Study the Effect of Parameters on Tire-Pavement Interaction Noise (TPIN)

Ammar A. M. Shubber[1, a*], Rasha H. A. Al-Rubaee[1, b] and Mustafa Hadi Taher[2, c]

[1]Civil Engineering Department, University of Technology, Baghdad, Iraq.

[2]Engineer in the Mayoralty of Baghdad, Baghdad, Iraq.

[a]40162@uotechnology.edu.iq, [b]40323@uotechnology.edu.iq and [c]m_almusuy@yahoo.com

*Corresponding author

Abstract. The present study was prepared to determine the effect of different parameters on tire-pavement Interaction noise (TPIN). TPIN was calculated utilizing the Onboard Sound Intensity Method (OBSI) using apparatus Lutron 801 sound level meter single probe 1 kHz of one microphone is placed at the right back test tire with a specific distance. A total of 30 sections were selected for the main roads in Baghdad city, with 134 meters for each test section in length. TPIN data was calculated for various parameters such as different pavement types, various test vehicles, different speeds (40, 56, and 72) km/h, various types of tires, different pavement aging, and different mean texture depth (MTD) values Which is measured by a sand patch test. The sound intensity dBA increases when MTD value and vehicle speed increase in both types of pavements. On the other hand, the sound intensity dBA increases when age increases for asphalt pavement type while it decreases in asphalt concrete pavement type. In addition, the sound intensity dBA in the asphalt pavement type is lower than in the asphalt concrete pavement when compared to the condition of the new pavement. The opposite is in the case of old pavement surfaces. As well as, the sound intensity dBA in Bus is greater than in the passenger car, and the silver stone tire is lower than the Dunlop tire in the passenger car. Finally, it is concluded that TPIN may be reduced or increased due to the effect of different parameters.

Keywords: Tire-pavement interaction noise; TPIN; onboard sound intensity; OBSI; parameters; sound intensity.

1. INTRODUCTION

Traffic noise pollution is a problem that has become widespread, particularly in urban areas .The areas near the highway where the population density is high for passengers as well as commercial traffic. Therefore, Recently, researchers have shown an increased interest in studying and reducing noise mechanisms [1]. Vehicle noise can be classified into aerodynamic noise, (power train) propulsion noise, and (TPIN) tire-pavement interaction noise . TPIN can be generated when Interaction occurs between the tire and pavement. In recent times, TPIN has been the most important source of vehicle noise due to the evolution in the vehicle's aerodynamic design has become less noise [2]. Recent evidence suggests that TPIN measuring is a highly complex process because of external influences. The OBSI method is the best method because researchers believe that the sound intensity mechanism is used to assess TPIN due to can restrict sound sources and refuse background noise [3]. Previous studies have reported that TPIN is clearly affected by several elements classified into five groups: tread pattern elements, tire-related elements, pavement-related, driver effect elements, and environmental standards[4].

Li [5] studied the effect of the vehicle's speed on the TPIN. There was a direct relationship between them.TPN increases due to the increase in the number of Interactions between tires and pavement per unit of time. Generally, TPIN increases by approximately three dBA for each (10 mph) increase for the pavement surface calculated [6]. Over time, pavement surface aging begins with a significant change in the surface layer due to friction. Therefore, it leads to an increase in the amount of TPIN due to the clogging of the air voids, and then the change begins to take a steady trend. Almost 0.5 dB is the amount of the increase in TPIN per year [7].

On the other hand, the effect of aging on cement concrete pavement principally longitudinally grooved pavements moderately and over time becomes quieter [8]. Saykin [9] Had done research linking the energy of sound produced by the tire-pavement Interaction to the mean texture depth (MTD) of the pavement surface it was illustrated that it is the potential to observe macrotexture through the use of the acoustic signal. A linear relationship between TPIN and air temperature differences is shown for bituminous pavements of about (0.1 to 0.06) dBA. On the other hand, no temperature influence is noticed on cement concrete pavements[10]. The comparison between rigid and flexible pavement requires several years to monitor, particularly since rigid pavements are predictable to provide considerably longer service life. In general, flexible pavements have proved quitter than rigid pavements with consideration to the pavement age [11].

Kumar [12] investigated an unambiguous relationship between TPIN and tire width. Generally, TPIN increased with the increase in width due to A wider tire, including increased air pumping and turbulence. However, TPIN decreased with an increase in overall tire diameter, having reverse effects on aerodynamic and mechanical noise generation techniques. Tire load can influence TPIN techniques. Increased load expands the interaction area between the surface texture and the tire tread, resulting in increased sidewall vibrations and air pumping. This will create noise. Typically, TPIN increases from (1 to 2) dBA. Inflation pressure could affect a similar technique as tire load.

Furthermore, Inflation pressure affects similarly on TPIN techniques as Tire load. Finally, the effect of the vehicle's load and inflation Pressure on the TPIN is insignificant [13]. A recent study by Sandberg and Ejsmont [14] involved Rubber hardness can be calculated by 40 Shore as specified by ISO 868, with Hardness ranging from (62 to74) according to ASTM D2240. TPIN increases between (1–2.5 dBA) per 10-unit upturn in Shore A40 hardness.

2. STUDY METHODOLOGY

In the present study the main objective of this study is to explore the influencing parameters on TPIN, which contain various parameters such as speed, aging, MTD, tire hardness, wheel load, inflation pressure, and pavement types. The methodology includes stages that are briefly described below: Site Selection, Data collection, Analysis of data, and Evaluation of tire pavement noise. Eleven roads were selection distributed of the main roads in Baghdad city. The roads are divided into four roads of asphalt concrete pavement and seven roads of asphalt pavement. A total of 30 sections were Divided evenly between the two previous types of pavements, with 134 meters in length. The sections test were prepared as described by [15] as follows: (A) Pavement Surface shall have the same surfacing and material and for its width and length of the sections tested. The test sections should be free of debris and dry. (B) Horizontal curves and steep downgrades should be avoided to reduce brakes use. (C) Wheel Path and location of the Reflective Surfaces should be documented in the sections tested.

3. DATA COLLECTION AND ANALYSIS

TPIN data was calculated for different pavement kinds (asphalt concrete pavements and asphalt pavements), various test vehicles (passenger car and Bus), different speeds (40, 56, and 72) km/h, various MTD values, various types of tires (Dunlop 185/70/R14, Bridgestone 215/70/R17, five and Silver stone 185/70/R14) and different pavement aging. The sections test was carried out utilizing (OBSI) Method, as demonstrated in Figure 1.

Figure 1: Sound intensity probe on the test vehicle.

The Onboard Sound Intensity (OBSI) method was calculated TPIN by using apparatus (Lutron 801) sound level meter with its calibration device. According to [15], a single probe of 1 kHz of one microphone is placed at the right back test tire at a specific distance. All sections are tested at three various speeds (40, 56, 72 km/h) with constant speed (±1.6 km/h), and each speed is reiterated twice according to the single probe location trailing and leading. Finally, the average of the two values is taken. The sand patch test was used to calculate MTD, as shown in Figure 2, because of its important effect on TPIN. The test is reiterated for each section 10 times according to the procedure used (ASTM E965, BS 598).

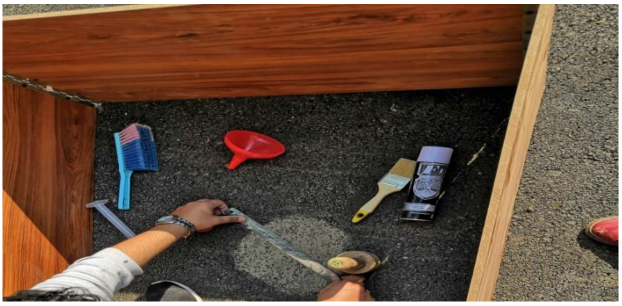


Figure 2: Sand patch test measurements.

TPIN data are collected for 30 test sections, covering 11 main roads in Baghdad city. These data were applied to study the effect of the parameters on sound intensity (dBA), which is measured by the OBSI method. In this study, the temperature is not considered as a parameter because all the OBSI method results were corrected to reference temperature (20°C) according to the equation [15].

$$\text{IL Normalized (dBA)} = \text{IL Measured (dBA)} + 0.072 * (\text{Air Temp °C \_20°C}) \quad (1)$$

IL Measured; sound intensity measured.
Air Temp; ambient air temp during the test period.
IL Normalized; sound intensity after normalized.

3.1 The Effect of Mean Texture Depth (MTD)

Figure 3 demonstrates the relationship between MTD and the sound intensity of asphalt concrete pavements and asphalt pavements at a 40 km/h speed for test sections of a passenger car. It can be seen that, for both types of pavements surface, the sound intensity increases when MTD increases because the volume increases between the pavement surface and the tire treads, resulting in TPIN generation. From the data in Figure 4, the variance in MTD values is (0.21-1.49) mm for asphalt pavements and the variance in MTD values (0.15-0.46) mm for asphalt concrete pavements. The variance in sound intensity of asphalt pavements is 5.6 dBA between the lowest and the most significant value of MTD. As well as the variance in sound intensity of asphalt concrete pavements is 1.7 dBA between the lowest and the greatest value of MTD.

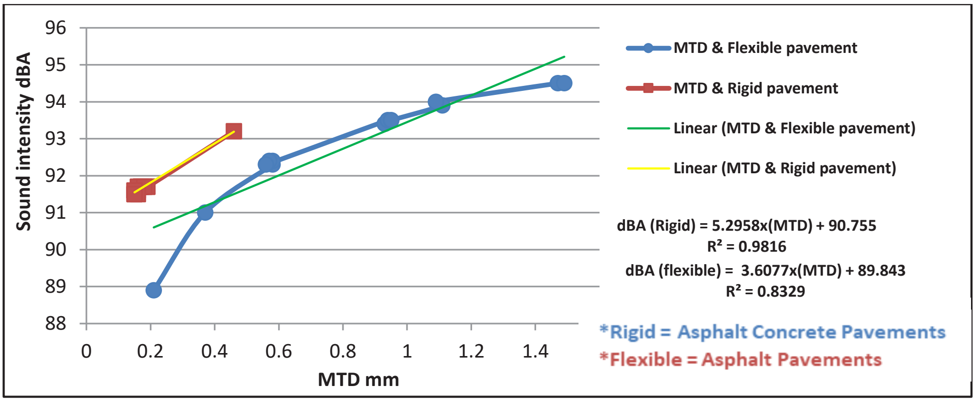
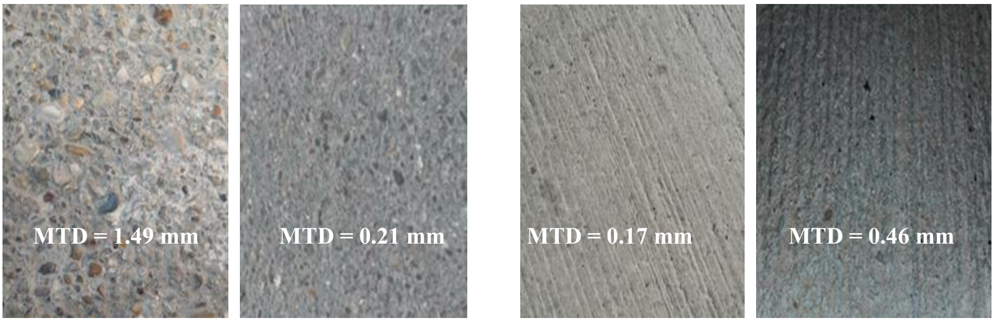


Figure 3: Relationship between MTD and sound intensity.



Asphalt Pavements Asphalt Concrete Pavements

Figure 4: Observed various MTD values for the studied sections.

3.2 The Effect of Pavement Age

Figure 5 shows the relationship between age and sound intensity of asphalt concrete pavements and asphalt pavements at a speed of 40 km/h for test sections of passenger cars. It is obvious that sound intensity increases when the age increasing of asphalt pavements due to pavement surface wears as age progress, loss of flexibility, and MTD value increase; there is a severe increase between the age of first year and three years at two dBA at one dBA per year. However, the increase was weak between the ages of 11 and 13 years, only 0.5 dBA, is gradually increasing between the ages of 3 and 13 years. On the other hand, sound intensity reduces with age increase of asphalt concrete pavements because the pavement surface wears transverse tined, leading to MTD decrease as age progress. There is a gradual decrease between the age of a first year and thirty-five years, about less than two dBA. However, the sound intensity was stationarily increased between 35 and 36 years at 91.5 ±0.2 dBA. It can be clearly seen that; the sound intensity of asphalt pavement changes much over time compared to asphalt concrete pavement.

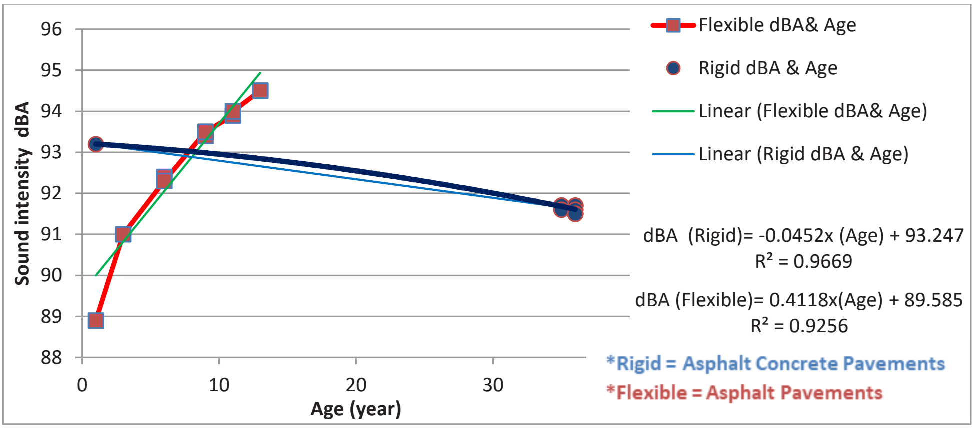


Figure 5: Relationship between age and sound intensity.

3.3 The Effect of Vehicle Speed

Figure 6 illustrates the relationship between speed and sound intensity of asphalt concrete pavements and asphalt pavements. It can be noticed that, for both pavements types, the sound intensity is increased while the speed increases. The value of the increase of sound intensity is four dBA for both pavements types between speeds (40 and 56) km/h. In addition, the noticed increase is three dBA between speeds (56 and 72) km/h. Therefore, the increase in sound intensity occurs as the vehicle speed increases. However, this increase is not constant, gradually decreasing due to doubling the noise generation source from the same distance.

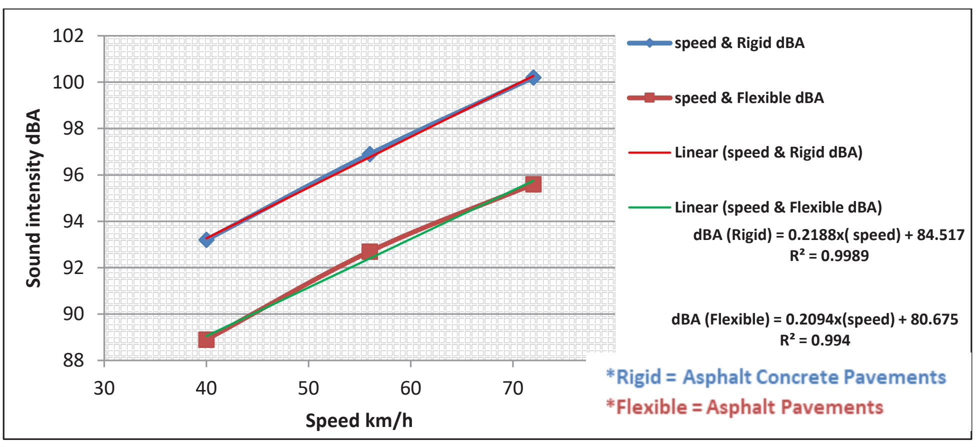


Figure 6: Relationship between speed and sound intensity.

3.4 The Effect of Pavement Types

Figure 7 demonstrates the relationship between types of pavements and sound intensity at speeds (40 and 72) km/h in the oldest and newest test sections. It can be clearly seen that sound intensity at newly surfaced asphalt concrete pavements is higher than that for asphalt pavements by about 4.3 dBA. Furthermore, the sound intensity at the old surface of asphalt concrete pavements is lower than that for asphalt pavements by nearly three dBA due to flexible pavement having a high Mean texture depth (MTD) and losing its flexibility.

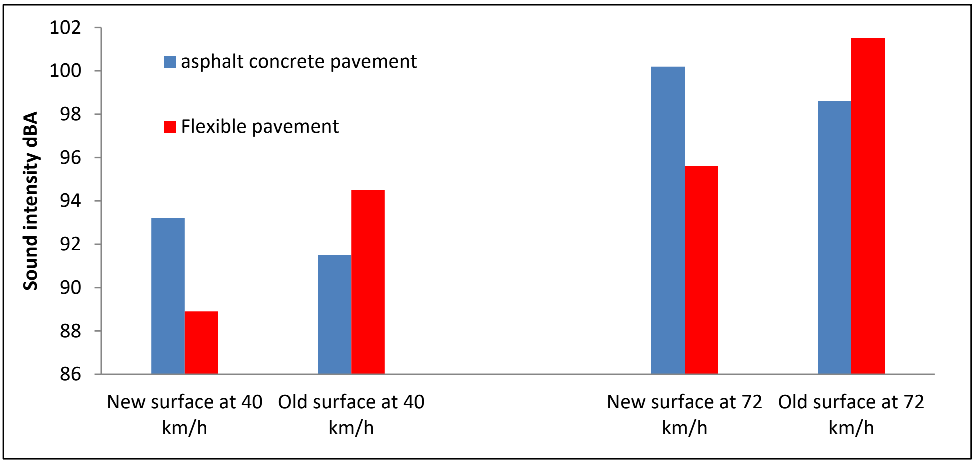


Figure 7: Relationship between types of pavements and sound intensity.

3.5 The Effect of Vehicles Type

Figure 8 presents the relationship between types of vehicles (passenger cars and buses) and sound intensity at three speeds (40, 56, and 72) km/h. The Figure compares two types of vehicles; the first vehicle is Bus (2017) with wheel load 880 Ib, Bridgestone tire (215/70/R17.5), contact area equal to 14.66 in^^{2,} and tire inflation pressure 60 psi, and a second vehicle is passenger car (2008) with wheel load 726 Ib, Dunlop tire (185/70/R14), contact area equal to 24.2 in^^{2} and tire inflation pressure 30 psi. Therefore, Bus's sound intensity is more significant than passenger cars by 2.5 ±0.3 dBA.

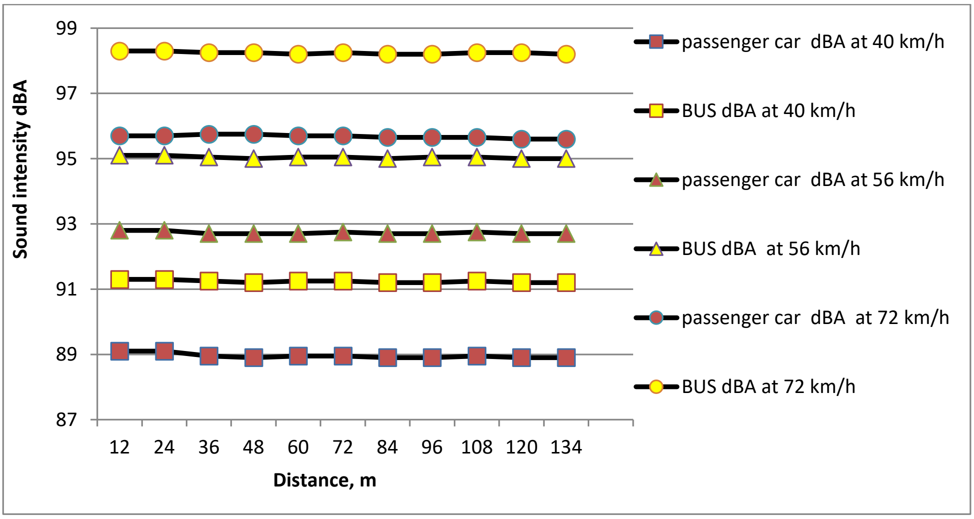


Figure 8: Relationship between vehicle types and sound intensity.

3.6 The Effect of Test Tires

Figure 9 shows the relationship between sound intensity level and vehicle type passenger car test tires. The Figure compares two test tires with the same tire inflation pressure of 30 psi, Dimension (215/70/R17.5), and wheel load 726 Ib. First, the test tire type is Silver stone with a Tread depth of 7.6 mm and Hardness Number 63; second, the test tire type is Dunlop with a Tread depth of 9 mm and Hardness Number 66. Therefore, Silver stone tire is lower in sound intensity than Dunlop by 0.7 ±0.1 dBA.

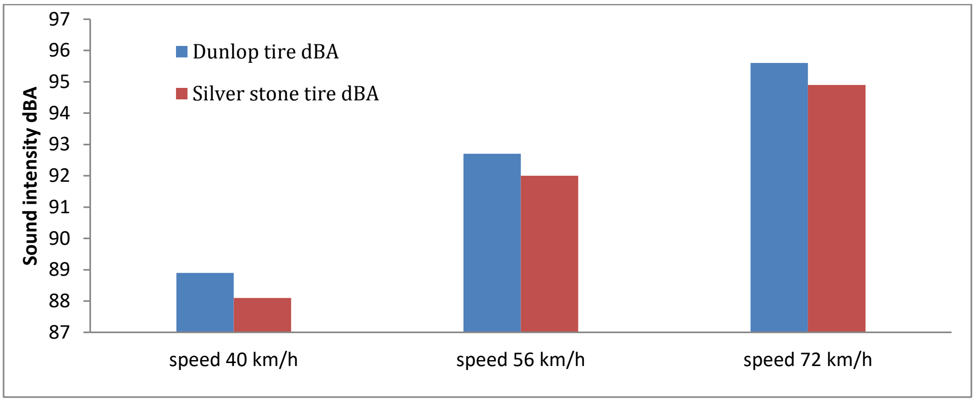


Figure 9: Relationship between sound intensity and test tires.

6. CONCLUSIONS

Finally, the following conclusions can be drawn from the current study:

- The sound intensity dBA increases when the MTD value increases in both pavements. Therefore, the increase for the asphalt pavements type is more than that for the asphalt concrete pavements because the value of MTD is greater in the asphalt pavements.
- The sound intensity dBA increases when age increases for asphalt pavement type due to pavement surface wear as age progresses, loss of flexibility, and MTD value increase. On the other hand, asphalt concrete pavement type decreases because the pavement surface wears transverse tined leads to MTD decrease as age progresses.
- The sound intensity dBA increases when the vehicle speed is increasing in both types of pavements at three speeds (40, 56, and 72) km/h, and the vehicle speed increases approximately from 4 to 3 dBA for each 10-mph due to the increase in the number Interaction between tires and pavement per unit time.
- The sound intensity dBA in the asphalt pavement type is lower than in the asphalt concrete pavement by 4.3 dBA while compared to the condition of new pavement surface due to the asphalt pavement type has less MTD and has Pavement porosity that provides interconnected voids channels absorb the resulting noise. on the other hand, the sound intensity dBA in asphalt pavement type is more than in the asphalt concrete pavement type in the condition of old pavement surface because it loses flexibility and MTD increases with time.
- The sound intensity dBA in Bus is greater than passenger car due to inflation pressure, wheel load, contact area, and dimensions in Bus is larger than passenger car.
- All tested at the same dimensions, wheel load, and tire inflation pressure, and the sound intensity dBA in Silver Stone tire is lower than Dunlop tire due to the hard number and tread depth in Silver Stone tire is lower than Dunlop tire.
- Finally, it is suggested to increase parameters that influence TPIN, for instance, various types of pavement surfaces, vehicle tires, and vehicles, and other important parameters that could be used to design a quieter pavement.

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