Effect of Pavement Surface Aging on Tire-Pavement Noise: A Case Study in the State of Qatar

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Abstract. The acoustical performance of asphalt pavements changes with time due to combined effects of environmental conditions and various distresses induced by repeated and heavy traffic. This study examined the changes in the acoustical performance of dense graded asphalt (DGA) pavements over time in the State of Qatar. Tire-pavement noise was measured using on board sound intensity (OBSI) method. The OBSI noise measurements were conducted on DGA pavements with different age and the results were analyzed to evaluate the effect of aging on tire-pavement noise. The results demonstrated that the tire-pavement noise increased with pavement age. The frequency analysis of three road segments showed that at early stage of pavement service life, the noise level is more affected at higher frequency due to the densification and increased air pumping mechanism. At later stage of pavement service life, the noise level is more affected at lower frequency due to the change in pavement surface conditions (e.g., cracking and raveling).

1 Background

The age of asphalt pavements has a significant influence on the level of tire-pavement noise. It is well documented in the literature that pavement noise increases with time [1-6]. Changes of acoustical performance of pavement with time occur due to combination of two factors i.e., i) physical and chemical changes of pavement due to environmental conditions, and ii) wear and tear caused due to moving traffic [1, 4]. For the first few years of pavement service life and before appearing of any visible distresses, mechanism of increasing noise is complex. For porous pavements with air void more than 15%, the increasing of noise is due to clogging of air voids which increases the air pumping mechanism [1, 4]. However, for dense graded or open graded asphalt pavements, increasing of noise is due to either further densification under repeated and heavy traffic or due to polishing effect of aggregate surface texture [4]. At later stage of pavement service life, tire-pavement noise increases due to presence of cracks or raveling of aggregates in pavement as pavement condition deteriorates due to repeated and heavy traffic with aging.

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Although, a number of research studies have evaluated the effect of pavement age on tire-pavement noise, little work has been conducted on this subjected in the gulf region where pavement surface is subjected to elevated temperature (i.e., the pavement surface temperature can reach up to 60°C). This elevated ambient temperature accelerates the aging of asphalt mixtures due to binder oxidation, leading to fatigue cracking and eventually pavement failure with heavy and repeated traffic loading. Therefore, this study was initiated to evaluate the effect of pavement age on the acoustic performance of in-service pavements in the State of Qatar. This study will be particularly important for the transportation authorities in this region to device sustainable policies and strategies for noise abatement. In addition, it will assist pavement engineers in this region to predict pavement noise with the use of traffic noise model (TNM) at various stages of pavement service life with good accuracy.

2 Experimental program

2.1 Noise assessment method

In this study, tire-pavement noise was measured by using onboard sound intensity (OBSI) method in accordance with AASHTO TP 360-16 [7] standard. The OBSI method for noise measurement was selected because it allows pavement engineers to investigate and compare tire-pavement noise in great details. In addition, the OBSI method provides a direct measure of sound intensity in close proximity to the tire-pavement interface and allows various influencing factors affecting pavement noise to be directly compared [8, 9]. The OBSI method consists of measuring the sound intensity at or near the tire-pavement interface. This method consists of placing sound intensity probes 4 inches (101.6 mm) from the center of the tire and 3 inches (76.2 mm) above the surface of the pavement. The microphones were mounted on a testing rig supplied by AVEC Inc. which is made of aluminum and stainless steel. Figure 1 shows the mounting of the microphones on the testing rig. Meteorological data (air temperature, barometric pressure, humidity, wind speed and direction) was also collected during noise testing as it has considerable influence on the noise measurement. Details of OBSI system and other equipment used for this study can be found in Ohiduzzaman et al. [10]. Although, the recommend speed limit for OBSI testing by AASHTO TP360-16 [7] standard is 97.6 Km/hr (60 mph), in this study, OBSI tests were conducted at 80 Km/hr (50 mph) as it was the maximum posted speed limit of the road at the time of testing.

Fig. 1. OBSI testing set up; a) Side view without windscreen, b) Front view with windscreen

OBSI tests were conducted on the link road between Doha Expressway and Al Khor on May 1, 2017 to assess the noise intensity of the pavement. This link road is a very old road (more than 10 years old). However, two segments of this road were reconstructed in July 2010 and June 2016. Figure 2 shows the location of three portions of the link road. At first, the researchers identified three segments with different age. The OBSI testing was performed on various sections of the three segments of the link road to evaluate the effect of pavement age on noise intensity. The pavement construction data showed that the segments constructed in 2016 and 2010 are dense graded asphalt (DGA) pavements with similar asphalt mixture type. The nominal maximum aggregate size (NMAS) of 14 mm was used while producing asphalt mixtures for two road segments. It was not possible to acquire the pavement data for the old segment of the link road. However, examining the surface very closely, it was identified as DGA surface as is the case for most of the pavement surfaces in the State of Qatar. Figure 3 shows the photographic view of the three different pavement surfaces. All the OBSI tests were conducted at similar environmental conditions to avoid any discrepancy due to changing testing conditions.

Fig. 2. Location of sections showing on the map for the link road of Doha expressway and Al Khor

c)

Fig. 3. Typical dense graded asphalt surfaces; a) constructed in June 2016, b) constructed in July 2010 and c) very old pavement

3 Data collection

The OBSI noise measurements were collected on multiple sections along the test road segments. At first, OBSI tests were conducted on 10 sections of newly constructed segment of the road (constructed in 2016) as the length of this segment is about 7 km. However, noise testing was performed only on 4 sections for other two segments of roads (constructed in 2010 and very old) since the length of these two segments were relatively short (2.5 km each). These sections were located in both traffic directions of pavement and selected according to AASHTO TP 360-162 [7] guidelines. Multiple test sections were tested because of slight variability over distance of asphalt pavement even for single pavement type. Figure 4 shows the measured A-weighted sound intensity level of tested sections of pavement constructed in July 2016 for both traffic directions. The noise intensity level of a test section is determined by performing at least three valid runs according to AASHTO TP 360-16 [7] guidelines and average of those intensity values is the noise intensity level of that section. It can be observed from Figure 4 that variability of noise intensity level among sections either east or west bound traffic is small. Therefore, the noise intensity level of all tested sections of east/west bound traffic for a portion of the link road was averaged. This average value represents the noise level of that segment of the link road. It is also noticeable from Figure 4 that in general the sound intensity level for east bound traffic sections is slightly higher in comparison with west bound traffic section. Further examination of these east bound sections showed that there was presence of dirt in these sections due to entering of construction trucks with dirt attached to its tire from the nearby construction site.

Fig. 4. Measured sound intensity levels for pavement sections constructed in 2016

4 Analysis and interpretation of test results

The overall average A-weighted sound intensity levels for both east and west bound traffic directions for the three road segments using the standard reference test tire (SRTT) [11] are shown in Figure 5. For both east and west bound test sections, there was a clear trend showing increasing of noise over time. The increase of noise intensity was almost 1.5 dBA when comparing pavement sections constructed in 2016 and 2010, whereas almost 3dBA increase of noise intensity was observed while comparing pavement constructed in 2016 and the old road segment. These results demonstrated that the acoustical performance of asphalt pavement deteriorated with time. This is one of the Federal Highway Administration’s (FHWA) [12] concerns to accept pavement surface as noise abatement procedure. Therefore, it needs to be considered while selecting pavement surface as a noise abatement procedure.

To identify the mechanism that affects the acoustical behavior over time, the frequency response of test segments was compared and shown in Figure 6. The changes in acoustical performance with time in one-third octave band are slightly more complex in comparison to overall A-weighted sound intensity level as shown in Figure 5. At lower frequency (i.e., below 800 Hz), the results indicate that there is significant difference between the old and new pavements while little change observed between pavement sections constructed in 2016 and 2010. However, in the frequency range between 800 Hz to 3150 Hz, the sound intensity levels increased somewhat uniformly with pavement age. This may be related to the decreasing air void content due to densification of pavement under heavy traffic which increases air pumping mechanism. The noise intensity of the old pavement is lying well above compared to the other two pavements surface at all frequency range. At a lower frequency below 1000 Hz, the increase of noise intensity for old pavement was more prominent. This indicates some changes in surface texture of pavement due to wear and tear caused by moving traffic. Examination of photograph [see Figure 3(c) compared to Figures 3(a) and 3(b)] reveals the presence of fatigue cracking as well as raveling of aggregates in the old pavement segment.

Fig. 5. Average sound intensity levels for three different aged pavements

Fig. 6. Frequency responses of three different aged pavement surfaces

5 Summary

This paper investigated the changes of acoustical performances of DGA pavement over time in the State of Qatar by using the OBSI method. Three similar DGA pavements with different age were selected to evaluate the effect of pavement age on tire-pavement noise. The following conclusions can be made based on the experimental results obtained from this study:

- The acoustical performance of DGA pavement deteriorates with pavement age. Therefore, this deterioration of acoustical performance should be considered for selecting ‘quieter pavements’ in order to devise sustainable policies for noise abatement.
- One-third frequency analysis showed that when there are no visible distresses on the pavement, noise increasing with pavement age due to increase of high frequency noise (frequency in between 800 Hz to 3150 Hz) which resulted due to further densification of pavement materials under heavy and repeated traffic.
- In the presence of distresses such as fatigue cracking or raveling, increase of noise with aging is mainly contributed by low frequency noise (noise below 1000 Hz) due to changes in surface texture of pavements.

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