Sealing The Cracks in the Wear Layer of the Road Surface by Friction against a Rotary Active Element

Stefan Ionita and Stefan Velicu

***Abstract*—The main objective of the research paper is the theoretical and experimental analysis of the method proposed for sealing (clogging) cracks in asphalt, by means of a cylindrical bitumen bar, enriched with plastic and rubber granules (obtained from the use of waste), which melts and infuses into the cracked zone by rotation and friction against it. After analyzing the technical characteristics of the sealed area and the time required to apply the bitumen layer, this method can be chosen in the future to the detriment of the expensive operations of partial milling of the cracked wear layer, making possible the repair of cracks by sealing(clogging), using the friction procedure. The research results highlighted the diminution of road maintenance costs using the method of friction, the decrease of cracks repair time, maintaining the initial characteristics of the repaired area, incorporating a waterproofing material (plastic and rubbber granules from recycled waste), keeping the wear layer in good conditions, possibility of embedding an intelligent system of traffic monitoring at low costs etc.**

***Index Terms*—Asphalt mixture, plastic granules, rubber granules, friction method, sealing.**

I. Introduction

Very large quantities of plastic and rubber waste appear in the European Union every year, out of which less than 30% are collected and recycled [1]. The world share of plastics in 2017 was about 348 million tons, and the European Union had a share of 18.5% approximately. Collection (for recycling) of this waste that currently fills up the agricultural areas – Fig. 1.

Fig. 1. Collection of waste for recycling.

The specialized studies highlighted that more than 80 % of all marine waste is plastic; because of the long time required for decomposition, the plastic accumulates in seas and oceans and is ingested by certain marine species, thus reaching in the human food chain.

At the same time, the trading companies whose actual object of activity is the recycling and storage of waste are facing the problem of worn out tires. Car tires are among the most problematic types of waste due to the very large volume occupied at the time of collection. However, tires are one of the most reusable types of waste because the rubber from which they are made is very durable and can be reused by various methods meant to recover its high energy value; this rubber can be used as a binder in asphalt.

At the same time, road safety is a field of great interest currently and is constantly in the attention of the relevant authorities. One of the important aspects that improperly influences road safety is the maintenance status of road infrastructure, amplified by its frequent use by the overloaded motor vehicles, exceeding the transit load value declared. In order to analyze and repair the degradations occurred in the asphalt surface because of motor vehicles weight, the use of hardly self-degradable recyclable materials was implemented - Fig. 2.

Fig. 2. Shredding of worn out tires.

Analyzing the current concerns in the field of road infrastructure, it is found out that one tries to give a new use to plastic and rubber waste that ends up in landfills. Experiments are conducted in order to study the possibility to use this waste as a base of the asphalt applied on roads. The experiments involve the transformation of plastic and rubber waste into granules that can be used for this purpose in certain percentages. In general, the asphalt on roads is a mixture of gravel, limestone and sand in a proportion of about 90%, while the rest is bitumen, which ”binds” all these ingredients. The plastic and rubber granules used in the mixture with asphalt manage to replace most of the bitumen needed to create the finished product. The granules can be made from almost any kind of plastic, respectively household or commercial waste [2].

This research paper shows the use of a rotating cylindrical bar made of bitumen on the affected (cracked) zone. This bar makes possible the deposition of a quantity of material by melting, following the development of a friction phenomenon at the surface of the road. Due to the

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combination of the modifier (rubber powder and plastic granules) with bitumen and binders, a material with performances comparable with the classic asphalt mixtures is obtained, having also reusable wastes in its composition.

II. Experimental Research for Sealing Cracks in the Wear Layer

A. Equipment and Technologies Currently Used to Seal Cracks

At the present moment those who deal with the management of the streets and road system have problems caused by the improper maintenance and repair. In this context, if the preventive maintenance operations of the road system are not taken into account, or if they exist but are performed improperly, damages appear and lead to a rapid deterioration over time. Cracks that occur in the road surface entail the appearance of pits as times goes on; these pits usually appear in the cold season, due to frost and thawing. Cracks and other degradations can be explained as a consequence of the significant hydrophobic effect, which occurs after impregnation of the snow-covered road surface with thawing agents. If urgent action is not taken, the cracks will increase and the condition of the road surface will worsen, increasing the risks in the road safety area.

The cracks that appear in the asphalt pavements of the road surface have an opening under 6mm. The cracks can be: longitudinal, transversal and multiple unidirectional. If they are not repaired properly, they will allow water to infiltrate the wear layer, which will lead to the premature damage caused by the phenomena specific to the cold season of the year, such as frost and thawing.

Currently, these deficiences of the road surface are fixed by the sealing operation. This operation consists in filling the cracks with liquid bitumen or bituminous mastic.

The current liquid bitumen filling technology consists of the following operations:

1) widen the contour of cracks when necessary;
2) clean the cracks with compressed air;
3) bitumen primer is introduced;
4) pour molten bitumen along the crack, with a ladle or a special device;
5) sprinkle fine sand for protection.

Several variants of equipment are used to seal the cracks in the road surface. Figs. 3 and 4 show the components of such an equipment and the work technology [7].

Fig. 3. SEALMASS M5 sealing equipment.

Fig. 4. Liquid bitumen application device

The industrial equipment [9] has a complex thermal heating system which keeps the clogging material in a liquid state.

The advantages conferred by this equipment are the following:

1) simple and efficient application of the liquid bitumen even if this one has a very big viscosity;
2) fast heating of bitumen;
3) efficiency of the clogging system, with minimization of the risks of workplace accidents;
4) more safety and protection for the operator.

Another equipment currently used is the one manufactured by Crystal Technologies Company; it has a different system for dispersing liquid bitumen in cracks. In this case, the block-shaped bituminous sealant is loaded into the equipment tank. The bitumen goes into a liquid state, due to the heating of the tank which has a jacket with oil at a certain temperature, which brings the bitumen to the temperature required for pouring into the cracks, without being overheated or burned [8]. At the same time, the equipment hose and the application lance are heated in special compartments – Fig. 5.

Fig. 5. HYOROG sealing equipment.

The equipment has a complex pump and the bitumen is pumped through the hose and the application lance into the crack. The flow of material is dosed in the application lance by means of a dosing valve. The equipment [10] is also provided with an air compresor for cracks cleaning with pressurized air before applying the bitumen – as per Fig. 6.

Fig. 6. Device for bitumen application into the crack.

B. Use of Friction between Two Materials to Seal Cracks in the Road Surface

The experimental method developed in this paper is based on the rotation of a consumable bitumen bar (with rubber powder and plastic granules in proportion of 2%), pressed against the surface to be repaired in order to deposit a layer of material in the crack and to perform the sealing (for stopping the penetration of water). The concentrated thermal energy developed in the contact area must be analyzed. This energy leads to the generation of a material layer that covers the crack, under the conditions of the existence of a feed motion made perpendicularly to the axis of the consumable material bar [3], [4]. The rotating bar is moved axially as it is consumed, to achieve the process of depositing and sealing, Fig. 7 (a, b, c).

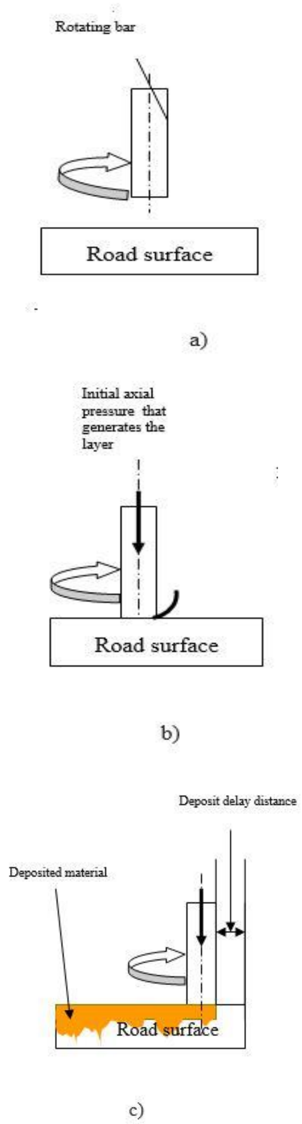

Fig. 7. Depositing by friction.

Fig. 8 shows the perimeters that make up the impact area, which highlights a different behavior of the bitumen and the material that comes off the bar [5]. We take into consideration that the difference between the rotation speed at the plastic perimeter (2) and the contact perimeter will entail the detaching of material from the bitumen bar and its infusion into the crack. Following the measurements, the deposited layer width is about 0.8 of the bitumen bar diameter. After reaching a controlled temperature of about 200°C at the impact surface, the detached material melts and penetrates the crack to a depth that depends on the temperature of the support layer. The higher over 5°C the temperature of the support layer, the bigger the penetration depth above the value of 7mm. In the case of temperatures over 20°C of the wear layer, the melted bitumen moves into the crack up to 15mm. At temperatures above 40°C of the wear layer, the bitumen bar feed rate must be increased so that the contact time decreases to obtain a constant depth of bitumen penetration into the crack.

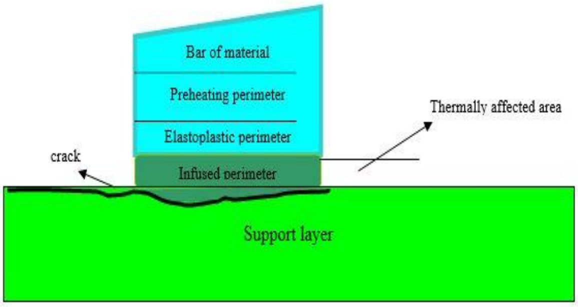

Fig. 8. Perimeters and phenomena specific to cracks sealing by friction.

To perform the operation of sealing the cracks in the supporting layer, we simulated an equipment that would generate: bitumen bar speed, feed rate, axial force necessary to develop a temperature of 200°C.

In order to make the equipment able to perform the operation of sealing the cracks in the wear layer with low costs and low skilled labor, we chose a thermal motor with the power of 2 Kw to achieve the rotational speed, axial force and feed. Experimental tests have shown that the motor power is sufficient to achieve the axial force required to perform the friction sealing.

III. Working System Components

The equipment proposed for the achievement of this operation is shown in Fig. 5.

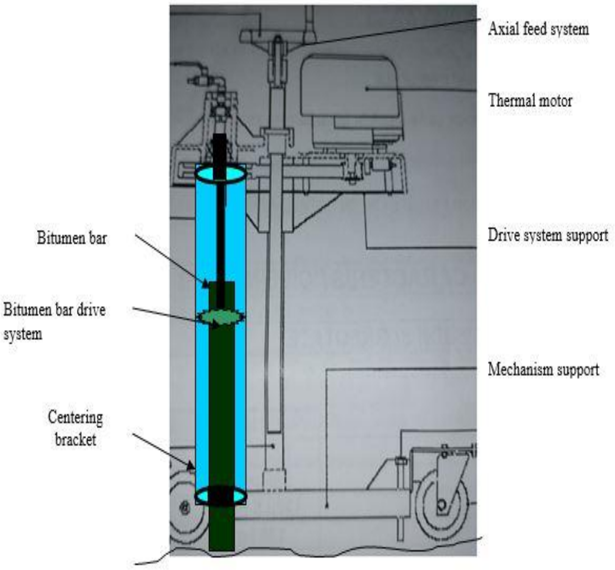

Fig. 9. Equipment for wear layer cracks sealing

The parameters of the sealing method are:

- The main parameters that ensure:
  1) rotation speed of the bitumen bar;
  2) temperature in the contact area;
  3) feed rate of the bitumen bar.
- the secondary parameters that ensure:
  4) positioning the bar in relation to the crack;
  5) length of bitumen bar;
  6) depth of penetration;
  7) bitumen bar composition.

IV. Experimental Determinations for Cracks Sealing

A set of experimental tests Fig. 10 was performed in order to determine the influence exerted by certain factors that led to the data listed in Table I.

During the experimental tests, two cylindrical bars were used, one made of standard bitumen, the second made of bitumen with 2% insertion of plastic and rubber granules.

Fig. 10. Cracks sealing by friction method

TABLE I: Comparison between Types of Bitumen

Combinations of material	Bar dia mm	Speed (RPM)	Applied force (kN)	Feed (mm/s)	Depth of sealing
Normal bitumen	40	1000	8	10	8mm/ 20°C
Bitumen with plastic and rubber granules	35	1000	10	8	7mm/ 20°C

The bitumen bar used has a hard plastic jacket that exfoliates after rubbing against the wear layer. The plastic jacket improves the rigidity of the bitumen cylinder by providing a high resistance to the pressure exerted by the equipment in order to maintain contact with the crack and to ensure the generation of the temperature necessary for sealing. Figure 6 shows some cracks in the wear layer that can be sealed using this method.

Fig. 11. Cracks in asphalt: a – repair of the crack classic method, b - crack affected by weather

V. Conclusion

The experimental method of sealing the cracks in the wear

The experimental method of sealing the cracks in the wear layer provides the following advantages over the operations currently performed, namely: sufficient adhesion and penetration into the crack; low porosity of the applied layer; microstructures similar to the basic material; use of recyclable materials that enter the crack and achieve efficient waterproofing; low thickness of the affected material; low costs; environmentally friendly operation (does not affect the environment); low labor; low skilled operators; possibility of embedding a low cost intelligent system for traffic monitoring.

An aesthetic and fast sealing is achieved with minimal impact on the environment.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Stefan Ionita obtained, analyzed the data and wrote the paper while Stefan Velicu supervised and suggested improvements to it. All authors had approved the final version.

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