Construction and Building Materials 160 (2018) 539–550

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Asphalt rubber concrete fabricated by the dry process: Laboratory assessment of resistance against reflection cracking

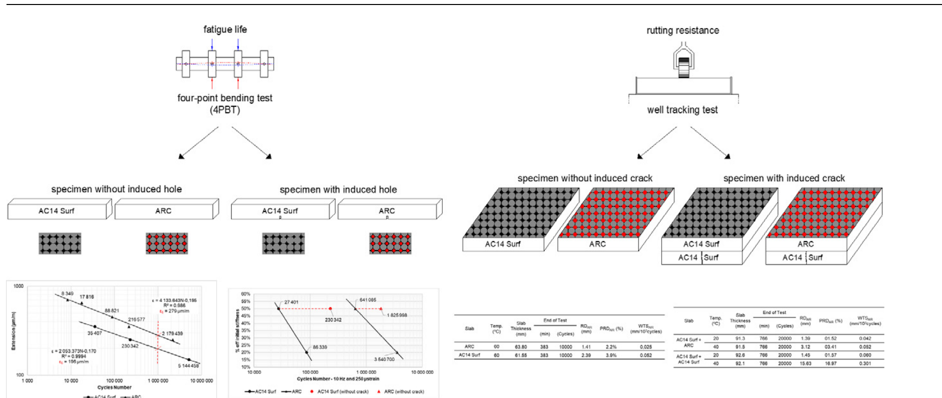
Luís da Silva [a,*], Agostinho Benta [b], Luís Picado-Santos [c]

[a] Departamento de Engenharia Civil – Universidade de Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
[b] RISCO, Departamento de Engenharia Civil – Universidade de Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
[c] CERIS, CESUR, Instituto Superior Técnico – Universidade de Lisboa, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

HIGHLIGHTS

- Bituminous mixtures with ultrafine-size rubber particles by the dry process (ARC).
- The fatigue behavior, rutting resistance, and evolution of crack were evaluated.
- ARC showed better resistance to fatigue and rutting, and slower crack propagation.
- ARC is a good option for pavement overlayers in road pavement rehabilitation.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 13 August 2017
Received in revised form 15 November 2017
Accepted 16 November 2017

Keywords:
Asphalt rubber concrete
Dry process
Fatigue
Rutting
Crack propagation
Reflection cracking

ABSTRACT

This research aimed to evaluate bituminous mixtures made with a high percentage of ultrafine-size rubber particles (Asphalt Rubber Concrete, ARC) using the dry process. Laboratory tests were performed on asphalt concrete samples with and without rubber addition to compare the results. The fatigue behavior (four-point bending tests on prismatic-shaped specimens), rutting resistance (wheel tracking tests on rectangular slabs), and evolution of crack propagation (induced cracks in prismatic-shaped and rectangular slabs) were evaluated. The results demonstrated that ARC obtained using the dry process showed better resistance to fatigue (at least 10 times more) and rutting (at least 2.5 times more). Slower crack propagation was also registered. These facts lead to the conclusion that ARC fabricated by the dry process is a good and sustainable option for pavement overlayers in road pavement rehabilitation.

1. Introduction

The destination of used tires has become a huge important environmental concern [1,2]. Moreover, with the aim of improving the performance of pavements, several solutions using rubber from end-of-life tires (ELTs, often called by crumb rubber, CR) to modify asphalt concrete have been proposed. Recycling of CR offers considerable environmental benefits such as reduced need for landfill and reduced atmospheric pollution from burning.

Three methods of producing asphalt rubber concrete (ARC) have been used so far: the wet process (Fig. 1), in which small sized (0–1 mm) rubber grains are added to bitumen and after a digestion period the resulting product is used as binder to produce ARC; the

* Corresponding author.
E-mail address: luisf@ua.pt (L. da Silva).

https://doi.org/10.1016/j.conbuildmat.2017.11.081
0950-0618/

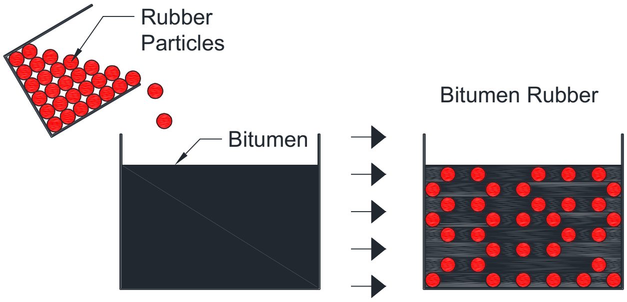


Fig. 1. Wet process, adapted from Hassan et al. [1].

dry process (Fig. 2), used in this study, in which small sized (0–1 mm) rubber grains are added directly to aggregate in a plant mixer, where they are heated, and then bitumen is added, producing an ARC similar to the one obtained by the wet process that can be used in construction after a period of rubber digestion before being laid down and compacted; and finally, terminal blend rubber bitumen, which is a binder prepared in refineries in order to be used to produce ARC in the same way as conventional asphalt concrete (AC).

Several studies addressing ARC compared with other type of mixtures have been executed in the last years. Lastra-González et al. [3] analyzed separately a reference asphalt concrete and four modified asphalt concretes with polymeric wastes (polyethylene, PE, from micronized containers; polypropylene, PP, from ground caps; polystyrene, PS, from hangers; and rubber from ELTs) using a type of dry process. The authors verified that, compared to the reference mixtures, the mixtures including rubber had better behavior in terms of resistance against plastic deformation and showed a more elastic behavior with a lower phase angle. Xie and Shen [4] investigated the dynamic modulus, rutting resistance, moisture susceptibility, and fatigue resistance of rubberized stone matrix asphalt (SMA) through laboratory performance tests and found that the introduction of CR may affect the high temperature dynamic modulus and rutting resistance, while no significant influence on the moisture susceptibility and fatigue life was registered. Wei et al. [5] evaluated the anti-icing performance of CR and diatomite-compound-modified asphalt mixture and concluded that the mechanical properties of the control asphalt mixture were improved by the CR and diatomite. Shafabakhsh et al. [6] show that the use of some wastes such as waste rubber powder in asphalt mixtures not only increases their lifetimes but also reduces production costs. With regard to asphalt rubber mixtures, Kaloush [7] summarizes findings from several research studies conducted at Arizona State University in the areas of binder and mixture performance. The authors found, for example, that the rubber mixtures had the highest potential to resist crack propagation when compared to other polymer-modified and conventional mixtures.

As can be seen, in all those studies, several types of ARC performed well and were proven to be a very competitive solution to improve road pavement performance.

The main methods of obtaining the CR from ELTs are ambient grinding and cryogenic grinding. Both processes consist of reducing the size of the tires and separating the steel belting and fiber from the crumb compound. Ambient grinding is the most common and productive process for obtaining CR. The cryogenic grinding process is carried out at negative temperatures. The CR obtained by mechanical grinding (used in this work) produces a binder with a viscosity higher than that of any other modified bitumen with the same amount of rubber obtained by the cryogenic process [8–10].

Important advances in the whole process of producing ARC and justifying its use have been studied and achieved. Farouk et al. [11] investigated the effects of mixture design variables on the rubber–bitumen interaction and properties of rubberized asphalt mixtures fabricated through the dry process and found that higher rubber–bitumen interaction can be obtained with the use of fine rubber size and high bitumen content. Sienkiewicz et al. [12] presented an overview of methods for improving the storage stability at high temperature of rubber-modified bitumen and concluded that the increase in stability can be achieved by using CR surface-activated by furaldehyde or ground tire rubber treated by gamma irradiation or modified by a devulcanization process. Shao et al. [13] proposed and evaluated a novel mixing technique, namely double-drum mixing, and carried out a comparative study to investigate the effect of double-drum mixing on the performance of hot recycled asphalt mixtures; they verified that this process can reduce the air voids if all other mix design parameters are kept the same and that the tensile strength, moisture damage resistance, rutting resistance, and low-temperature cracking resistance were improved to a certain extent. Farina et al. [14] carried out a Life Cycle Assessment (LCA) of different types of road paving technologies based on the use of bituminous mixtures containing recycled materials such as CR from ELTs and reclaimed asphalt pavement, considering different scenarios stemming from the combination of production, construction, and maintenance operations and comparing them with a reference case involving the use of standard paving materials. LCA results, expressed in terms of gross energy requirement and global warming potential, showed that the use of rubberized bituminous mixtures leads to significant benefits in comparison with standard paving solutions. Wang et al. [15] presented the recent developments in the application of chemical approaches to rubberized asphalt and found that rubberized asphalt is suitable for use with a wide range of different additives. Sangiorgi et al. [16] assessed the effectiveness of adding CR by the dry method to porous asphalt (PA) mixtures and proved that although the application of CR reduces the vertical permeability and permanent deformation resistance, it improves the bitumen/aggregate affinity and controls the draindown rate without adding fibers. Lastra-González et al. [17] analyzed the skid resistance and

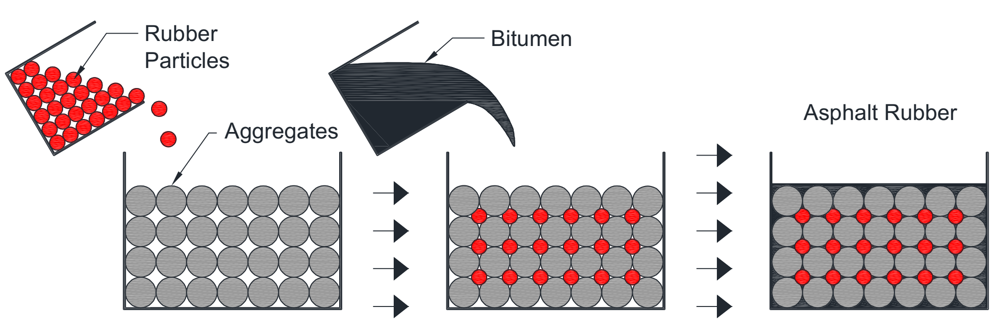


Fig. 2. Dry process, adapted from Hassan et al. [1].