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Measurement of pavement absorption of pass-by tracks based on ISO 13472-2

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ABSTRACT

In this paper a new international standard for the measurement of pavement absorption is reviewed and its implementation using easy to construct hardware, software, and instrumentation is demonstrated. A stand alone measurement system has been designed and tested according to the standard; this system is described in the paper. Test results are shown for a typical asphalt pavement, and suggestions for using the standard in typical applications are also provided.

1. INTRODUCTION AND OVERVIEW OF THE STANDARD

The new international standard ISO 13472-2¹ (hereinafter “Standard”) is intended to guide the measurement of the absorption coefficient of pavements at vehicle pass-by facilities according to ISO 10844.² The procedure is based on the two-microphone method, ISO 10534-2,³ in which a specially-designed impedance tube is oriented vertically above the pavement. Figure 1 is a photo of such an impedance tube taken during a pavement characterization.

The Standard covers the frequency range from 200 Hz to 2000 Hz which corresponds approximately to one-third octave bands from 250 Hz through 1.6 kHz center frequencies. Measurements are made over a set of locations representative of the pass-by track and then averaged; 10 locations are suggested. The sound absorption measurements are made in narrow bands and converted to one-third octave results using simple frequency averaging. Because the Standard is meant to cover only relative smooth, reflective pavements (defined as having an average absorption coefficient less than 0.15), it is necessary to correct for internal losses of the impedance tube. This is done by measurement of the latent or parasitic absorption of the tube when placed against a smooth, flat steel plate with a thickness of at least 10 mm. This reference

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absorption is subtracted from the average of the results of all measurement locations to obtain the pavement absorption.

The absorption measurements are conducted in a manner consistent with the two-microphone method.³ In fact, the underlying theory is the same for both standards. A sound source introduces random noise into the impedance tube, and the transfer function is measured between two flush-mounted microphones a known distance apart and at a fixed distance from the pavement, as seen in Figure 1. For the pavement standard, however, the sample holder used in ISO 10534-2 is replaced by a special test fixture designed to create an acoustically air-tight connection between the impedance tube and the pavement surface. A soft material such as water soluble modeling clay is used between the pavement and the test fixture to improve the seal.

Because the measurement of absorption is based on the two-microphone method, it is not necessary to perform an absolute amplitude calibration of the microphones, nor is it necessary to use so-called “phase-matched” microphones. Instead, a relative amplitude and phase (transfer function) calibration is determined using a microphone switching³ procedure; this calibration is used to correct the measured transfer function of the pavement. In this way, any amplitude and phase differences in the microphones are removed from the measurement.



Figure 1: System for measurement of pavement absorption.

2. DETAILS OF THE TEST HARDWARE

The test apparatus in Figure 1 consists of the acoustic driver, the impedance tube, and the test fixture that rests on the pavement. The acoustic driver is a high quality JBL compression driver with an input capacity of 100 electrical watts. It can produce a continuous sound pressure level exceeding 120 dB inside the tube. A high intensity sound field insures sufficient signal-to-noise levels in virtually any ambient noise situation.

Because the pavement is in general highly reflective, signal-to-noise ratio can be a serious problem at frequencies where the microphone locations correspond to odd multiples of approximately one-quarter of a wavelength; this occurs at a number of frequencies below 2000 Hz. If a cone loudspeaker is used instead of a compression driver, low signal-to-noise ratios at these frequencies may result, thereby increasing the uncertainty of the measurement. The Standard has anticipated this problem when using low-power loudspeakers and recommends that a third microphone be considered, allowing the use of three microphone spacings. In principle, at least, this allows the user to patch together three sets of absorption results to obtain a single set having high signal-to-noise ratio at all frequencies. On the other hand, the use of a high-output compression driver obviates the need for three microphones because sufficient signal-to-noise levels can be obtained at all frequencies using a single pair of microphones.

The Standard requires that the impedance tube be “rigid” and suggests that the wall thickness be five percent of the inside diameter to prevent unwanted loss of sound energy and also to minimize the transmission of sound into the tube from external sources. Some materials are more “rigid” than others; in particular, light-weight materials such as aluminum and plastic should be avoided in favor of a material such as steel which is denser and more highly damped than aluminum. The impedance tube in Figure 1 is constructed of steel and has a wall thickness

approximately seven percent of the inside diameter. This construction results in a theoretical transmission loss of approximately 40 dB at 200 Hz.

The test fixture at the open end of the impedance tube serves two functions: it creates an air-tight seal with the pavement and provides stability via its flanged base to the entire apparatus. Figure 2 shows the details of the surface of the test fixture that is placed in contact with the pavement. This figure also shows the groove into which the sealant material is placed to provide an air-tight seal between the test fixture and the pavement.



Figure 2: Test fixture showing groove and sealant.



Figure 3: Exerting a uniform pressure on the test fixture at a typical measurement position.

A typical sealant is water-soluble modeling clay. Only enough sealant to fully seal between the test fixture and the pavement should be used. If there is too much sealant, the excess will squeeze into the inside of the test fixture and onto the pavement, resulting in a biased result. Some trial and error is necessary to determine the proper amount of sealant. Figure 3 shows one way to place the test fixture on the pavement to obtain uniform results. Before inserting the impedance tube into the test fixture, the user should remove any excess sealant that was squeezed into the area inside the test fixture.

3. Experimental Results

The system shown in Figure 1 was assembled and tested in the field to evaluate the Standard and to develop procedures for its implementation. In this section the use of measurement system will be described, and a typical set of results will be shown. In addition to the hardware in Figure 1, a commercial data acquisition system (DAQ) was used to measure the transfer function between the two microphones at each measurement position. Software was written to read the transfer functions from the DAQ and determine the absorption coefficient at each pavement measurement location. 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.

It is helpful to explain the implementation of the Standard by looking at the screen shot of the software in Figure 4. The first step is to determine the amplitude and phase calibration of the microphones. According to the Standard this is accomplished using a microphone switching procedure, identical to that used in ISO 10534-2.³ In the switching procedure, a sample of acoustically absorbent foam is placed at the end of the impedance tube. A transfer function is measured with the microphones in the standard position (microphone #1 is normally the one closest to the sound source). The microphone positions are then interchanged (without changing

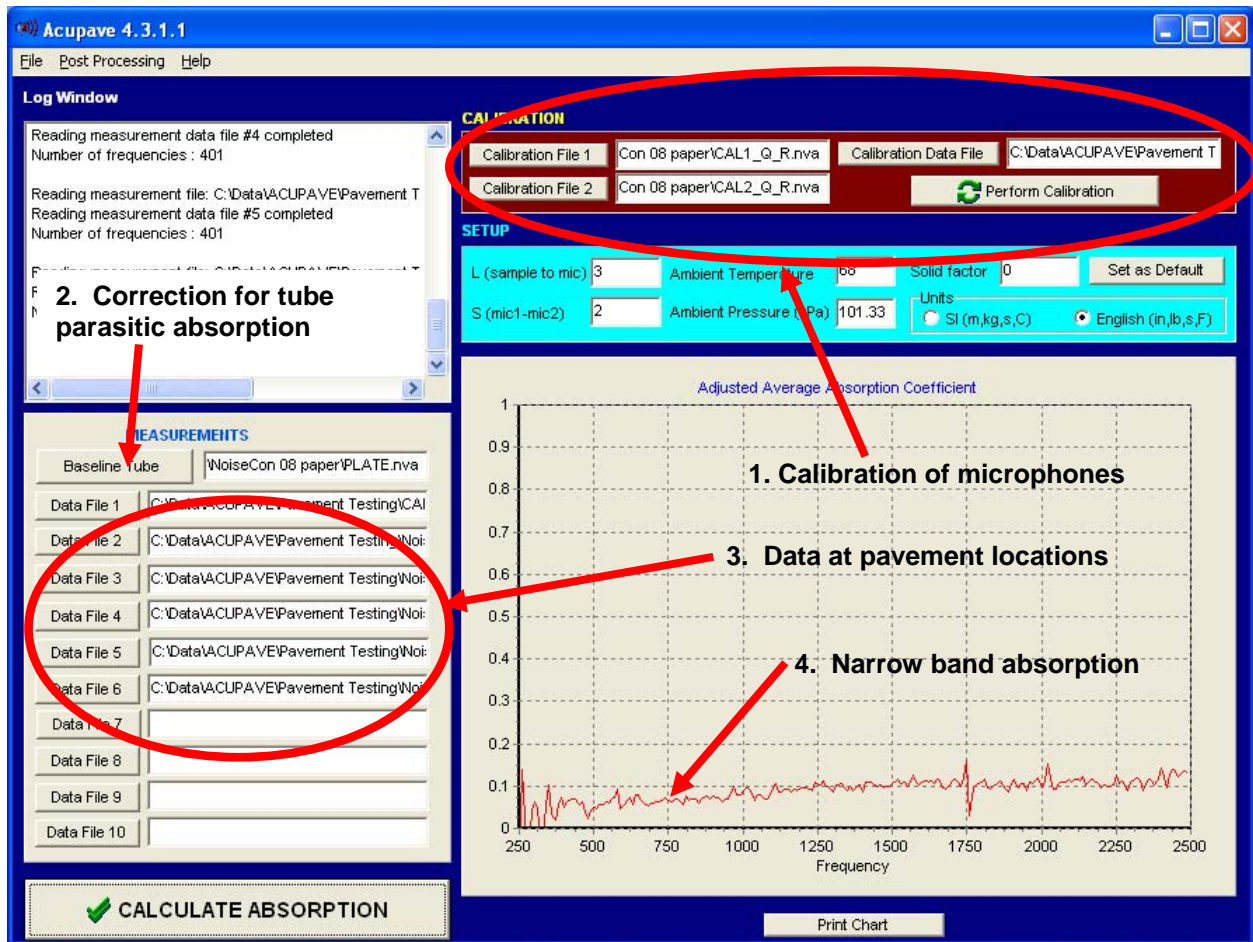


Figure 4: Procedure for measuring pavement absorption.

the connections at the DAQ), and a second transfer function is obtained. The first transfer function is divided by the second; the resultant is a complex quantity whose magnitude is the sensitivity ratio of the two microphones and whose phase is the phase difference between the microphones.

The second step is to compensate for any internal (parasitic) losses of the impedance tube. This is done by measuring the absorption of the tube when it is terminated by a steel plate, as shown in Figure 5. This is an important step because the pavement absorption is typically less than approximately 0.1 and the parasitic absorption can be as high as 0.03.

The third step is to determine the absorption coefficient at each of the selected pavement locations. These are averaged and the parasitic absorption is subtracted to determine the *Adjusted Average Absorption Coefficient*, shown on the graph in Figure 4.



Figure 5: Measurement of tube parasitic absorption.

The Standard allows the reporting of the pavement absorption in narrow bands, as shown in Figure 4, or in one-third bands from 250 Hz to 1.6 kHz center frequencies. The one-third octave band values are obtained by a linear frequency average of the narrow band absorption values, allowing for negative values (negatives will almost always occur because the pavement absorption is very small, typically). If a one-third octave value is negative, the absorption coefficient is reported as zero, according to the Standard. Figure 6 shows the additional processing of the narrow band absorption data in Figure 4 to obtain the one-third octave values.

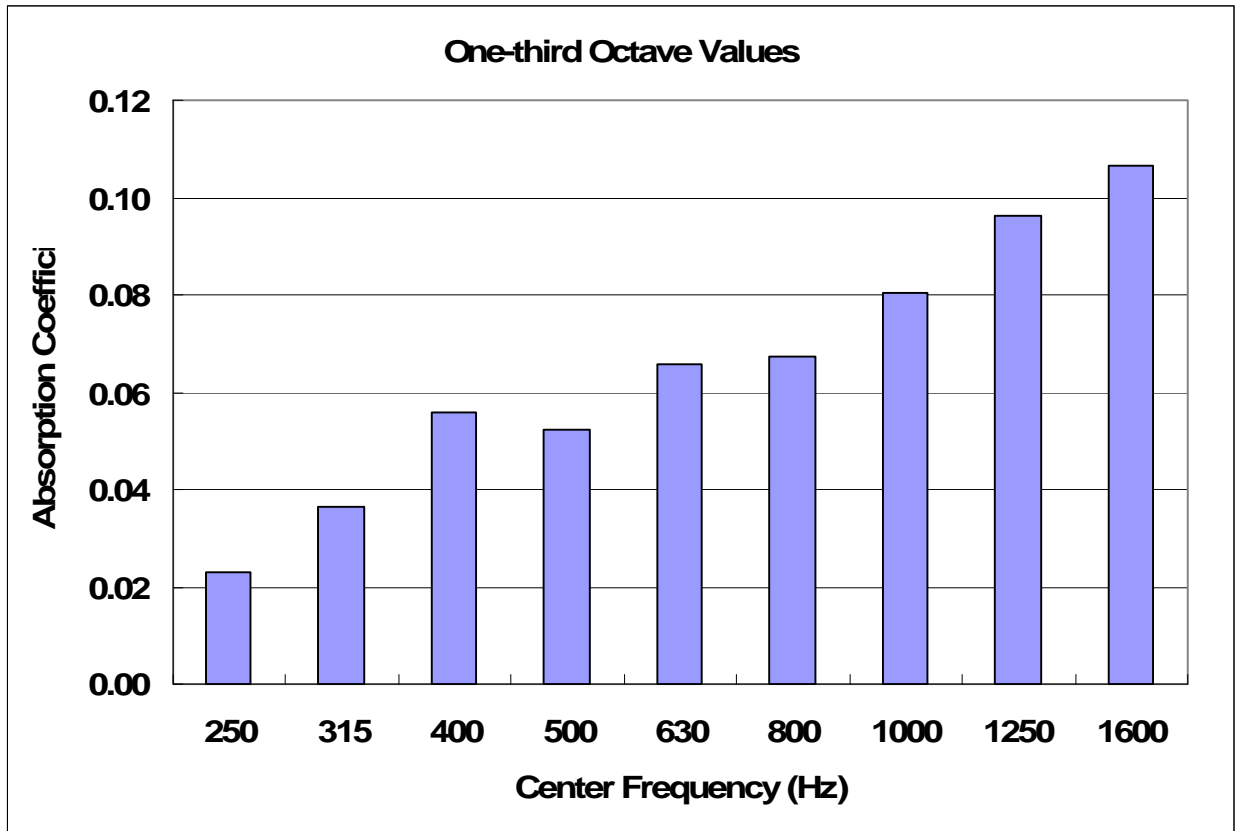


Figure 6: Absorption Coefficient in one-third octave bands.

4. Summary and Conclusions

ISO 13472-2, the new international standard for the measurement of pavement absorption may be used for the qualification of pass-by test facilities and for general pavement measurements. In this paper the new standard has been reviewed and demonstrated for a typical series of pavement measurements.

Although not discussed above, portability is important as many pavement absorption measurements must be made where there is no AC power. Figure 7 shows a portable, stand-alone pavement absorption measurement system that consists of the hardware, described above, a USB-powered data acquisition system, and software running on a laptop. Even without power amplification, the system achieves high signal-to-noise ratio due to the impedance tube's relatively high mass and wall thickness. The entire system can be assembled for a few thousand US dollars or is available commercially (www.spectronics.NET).



Figure 7: Stand alone system for pavement absorption measurement.

REFERENCES

¹ISO 13472-2, “Acoustics – measurement of sound absorption properties of road surfaces *in situ* – Part 2: Spot method for reflective surfaces.”

²ISO 10844, “Acoustics – Specification of test tracks for the purpose of measuring noise emitted by road vehicles.”

³ISO 10534-2:1998, “Acoustics – Determination of the sound absorption coefficient and impedance in impedance tubes – Part 2: Transfer-function method.”