Physical Review & Research International
1(2): 45-56, 2011

SCIENCEDOMAIN *international*
www.sciencedomain.org

SCIENCEDOMAIN

Comparative Study of Sound Absorption Coefficients on Different Types of Road Surfaces Using Non-Destructive Method as per ISO 13472-2:2010

Abhishek Kumar[1], P. Mondal[1*], Prashant Vijay[1], U. D. Bhangale[1] and Dinesh Tyagi[1,2]

[1]International Centre for Automotive Technology, Manesar, India
[2]National Automotive Testing and R&D Infrastructure Project, New Delhi, India

Research Article

Received 24th April 2011
Accepted 30th April 2011
Online Ready 5th May 2011

ABSTRACT

Road Traffic Noise is causing huge socio-economic loss to the nations all around the world. In a study it is estimated that in Europe itself the traffic noise accounted for at least €38 billion per year (0.4% of total GDP of EU22). It is almost as high as one-third of socio-economic cost associated with traffic accidents. Tire Pavement noise is major component of traffic noise which is combined result of interaction of Tire and pavement. Sound Absorption Coefficient being an important property of the Road/Pavement plays an important role in the amount of noise generated from the Tire-Pavement Interaction. This paper discusses the test method and result obtained for sound absorption coefficient measurement as per newly developed non-destructive ISO 13472-2:2010 standard on three different road surfaces. It has been found that sound absorption coefficient values for all the road surfaces are within the limits (0.1) as specified under UNECE R117 regulation. The average sound absorption coefficient for the asphaltic road surface was found to be 0.014, which was 39.13% lower than the sound absorption coefficient obtained on the concrete road surface.

Keywords: Sound Absorption Coefficient; Impedance Tube; Asphaltic Roads; Concrete;

**Corresponding author: Email: mondal.pinaki@gmail.com*

1. INTRODUCTION

Road Traffic noise is by far the most pervasive of all noises and over 80 million people are exposed to traffic noises of unacceptably high levels in the European Union alone (Lambert, 2000). The WHO recognizes traffic noise as a serious threat to public health. Excessive traffic noise is more dangerous than both passive smoking and NOx pollution (Van den Berg et al.,2005). In the year 2000 over 210 million people of the EU25 were exposed to road traffic noise levels above 55 dB(A) (guideline value for outdoor noise levels and the threshold for 'serious annoyance') and more than 54 million people were exposed to road traffic noise levels over 65 dB(A) (denBoer and Schorten, 2007). Besides annoyance, exposure to high noise levels also causes sleep disturbance, impaired cognitive functioning, cardiovascular diseases and mental illness. Sleep disturbance starts at noise levels of 30 dB (A) for steady state continuous noise at the sleeping persons ear (WHO, 1999).

The total cost of traffic-noise includes directly attributable costs (constructing noise barriers, installing insulation, and negative effects on property prices) indirect costs (healthcare costs paid by health services, insurance or individuals, the costs of lost productivity, discomfort, anxiety and inconvenience (Navrud, 2004). The social cost of road traffic noise in the EU22 is estimated to be at least 38 (30 - 46) billion per year, which is approximately 0.4% of total GDP in the EU22. The social costs of road traffic noise in the EU22 are almost one-third of those associated with road traffic accidents (denBoer and Schroten, 2007). Studies in Denmark have estimated that the health costs of traffic noise alone are €80-€450 million per year. (Anonymous[1], 2006) In a Swedish study it was estimated that current road traffic noise damage costs USD 330 million per year (Hesselborn, 2000). An estimate by CE Delft for T&E reported an average social cost due excessive traffic noise level of 40 Billion € per year on EU22 countries (denBoer and Schorten, 2007), which is approximately 0.4% of the total GDP. It is approximately one-third the social cost incurred due to traffic accidents.

Pavement properties along with the tire play vital role in generation and propagation of noise thus generated during tire-pavement interaction. Sound absorption co-efficient of road surface plays an important role on deciding the amount of tire-road noise reached to the human ear and creation of corresponding annoyance. As per UN ECE R117, characterization of sound absorption coefficient of road surface is required to measure the tire noise and for type approval of new tires. Until now destructive measurement method were used by industry to measure sound absorption coefficient. These methods required taking out sample (cores sampling method) from the test surface and carrying it to laboratory where with the help of impedance tube, measurement were carried out (ISO 10534-1:1996). This method had its intrinsic limitations, like damage to the test surface, time consuming, cumbersome. Therefore, there was an acute need of fast, non-destructive and easy measurement of sound absorption coefficient of road to help tire-road noise research to reduce traffic noise.

Recently one standard, namely, ISO 13472-2:2010 has been released, which describes a non-destructive Sound Absorption Coefficient Measurement Method. Therefore the objective of the present paper is to measure in-situ sound absorption coefficients of different road surface in the narrow-band frequencies ranging from 400 Hz to 1,600 Hz under normal incidence conditions by following ISO 13472-2:2010 and validate the data as per the requirement of UN ECE R117 regulation.

2. MATERIALS AND METHODS

A fixed Basic component of the measurement system includes acoustic driver, impedance tube, test fixture, plate, data acquisition system, microphones etc, which are described below:

2.1 ACOUSTIC DRIVER

Acoustic driver is a high quality JBL Compression Driver with an input capacity of 100W. It is capable of producing a sound pressure level (SPL) of 120 dB(A) and above inside the impedance tube. The high-output compression driver allows sufficient signal-to-noise levels at all the desirable frequency range for two-microphone measurement method.

2.2 IMPEDANCE TUBE

It is a rigid tube made of brass with wall thickness approximately seven percent of the inside diameter of tube as per the standard recommendation. This is in order to prevent any loss of sound energy and minimize any transmission of sound from the ambient.

2.3 TEST FIXTURE

Test fixture as shown in figure 1 is made to provide excellent air-tight sealing with the pavement. Additionally a standard water modeling clay is also used along with the fixture to further enhance the sealing effect so as to minimize the sound loss through any opening from the base of Impedance tube. The flanged base of the fixture provides necessary stability to the equipment.

Fig. 1. Details of the test Fixture for impendence tube

2.4 DATA ACQUISITION SYSTEM AND SOFTWARE

4-Channed LMS SCADAS Mobile Data acquisition system with sampling rate of 102.4 kHz is used. Multi channel FFT (Fast Fourier Transform) capable of determining the narrow band complex transfer functions from the data acquisition system and further determine the absorption coefficient of the road surface is used. The software also compensated for the amplitude and phase difference between the microphones and for any internal losses in the tube, as required by the Standard.

2.5 MICROPHONES

1/2" Free-Field Pre-polarized Microphone (Make: G.R.A.S, Type: 40AE) were used. These microphone measures the sound pressure which existed before it was placed in the sound field pointing towards the sound source. The disturbing effects of its presence in the sound field are minimal at low frequencies. The sensitivity of the microphone was 50mV/Pa over a range of 3.15Hz to 20 kHz.

2.6 ROAD SURFACE

Three different types of Road surfaces at were considered for the experimental purpose:

1. ISO 10844 Test Surface (Pass-by/Coast-By Test Track)
2. State Highway
3. Concrete Road Surface

2.7 STANDARDS

The test method described in ISO 13472-2 is intended for:

- determination of the sound absorption coefficient of semi-dense to dense road surfaces
- determination of the sound absorption properties of test tracks in accordance with standards such as ISO 10844
- and test surfaces defined in national and international type approval regulations for road vehicles and vehicle tyres
- Verification of the compliance of the sound absorption coefficient of a road surface with design specifications or other requirements.

Although the standard covers the frequency range from 250 Hz to 2500 Hz corresponding to one-third octave bands from 315 Hz through 2kHz centre frequencies, measurements have been made at four different locations as a representative of the pass-by track as per UNECE R117, which are then averaged to give the final value. The sound absorption measurements are made in narrow bands between 400 Hz and 1600 Hz range as specified in UNECE R117. Internal losses of the impedance tube are corrected by measurement of the latent or parasitic absorption of the tube when placed against a smooth, flat steel plate of at least 10 mm thickness.

The method comprises of a sound source which introduces random noise into the impedance tube. The transfer function is measured between two flush-mounted microphones with a known distance between them and at a fixed distance from the pavement.

A test fixture designed to create an acoustically air-tight connection between the impedance tube and the road surface is used along with water soluble modeling clay to improve the seal (Figure 1).

In order to remove any amplitude and phase differences in the microphones a microphone switching method is used. In this method relative amplitude and phase (transfer function) calibration is determined to correct the measured transfer function of the pavement.

2.8 METHOD

Amplitude and phase calibration of the microphones is determined according to the Standard, using a microphone switching procedure, identical to that used in ISO 10534-2. Here a completely acoustic absorbent material (Open ended Foam) is placed at the end of the impedance tube. Transfer functions are measured with the microphones in the standard position (Microphone A is closest to the sound source) and then interchanged (without changing the connections at the DAQ). The ratio of the first transfer function to second gives a complex quantity which is the sensitivity ratio of the two microphones and whose phase is the phase difference between the microphones.

Internal (parasitic) losses of the impedance tube are compensated by measuring the absorption of the tube when placed against the steel plate (Figure 2).

Fig. 1. Impedance Tube Placed Against the Steel Plate

Absorption coefficient are then determined at each of the selected pavement locations by putting the impedance tube against the road surface with the proper sealing with use molding clay to avoid any sound leakage (Figure 3).

Fig. 3. In-situ measurement of road sound absorption coefficient by Impedance Tube

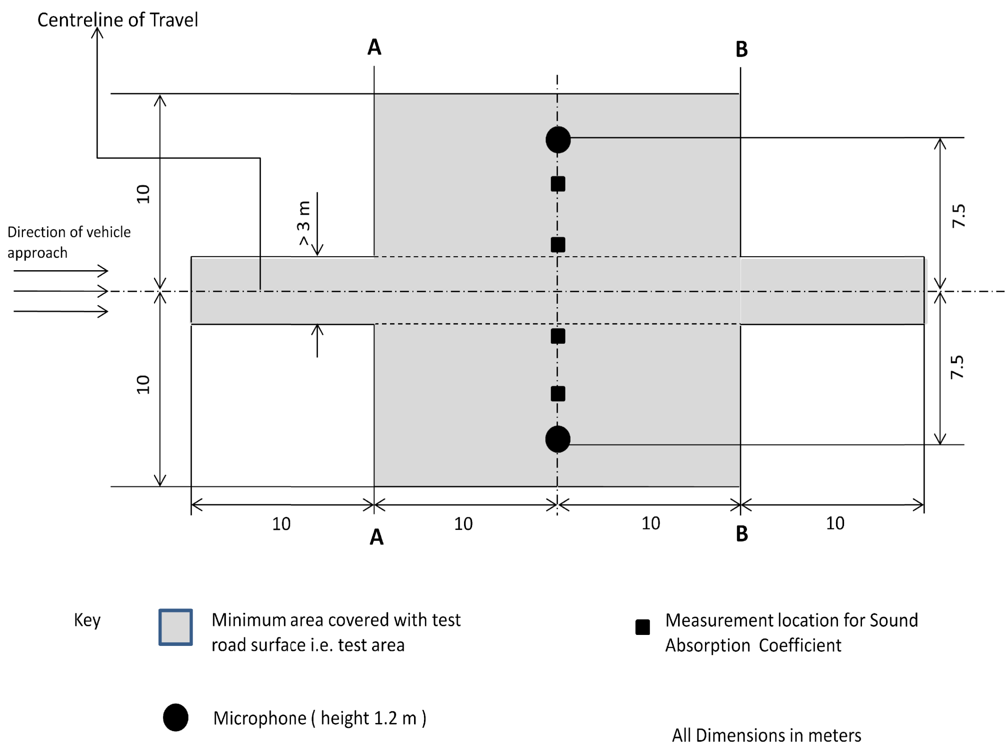

Fig. 4. Sound Absorption Measurement Locations

The parasitic absorption is subtracted from each measurement to determine the final Absorption Coefficient. Sound Absorption measurements were conducted at four different locations as mentioned in UNECE R117 (Figure 4).

2.9 TEST MATRIX

Table 1 shows the test matrix of the proposed tests. Tests were conducted at four locations of the three test surfaces i.e. ISO Test track, State Highway (asphaltic) and State Road (concrete).

Table 1. Sound Absorption Coefficient Measurement Test Matrix

Surface Type	ISO Test Track	State Highway (asphaltic)	State Road (concrete)
No. of Test	4	4	4

3. RESULTS AND DISCUSSION

3.1 SOUND ABSORPTION COEFFICIENT OF ISO 10844 TEST TRACK

ISO 10844 standard compatible test track is used for the vehicle pass-by and coast-by noise test. One of the main criterions for the ISO track is its absorption coefficient values.

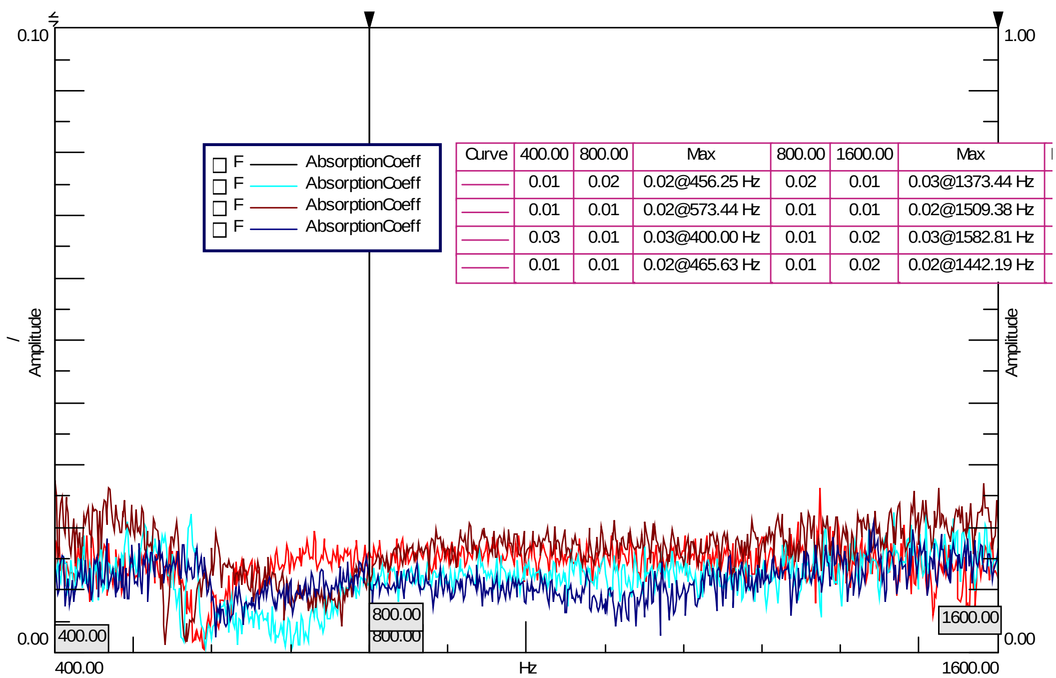

Fig. 5. Sound Absorption Coefficient on ISO Test Track Surface in narrow band Spectrum (400 Hz to 1600 Hz)

As per the UNECE Regulation R117 this requires the values from 400 Hz to 1600 Hz to be measured and averaged for the final value. The maximum value from 400 Hz to 800 Hz and from 800 Hz to 1600 Hz are calculated separately and then averaged to get the final value of Sound Absorption Coefficient. Figure 5 shows the absorption coefficient pattern for the ISO Test Track.

For 400 Hz to 800 Hz frequency range, sound absorption coefficients were found to be in the range between 0.01 to 0.02. For 800 Hz to 1600 Hz frequency range, sound absorption coefficients were found to be in the range between 0.02 to 0.03. Generally higher absorption coefficients were measured between 800Hz to 1600Hz. The average value of sound absorption coefficient for the ISO Test Track was found to be 0.019. The sound absorption values for all the test locations on ISO test Track are substantially below the limit of 0.1 (α) which is one of the most important criterion for the test track specifications among others. Table 2 gives the value of individual reported absorption coefficient for ISO 10844 Test track.

Table 2. Sound Absorption Coefficient Values Measures on ISO 10844 Track (Asphaltic Surface) at four different locations

ISO 10844/ Pass-by/Coast-by Test Track					
Location	**Max. Absorption Coefficient (400 Hz to 800 Hz) (A)**	**Measurement Freq. (Hz)**	**Max. Absorption Coefficient (800 Hz to 1600 Hz) (B)**	**Measurement Freq. (Hz)**	**Average Absorption Coefficient, ((A+B)/2)**
1	0.02	456.25	0.03	1371.44	0.025
2	0.01	573.44	0.02	1509.38	0.015
3	0.01	400.00	0.03	1582.81	0.020
4	0.01	465.63	0.02	1442.19	0.015

3.2 SOUND ABSORPTION COEFFICIENT OF STATE HIGHWAY (ASPHALTIC SURFACE)

Absorption coefficient measurements were performed on a state highway and following value were reported. Four different locations along the width of the road section were selected and sound absorption coefficients were measured. Figure 6 shows the absorption coefficient pattern for the State Highway.

Table 3 gives the value of individual reported absorption coefficient for state highway. For 400 Hz to 800 Hz frequency range, sound absorption coefficients were found to be in the range between 0.009 to 0.01. For 800 Hz to 1600 Hz frequency range, sound absorption coefficients were found to be in the range between 0.008 to 0.01. The average value of sound absorption coefficient for the state highway was found to be 0.009. The sound absorption values for all the test locations on state high way are found to be substantially below the limit of 0.1 (α) which is one of the most important criterion for the test track specifications among others.

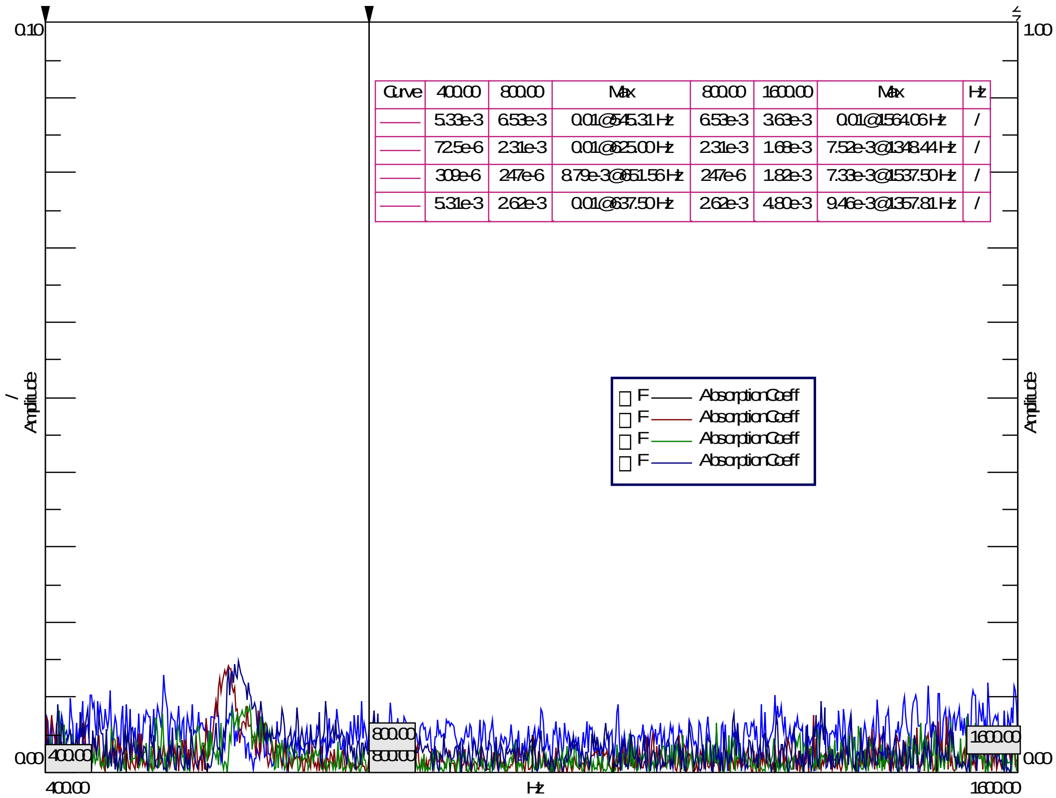

Fig. 6. Sound Absorption Coefficient on State Highway (Asphalt) in narrow band Spectrum (400 Hz to 1600 Hz)

3.3 SOUND ABSORPTION COEFFICIENT OF STATE ROAD (CONCRETE SURFACE)

Absorption coefficient measurements were performed on a state road (Concrete Surface) and following value were reported. Four different locations along the width of the road section were selected and sound absorption coefficients were measured. Figure 7 shows the absorption coefficient pattern for the state road (Concrete Surface).

Table 4 gives the value of individual reported absorption coefficient for Concrete Road Surface. For 400 Hz to 800 Hz frequency range, sound absorption coefficients were found to be in the range between 0.03 to 0.04. For 800 Hz to 1600 Hz frequency range, sound absorption coefficients were found to be in the range between 0.025 to 0.02. The average value of sound absorption coefficient for the Concrete Road Surface was found to be 0.023. The sound absorption values for all the test locations on state high way are found to be substantially below the limit of 0.1 (α) which is one of the most important criterion for the test track specifications among others.

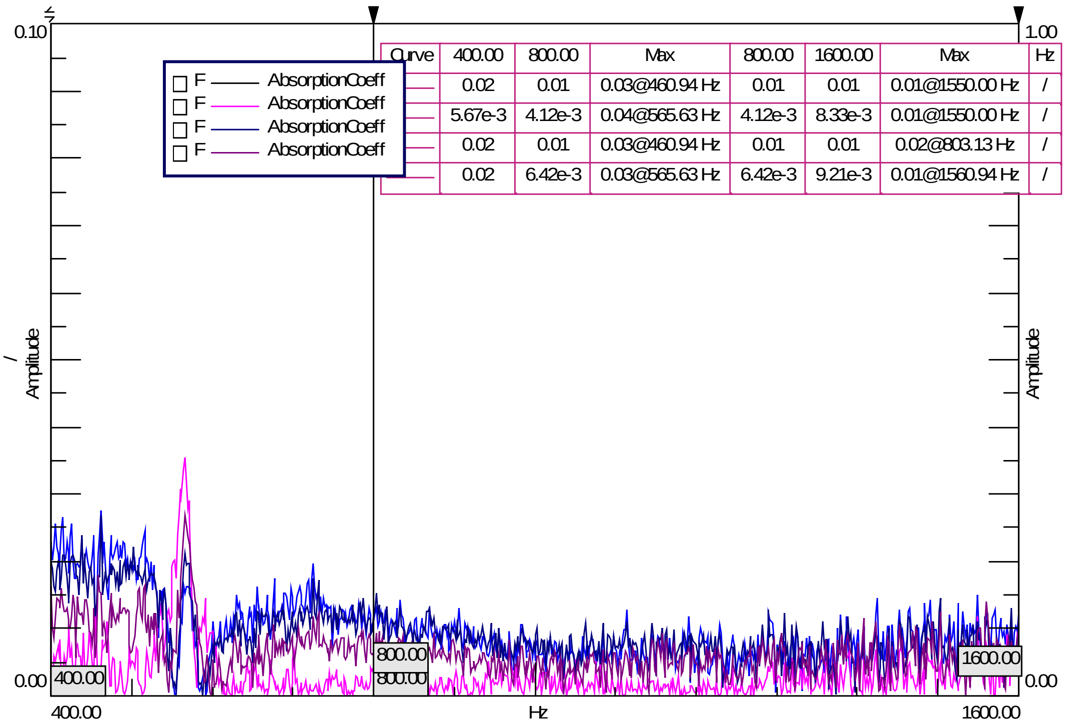

Fig. 7. Sound Absorption Coefficient on Concrete Road Surface in narrow band Spectrum (400 Hz to 1600 Hz)

Table 3. Sound Absorption Coefficient Values Measures on State Highway Road (Asphaltic Surface) at four different locations

State Highway (KMP Highway)					
Location	**Max. Absorption Coefficient (400 Hz to 800 Hz) (A)**	**Measurement Freq. (Hz)**	**Max. Absorption Coefficient (800 Hz to 1600 Hz) (B)**	**Measurement Freq. (Hz)**	**Average Absorption Coefficient, ((A+B)/2)**
1	0.010	545.31	0.010	1564.06	0.0100
2	0.010	625.00	0.007	1348.44	0.0085
3	0.009	651.56	0.007	1537.50	0.0080
4	0.010	637.50	0.009	1357.81	0.0095

Table 4. Sound Absorption Coefficient Values Measures on Concrete Road Surface at four different locations

Concrete Road Surface					
Location	**Max. Absorption Coefficient (400 Hz to 800 Hz) (A)**	**Measurement Freq. (Hz)**	**Max. Absorption Coefficient (800 Hz to 1600 Hz) (B)**	**Measurement Freq. (Hz)**	**Average Absorption Coefficient, ((A+B)/2)**
1	0.03	460.94	0.01	1550.00	0.020
2	0.04	565.63	0.01	1550.00	0.025
3	0.03	460.94	0.02	803.13	0.025
4	0.03	565.63	0.01	1560.94	0.02

3.4 COMPARATIVE RESULTS

Figure 8 shows comparison of average Sound Absorption Coefficients of three different test surfaces. The Sound absorption coefficient on state highway was 52.63% lower than the sound absorption value measured on ISO test track. The average sound absorption coefficient for both asphaltic surfaces was found to be 0.014. It was 39.13% lower than the sound absorption coefficient measured on concrete road surface, which had a value of 0.023. On all test surfaces the coefficient of Sound Absorption was within the minimum requirement set by UNECE Regulation 117 for noise measurement test surfaces.

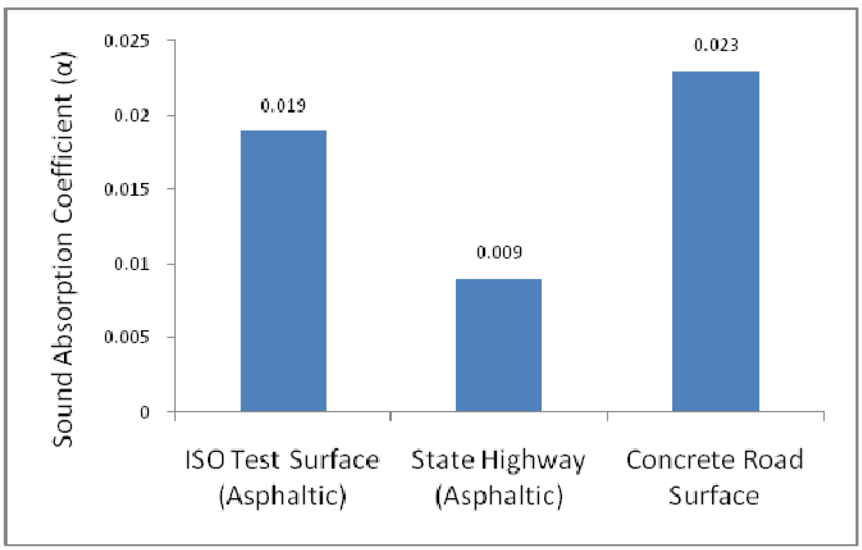

Fig. 8. Comparison of Sound Absorption Coefficients of Three Different Road Surfaces

4. CONCLUSION

- The Sound Absorption Coefficient Measurement were performed on three different road surface according to the method prescribed in ISO 13472-2:2010
- Measurements were made in narrow band spectrum from 400 Hz to 1600 HZ to validate the measurement as per limits provided in UNECE Regulation 117.
- The average Sound absorption coefficient for ISO test track, State Highway Asphaltic Road and Concrete Road surface was found to be 0.019, 0.009 and 0.023 respectively.
- Sound absorption Coefficient on State Highway was 52.63% lower than the value obtained for ISO test Track.
- The average sound absorption coefficient for the asphaltic road surface was 0.014, which was 39.13% lower than the sound absorption coefficient obtained on the concrete road surface.
- All surfaces confirmed to the minimum requirement set by UNECE Regulation 117 of Sound Absorption Coefficient (α) of 0.1.

REFERENCES

Lambert, J. (2000). Report on Noise Exposure of the Population, Health Risk and social welfare costs. In Proc. “Noise in Europe”, Conference, Paris.

Van den Berg, M., et al. (2005). Effectiveness of Noise Measures. RIVM (Dutch Institute for Environment and Health), p.7.

Eelcoden Boer, L.C., Arno Schroten, A. (2007). Traffic Noise Reduction in Europe. CE Delft. Publication code: 07.4451.27 (www.ce.nl): pp 1-70.

Navrud, S. (2002). “The State-Of-The-Art on Economic Valuation of Noise: Final Report to European Commission DG Environment”, Department of Economics and Social Sciences, Agricultural University of Norway.

Hesselborn, Per-Ove. (2010). “Oversyn av forutsattningarna for marginalkostnadsbaserade avgifter i transportsytemet” SIKA Report 2000:10, Swedish Institute for Transport and Communication Analysis, Sweden.

ISO 10534-2, “Acoustics – Determination of Sound Absorption Coefficient and Impedance in Impedance Tubes – Part 2: Transfer-Function Method."

ISO 10844, “Acoustics – Specification of the test track for the purpose of measuring noise emitted by road vehicles”.

ISO/DIS 13742-2 (2010). “Acoustics – measurement of sound absorption properties of road surfaces in-situ – Part-2: Spot method for reflective surfaces”.

Seybert, A.F., Han, J. (2008). Measurement of Pavement Absorption using ISO 13472-2. Acoustics-08, Paris.

UNECE R117. (2007). Uniform Uniform Provisions Concerning The Approval Of Tyres With Regard To Rolling Sound Emissions And To Adhesion On Wet Surfaces.

ISO 10534-1:1996. (1996). Acoustics – Determination of sound absorption coefficient and impedance in impedance tubes – Part 1: Method using standing wave ratio.

Anonymous. (2006). Danish Road Institute, quoted in FEHRL (2006/02), Guidance manual for the implementation of low-noise road surfaces, SILVIA project report.

Berglund, B., Lindvall, T., Schwela, D.H. (1999). Guideline for Community Noise. WHO.