International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Online International Journal Available at http://www.cibtech.org/jet.htm
2012 Vol. 2 (2) April-June, pp.49-55/Akhtar et al.
Research Article

REFLECTION AND ABSORPTION OF SOUND, IN DIFFERENT TYPES OF ROAD SURFACE - USING MICROFLOWN SURFACE IMPEDANCE METER

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ABSTRACT
To find the reflection and absorption in different types of pavements i.e. rigid pavement surface and flexible pavement surface, it was necessary to monitor the in-situ test on existing road. For this, microflown surface impedance meter PU probe (based on sound pressure and particle velocity movement) was used. It was found that in flexible pavement surface noise absorption is more and reflection is less as compared to rigid pavement surface.

Key Word: *Reflection, Absorption, Rigid Pavement, Flexible Pavement, Surface Impedance Meter*

INTRODUCTION
Microflown, PU probe is the best method to measure the noise source as compared to microphone. It is a fact that very few studies have been done in the past to find the noise absorption and reflection in different types of road surface. Daniel and Jacobsen, (2008) in their study used an initial model of the unknown impedance to simulate a measurement which is then compared with a real measurement (Schedlinski *et al*., 2008). In another study by Hirosawa, (2008) two-microphone method and two particle velocities method were compared in regard to in-situ measurement technique of normal absorption coefficient. They had found that PU-method is more stable against the influence of the edge effect than other methods, against original expectation (Tijs and Bree, 2009). A modeling strategy for damping and absorption is presented that is based on computational optimization and model updating techniques. For the structural part, individual structural damping is assigned to the individual components and subsequently updated utilizing test data obtained from classical modal analysis testing (Tijs, 2010) by Schedlinski *et al*., (2008). In a study in Netherlands, Tijs and Bree, (2009) used PU surface impedance method, measuring in situ both sound pressure and acoustic particle velocity, be applied to measure the road surface impedance in a laboratory environment, but also outdoors in different speed on completed roads. The main advantage compared to other methods, is that it does not require the sample to be cut out and it has a low susceptibility to background noise (Brandão *et al*., 2011). Tijs, (2010) find that the spatial accuracy of the measurement was examined and a visualization technique were presented with a display of the spatial distribution (2D picture) of the damping properties as function of frequency (Daniel and Jacobsen, 2008). In a different study by Brandao *et al*., (2011), three methods q-term, F-term and PWA, are compared mainly for small sound-source to sensor distances and it was seen that they tend to converge as this distance increase. This comparison was relevant to *in situ* impedance measurements, since a bad choice of the calculation method may lead to a poor result (Hirosawa, 2008).

METHODS
Surface Impedance and Absorption Coefficient Calculation Methods
The methods calculate the surface impedance (Z) with the specific impedance measured at the receiver position (Zm). The absorption coefficient is related to the normalized surface impedance in equation,

$$\alpha = 1 - \left| \frac{Z-1}{Z+1} \right|^2 .$$

Noise measure with a standard microphone will not only measure the source but also all the background noises and reflections while the microflown does only measure the source and not the background noises and reflections, due to difference in polar response of sound pressure and particle velocity. Sound pressure, it has an omni-directional response while Particle velocity is a vector and so is directional.

Impedance Model

Plane wave

The simplest possible model assumes that the material under test is exposed to a plane wave of normal incidence which gives rise to a reflected plane wave. The normalized specific impedance at a position at a distance of *h* from the material flows from simple plane wave is given by:

$$Z = \frac{1+R}{1-R} .$$

Mirror source

A slightly more complicated model combines the concept of an image source with the plane wave reflection factor. The plane-wave reflection factor depends only on the impedance of the material.

$$Z = \frac{1+R}{1-R} \frac{jkh_s}{jkh_s+1} .$$

Q term

The reflection involves the spherical reflection coefficient *Q* unless the source is unrealistically far from the surface. For incidence Laplace transform formulation for the calculation of *Q* becomes:

$$Q(Z,h,h_s) = 1 - \frac{2k}{Z} \frac{h_s+h}{e^{-jk(h_s+h)}} \int_0^\infty e^{-q\frac{k}{Z}} \frac{e^{-jk(h_s+h-jq)}}{h_s+h-jq} \mathrm{d}q .$$

The spherical reflection factor *Q* depends on the unknown impedance of the material *Z* in a much more complicated manner than the plane wave reflection factor *R*; and it also depends on *h* and *hs*. The impedance is given by:

$$Z_{k+1} = Z_k - \frac{Z_k - Z_{k-1}}{f(Z_k) - f(Z_{k-1})} f(Z_k), k = 0,1,2,\ldots$$

Study Area

For this study, concrete (rigid) road surface and black top (flexible) road surface were selected in Rohini-Delhi, Noida-UP. Instruments, Microflown Surface Impedance meter and software Si++ were used for this finding. For every measurement mode, a fixed sound was released by surface impedance meter toward the road surface in calibration mode till 6 second. After completion of calibration mode, the instrument is put in actual measurement mode and the sound is released till 6 second for absorption and reflection of road surface.

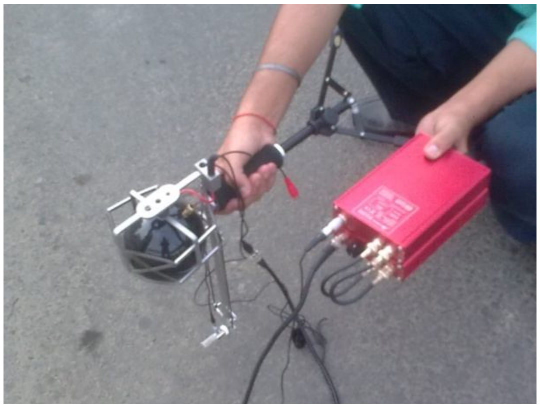
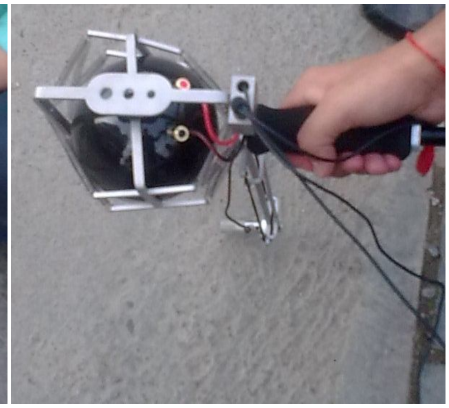

Figure 1: In-situ measurement in flexible pavement; Figure 2: In situ measurement in rigid pavement

RESULTS AND DISCUSSION:

Figure numbers 1, 3, 5, 7 shows the values of rigid pavement, while fig. No. 2,4,6,8 shows the values of flexible pavement**.** In Fig. 1 & 2; noise absorption at frequency 10^4 (Hz) is nearly 70 dB(A) in rigid pavement while it is 90 dB(A) in flexible pavement. There is 20 dB(A) more noise absorption in Flexible pavement as compared to rigid pavement. Amplitude (v) varies +2.0 to -2.0 in rigid pavement while it is +8.0 to -4.0 in flexible pavement. Absorbing coefficient of rigid pavement is almost zero, while it is -6.0 to +1.5 in flexible pavement. Coherence in rigid pavement is increasing till 10^3 (Hz) frequency and then flat; while in flexible pavement it is continuously changing from 10^2 till 10^3 (Hz) frequency and then is flat till 10^4 (Hz).

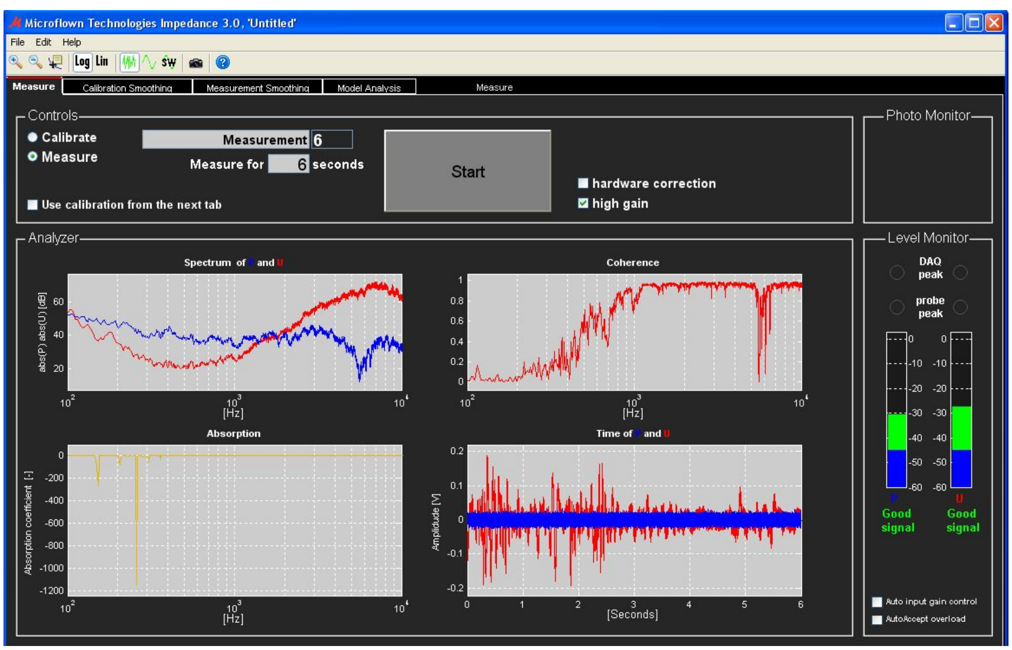

Figure 3: Spectrum of P&U, Coherence, Absorption and Time of P&U in rigid pavement surface

Figure 4: Spectrum of P&U, Coherence, Absorption and Time of P&U in flexible pavement

In figure 4 &5 absorption in P(pressure-sensor) & U (particle velocity-sensor) are different in the same pavement, it is shows downward trend between 10^2 to 10^3 (Hz) frequency and after that trend the is upward till 10^4 (Hz) frequency.

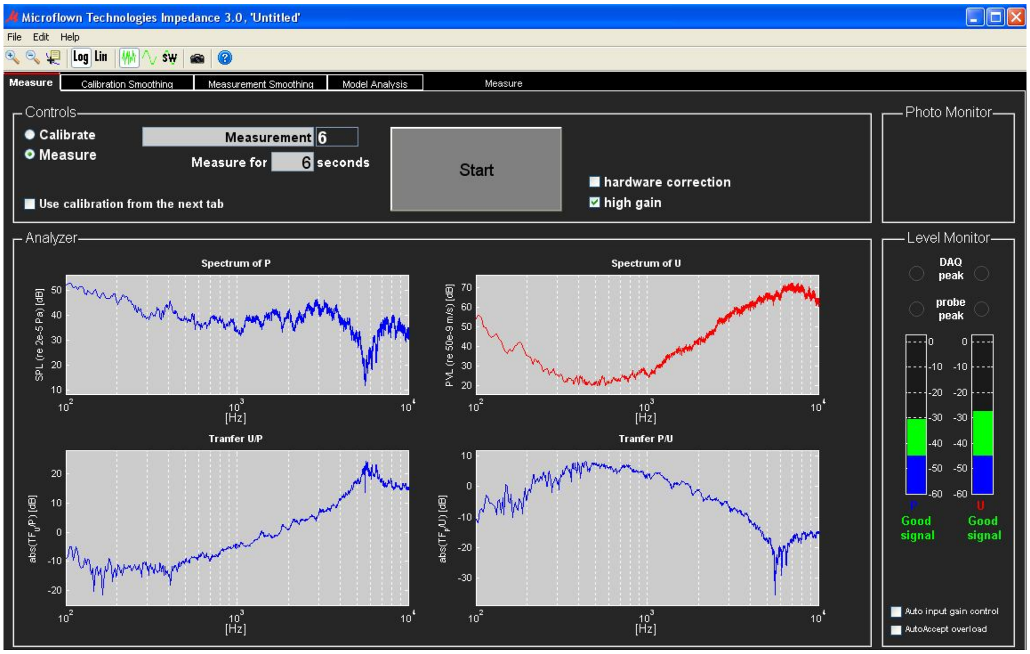

Figure 5: Spectrum of P, Spectrum of U, Tranfer U/P and Tranfer P/U in Rigid Pavement

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Figure 6: Spectrum of P, Spectrum of U, Tranfer U/P and Tranfer P/U in Flexible Pavement

In figures 5 & 6 real parts of Impedance, imaginary part of Impedance, impedance magnitude and phase of impedance in both types of pavement have been clearly differentiated. Phase of impedance in rigid pavement at low frequency 10^2 to 10^3 (Hz) is showing too many fluctuations, while in flexible pavement there are minor fluctuations.

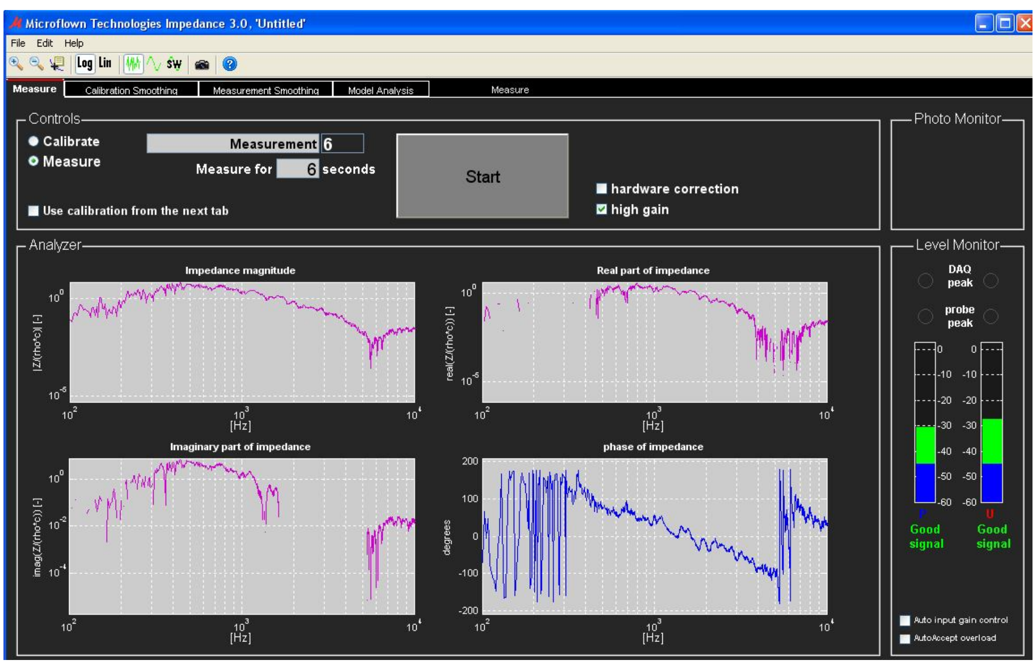

Figure 7: Impedance magnitude, Real part of Impedance, Imaginary part of Impedance and Phase of Impedance in Rigid Pavement

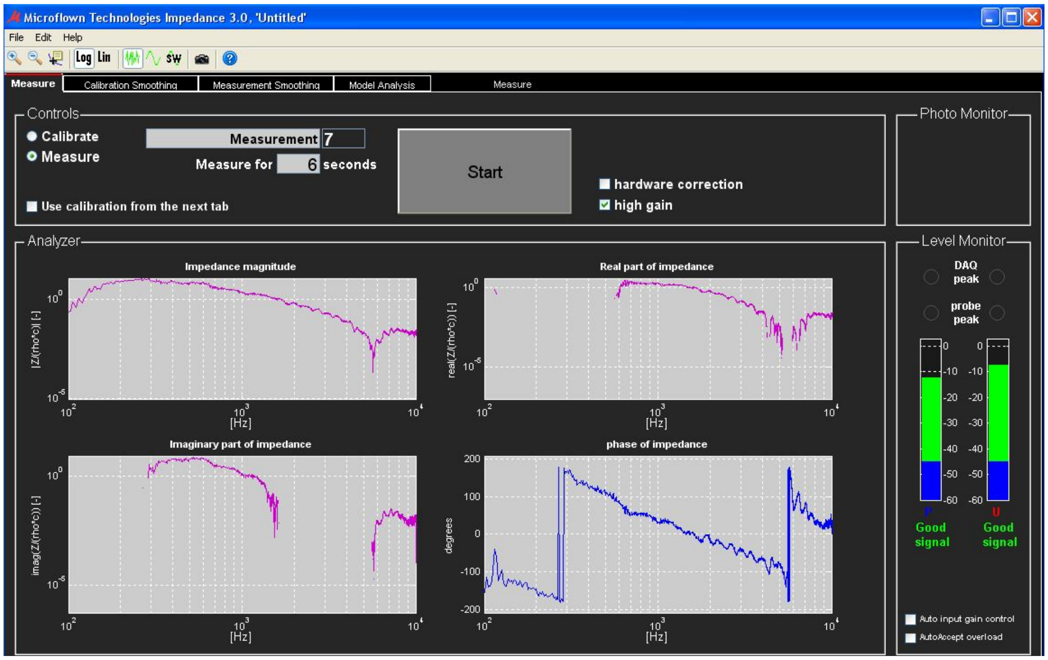

Figure 8: Impedance magnitude, Real part of Impedance, Imaginary part of Impedance and Phase of Impedance in Flexible Pavement

In figures 8 & 9 absorption measured by P(pressure-sensor) & U (particle velocity-sensor) at low frequencies 10^2 to 10^3 (Hz) in rigid pavement is 40 dB (A)& is 20 dB (A) respectively. But absorption at high frequencies 10^3 (Hz) to 10^4 (Hz) is 10 dB (A)& U is 70 dB (A)respectively. In flexible pavement at low frequency 10^2 to 10^3 (Hz) the absorption measured by p is 60 dB (A), & U is 40 dB (A), and at high frequency 10^3 (Hz) to 10^4 (Hz) it is 45 dB (A) and is 95 dB (A) respectively.

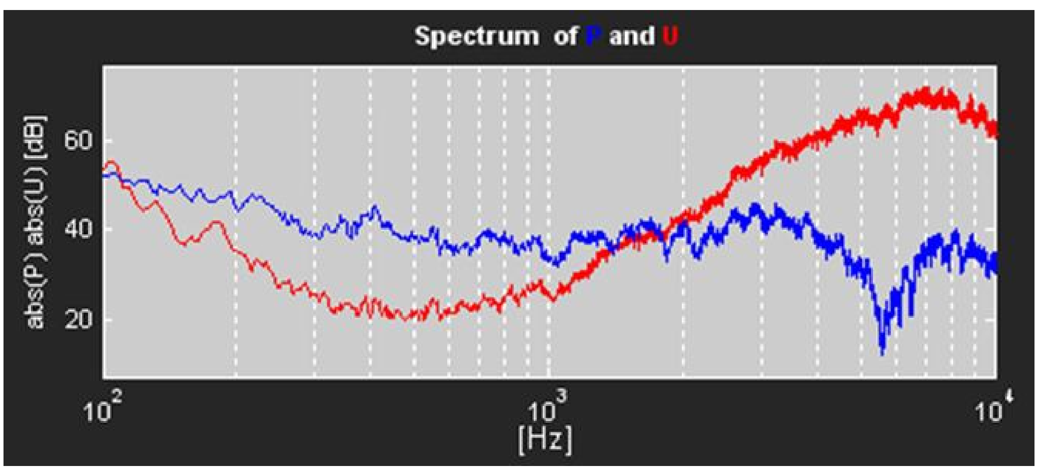

Figure 9: Spectrum of P & U in Rigid Pavement

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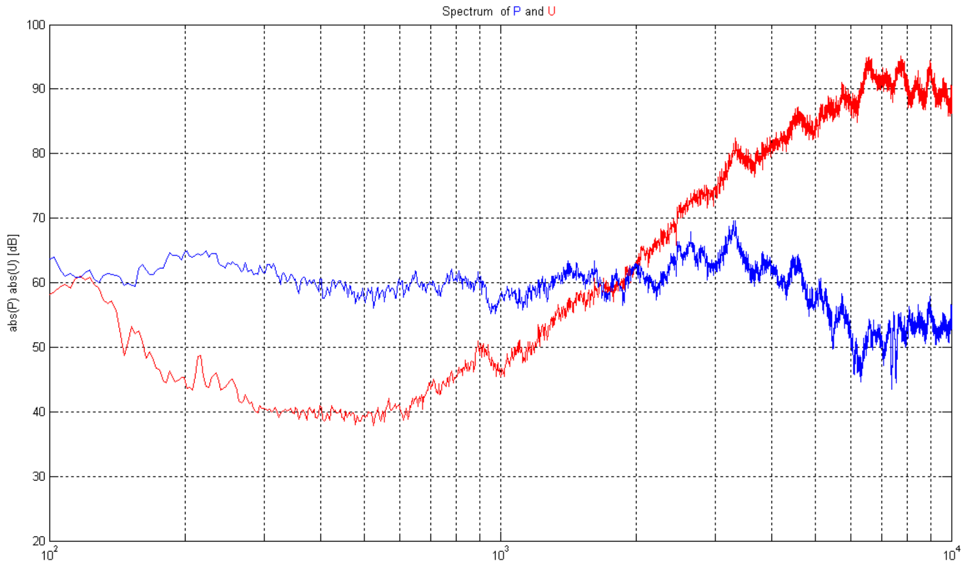

Figure 10: Spectrum of P & U in Flexible Pavement

CONCLUSIONS
It is clear from the study that flexible pavement surface absorbed more noise as compared to rigid pavement surface. Reflection is more in rigid pavement surface in comparison with flexible pavement surface. Noise absorption measured by P (pressure-sensor) & U (particle velocity-sensor) is different in same pavement. Pressure- sensor shows less variation in both types of pavements, while particle velocity-sensor shows downward trend till 10^3 (Hz) frequencies and upward trend till 10^4 (Hz) frequency. Hence, particle velocity sensor U, gives better result as compared to pressure- sensor P.

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