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A fast pothole repair method using asphalt tiles and induction heating

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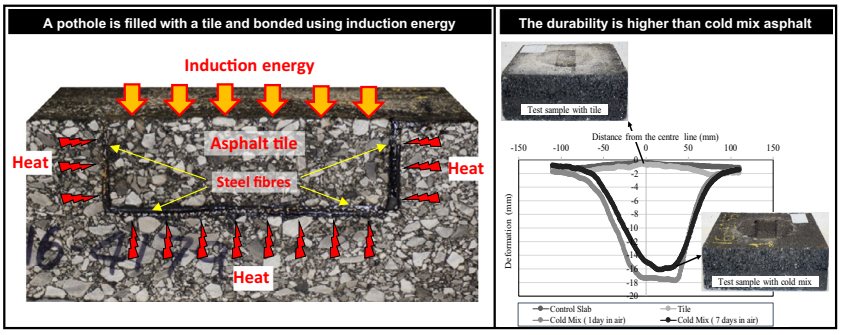
HIGHLIGHTS

- Asphalt tiles are used to fill potholes and bonded using induction heating.
- The shear strength of the bond is higher than the original materials.
- The rutting resistance is 40 times higher than cold mix asphalt.

GRAPHICAL ABSTRACT



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ABSTRACT

In this paper, a new method to repair potholes in asphalt roads is presented. It consists of an asphalt mixture tile with a bottom bonding layer made of bitumen, and steel fibres. To use this technology, potholes have to be first cleaned, second filled with an asphalt tile and third, exposed to high frequency electromagnetic fields to heat the fibres up and melt the bitumen in the bonding layer. This article assess the bonding properties of tiles built with bonding layers of various thicknesses and amounts and distributions of fibres. Furthermore, the effect of moisture on the bonding properties of asphalt tiles has been examined and the functionality of the tiles observed using wheel track tests. It has been concluded that asphalt tiles are a suitable method to repair potholes, and the durability of the repaired surface is comparable to that of a newly built road.

1. Introduction

Asphalt materials are composed of aggregates and bitumen. Aggregates form the structure that resists vehicle loads and provide skid resistance, while bitumen binds the aggregates together. With time and environmental exposition, bitumen degrades chemically and becomes brittle [1]. In addition, moisture may penetrate in the pavement structure, causing loss of adhesion between aggregates and binder [2]. Furthermore, thermal efforts [3] and vehicular loading over aged asphalt pavements [4] may be the cause of crack propagation and aggregate losses that lead to formation of bowl-shaped potholes [5]. These are the main cause of reductions in roads service level and the most aggravating pavement distress for traffic safety [6].

The properties commonly sought in pothole repair materials are good workability and cohesion [7], traffic loading and environmental durability [8], bonding, freeze-thaw and rutting potential [9]. To accomplish these, there is a very wide range of procedures and pothole repair materials that have been listed in many previous studies. These are (1) hot mix asphalt, (2) cold mix asphalt and (3) other polymeric materials or resins [10]. In general, it is commonly accepted that hot mix asphalt, the combination of aggregates and bitumen, gives the best quality of repairs, although it has limited applicability due to minimum mixing batches requirements and laying temperature constrains. On the other hand, cold mix

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asphalt, the combination of aggregates, bitumen emulsion and cementitious materials [11], produces repairs of lower quality but shows higher flexibility of application, i.e. small amounts can be packed and used to repair individual potholes, under most weather conditions [12]. Moreover, there is a range of polymeric materials and resins that have been developed to produce high-quality pothole repairs, such as dicyclopentadiene (DCPD) [13] or rapid setting urethane resins [14], although these are generally expensive and not commonly used. In practice, pothole repair materials are selected depending on the level of distress, resources available or political and administrative circumstances.

Furthermore, induction heating is another road's repair and maintenance method of particular importance for the research presented in this article. Induction energy heats the metallic fibres by means of high-frequency alternating electromagnetic fields, able to induce eddy currents in materials that are electrically and magnetically susceptible [15]. Currently, there are two technologies that use this technique, Rollpave [16] and asphalt induction-healing [17]. The first one is a prefabricated asphalt mixture layer that can be extended over an old road surface and used for traffic circulation. The prefabricated layer is fixed to the old road surface by means of a bituminous membrane, the bonding element, containing a steel mesh that can be heated using induction energy, to melt the membrane [18]. The second technology is a preventive rather than a repair method. It consists in embedding steel fibres in asphalt mixture and heating them using induction energy when microcracks appear on the road [19]. As bitumen is a liquid which viscosity is temperature dependant, it can drain into the cracks and fill them when is hot [20].

An ideal pothole repair method should (1) be readily available to be used in any environmental condition, (2) create a patch of comparable quality and durability to the original road material, (3) not produce debris materials, such as hot mix asphalt, (4) minimise traffic disruption and (5) have comparable life-cost to current asphalt patching methods (based on information obtained from Ref. [10]). The objective of this article is to develop a new pothole repair method that accomplishes the previous points.

2. Description of the proposed technology

As shown in Fig. 1, the proposed technology consist in an upper layer of asphalt mixture (similar to an asphalt tile) wrapped in a bonding layer made of elastic polymer modified (SBS) bitumen [21] and conductive particles susceptible to be heated by electromagnetic induction. For the present investigation, besides commercial products, recycled steel fibres from old tyres have been used in order to minimise the environmental impact and reduce the operational costs.

When a pothole appears in the road, it can be sanitised (cut to standardized dimensions by means of a hole saw) and gently filled with an asphalt tile. The bond between the tile and the old road is created by heating the fibres, by means of induction energy, and applying light compaction (i.e. manual compactor). With this technology, within seconds of induction heating (less than 1 min), the bonding layer reaches temperatures above 100 °C and tile and old pavement stick together, maximising the benefits of in-factory prefabrication, such as high-quality results, shorter production time, reduced debris production and improved health and safety conditions for workers.

Since the asphalt tiles are prefabricated in an asphalt plant, they can be made of the most suitable mixture for the road where a given pothole (or series of potholes) is being repaired. In other words, aggregate gradation, bitumen type/content, compaction level, etc. can be modified *a-la-carte* obtaining optimum performance and without affecting the rest of the production process. The sizes of the tiles can also be easily modified or just selected according to a given set of standardised sizes that perfectly match the inner diameter of the sanitised potholes.

3. Materials and methods

3.1. Description of materials used for the tiles

As explained before, the top layer (the tile) should be made of the most suitable kind of asphalt mixture depending on the

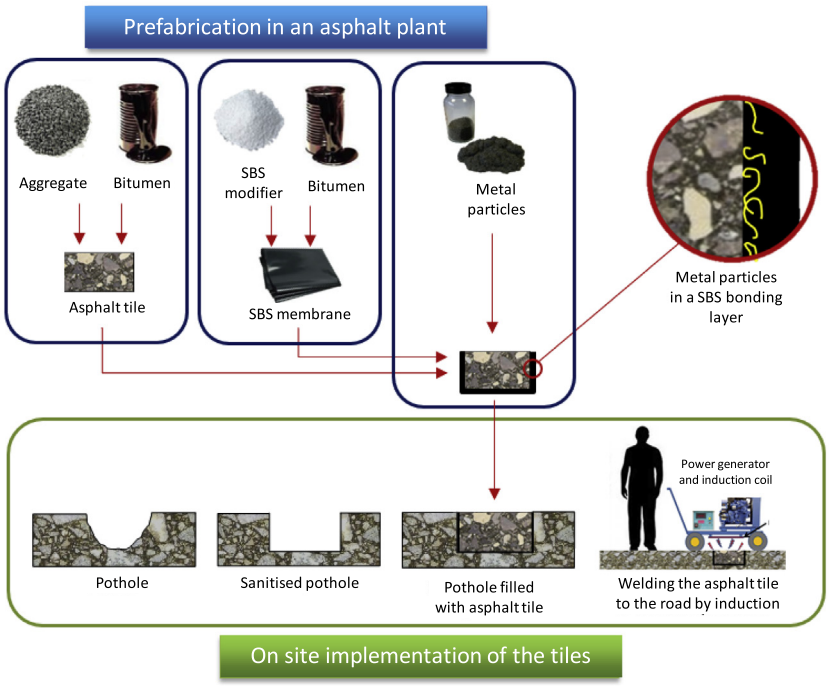

Fig. 1. Schematic implementation of the proposed technology for potholes repairing.