A METHOD FOR MEASURING THE DYNAMIC REFLECTION AND ABSORPTION OF CONCRETE WALLS USING A MICROCONTROLLER

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ABSTRACT

This research presents a method of the dynamic measurement of the reflection and acoustic absorption of the concrete walls, using the Arduino UNO R3 Version 1.5.8 microcontroller and noise level analysis. The result is displayed in the decibel level by using the sound signal within the frequency range from 20 to 20,000 Hz, and the volume of 0 to 130 decibels are employed to measure the absorption, reflection and transmission of the tested wall. Before the calculation, the viewing reflection coefficient and loss of passage of concrete wall was investigated. The result obtained has shown that the viewing coefficient is 0.75 - 1.0, the reflection coefficient is 0 - 0.5, and the loss of concrete wall transmission is 3.5 - 20 decibels. The system error have a value of 2.497%. In application, the proposed method can be applied to the measurement of the absorption coefficient and the transmission of sound signals in the various forms. The deterioration of the sound insulation and the loss of sound transmission of different types of walls can also be measured and investigated. The coefficient affects the change in the condition of the concrete walls, from the rate of deterioration of the surface of a concrete wall. This design of the concrete wall is suitable for housing condition design and implementation.

KEYWORDS: Reflection, Absorption Transmission coefficient and Microcontrollers

1. Introduction

Thailand has a competitive edge in technology transportation and competition in the economy will bring competition in all aspects. The current building is the high-risen building because the land price is high. To build a dwelling house, it is necessary to find materials that are cost-effective and save the most resources. In the rapid expansion, as a result, brings about many problems such as air pollution, soil, water and noise pollution according to statistics from the Situation Report on Disability in Thailand in March 2016, with there were 278,550 people, the hearing impaired in 2016, second only to the physical disability. The cause is found most in urban in urban communities in industries or homes near the source of the noise. It usually happens to people aged 20- 60 years, who in this age is in the development of the nation. Noise has a significant effect on quality of life. There is a need for a standard of sound control in the building [1, 2] and vibration and interference standards [3]. Various research studies have made on sound effects such as sound barrier performance evaluation [4]. Physical properties and efficiency of sound attenuation. [5].Fourier transform methods for measuring sound reflectance coefficients at different slope rates and method of testing acoustic impedance in rectangular ducts [6-8]. The examination of sound mechanism for sheet in mouth pipe [9] independent magnetic field impedance measurement and absorption coefficient sound-absorbing materials with total particle velocity sensor [10], porous porosity of porous concrete by considering the gradient and aggregate shape and loss ratio [11]. The critical tone of reinforced cement concrete and asphalt concrete [12], the application of sound waves to the industry that is link to the construction schedule, such as the proper construction of the ultrasonic. In order to increase the density of the acoustic wave process by mathematical and computer methods [13], it is necessary to develop research into the community. Reduce costs and increase productivity and income to the community. Find new innovations to solve problems especially in concrete walls that are used as a popular material to easy and no expansive, which lack of research interests in measuring, reflecting, absorbing, and transmitting sound dynamically. This issue is expected to be beneficial to the quality control of building materials and materials that affect many people.

This research aims to develop a model for measuring the acoustic absorption of acoustic waves with dynamic concrete walls for the reflection coefficient, the absorption coefficient and sound transmission, the transmission coefficients for different wall surface were used by the microcontrollers to help process and store real-time data logger. The second part of this article will explain how to and equipment used in research to record the data of the acoustic absorption of sound waves to the wall. The results of these measurements are show in the third section. The results of the experiments show the relationship between reflection, absorption and transmission of sound is in the fourth part. In the final part is a summary and end result.

2. Materials and Methods

2.1 Used equipment in research

2.1.1 Sound Level Meter

2.1.2 Measuring Instruments Sound Absorption and transmission by the microcontroller.

2.1.3 Concrete wall 2 x 2 x 2 meters

2.1.4 The oscilloscope 1 unit

Figure 1 Digicon DS-42 sound meter

Figure 2 The concrete walls used in experimental preparation 2 x 2 meters.

2.2 Method of experiment

In Figure 3 the operation of the acoustic meter for measure the absorption and transmission of noise by the microcontroller when connected to the USB port to the battery.

The direct current to the Arduino microcontroller series and transmitted to the sound sensor 1, sound sensor 2 and sound sensor 3 will detect the sound signal [14] sent from the sound source. A sound sensor 1 will receive audio from audio source from speakers and amplifiers with a single frequency of 8 kHz at a noise of 90 decibels set by the Digicon DS-42 standard. The second sound sensor will collect the signal. The sound of the sound from the concrete wall and sound sensor 3 will measure the sound of the sound through the concrete wall to the opposite side of the sound source. The value will be sent to the Arduino R3 microcontroller operating for processing. The result is displayed on the LCD screen, which displays 4 rows of 16 characters. The data is stored dynamically in the data logger by SD-card capacity is 32 Gbyte. The charger circuit is used if the battery is depleted, it will be charged immediately by the automatic battery charger circuit. This system have a backup battery for 2 hours and can be used with 220V AC power, which details the equipment shown in Figure 4.

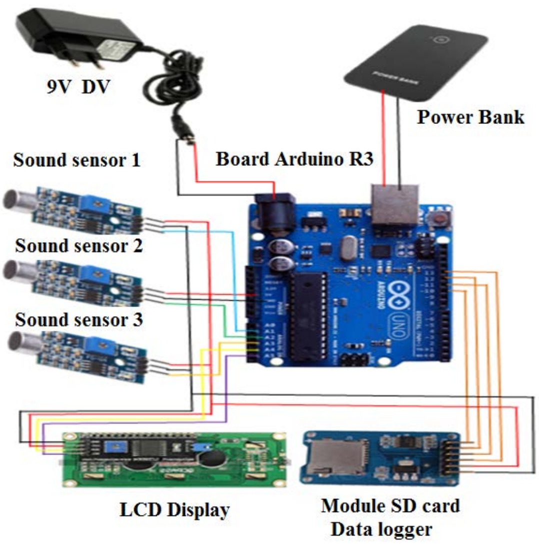

Figure 3 The diagram and equipment of the sound level meter.

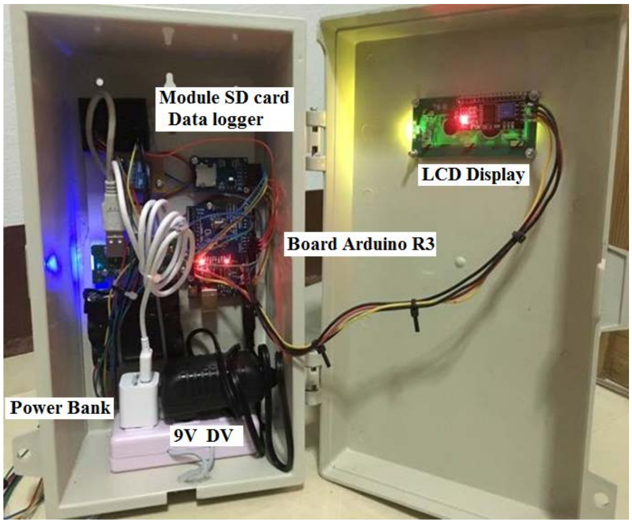

Figure 4 The Instruments and sensors used in measuring instruments.

Test of sound level measurement of sensor 1 against standard instrument by distance of sound source 1 meter. The percentage error can be found by the equation (1) [1].

$$\%\ error = \left|\frac{Y_n - X_n}{Y_n}\right| x\ 100\ \% \tag{1}$$

where $\%\ error$ is the percentage error.

Y_n is the true value of the measurement.

X_n is the readable value of the measure.

The percentage error is the measurement deviation in percent. Y_n is the value measured by the Digicon DS-42. The decibel X_n is the value measured by the sound sensor device. The microcontroller unit is a decibel.

Table 1 Error detection, standard sound and dynamic sound level meter.

Time	Sound level used in the test (dB)	Measured volume (dB)			Percentage error (%)			percent average Error $\sum \overline{X}$ (%)
		S_1	S_2	S_3	S_1	S_2	S_3	
1	90	87.75	87.75	87.73	2.50	2.50	2.53	2.50
2	90	87.75	87.76	87.74	2.50	2.48	2.51	2.49
3	90	87.75	87.75	87.75	2.50	2.50	2.50	2.50
4	90	87.74	87.75	87.75	2.51	2.50	2.50	2.50
5	90	87.75	87.75	87.75	2.50	2.50	2.50	2.50
6	90	87.76	87.75	87.74	2.48	2.50	2.51	2.49
7	90	87.75	87.74	87.74	2.50	2.51	2.51	2.50
8	90	87.76	87.75	87.75	2.48	2.50	2.50	2.49
9	90	87.75	87.75	87.75	2.50	2.50	2.50	2.50
10	90	87.75	87.75	87.75	2.50	2.50	2.50	2.50
Average error value (Σ % error)								2.497

In the table 1, the distance from the sound source used to test the sound is 1 meter, the three sensors are 1 meter and the standard volume is 90 dB. The result of the table can be concluded that the total form 10 experiments. The error rate for standard measuring instruments is 2.497%

2.3 Calculation and analysis of data

2.3.1 The speed of sound

In general, the temperature also affects the oscillation of the medium, so the speed of sound in one medium is different at a certain temperature. The relative speed of the sound is given by equation (2)

$$V = 331 + 0.6 \cdot T \tag{2}$$

where V is the speed of sound is meters per second (m/s).

T is the temperature is in degrees Celsius. (C°)

2.3.2 Sound intensity level

In addition to hearing 20 - 20,000 Hz frequency can also hear the sound intensity in the range 10^{-12} W/m^2 to 1W/m^2. The intensity of the sound is decibels β and the abbreviation dB is derived from the fact that use a logarithmic scale [2].

$$\beta = 10 \log \frac{I}{I_0} \tag{3}$$

where β is the intensity of the sound is in decibels (dB).

I is the lowest sound intensity that a human can hear is that the sound intensity level starts from 0 dB -120 dB.

I_0 is equal to P/A or sound power per unit area, while the sound power P is energy E per unit time and $P = E/t$.

Hearing noise level greater than 120 dB will cause hearing to change into eardrum pain. The eardrum is broken at 160 dB. The change in the sound level of each 10 dB is equal to the change in sound intensity to 10 times.

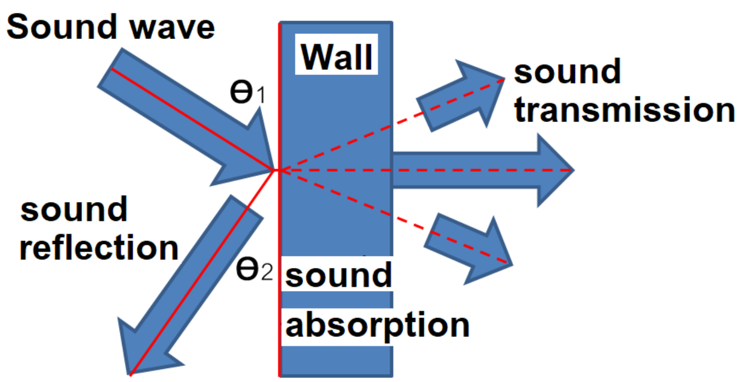

Figure 5 The sound reflection, sound absorption and sound transmission to the wall.

The equation for reflection sound absorption and sound transmission

Absorption coefficient (α) is the ability to absorb sound of an object which can be explained by the sound absorption coefficient. It depends on the energy of the impact and the absorption of the object can be calculated from the equation (4) [5].

$$\alpha = 1 - |T|^2 \tag{4}$$

where α is sound absorption coefficient

T is sound reflection coefficient

The reflection coefficient can be calculated from equation (5) [5].

$$|T| = \frac{[SWR-1]}{[SWR+1]} \tag{5}$$

SWR is Standing wave ratio, the difference between maximum compression and the maximum amplification of the noise inside the *Vmax / Vmin* impedance fluorescence, which is a phenomenon that occurs in accordance with the principle of noise interference. The sound insulation value of the structure is measure as the quantity called. Sound transmission loss (TL), which refers to the amount of decibels of sound energy lost when transmitted through the structure. The American Society for Testing and Material (ASTM) E*90-70*T standard loss of sound transmission capability can written as follows. [15]

$$TL = 10log\left(\frac{W1}{W2}\right) \tag{6}$$

where TL is the loss of sound transmission of a wall, floor, ceiling is in decibels (dB)

W1 is the sound power that hits the wall.

W2 is the sound power transmitted through the wall.

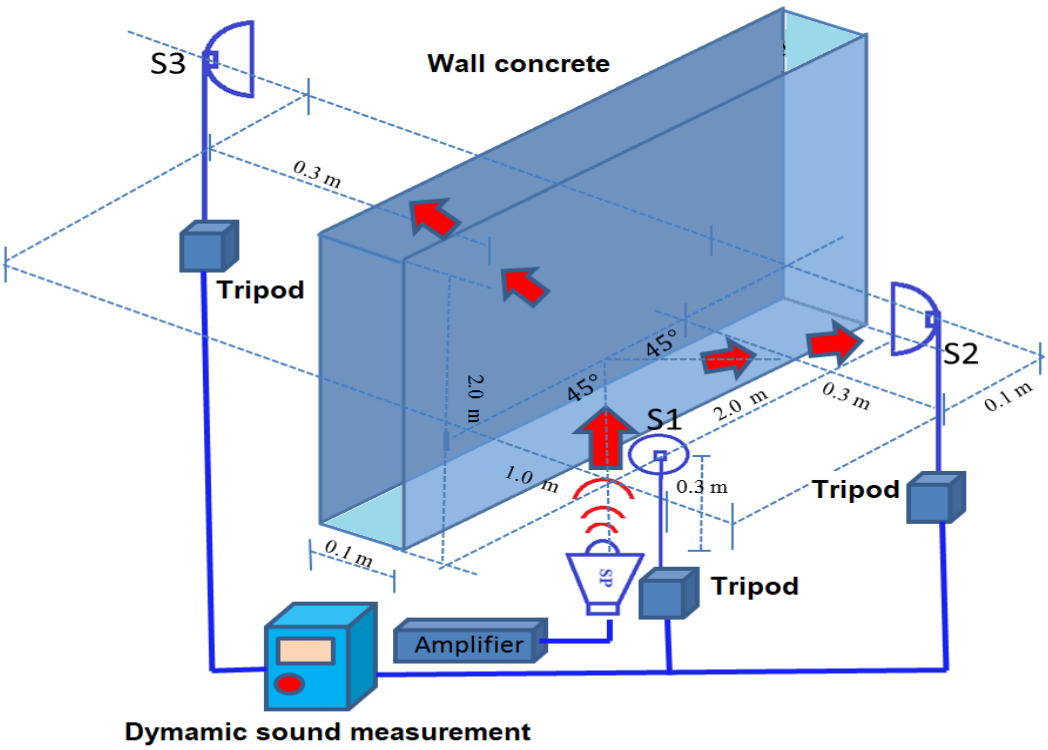

Figure 6 The measurement of resonance and sound transmission in concrete walls.

From the figure 2, the principle of operation and measurement is that when sound from a sound source of 96.0 dB is record from the sound source. Bring the sound signal through the amplifier and speaker so that it can repeatedly tested. Sensor 1 (S1) measures the sound coming into the concrete wall at a 45 degree angle in the direction of the arrow. The sound is reflected from the concrete wall in a 45 degree angle, and we can measure the acoustical noise from the concrete wall in sensor 2 (S2) and sensor 3 (S3). Measure sound signals that are transmitted from the installed concrete wall opposite each other. All three signals from the sensor will be recorded to the SD card by a dynamic acoustic sensor.

3. Result

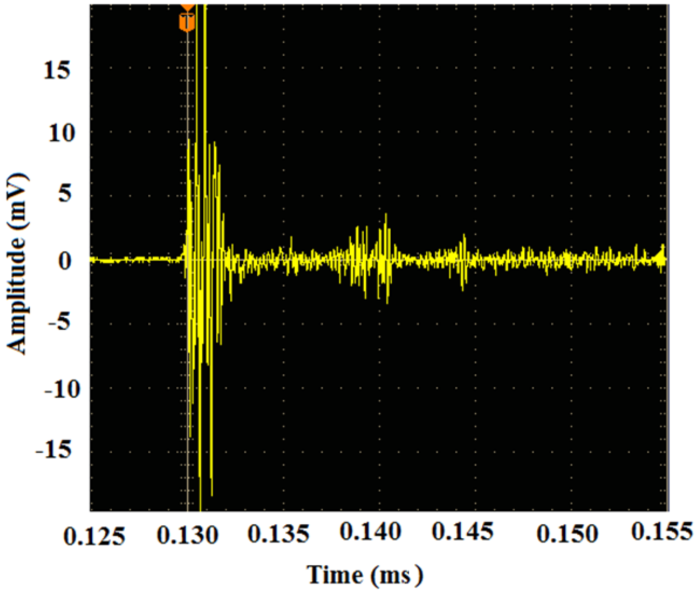

Figure 7 0.22 mm gun at 96.0 decibels.

Figure 7 shows a sound volume of 96.0 decibels, measured by the Digicon DS-42, and can be recorded by a voice recorder and amplified for testing the measured frequency of 8.0 kHz and the peak to peak voltage is 40 mVp-p measured by Tektonix oscilloscope TBS172B-EDU.

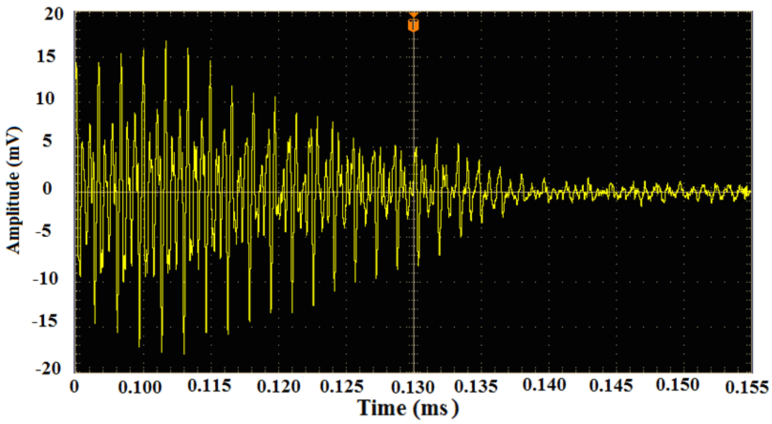

Figure 8 A measured from sensor 1.

In the figure 8 show measurement of the magnitude of the sound level measured from the first sensor device, that receives a direct signal from a 30 cm long source of sound at a frequency of 7.14 kHz at a time interval of 0 - 0.14 ms. The velocity of the air in the air is about 343 m/s, consistent with equation (2) and the velocity of the concrete is 3,100 m/s. The purpose of the measurement of the tracking oscillator of oscilloscope at 34 mV and figure 9 is a measurement of the signal caused by the reflection of sound from a concrete wall, in which the experiments can read the signal 2 mVp-p means the image. There are very few reflections from concrete walls, so the sound absorption is good in concrete wall.

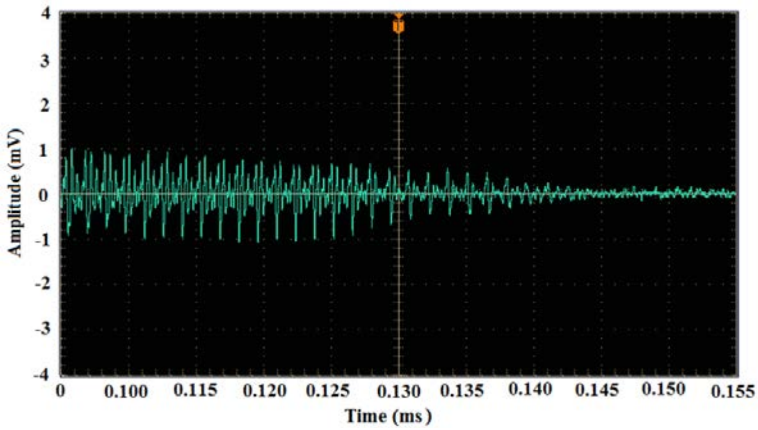

Figure 9 The measured signal from the second sensor reflecting the concrete wall.

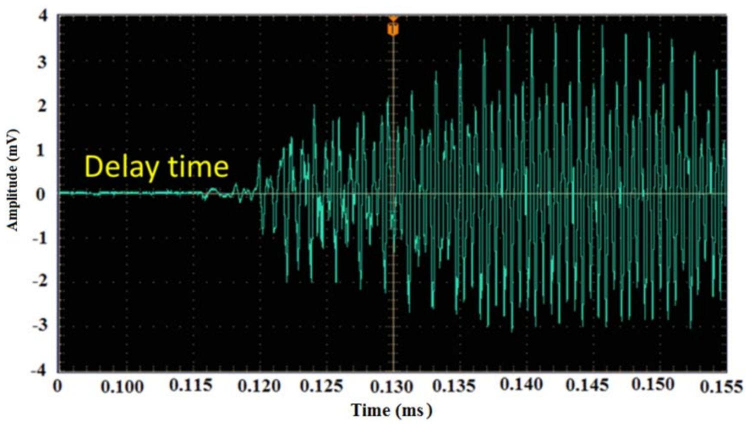

Figure 10 The measured signal from the third sensor of transmission through the concrete wall.

From Figure 10, the signal measured by the sound transmission through the concrete wall is significantly lower than the signal strength at 7.0 mV and the frequency at 25.64 kHz. The time in the range 0.116 - 0.155 ms is 20.58% of the incoming signal and the delay time is the measured signal to convert from air to solid. Measurement time is slightly shifted, because the change in the speed of the sound which can be seen from the graph is in the period 0-0.116 ms.

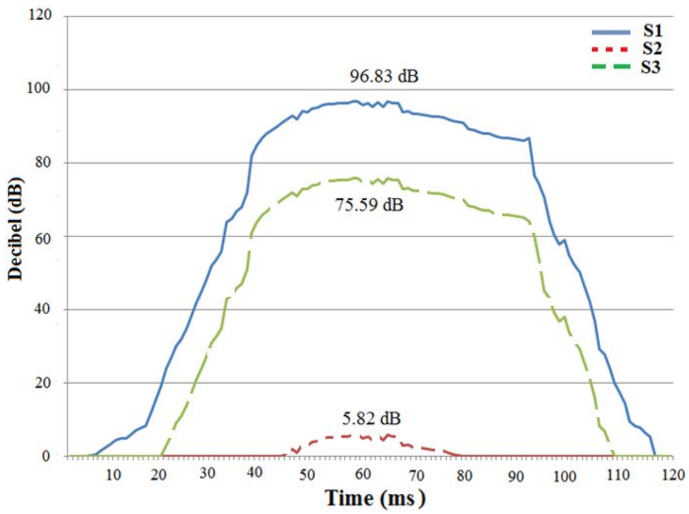

Figure 11 The relationship between the sound level and recording time dynamic volume.

Figure 11 shows the dynamic signal generated by the microcontroller. To store in the SD card, to record and display the level of the audio signal. Measurement time is in the milliseconds ms, which shows the volume by the blue line from the 1st sensor, which the sound was measured from the sound source that affects the concrete wall, indicates a maximum sound level of 96.83 decibels by solid line. The 2nd sensor measures the volume of the reflected sound from the wall of the concrete wall to display by dot lines, indicates a maximum noise level of 5.82 decibels. The 3th sensor is used to measure the sound level to show the value of the sound transmission measured from the concrete wall of the concrete wall on the opposite side of the wall as shown, where the value shown in the dash lines has a maximum sound level of 75.59 decibels.

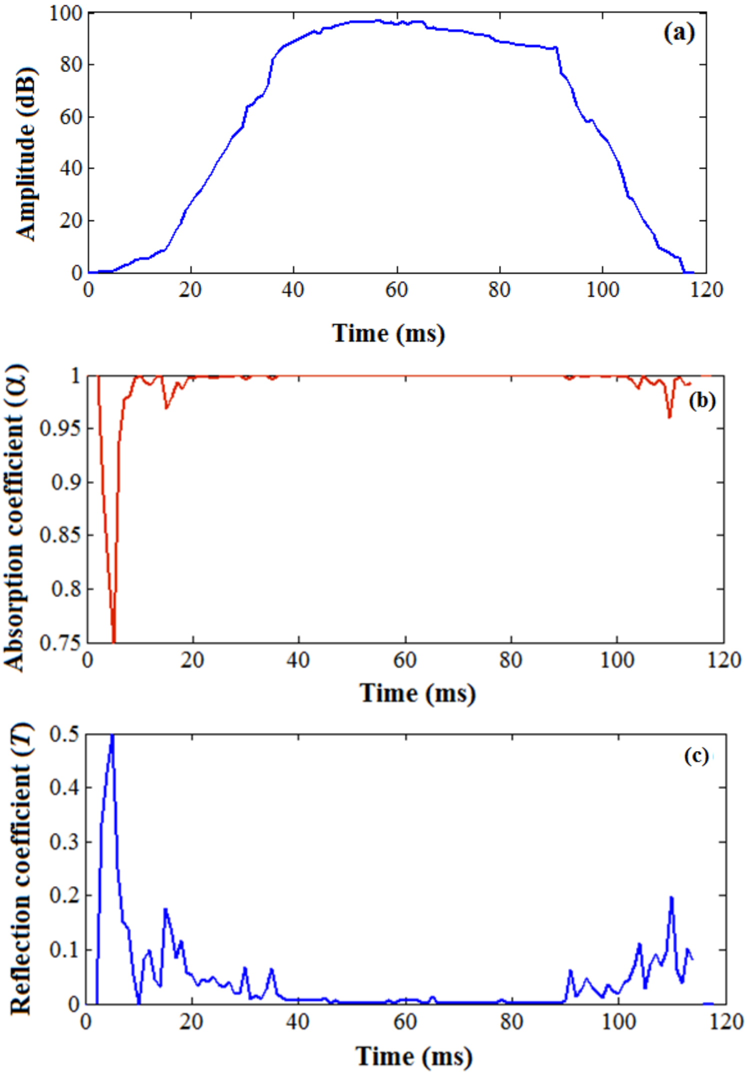

Figure 12 The absorption coefficient (α) and reflection coefficient (T) coefficients from the concrete wall.

Figure 12 shows the graph of the sound volume measured dynamically from sensor 1, and analysed by computer program (MATLAB 2016). Figure 12 (a) shows the level of sound at 96.86 decibels, and the correlation coefficient of sound absorption coefficient (4) can expressed in Figure 12 (b). Has a maximum absorption value of 1.0, which is the opposite of the value of the reflection coefficient. The value of reflection coefficient show in Figure 12 (c), which shows the maximum reflection from 0.5 at 5 ms and lower up at 0.0 for 39 - 90 ms, which is consistent with equation (5).

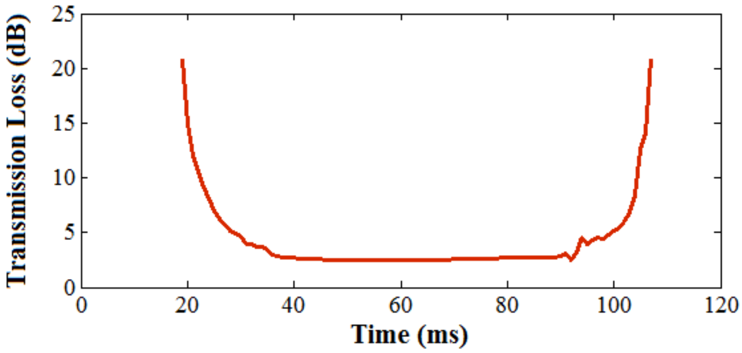

Figure 13 The loss of sound transmission of concrete wall.

In Figure 13 show the conclusion that the transmission loss of dynamic concrete walls is 20 dB, which is about 20 msec. From 40 ms to 92 ms, the value of loss is gradually increased at 100 ms, which can be compared with Figure 11 showing the value of sensor 1 and the sensor 3 and the value is consistent with the absorption coefficient (α) and the reflection coefficient (T). If the value of the absorption coefficient and the sound reflection coefficient is very high, the loss of sound transmission is low as well. This is in accordance with the equation (6), which is derived from the volume of the sound coming in and passing through the plastered concrete wall.

4. Conclusions

Based on the findings, we can measure that at the same time, we can measure the volume of the sound source, the value of sound reflection and the level of sound transmission through dynamic concrete wall. The measured values for the reflection coefficient, absorption coefficient and the transmission loss of concrete wall measured dynamic. This implies a consistent behaviour and complies with ASTM C423-84A standards. Based on this research we can apply the measurement of wall coefficients in various ways, where the deterioration of the sound insulation, the loss of sound transmission to different types of walls. The sound reflection coefficient, sound absorption and the coefficients affect the change in the surface condition of concrete walls, the rate of deterioration of the surface of the wall or the concrete ceiling and the design of concrete walls suitable for housing conditions. In the future, we may be able to design dynamic measurements with various types of reflections such as anti-radio reflective walls.

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