Technical Note

ISSN 1997-1400 Int. J. Pavement Res. Technol. 8(1):58-61

Noise Abatement of Rubberized Hot Mix Asphalt: A Brief Review

Fariborz M Tehrani [1+]

Abstract: Rubberized hot mix asphalt (RHMA) is widely used in pavement projects. Substitution of natural aggregates with recycled rubber has been considered a key advantage of this material. Further, the material characteristics of the rubber are expected to improve the performance of pavement. Noise abatement, as a performance measure in most pavement projects, is reviewed in this paper. The presented review discussed literatures on the effect of RHMA on noise abatement in comparison with conventional hot mix asphalt (HMA). Moreover, the field performance of selected pavement projects is presented. Results indicate that the inclusion of recycled rubber has positive impacts on the environment as well as the pavement properties. However, the noise abatement is not a long lasting effect of RHMA. Further, the frequency content of the noise on RHMA surface is as important as the intensity of the noise. Thus, application of RHMA may not fully replace other means of noise management in roadway projects.

DOI: 10.6135/ijprt.org.tw/2015.8(1).58

***Key words**: Noise abatement; Rubberized hot mix asphalt; Sound mitigation; Traffic noise.*

Introduction

Sound mitigation is an important objective in highway design considering environmental impacts. The road traffic noise is reported as the major source of nuisance. There are several strategies to reduce the sound generated at roads. These strategies tend to reduce pressure, duration, loudness, roughness, or sharpness of the sound. The effectiveness of these strategies is linked to the human perception of unpleasant sounds, also known as noise. Further, the interaction of sound characteristics can contribute to the perception of the noise as a pollutant. For instance, duration of the sound impacts human tolerance for the loudness of the sound. Thus, noise mitigation policies and strategies may focus on various elements, such as pavements and surfacing, zoning and planning, sound insulation, or traffic management [11-4].

The noise mitigation plans should be appropriated to the source of the noise. The noise associated with road traffic has multiple sources. This review focuses on the noise generated by the tire-road interaction. Other potential sources of the noise are engine, exhaust, and the aerodynamic interaction between the vehicle and the air. For light vehicles such as automobiles, the interaction between tire and pavement is the main source of traffic noise, which is generated at the pavement surface. However, for trucks, the vehicle engine and exhaust makes larger contribution, where the source of noise is located well above the pavement surface. In addition, the interaction between tire and roadway can contribute to two categories of noise: air-borne and structure borne. The structure borne noise is an outcome of the mechanical actions and interaction between the rubber and pavement, and involves normal pressure and friction between these surfaces. The air borne noise is generated and impacted by the air flow through tire treads. Thus, the interaction between tire and pavement can manifest itself in both mechanisms. Federal highway Administration and International Standard Office have proposed standards on tire-road noise, and models to measure and predict the reduction of noise considering various parameters, including AASHTO TP 99, AASHTO TP 76, FHWA 108 Model, FHWA TNM, and ISO 13325 [1, 5-11].

The surface texture of pavement material is a key parameter in noise control, which requires careful consideration during design, construction, and maintenance. The smoothness of surface is an advantage for noise control, but, it is also a concern for skid resistance. Thus, achieving and maintaining an optimum balance is necessary during the life time of the pavement. Further, the texture is a function of material type and mix design, as well as placement and finishing procedure. In addition, the mix design is also linked to other pavement characteristics, like thickness of the pavement, air-void content, binder, and permeability, which have direct or indirect potentials to alter the noise level. Environmental and traffic conditions also interact with pavement properties and affect the generated noise. Thus, a balanced design and selection of the pavement material, say rigid concrete or flexible asphalt, requires full consideration of these parameters, with priorities given to safety and durability. Further, development of noise reduction strategies is also a function of above-mentioned characteristics. For instance, the noise from rigid concrete pavements, also known as Portland cement concrete (PCC) pavements, can be reduced by grinding and avoiding transverse tining; while the noise reduction strategy for flexible pavements, such as hot mix asphalt (HMA), tends to rely on adding voids to the mix design and using smaller rock size [3, 12-16].

Rubber crumbs obtained from recycled tires (also known as tire-derived aggregates) have been used in asphalt-based pavements for nearly half a century. Reclaiming tires helps to reduce solid waste, which is a nuisance for environment. Generally, a blend of asphalt, cement, additives, and reclaimed tire rubber with 15% rubber content by weight is considered rubberized hot mix asphalt (RHMA), also known as rubberized asphalt concrete. Rubber crumb can replace natural aggregates in the mix. Thus, the aggregate is gap-graded to accommodate the required space for rubber crumb in the compacted mix. Reduction of natural aggregate by itself is in

[1] Department of Civil and Geomatics Engineering, California State University, Fresno, CA, 93740, USA.

[+] Corresponding Author: E-mail ftehrani@csufresno.edu

Note: Submitted July 12, 2014; Revised October 26, 2014; Accepted November 14, 2014.

line with sustainable practices to preserve natural resources. So, the synergy of using solid waste instead of natural resources is very appealing for sustainable development [17- 20].

Presence of rubber can improve properties of hot mix asphalt as pavement material. Key factors in pavement management include structural performance, durability, and environmental effects. The structural performance of the pavement, in terms of material behavior and crack control, is an essential design objective. Higher performance allows designers to reduce the thickness of the section. In this arena, many studies have found RHMA to perform better than conventional materials due to presence of flexible rubber crump. Further, better crack resistance increases the life of the pavement. High cost of maintenance, which often includes expensive traffic control measures and substantial impacts on economy, requires designers to consider durable pavement sections. Thus, based on these characteristics, the RHMA pavement sections are expected to last longer than conventional sections with less maintenance efforts [17-20].

Noise abatement is another desired environmental impact of pavement sections, in addition to preservation of natural resources and reduction of environmental pollutants. Various studies have shown that application of RHMA reduces the noise loudness by 40 to 88% for both open-graded and gap-graded mixtures in comparison with conventional pavement materials, e.g. hot mix asphalt. However, long-term impact of RHMA on noise abatement is yet to be fully understood [5]. Further, the noise level measurements show up to 1.5 dB variation which would make it more challenging for researchers to provide recommendations [3]. Nevertheless, a 3-dB reduction in noise, which might not be even perceptible by human ears, equates 50% reduction in noise loudness. Alternative strategies to obtain such reduction may include 50% reduction in traffic volume, 25% reduction in speed, building a 6-ft high sound wall, or widening the right-of-way limits of the road to double the distance between the roadway and residences near the road [1, 18, and 21]. Regardless, the residents' experience in close proximity of roadways should be considered as the main performance measure of these strategies [22, 23].

Review of Experimental and Analytical Studies

Experimental studies on pavement materials often rely on field measurements. The long life of pavement infrastructures requires researchers to consider long-term performance of studied sections in these studies. Further, recent advances in computational engineering have facilitated analytical approaches to pavement analysis, such as finite element and boundary element methods, which typically require intensive numerical simulations.

Multiple studies have indicated the advantage of rubberized asphalt over non-rubberized asphalt in noise abatement. A six-year study by Bollard & Brennan Inc. [5] showed that rubberized asphalt reduces the traffic noise level by 4 dB more than conventional non-rubberized asphalt. Researchers were able to verify this difference up to six years after placement of the material, even though, the noise abatement declined with age for both materials [5]. Similarly, Bucka [24] concluded from a ten-year study that rubberized overlays reduce the noise by 3 to 7 dB, where conventional asphalt would reduce the noise by 1 to 2 dB only. But, the noise abatement after ten years was measured to be between 0 to 3 dB only. Thus, the difference between rubberized and non-rubberized overlays diminishes with time [24]. A more recent study by Ongel et al. [25], obtained field measurements from 23 test sections in multiple locations across California, verified that rubberized mixes had lower sound intensity level. Results also revealed a potential correlation between the noise level and the thickness of the section, as well as the air-void content of the mix [25]. This observation provides an insight for pavement designers, who generally aim to reduce the thickness of overlay using high performance materials, such as rubberized mixes. The effect of thickness on noise abatement was analytically confirmed by Wang and Zeng [26]. These researchers provided a finite-element based model to evaluate the vibration attenuation of various materials, including rubberized asphalt. Although the objective of this study was beyond the scope of the rubberized asphalt application on highways, the conclusions were notable. In this study, authors reported that although increasing the thickness of materials improves the noise reduction; the magnitude of such improvement is not noticeable for 0.15-m (6-in) or thicker layers [26].

Further, the results of the study by Bollard & Brennan Inc. [5] showed that rubberized asphalt reduces the noise energy by 60%, which implies a high damping ratio in this material [5]. Biligiri [27] confirmed that rubberized mixes contribute to higher damping ratios that would decay the tire-road noise.

Presence of rubber can also alter the noise frequencies to lower frequencies, where human ears feel less discomfort. Particularly, Bollard & Brennan Inc. [5] reported that most noise reduction in rubberized asphalt sections falls within 500 to 4,000 Hz, which is consistent with the natural frequency of tire noise [5]. McNerney et al. [28] reported a more detailed result on the frequency range, and showed that rubberized asphalt sections are more effective in reducing noise with frequencies higher than 1600 Hz [23, 28].

Field studies have also included the effect of traffic speed on noise abatement. Bucka [24] reported higher noise abatement for faster traffic flow. This was confirmed by Bennert et al. [29] in a study on 42 pavement surfaces in New Jersey. Researchers studied generation of tire/pavement noise and the effect of vehicle speed on such noise. Results show that noise generally increases linearly with the speed at a rate of 0.2 to 0.3 dB for each mph. The sensitivity of noise level to speed for asphalt pavements found to be less than concrete pavements [29]. Regardless, these results can hint toward application of RHMA for noise mitigation in expressways and freeways versus local streets.

Results and Discussions

Rubberized hot mix asphalt primarily improves certain characteristics of pavement materials, including structural performance and durability. Designers tend to rely on these improved properties to specify thinner surface overlay with longer life. Therefore, rubberized asphalt properties need to remain stable and effective at such reduced thickness or extended lifetime of resulted pavements.

Noise abatement is an environmental benefit of RHMA pavements, where using RHMA reduces the level of noise generated at tire/pavement interface. Tire-pavement interaction makes the largest portion of the noise generated by automobiles at the surface of the road. RHMA is less effective on reducing the noise generated by medium and large trucks, which their engines and exhausts are responsible for larger portion of the traffic noise.

On the average, RHMA reduces the noise by nearly 2 to 3 dB more than conventional hot mix asphalt (HMA) and 4.5 to 6 dB more than Portland cement concrete (PCC). Open graded asphalt reduces the noise up to 1.5 to 3 dB more than dense graded and gap graded asphalts due to higher void ratio.

The effect of RHMA on noise abatement decreases through the life of the pavement. Long term studies have shown that RHMA might still be effective on noise reduction after six to ten years. At the same time, HMA overlay might reduce the noise for up to 4 years only. Open-graded friction course (OGFC) has shorter effective life span for noise reduction than dense-graded hot mix asphalt.

Application of rubber tends to shift the frequency of noise to lower frequencies, which is basically closer to natural frequency of tire noise. In the other word, rubber does not resonate at high-frequency, and therefore, does not amplify the high frequency content of the sound. Therefore, resulted noise would be more tolerable and less uncomfortable for human ears. The frequency content might also shift back to higher frequencies as RHMA becomes more compact and rubber becomes stiffer through aging.

Application of RHMA might not eliminate the need of other sound mitigation strategies, e.g. sound walls, where noise level is higher than acceptable levels, e.g. 67 dB at residential areas.

The reported variation of measured noise level for a single pavement is nearly 1.5 dB, depending on the measurement technique. Regardless, a 3-dB difference in noise level is barely perceptible by human ears. Therefore, making conclusions on RHMA effect on noise abatement is challenging. Testing methods, prediction models, and long-term experimental results are current challenges in evaluating the impact of RHMA on noise reduction.

Summary

Adding rubber to hot mix asphalt improves noise abatement characteristic of the resulted material. RHMA reduces the noise generated at tire-pavement interface, and therefore, application of RHMA is more effective where the noise from other sources is not substantial, such as the case when the traffic consists of light vehicles with low engine or exhaust noise. Rubber would also filter high frequency contents out and absorbs portion of the energy of the generated sound. Noise abatement of RHMA becomes less effective through aging, when surfacing materials loose are compacted and rubber loose the original flexibility. The smaller thickness and denser grading of material would also reduce the efficiency of RHMA in noise reduction. Using RHMA might not address all requirements of the sound mitigation during the lifetime of the pavement and other strategies need to be implemented. Further studies on testing techniques, prediction models, and long-term behavior of RHMA are the main subjects of current researches on the effect of RHMA on noise abatement.

References

1. Freitas, E., Mendonca, C., Santos, J.A., Murteira, C., and Ferreira, J.P. (2012). Traffic Noise Abatement: How Different Pavements, Vehicle Speeds, and Traffic Densities Affect Annoyance Levels. *Transportation Research Part D: Transport and Environment*, 17(4), pp. 321-326.
2. Descornet, G., and Goubert, L. (2006). Noise Classification of Road Pavements. European Commission Directorate-General Environment, Brussels, Belgium.
3. California Department of Transportation (2005). Designing Quieter Pavement, Pavement Advisory PSTPA-02, California, USA.
4. Lara Saenz, A., Stephens, R.W.B. (1986). *Noise Pollution*. International Council of Scientific Unions, Scientific Committee on Problems of the Environment (SCOPE), John Wiley and Sons, Chichester, West Sussex, England.
5. Bollard & Brennan Inc. (1999). Report on the Status of Rubberized Asphalt Traffic Noise Reduction in Sacramento County, Sacramento County Department of Environmental Review and Assessment, California, USA.
6. AASHTO (2011). *Standard Method of Test for Measurement of Tire/Pavement Noise Using On-Board Sound Intensity (OBSI) Method*, AASHTO Specification TP 76-11, American Association of State highway and Transportation Officials (AASHTO), Washington, DC, USA.
7. AASHTO (2011). *Standard Method of Test for Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)*, AASHTO Specification TP 99-11, American Association of State Highway and Transportation Officials (AASHTO), Washington, DC, USA.
8. Menge, C.W., Rossano, C.F., Anderson, G.S., and Bajdek, C.J. (1998). FHWA Traffic Noise Model (TNM) Technical Manual. Report No. *FHWA-PD-96-010*. U.S. Department of Transportation, Cambridge, MA, USA.
9. Rochat, J.L., Hastings, A.L., Read, D.R., and Lau M. (2012). FHWA Traffic Noise Model (TNM) Pavement Effects Implementation Study. Report No. *DOT-VNTSC-FHWA-12-01*. U.S. Department of Transportation, Cambridge, MA, USA.
10. ISO 13325 (2008). *Tyres – Coast-by Methods for Measurement of Tyre-To-Road Sound Emission*. International Organization for Standardization (ISO), Geneva, Switzerland.
11. Sandberg, U., and Ejsmont, J. (2002). Tire/Road Noise Sources and Generation Mechanisms, in *Tire/Road Noise Reference Book.* Edited by J. Ejsmont and U. Sandberg, Informex, Kisa, Sweden.
12. Ahammed, M.A. and Tighe, S.L. (2010). Pavement Surface Friction and Noise: Integration into the Pavement Management System. *Canadian Journal of Civil Engineering*, 37(10), pp. 1331-1340.
13. Bennert, T., Hanson, D., and Maher, A. (2004). Demonstration Project – The Measurement of Pavement Noise on New Jersey Pavements Using the NCAT Noise Trailer. Report No. *FHWA-NJ-2203-021*. New Jersey Department of Transportation, NJ, USA.
14. Liao, G. Sakhaeifar, M. S., Heitzman, M., West, R., Waller, B., Wang S., and Ding, Y. (2014). The Effects of Pavement Surface Characteristics on Tire/Pavement Noise. *Applied*

Acoustics, 76, pp. 14-23.
15. Sandberg, U. (1992). Low Noise Road Surfaces: A State-of-the-Art Review. *Eurosymposium The Mitigation of Traffic Noise in Urban Areas*. Swedish Road and Transport Research Institute, Linkoping, Sweden.
16. Hibbs, B.O., and Larson, R.M. (1996). Tire Pavement Noise and Safety Performance. Report No. *FHWA-SA-96-068.* Federal Highway Administration, Washington, DC, USA.
17. Donovan, P.R. (2006). Comparative Measurements of Tire/Pavement Noise in Europe and the United States. A summary of the NITE Study. California Department of Transportation, California, USA.
18. Catalina Engineering Inc. (2001). Rubberized Asphalt Concrete: State of the Practice, Pima County Department of Transportation, Tucson, Arizona, USA.
19. Amirkhanian, S.N. (2001). Utilization of Crumb Rubber in Asphaltic Concrete Mixtures – South Carolina's Experience, *Recycling and reuse of used tyres: Proceedings of an International Symposium*, London, UK, pp. 163-174.
20. Jorgenson, L. (2003). Tires Make the Road - Asphalt Rubber Pavement Construction. *Public Works*, 134 (1), pp. 30-31.
21. Neivelt, G., Stehno, G., Stickler, H., and Ertl J. (n.d.). Noise Level Reduction through Silent Asphalt, CT-Bitumentgesellschaft m.b.H., Vienna, Austria.
22. Hall, D. (2009). North: City To Lay Rubberized Asphalt on Arterial Roads, *Orange County's News Source*, California, USA.
23. Reiter, D., Bowlby, W., Herman, L., and Boyer, J. (2004). Traffic Noise in Montana: Community Awareness and Recommendations for a Rural State, Montana Department of Transportation, Montana, USA.
24. Bucka, M. (2002). Asphalt Rubber Noise Study Update, Acoustical Analysis Associates, Inc. Report 1272. California, USA.
25. Ongel, A., Kohler, E., Lu, Q., and Harvey, J. (2008). Comparison of Surface Characteristics and Pavement/Tire Noise of Various Thin Asphalt Overlays. *Road Materials and Pavement Design*, 9(2), pp. 333-344.
26. Wang, J. and Zeng, X. (2004). Numerical Simulations of Vibration Attenuation of High-Speed Train Foundations with Varied Trackbed Underlayment Materials, *Journal of Vibration and Control*, 10, pp. 1123-1136.
27. Biligiri, K.P. (2013). Effect of Pavement Materials' Damping Properties on Tyre/Road Noise Characteristics. *Construction and Building Materials*, 49, pp. 223-232.
28. McNerney, M.T., Landsberger, B.J., Tracy T., and Pandelides, A. (2000). Comparative Field Measurement of Tire/Pavement Noise of Selected Texas Pavements, *Transportation Research Record*, 1626(1), pp. 78-84.
29. Bennert, T., Hanson, D., Maher, A., and Vitillo, N. (2005). Influence of Pavement Surface Type on Tire/Pavement Generated Noise, *Journal of Testing and Evaluation*, 33(2), pp. 1-7.