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Evaluation of sound absorption capacity of asphalt mixtures

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ABSTRACT

Noise generation is an environmental problem that affects human beings, animals and even plants. Several serious diseases have their development associated to the exposure of human beings to high levels of noise pressure, such as arterial hypertension, gastrointestinal changes, alterations in blood glucose and high heart rate, among others. Vehicle traffic is part of a group of noise-generating factors. Various mechanisms govern the generation and propagation of vehicle noises, which are produced mainly by motor vibration at speeds below 50 km/h and by the tire-pavement contact at speeds above 50 km/h. The noise generated by tire-pavement contact is the result of two components: aerodynamic noise (mainly related to the coating porosity), and mechanical noise (related to the coating texture). The noise generation according to these two components may be mitigated by using special asphalt mixtures. This work evaluates the sound absorption of four different types of asphalt mixtures (common dense-graded asphalt mixture, dense-graded rubberized asphalt mixture, rubberized porous coat with void volumes varying from 22% to 27%, and rubberized open-graded friction course) and the effect of granulometry and void volume of each mixture on the sound absorption coefficient. Mixture slabs were molded in a slab compactor developed by LCPC (Laboratoire Central des Ponts et Chaussées) and specimens were extracted from each one for assessing the sound absorption capacity in the laboratory. The acoustic behavior was evaluated according to standard ISO 10534-2, using impedance tubes. Results showed that sound absorption is strongly influenced by void percentage, interconnected void percentage and layer thickness.

1. Introduction

Traffic noise is one of the most relevant environment problems in urban areas. An extensive list of symptoms and diseases have become subject of medical studies over the past decades: stress, insomnia, mental and memory loss, headache, nausea, temporary and permanent hearing loss, tinnitus, and disorders in the circulatory, respiratory and immune systems are among the evils of noise [1].

The fauna is also affected by the high levels of roadway noise. The reproduction of some bird species is reduced by communication interference and hormonal stress, and their population begins to decline with medium noise levels starting from 42 dB. Several species of large mammals also have very low populations in areas that are 100–200 m away from highways [2].

Research aiming to minimize harmful noise levels to human health has been developed in various countries in order to improve life quality. As a result, some solutions have been adopted to reduce traffic noise, such as the construction of silent coatings, the installation of noise barriers, speed control, and changes in road geometry design.

Silent asphalt mixtures have good sound absorption capacity. The sound absorption coefficient of these mixtures is considered one of the most important parameters influencing noise generated by the tire-pavement interaction. Studies show that the sound absorption coefficient is effective for reducing tire-pavement noise at frequencies between 800 and 1600 Hz [3,4]. The pavement surface porosity can decrease noise at most of the frequency range, being less efficient at a frequency close to 2500 Hz [5].

Acoustic absorbent asphalt mixtures, known as porous mixtures, have the primary function of reducing amplification due to the effect of aerodynamic mechanisms and thereby reducing sound radiation [4,6].

The high sound absorption materials are normally porous and fibrous. In porous materials, the incident acoustic energy enters

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the pores and dissipates by multiple reflections of the sound wave and viscous friction between the pores, turning into thermal energy [7].

Brazil is currently considered a country with highly elevated vehicular noise levels. The cities of Sao Paulo and Rio de Janeiro, for instance, are among the cities with the highest traffic noise levels in the world [8].

This article presents a study on the evaluation of the sound absorption capacity of asphalt mixtures through the manipulation of granulometry, void volume, interconnected voids, and thickness of the coating layer, in order to improve the building of silent pavements in Brazil.

2. Research method

In order to evaluate the sound absorption using the impedance tube method for some types of asphalt coatings, specimens of asphalt mixtures (common dense-graded asphalt mixture, rubberized porous coat, rubberized open-graded friction course and a dense-graded rubberized asphalt mixture) were molded. For the rubberized porous coat, the grading curve was first defined from previous works that have demonstrated adequate performance to mechanical and performance characteristics. The other mixtures were produced on the basis of asphalt mixture designs already implemented in the state of Santa Catarina, southern Brazil. The materials were selected and characterized and after the mixtures were compressed using the Marshall method and the French slab compactor developed by LCPC (Laboratoire Central des Ponts et Chaussées). Three specimens were extracted from each molded slab using the wheel tracker for performing sound absorption capacity tests in the impedance tube according to ISO 10534-2.

2.1. Granulometric compositions and percent of bituminous binder

Fig. 1 shows the graphic of all granulometric curves of the mixtures studied, and Table 1 shows the binder content of the asphalt mixtures designed according to the Marshall method. The asphalt-rubber ground waste tire was incorporated into the binder using the continuous blend system, with 15% rubber of the total weight.

2.2. Mechanical characterization assays

Five Marshall specimens were molded for each type of asphalt mixture in order to carry out the mechanical characterization assays.

Initially, the percentage of voids for all specimens was determined. The tensile strength test (ASTM D 4123) [9] was performed using all asphalt mixtures studied while the Cântabro's assay (NLT-352/86) [10] was performed using the rubberized porous coat and rubberized open-graded friction course. The difference between a rubberized porous coat and the rubberized open-graded friction course is in the granulometry. The rubberized porous coat has a gap in its granulometry and thereby its voids are more interconnected than the rubberized open-graded friction course which, despite having an open granulometry, has the highest percentage of non-interconnected voids.

2.3. Slab molding

The slabs were compressed using the LCPC slab compactor in order to obtain a texture and a structural matrix similar to one obtained in the field, compressed by tire rollers. In open mixtures (rubberized porous coat and rubberized open-graded friction course), compression was performed using a metal slab to simulate the field compression with single drum rollers.

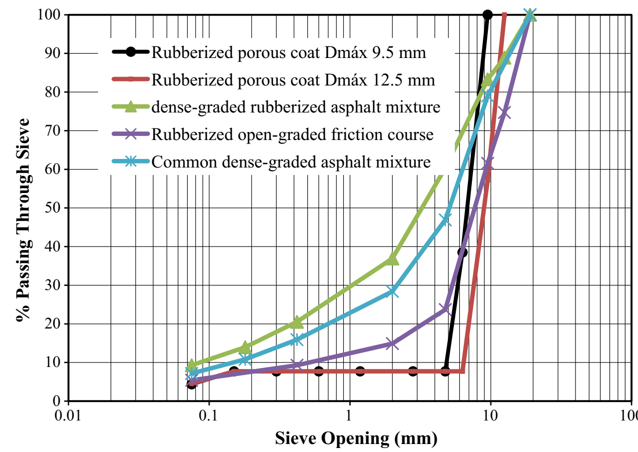

Fig. 1. Aggregate gradation of mixtures.

Table 1
Characteristics of mixtures.

Mixture	Binder	Binder content (%)	Max. aggregate size (mm)
Common dense-graded asphalt mixture	Asphalt binder 50/70 pen	4.91	19.1
Rubberized porous coat	Asphalt rubber binder	4.20	9.5
Rubberized porous coat	Asphalt rubber binder	4.40	12.5
Rubberized open-graded friction course	Asphalt rubber binder	4.30	19.1
Dense-graded rubberized asphalt mixture	Asphalt rubber binder	5.60	19.1

The common dense-graded asphalt mixture slabs, dense-graded rubberized asphalt mixture and rubberized open-graded friction course were molded with a strong compressing energy, according to the French standard AFNOR NF P-98-250-2 (1991) [11].

For the rubberized porous coat, the energy of compression was varied with the aim of shaping slabs with different void volumes. Six slabs were molded with void percentages between 22% and 28% for two maximum sizes of aggregates: 3 slabs for maximum aggregate size of 12.5 mm and 3 slabs for maximum aggregate size of 9.5 mm.

The void volumes were determined for all specimens extracted from the slabs and the interconnected voids were also determined for the porous specimens (rubberized porous coat and rubberized open-graded friction course).

2.4. Determination of the interconnected void volume

For determining of interconnected voids, the amount of water entering the specimen at its surface is measured, while the side walls and the bottom are sealed with waterproof tape and paraffin. A constant water film is kept at the surface for 10 min [12]. The test is conducted using standard AFNOR NF P 98-254-2, 1993.

The percentage of interconnected voids is obtained from equation (1) and the reduced height of the specimen from Eq. (2) [8].

$$V = \left(\frac{P_{ab}}{A_f \times h_{redu}}\right) \times 100 \tag{1}$$

$$h_{red} = h_m - \left(\frac{D_{máx}}{20}\right) \tag{2}$$