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Influence of Tyre's Dimensional Characteristics on Tyre-Pavement Noise Emission

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Research Article

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ABSTRACT

Road Traffic Noise is causing huge socio-economic losses to the nations all around the world by lowering the quality of life and property values. India, poised with the annual projected automotive industry growth of 12% to 15% for 2011-12 and ever increasing traffic on its roads draws serious concern related to traffic noise pollution. The noise associated with tyre-pavement interaction is known to be a major component of traffic noise. The paper addresses the influence of dimensional characteristics of tyres i.e. tyre section width and overall tyre diameter on the noise emission associated with tyre-pavement interaction. The principle focus of the study was to identify a conceivable trend showing not only the effect of tyre dimensions on tyre-pavement noise but also the extent of the influence. The tyres used for the study belong to C1 Class of tyres as per United Nations Economic Commission for Europe Regulation 30 (UNECE R30). For each set of tyres, the dimensional characteristics were first recorded and then the Coast-By Noise Measurement method in accordance with ISO-13325(2003) was employed to evaluate the tyre-to-road sound pressure emission level [SPL in dB (A)] on two different test sites. Based on the data obtained, a detailed analysis was carried out and the relation between tyre-pavement noise emission and said dimensional characteristics was established. The results were found to indicate that the on both test surfaces (rough), the tyre-pavement noise increases with increase in tyre section width and decreases with increase in overall tyre diameter. Plausible reasons in support of the results obtained were then identified and discussed.

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Keywords: Sound Pressure Level (SPL); coast by; tyre section width; tyre overall diameter; aerodynamic noise; mechanical noise.

1. INTRODUCTION

Traffic noise has come into the limelight with growing societal concerns on the issue of noise pollution. The detrimental effects of noise extend to both physiological as well as psychological well-being of humans and animals alike. Noise pollution can cause annoyance, aggression, hypertension, high stress levels, tinnitus, hearing loss, sleep disturbances and other such disorders (Anonymous[1], 2011). The total impact cost of traffic-noise includes directly attributable costs (constructing noise barriers, installing insulation, and depreciation of residential homes) and indirect costs (healthcare costs, productivity losses, discomfort, anxiety and inconvenience) (Navrud, 2004). Studies in Denmark have estimated that the health costs of traffic noise alone are €80-€450 million per year (Anonymous[4], 2006). A Swedish study estimated that road traffic noise damage costs on Sweden is USD 330 million per year (Hesselborn, 2000). In yet another study it was estimated that across the European Union, the external cost of transport noise alone ranged from 0.2% to 2% of GDP (Commission of the European Communities, 1996)

An identifiable contributor to environmental noise is the excessive sound produced by automobiles through tyre-pavement interaction that exceeds the prescribed loudness limits, thereby leading to traffic noise. In automobiles, at velocities greater than 50 km/h, it is the tyre-road noise that dominates over the more typical sources of external noise such as the driveline of the vehicle (Roovers and van Blokland, 2002).

In view of the above, the need for control of tyre-road interaction noise was realized through the formulation of Regulation 117 by the United Nations Economic Commission for Europe (UNECE R 117, 2007) which provides standard references of sound pressure levels [SPL in dB (A)] for rolling sound emitted by tyres under prescribed test conditions based on their nominal section widths (for class C1 tyres) or their category of use (for class C2 and class C3 tyres). The regulation has compelled and necessitated the gain of more insight into the basic fundamentals underlying the mechanisms governing tyre-pavement noise generation and the effect that the tyre characteristics have on them.

Therefore the present paper investigates the influence of Dimensional Characteristic of Tyres viz. Tyre Section Width and Overall Tyre Diameter on Tyre-Pavement Noise Emission.

2. EXPERIMENTAL DETAILS

2.1 Parameters Considered

The dimensional characteristics chosen for consideration are (figure 1):

2.1.1 Tyre section width

This is the average of at least six measurements, at approximately equidistant positions over smooth sidewalls of the tyre body (Not over elevations such as engravings, protective ribs, etc.) when kept inflated for 24 hours minimum, but not loaded, on the measuring rim at the maximum specified pressure for duals if listed and prevailing atmospheric temperature, and then adjusted to the original pressure before taking measurements. The tyre section width can be found on the tyre sidewall marking (Anonymous, 2008).

2.1.2 Tyre aspect ratio

The aspect ratio of a tyre is the section height divided by the nominal section width multiplied by 100 (expressed as a percentage), where the section height is the overall tyre diameter minus the nominal rim diameter, divided by 2. The tyre aspect ratio can be found on the tyre sidewall marking (Anonymous, 2008).

2.1.3 Overall tyre diameter

The overall tyre diameter is the diameter of an inflated tyre at the outermost surface of the tread, or twice the inflated section height of the tyre plus nominal rim diameter (Anonymous, 2008).

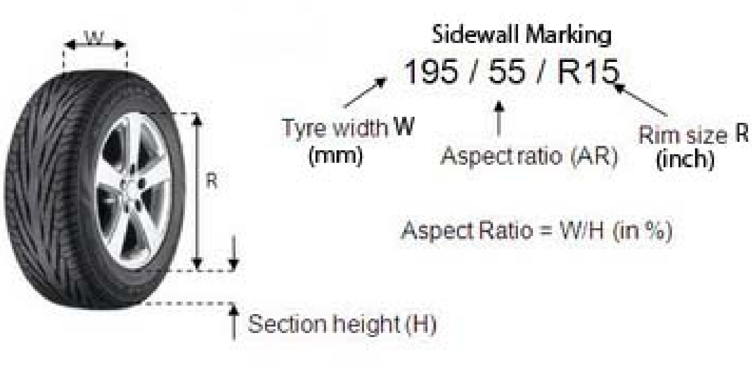


Figure 1: Tyre Dimensions and Sidewall Markings (Anonymous^2, 2011)

2.2 Materials

Basic components of the Sound Pressure Level [dB (A)] measurement system used for the Coast-By method as per ISO 13325 include microphones, precision laser barriers, Doppler radar, data acquisition system, etc. whose details are given below:

2.2.1 Microphones

Two 1/2” Free-Field Pre-polarized condenser microphones (Make: G.R.A.S, Type: 40AE) were used for sound pressure measurement. The disturbance caused by the microphones’ presence in the sound field is negligible at low frequencies. The sensitivity of the microphones is 50mV/Pa over a range of 3.15Hz to 20 kHz.

2.2.2 Data acquisition system

An LMS SCADAS Mobile Data acquisition system (LMS SCM05) having 5 slots for up to 40 input channels was used. It complies with the EN61010, EN50081-1 and EN50082-1 standards. The throughput rate of the SCM05 via Ethernet interface goes up to 14MSamples/sec.

2.2.3 Doppler radar

A pre-calibrated low power Doppler Radar (TESCON 3210 SPEED RADAR) was used for speed measurements on vehicles. The speed range of the radar is 16km/h – 320km/h. The accuracy of the radar is ± 0.2% of the measured value at 22°C measured 10 minutes after being switched on. The measurement range of the radar is typically 100m – 200m.

2.2.4 Laser barriers

Two precision laser barriers (TESCON 3246C LASER BARRIER) were used for accurate position and time measurements for the vehicle being tested in order to trigger the commencement and completion of each coast-by test. The range of the light barriers is 15m minimum. They emit polarized light of wavelength 675nm.

2.2.5 Road surface

Two different types of road surfaces were selected for the experimental purpose.
1. State Highway (Rough Asphaltic Surface)
2. ISO 10844 Test Surface (Pass-by/Coast-By Test Track)

2.2.6 Tyres used

The tyres used for the study are passenger car tyres belonging to C1 category in accordance with UNECE Regualton-30. Some of the important parameters of the tyres chosen for consideration are shown below:

2.3 Methods

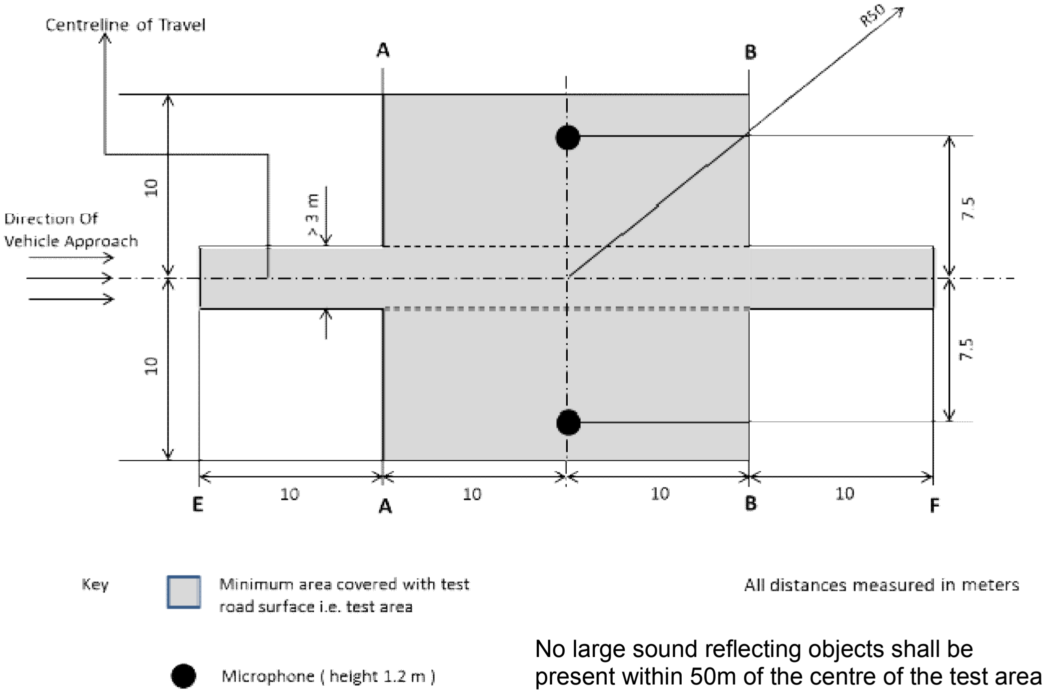
The test methodology adopted was in strict accordance with the ISO Standard 13325 – “Coast-by methods for measurement of tyre-to-road sound emission”. The Standard specifies the test method for measuring tyre-to-road sound emission from tyres fitted on a motor vehicle under coast-by condition (when vehicle is in free rolling, non-powered operation, with transmission in the neutral position and the engine as well as all auxiliary system not necessary for safe driving switched off) (ISO 13325, 2003). A representative site for conducting the coast-by noise measurement is shown in figure 2. Sound Absorption Coefficients on of State Highway and ISO surface were measured by following non-destructive method of ISO 13472-2:2010 and the average values were found to be 0.009 and 0.019, respectively, which satisfied the UN ECE R117 requirements (Kumar et al., 2011.)

Vehicle is prepared for the testing as per conditions mentioned in ISO 13325. The tyre load and tyre inflation pressure were maintained as per ISO 13325 specifications for C1 category of tyres for each Coast-By test. The test vehicle speed at the time when it was at a position perpendicular to the microphones was also maintained as per ISO 13325 specifications for C1 category of tyres.

The test vehicle was made to approach line A-A with the engine off and the transmission in neutral position, and with the vehicle centre following as closely as possible the ‘centreline of travel’, as shown in Figure 2. Finally the normalized and temperature corrected Sound Pressure Levels were obtained in accordance to UNECE R117, 2007. The actual ISO site has been shown in figure 3.

Table 1: Specifications of Tyres used for the Coast-by Noise Measurement Purpose

Sl. No.	Reference Name	Section Width (mm)	Aspect Ratio	Rim Diameter (inch)	Tyre Overall Diameter (mm)	Load Index	Speed Symbol	Tyre Category (UNECE R30)	'Reinforced' or 'Extra Load'?
1	Tyre A	145	70	13	533.2	71	S	C1 A	No
2	Tyre B	155	70	13	547.2	75	H	C1 B	No
3	Tyre C	165	65	13	544.7	77	T	C1 B	No
4	Tyre D	175	70	13	575.2	82	T	C1 C	No
5	Tyre E	185	60	14	577.6	82	H	C1 C	No
6	Tyre F	165	80	14	619.6	85	T	C1 B	No
7	Tyre G	175	70	14	600.6	82	H	C1 C	No
8	Tyre H	185	65	14	596.1	86	H	C1 C	No
9	Tyre I	195	60	15	615	88	V	C1 D	No
10	Tyre J	195	65	15	634.5	91	V	C1 D	No
11	Tyre K	205	65	15	647.5	94	V	C1 D	No
12	Tyre L	185	70	14	614.6	88	H	C1 C	No
13	Tyre M	235	70	15	710	102	S	C1 E	No
14	Tyre N	235	75	15	733.5	105	S	C1 E	No



No large sound reflecting objects shall be present within 50m of the centre of the test area

Figure 2: Representative Test Area with Microphone Locations

Figure 3: ISO 10844 test surface used for testing

2.4 Test Matrix

In table 2, test matrix has been explained. Total 14 sets of tyres have been tested in two kinds of surfaces. For each set of tyre one coast by test has been conducted in each surface.

Table 2: Test Matrix

Surface Type	ISO Test Track	State Highway
No. of tyres tested	14	14
Total no. of coast by noise test	14 (1 test/tyre set)	14 (1 test/tyre set)

3. RESULTS AND DISCUSSION

3.1 Influence of Tyre Section Width on Tyre-Pavement Noise Emission

Figure 4 and Figure 5 show the influence of tyre width on tyre-pavement noise, when tyres were tested on Test Site 1 and Test Site 2 respectively. In order to account for different tyre outside diameters, the data was grouped in three sets (Set1 – Overall Diameter: 530-580mm, Set 2 – Overall Diameter: 580-620mm, Set 3 – Overall Diameter: 620-650mm). For each group, bar graphs were plotted.

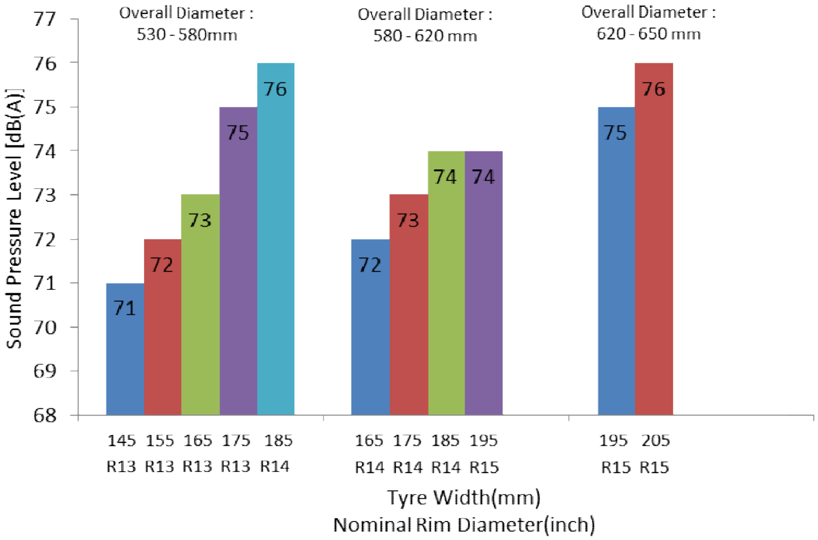


Figure 4: Coast-By Sound Pressure Level [dB (A)] vs. Tyre Section Width (mm) for 3 constant ranges of overall tyre diameter (TEST SITE 1 – STATE HIGHWAY)

<u>3.1.1 Results for test site 1</u>

1) For overall tyre diameter range 530 – 580mm, with tyre section width varying from 145 – 185 mm, the Coast-By Sound Pressure Level ranges from 71 – 76dB.
2) For overall tyre diameter range 580 – 620mm, with tyre section width varying from 165 – 195 mm, the Coast-By Sound Pressure Level ranges from 72 – 74dB.
3) For overall tyre diameter range 620 – 650mm, with tyre section width varying from 195 – 205 mm, the Coast-By Sound Pressure Level ranges from 75 – 76dB.

It appears that the trend for each set is very similar. It is sufficiently clear that with an increase in the tyre section width the tyre-road noise emission also increases for each set of overall tyre diameters. Similar trend were also report in a study conducted in TUG, Poland, on a rough GRB-R replica road surface (Sandberg and Ejsmont, 2002).

3.1.2 Result for test Site 2

1) For overall tyre diameter range 530 – 580mm, with tyre section width varying from 145 – 185 mm, the Coast-By Sound Pressure Level ranges from 68 – 71dB.
2) For overall tyre diameter range 580 – 620mm, with tyre section width varying from 165 – 195 mm, the Coast-By Sound Pressure Level ranges from 68 – 72dB.
3) For overall tyre diameter range 620 – 650mm, with tyre section width varying from 195 – 205 mm, the Coast-By Sound Pressure Level ranges from 72 – 73dB.Results at Test Site 2 also revealed similar trend as in Test site 1 for all three ranges of overall tyre diameter.

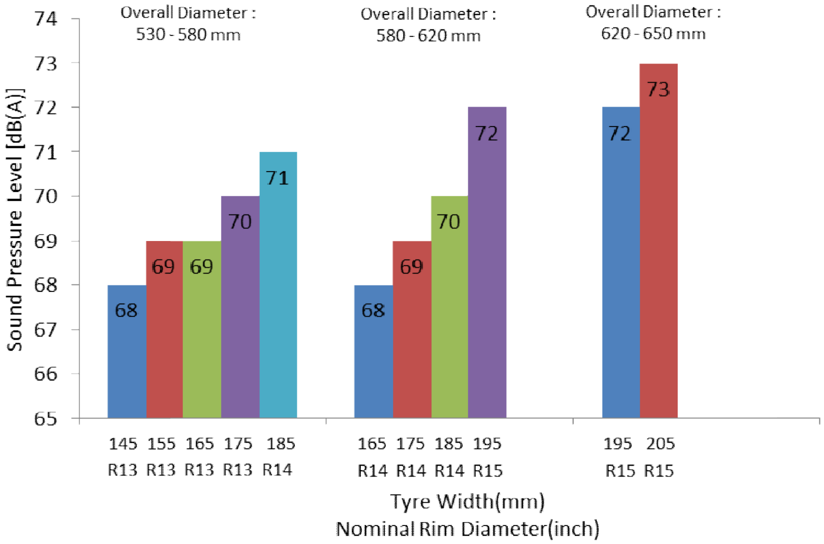


Figure 5: Coast-By Sound Pressure Level [dB (A)] vs. Tyre Section Width (mm) for 3 constant ranges of overall tyre diameter
(TEST SITE 2 – ISO 10844 TEST SURFACE)

In order to estimate the degree of influence of tyre section width on tyre-pavement noise generation an average Increase of Sound by Pressure level per 10 mm increase in Tyre section width has been calculated for each set of overall tyre diameter. These values have been tabulated in Table 3 shown below:

Table 3: Average Increase in Sound Pressure Level per 10 mm increase in tyre width

Overall Diameter Range (mm)	Tyre Section Width Values (mm)	Average Sound Pressure Level (dB)		Average Increase in Coast-By Sound Pressure Level (dB/10mm increase in tyre width)	
		Test Site 1	Test Site 2	Test Site 1	Test Site 2
530 – 580	145,155,165,175,185	73.4	69.4	1.25	0.75
580 – 620	165,175,185,195	73.25	69.75	0.67	1
620 – 650	195, 205	74.5	72.5	1	1

The average increase of tyre-pavement noise emission was found to be 0.973 dB/10mm increase in tyre section width for Test Site 1 and 0.916 dB/10 mm increase in tyre section width for Test Site 2. In a similar study conducted by University of Gdansk (TUG) the increase of noise was estimated at 0.3 dB/10mm increase in width (Sandberg and Ejsmont, 2002). Another study at TRL have established that car tyre noise levels increase by between 0.2 and 0.4 dB[A] for each 10mm increase in tyre section width (Phillips, 2001).

3.1.3 Discussion on results of tyre noise with varying tyre section width

Different levels of tyre noise obtained in Test site 1and2 with varying tyre section width have been tried to be explained below with two approaches, namely, i. Mechanical Noise Generation Mechanisms and Tyre Section Width and ii. Aerodynamic Noise Generation Mechanisms and Tyre Section Width.

3.1.3.1 Relation between mechanical noise generation mechanisms and tyre section width

A tyre with a wider section involves greater interaction of tread blocks and other profile elements with the road surface per unit time. It is, therefore, plausible to say that there exists a positive relation between tyre width and mechanical noise. The tread impact (Sandberg and Ejsmont, 2002) on the road surface as well as the impact of the road surface texture on the tyre tread is more extensive for wider tyres leading to excitation of greater tread area which magnifies the radial and tangential vibrations in comparison to the tyres with leaner section width. This, in turn, leads to greater sidewall vibrations (Kim et al., 1997) as well. The stick-slip phenomenon (Sandberg and Ejsmont, 2002; Morgan et al., 2003; Abbott et al., 2010), involving tangential tyre vibrations arising due to the difference between the co-efficient of static friction and the co-efficient of kinetic friction between tyre and road surface, as well as the stick-snap phenomenon (Sandberg and Ejsmont, 2002; Morgan et al., 2003; Abbott et al., 2010), involving radial vibrations arising due to the adhesive bond strength between the tyre and the road surface are, both, augmented by increase in tyre section width as they are directly influenced by the area of contact (Sandberg and Ejsmont, 2002).

3.1.3.2 Relation between aerodynamic noise generation mechanisms and tyre section width

A tyre with a wider section involves greater displacement of air within the tyre-road interface, as well as its leading and trailing edges. It is, therefore, reasonable to reckon that there is a positive relation between tyre width and aerodynamic noise. Greater the tyre section width, greater the amount of air in contact with the tyre. This magnifies the noise caused by air turbulence (Sandberg and Ejsmont, 2002) which involves displacement of the surrounding air by the tyre when rolling on the road. The number of cavities between the road surface and tyre tread are also greater for wider tyres. A rolling tyre displaces air into these cavities in or between the tyre tread and road surface when it deforms while entering the contact patch region leading to entrapment of air at the leading edge and subsequent compression. Subsequently it returns air as the tyre tread goes back to the un-deformed state causing sound production by air pumping mechanism (Morgan et al., 2003; Abbott et al., 2010). Also when the cavities reach the trailing edge of the tyre and releases contact with the road surface, the higher-pressure air inside flows out. However, this surge of air flowing out will tend to over-compensate, due to the inertia of the air in the neck, and the cavity will be left at a pressure slightly lower than the outside, causing air to be drawn back in, also known as Helmholtz resonance phenomenon (Sandberg and Ejsmont, 2002; Anonymous[3], 2011). Therefore, both, air pumping mechanism as well as Helmholtz resonance phenomenon are supported and augmented by increase in tyre section width (Sandberg and Ejsmont, 2002).

3.2 Influence of Overall Tyre Diameter on Tyre-Pavement Noise Emission

Figure 6 and Figure 7 show the influence of overall tyre diameter on tyre-pavement noise, when tyres were tested on Test Site 1 and Test Site 2 respectively. In order to account for different tyre section widths, the data was grouped in four sets (Set1 – Tyre Section Width: 165mm, Set 2 – Tyre Section Width: 185mm, Set 3 – Tyre Section Width: 195mm, Set 4 - Tyre Section Width: 235mm). For each set, bar graphs were plotted.

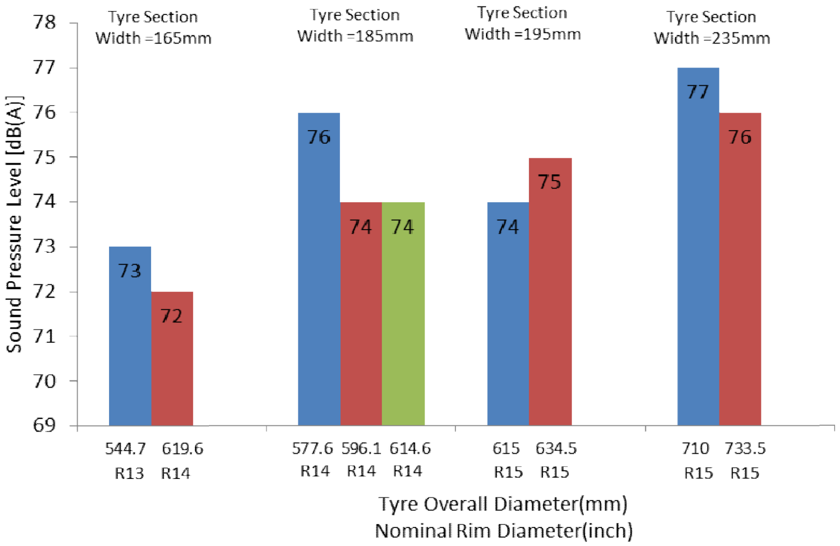


Figure 6: Coast-By Sound Pressure Level [dB (A)] vs. Tyre Overall Diameter (mm) for 4 fixed values of tyre section width (TEST SITE 1 – STATE HIGHWAY)

3.2.1 Results for test site 1

1) For tyre section width = 165mm, with overall tyre diameter varying from 544.7 – 619.6 mm, the Coast-By Sound Pressure Level ranges from 73 – 72dB.
2) For tyre section width = 185mm, with overall tyre diameter varying from 577.6 – 614.6 mm, the Coast-By Sound Pressure Level ranges from 76 – 74dB.
3) For tyre section width = 195mm, with overall tyre diameter varying from 615 – 634.5 mm, the Coast-By Sound Pressure Level ranges from 74 – 75dB.
4) For tyre section width = 235mm, with overall tyre diameter varying from 710 – 733.5 mm, the Coast-By Sound Pressure Level ranges from 77 – 76dB.

3.2.2 Results for test site 2

1) For tyre section width = 165mm, with overall tyre diameter varying from 544.7 – 619.6 mm, the Coast-By Sound Pressure Level ranges from 69 – 68dB.
2) For tyre section width = 185mm, with overall tyre diameter varying from 577.6 – 614.6 mm, the Coast-By Sound Pressure Level ranges from 71 – 70dB.
3) For tyre section width = 195mm, with overall tyre diameter varying from 615 – 634.5 mm, the Coast-By Sound Pressure Level ranges from 72 – 73dB.
4) For tyre section width = 235mm, with overall tyre diameter varying from 710 – 733.5 mm, the Coast-By Sound Pressure Level has the value 74dB.

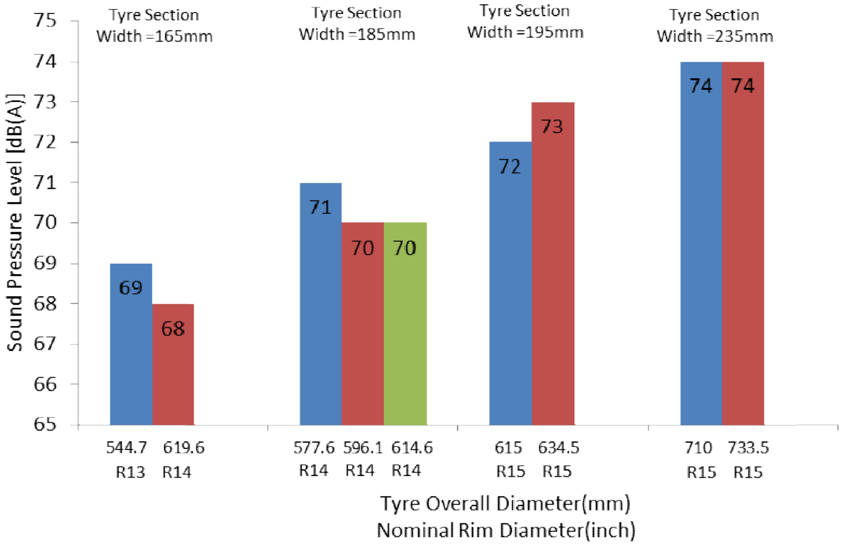


Figure 7: Coast-By Sound Pressure Level [dB (A)] vs. Tyre Overall Diameter (mm) for 4 fixed values of tyre section width
(TEST SITE 2 – ISO 10844 Test Surface)

The plots, as shown, do not provide an entirely conclusive trend. However, on the whole the plots can be said to depict a decrease in the tyre-road noise with an increase in the tyre overall diameter for most sets of tyre section width i.e. Set1 – Tyre Section Width: 165mm, Set 2 – Tyre Section Width: 185mm and Set 4 - Tyre Section Width: 235mm.

The plots are influenced by complicated interactions of noise with Overall tyre diameter. They suggest that there may be conflicting relations of the different noise generation mechanisms with tyre diameter.

In order to estimate the degree of influence of tyre overall diameter on tyre-pavement noise generation an average increase of Sound by Pressure level per 10 mm increase in Tyre overall diameter has been calculated for each set of tyre section width. These values have been tabulated in Table 4 shown below.

Table 4: Average Decrease in Sound Pressure Level per 10 mm increase of tyre width

Set No.	Tyre Section Width (mm)	Overall Tyre Diameter Values (mm)	Average Coast-By Sound Pressure Level (dB)		Average Decrease in Coast-By Sound Pressure Level (dB/10mmincrease in tyre diameter)	
			Test Site 1	Test Site 2	Test Site 1	Test Site 2
1	165	544.7,619.6	72.5	68.5	0.1335	0.1335
2	185	577.6,596.1,614.6	74.67	70.33	0.5405	0.2702
3	195*	615,634.5*	74.5*	72.5*	-0.5128*	-0.5128*
4	235	710,733.5	76.5	74	0.4255	0

*The marked tyres (Set 3) having tyre section width of 195mm and overall diameters of 615mm and 634.5mm respectively, showed an increase in the coast-by sound pressure levels with increase in Overall tyre diameter. This particular observation is contradictory to the general trend observed in the plots (decrease in sound pressure level with increase in overall diameter) and may be attributed to the increase in overall tyre diameter having opposing effects on mechanical and aerodynamic noise generation mechanisms respectively as explained below.

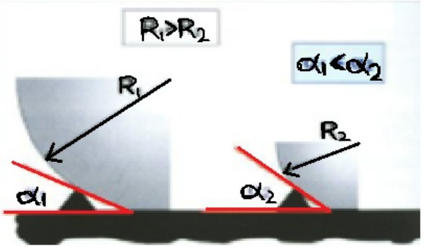
The average decrease of noise emission was found to be 0.1459dB/10mm increase in overall tyre diameter for Test Site 1 and -0.0272/10 mm increase in overall tyre diameter for Test Site 2.

3.2.3 Discussion on results of tyre noise with varying tyre diameter

Different levels of tyre noise obtained in Test site 1and2 with varying tyre Diameter have been tried to be explained below with two approaches, namely, i. Mechanical Noise Generation Mechanisms and Tyre Diameter and ii. Aerodynamic Noise Generation Mechanisms and Tyre Diamerer.

3.2.3.1 Relation between mechanical noise generation mechanisms and overall tyre diameter

With increase in the overall diameter of the tyre there is an observable decrease in the attack angle (refer to Figure 8) causing a noticeably gradual displacement change when the tyre and road surface meet. The change from the first impact to the maximum penetration of the rubber takes place over a longer period of time. On the other hand, a higher attack angle would mean that the tread and road surface texture impacts become more abrupt. It is, therefore, reasonable to say that an increase in the tyre's diameter on the whole would result in the tread and texture impacts being less pronounced and abrupt than the impacts that the same tyre may have produced with a smaller overall diameter, thereby suggesting that there exists an inverse relation between a tyre's overall diameter and mechanical noise (Sandberg and Ejsmont, 2002).



α – Attack Angle; R – Overall Tyre Radius

Figure 8: Attack Angle (Sandberg and Ejsmont, 2002)

3.2.3.2 Relation between aerodynamic noise generation mechanisms and overall tyre diameter

Near the tyre/road contact area, the road surface and the tyre belt form a horn-like geometry. There is a reflection of the sound waves from the walls of the dihedral formed by the surfaces of the tyre and road. This phenomenon is called the horn effect (Graf et al., 2002; Morgan et al., 2003; Abbott et al., 2010) and it causes a considerable amount of amplification of the generated noise as the gap between the tyre and the road surface increases progressively on moving away from the point of contact. The increase in overall diameter causes a decrease in the attack angle (Figure 8) which plays a pivotal role for the horn effect. The decrease in attack angle augments an increase in the aerodynamic noise generated by tyre-pavement interaction. A plausible explanation for this would be that the horn effect becomes more impellent and effective in amplification of the aerodynamic noise when the opening of the horn is not too rapid from the point of contact. Therefore, an increase in the tyre's overall diameter results in greater aerodynamic noise amplification thereby suggesting a positive relation between the two (Sandberg and Ejsmont, 2002)

The discussion and results obtained above suggest that variation in tyre section width has similar effects on both mechanical and aerodynamic noise generation mechanisms. Variation in overall tyre diameter, however, is seen to have opposing effects on them. This explains why the graphs depicting sound pressure level plotted against the tyre section width (Figure 4 and 5) provide a clearer and pronounced relation between the two whereas the graphs depicting sound pressure level plotted against overall tyre diameter (Figure 6 and7) are comparatively less conclusive.

On rough surfaces, the tread and texture impact mechanisms dominate as opposed to air displacement mechanisms (Sandberg and Ejsmont, 2002) and since both the test surfaces used for the study were rough textured, we observe that the impact mechanisms influence the results to a greater degree than the horn effect (Set 3 as shown in Table 4 being the exception).

4. SUMMARY and CONCLUSIONS

1. Coast-By noise measurements were performed on 14 sets of tyres belonging to C1 category (UNECE R-30) on two different test sites (Site 1: State Highway, Site 2: ISO 10844 Test Surface).

2. These noise measurements were done in accordance with ISO 13325:2003 and final dB (A) values were calculated as per UNECE R117.

3. Tyre-Pavement noise increased with the increase of tyre section width. The average increase of tyre-pavement noise emission was found to be 0.973dB/10mm increase in tyre section width for Test Site 1 and 0.916dB/10 mm increase in tyre section width for Test Site 2. Therefore, a definitive positive correlation is seen i.e. increase in tyre-road noise with increase in tyre section width.

4. Tyre-pavement noise did not show a consistent trend with increase of tyre overall diameter. This may be attributed to the increase in overall tyre diameter having opposing effects on mechanical and aerodynamic noise generation mechanisms respectively as already explained. However, most sets showed a decrease of Tyre-Pavement noise with increase in overall tyre diameter. The average decrease of noise emission was found to be 0.1459dB/10mm increase of overall tyre diameter for Test Site 1 and -0.0272/10 mm increase of overall tyre diameter for Test Site 2.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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