International Journal of Sustainable Built Environment (2016) 5, 183–196

HOSTED BY
ELSEVIER

Gulf Organisation for Research and Development

International Journal of Sustainable Built Environment

ScienceDirect
www.sciencedirect.com

CrossMark

Original Article/Research

Effects of double layer porous asphalt pavement of urban streets on noise reduction

Mei Liu [a,*], Xiaoming Huang [b], Guoqiang Xue [b]

[a] *China Institute of FTZ Supply Chain, Shanghai Maritime University, Shanghai 201306, China*
[b] *School of Transportation, Southeast University, Nanjing 210096 China*

Received 6 June 2014; accepted 12 February 2016

Abstract

Road traffic is the major noise source that impacts the largest numbers of city dwellers. Urban traffic noise control at the source typically involves providing quieter i.e. low noise pavement and regular maintenance. The aim of this paper is to propose a double-layer porous asphalt pavement for keeping the traffic noise at a low level with good durability. It contains the top layer of fine aggregates and bottom layer of course aggregates. The noise-absorption performance of this asphalt pavement is evaluated by adjusting the parameters of the pavement structure simulated in air–solid coupled numerical models. The reduction of noise by using the newly proposed asphalt pavement is compared with those of the traditional pavements such as the thin surfacing (TSF) with small aggregates and rubberized asphalt pavement (RAP). The results from the outdoor noise tests for the double-layer porous asphalt pavement verifies the virtual pavement models and noise reduction effects in practice. This asphalt pavement is designated to lower the noise level of urban road traffic and boost the living environments of the city dwellers.

Keywords: Low noise; Asphalt pavement; Double-layer; Porous

1. Introduction

As the city populations have grown in recent decades, so have the volumes of traffic on the streets and the noise levels the traffic generates. Noise is often defined as 'unwanted sound' and widely recognised as a form of environmental pollution (Federal Aviation Administration, 2004; Wakefield Acoustics, 2005). It could interfere with activities like speech and sleep and cause annoyance and fear. Therefore guidelines for acceptable levels of urban noise, especially traffic noise as its major source (Wang, 2007) have been established in many countries (Zhang and Wang, 1996; Berglund et al., 1999; Wakefield Acoustics, 2005; Environment Protection Authority (EPA), 2008). For example the widely referenced 24-h average noise level of 55 dB ($L_{\mathrm{Aeq,24h}} = 55$ dB) was established for urban street traffic noise by the Canada Mortgage and Housing Corporation (CMHC, 1986). The maximal levels of acceptable noise for different activities were respectively regulated in World Health Organisation (WHO, 2009).

---

* Corresponding author.
E-mail addresses: miduza1985@gmail.com, meiliu@shmtu.edu.cn (M. Liu), huangxm@seu.edu.cn (X. Huang), xxyyjsjt@yahoo.com.cn (G. Xue).
Peer review under responsibility of The Gulf Organisation for Research and Development.

http://dx.doi.org/10.1016/j.ijsbe.2016.02.001
2212-6090/

WHO argued that for a good night sleep the sound level should not exceed 30 dB for continuous background noise and individual noise events exceeding 45 dB should be avoided. In Environment Protection Authority (EPA, 2008) the noise levels for different types of activities in urban areas such as construction, road repair and maintenance, domestic refuse collections, aircrafts and helicopters were managed on varied periods of time on weekdays and weekends.

Methods to control traffic noise at low levels are generally from three aspects: at the source, along the sound path and at the receiver. Noise control at the source typically involves providing inherently quieter i.e. low noise pavements and vehicle tiers for less noise generation. Once the noise has been created and escaped from the source ways to prevent it from reaching the receivers may include noise barriers such as screens, solid fences, non-sensitive buildings and rows of trees. Noise control at the receiver may involve the upgrading of windows, doors and walls.

It is not surprising that low noise pavements have been receiving growing interests as the very effective way of noise reduction. Existing low noise pavements typically include (1) porous asphalt pavements such as the Open-Graded Friction Course (OGFC) developed in the USA (Leasure and Bender, 1975; Zhu, 2003; Putman, 2012) and used across European countries (Federal Highway Administration, 2005; Morgan, 2006). Porous asphalt pavements were initially designed to provide drainage and reduce surface water and spray during heavy rainfall. It was found out that these pavements also have acoustic benefits (Shen, 1994; Lin, 1992; Ministry of Transport, 2012). These asphalt mixture contains a small amount of aggregates entailing pavements with relatively large air voids. These connected air voids absorb a large amount of noise generated by the interaction between the vehicle tires and pavements. (2) Very thin small aggregates asphalt pavements: Most of the pavements are produced by hot-mix materials being laid to a thickness of between 20 and 40 mm. Products of asphalt mixture such as SMA10 (Stone Mastic Asphalt), SMA5 and Ultra-Thin Asphalt (APRG, 1999) have been developed to provide sustainable, quiet and durable pavements. The air voids of the asphalt mixture are large thus the traffic noise is absorbed during its downward transmission. The rough surface of thin layer pavements also repeatedly reflects the noise and at the same time absorbs the vibration energy due to its small aggregates and consequently deep texture depth. (3) rubberised asphalt pavements: Asphalt mixture used in these pavements contains reclaim crumb rubber (10–20%) to improve the elasticity of asphalt mastic. The toughness and durability of the pavement is enhanced in the way that the cracks and rutting are reduced markedly (Piggott and Woodhams, 1979). The deformation of pavements under the vehicle wheels dissipates the sound energy. The viscous–elasticity of rubber ensures conservation and absorption of the noise due to the complex deformation of its molecule chains. Traffic noise on the rubberised pavements can be significantly reduced (Cao and Ren, 2007). The used rubber tires as the material source of rubber are recycled (Piggott and Woodhams, 1979).

The effects of low noise pavements described earlier have been measured and compared in several studies (Shen, 1994; Lin, 1992; Morgan, 2006). In these studies the range of noise levels encountered from different types of vehicle traveling on different types of pavements with various ranges of speeds has been illustrated. It has been concluded that average noise levels at thin surfacing tend to be 3 dB lower for cars and 1 dB for heavy vehicles than at asphalt concrete. Porous pavements provide average noise reductions of 3–4 dB (Anderson et al., 2005). Analysis has shown that the use of rubberised asphalt pavements can reduce average noise level of 4 dB on the investigated road sections (1999). The performances of noise reduction would be deteriorated along with the ageing of the pavements especially the porous ones. Thin surfacing and rubberised asphalt pavements have a long durability however the effects of noise reduction are less significant than porous asphalt pavements.

In this paper a double layer porous asphalt pavement is proposed for sustainable noise reduction with a long service life. The top layer of the pavement contains fine aggregates while the below layer contains course ones with larger air void ratios. The top later is designed to avoid clogging and pavement material loosing and lost. The air voids in the two layers are connected to ensure the drainage of rain water for avoiding spray and splash. The air voids also acting as the mitigation tubes of air flow pressed by the rolling tires can reflect and absorb the noise energy. This pavement incorporates the benefits of single layer porous asphalt pavements and thin surfacing pavements as will be illustrated in the following sections.

In Section 2 the mechanism of noise reduction of porous asphalt pavement is illustrated. The numerical model of the double layer porous pavement is established in Section 3 with appropriate structure parameters. In Section 4 specimens of double layer porous pavements, thin layer pavements and rubberised asphalt pavements are produced for indoor noise measurement tests. Outdoor tests are also introduced in this section.

2. Mechanism of noise reduction of porous asphalt pavements

Porous asphalt pavement as one of the major low noise pavement has a relatively high air void ratio between 15% and 20%. These air voids are distributed within the asphalt mix being connected with each other and the outside air. When the sound wave reaches the pavement, part of it is reflected back from the surfaces and another part is transmitted through the interior structure of the pavement. During the transmission the air in the voids is vibrated. The generated sound energy is transmitted into heat energy due to the friction at the solid walls of voids. The reflected sound wave may be transmitted into the surface again when it reaches the surface the second time or for more