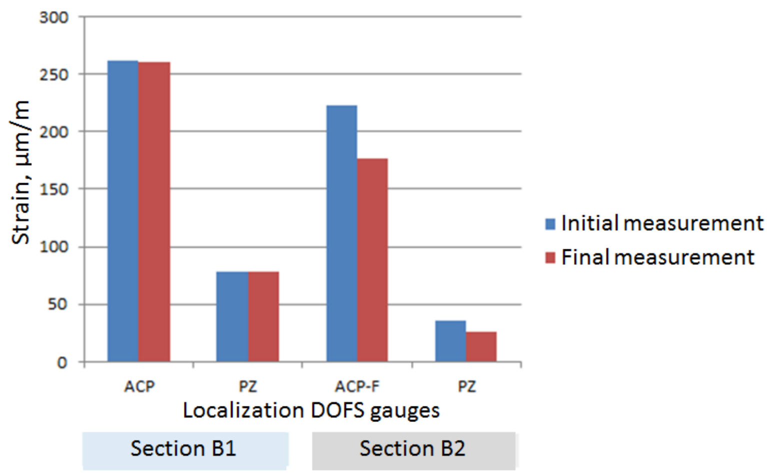

Fig. 4. Comparison of maximum deformations at the bottom of the observed layers.

5. Conclusion

The presented program of laboratory and field tests on the impact of asphalt granules on the properties of the mineral-asphalt mixture is in line with current research needs on the re-use of materials from the demolition of existing pavements. In the field tests, the surface was examined on a real scale using DOFS sensors, which are rarely used, which enable direct measurement of deformations at the bottom of the mineral and asphalt package.

The presented scope of research confirms the possibility of using asphalt granules in the range of 40% for asphalt concrete without deterioration of its properties.

The research program provided a lot of data, which will be the subject of further analyzes aimed at determining the fatigue life based on measured actual deformations in the asphalt concrete base.

Acknowledgments

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