Evaluation of Noise Absorption Capacity of Various Materials

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Abstract. Noise absorption and transmission property of materials is of great importance in order to determine the amount of noise transmitted from source to receiver. Unwanted noise can cause various biological and psychological effects to humans and other organisms in nature. This paper deals with the experimental study on noise absorbing and deflecting ability of various available materials. These materials could be utilized in industrial complexes and building construction applications for noise level reduction purposes. The materials such as glass, plywood, thermocol (scientifically known as polystyrene), fiber plastic sheet and coconut fiber sheet have been used in the experiment as a noise barrier. Through experimental analysis, the reduction noise level was obtained in terms of decibel (dB), sound power level and loss of sound energy using hand held noise analyzer. The finding suggests that thermocol has the best sound absorbing capacity at medium to low sound pressure levels, whereas glass has the best sound absorbing capacity at high sound pressure levels.

1. Introduction

Noise is generally defined as an unwanted or unpleasant sound which causes undesired effects. Various methods have been adopted in the last few decades to reduce the noise levels for increased pleasure and comfort. One of the major contributions to this cause has been the use of sound absorbing materials. Various materials with different sound absorbing capacities have been used effectively. Mihai Bratu et al. [1] presented a research on the sound absorbing capacity of composites reinforced with various types of wastes which are harmful to the environment. The authors determined the absorption coefficient for each sample and deduced the effect of reinforcement material on the absorption coefficient. Md. Ayub et al. [2] analyzed the sound absorption capacity of natural coir fiber using Delany-Bazley model. The analytical results were validated using experimental investigation. It was concluded that the proposed method perfectly justifies the overall trend of absorption coefficient. Shu yang et al. [3] investigated the sound absorption properties of fiber assemblies using standing wave tube method. The authors also proposed a theoretical model to analyze and predict the absorption coefficient as a function of frequency. Similar analysis were done on sound absorption behavior of knitted fabrics by Yanping Liu and Hong Hu [4] and on asphalt mixtures by Ramon Mendes Knabben et al. [5]

Similar research work has been conducted by other researchers on woven fabric [6, 7] and knitted fabric [8, 9]. Research work has also been conducted on porous polymer spheres [10] and perforated panels [11, 12].

The literatures have suggested different methods to analyze the noise absorption capacity of the material. The objective of this paper is to estimate the noise data in the field regarding reduction in noise levels using various easily available materials. The study may be useful for various apartments in the densely populated cities such as in India to reduce the noise levels in terms of sound energy and noise levels (dB(A)) scale for each materials individually. Further, mathematical analysis has also
been done to calculate the power transmitted and energy loss through the noise barrier for different materials.

1.1 Mathematical background
It well known that, whenever a sound travels from one medium to another medium, some fraction of sound is reflected from the surface, some fraction is absorbed by the medium and the remaining part is transmitted from one side of the barrier to other. The sound energy lost during this process is called the transmission loss, and is given by the equation-

\[
Transmission\ Loss\ (TL) = Incident\ Power\ (IP) - Transmitted\ Power\ (TP)
\]

Incident power is given by the equation-

\[
IP = 10^{\frac{L_i}{10}} \times P_{\text{ref}}
\]  

Where, \( L_i \) is the incident sound level in dB, \( P_{\text{ref}} \) is the reference sound power (10\(^{-12}\) Watts)

Similarly, transmitted power is given by-

\[
TP = 10^{\frac{L_t}{10}} \times P_{\text{ref}}
\]  

Where, \( L_t \) is the transmitted power in dB,

The reduction in sound energy when passing through a medium is given by the equation-

\[
\Delta E = 10^{\frac{TL}{10}}
\]

Where, \( \Delta E \) is the reduction in sound energy and \( TL \) is the total transmission loss.

During the transmission, some amount of energy is lost through leakage. The power transmission taking the leakage into consideration is given by the equation-

\[
P_t = IP \times \text{Attenuation}
\]

Or

\[
P_t = IP \times (1 - LF) \times \frac{1}{TL}
\]

Where, \( P_t \) is the power transmitted, \( LF \) is the leakage factor (\( LF \) has been considered as 1\% in this article.

2. Experimental setup
The experiments were conducted by preparing a scale down model of a house using bricks and clay cement. The dimensions of the closed cavity are 50x30x40 cm\(^3\). The instrument used for noise measurement was type 2270 hand held noise analyzer by Brue\l and Kjaer. The experimental setup and the instrument used have been shown in Figure 1.
Figure 1. (a) Closed cavity (model) developed for experimental setup; (b) Bruel and Kjaer type 2270 hand held analyzer

One of the faces of the model was kept open to fix the noise barrier material to that face. To take the observations, different materials were fixed on the open face one by one. A motor vehicle engine was used as the noise source. Different noise levels were generated by varying the RPM of the engine. A noise analyzer was placed inside the box model and the noise barriers were used to seal the model. The materials used as noise barrier in the experiment were: glass, plywood, thermocol, plastic fiber and coconut fiber sheets as depicted in the Table 1.

Table 1. Noise barriers used for the experimental data analysis

| Glass Sheet | Thermocol sheet | Plywood sheet | Coconut fiber sheet | Plastic fiber sheet |
|-------------|-----------------|---------------|---------------------|---------------------|

For data acquisition purpose, the noise analyzer and microphone were connected through extended cables. The microphone was kept inside the especially cavity with mortars and bricks. The motorcycle engine speed was varied sequentially in order of 2000 rpm up-to 10000 rpm and noise levels were recorded in dB(A) i.e. decibel scale with A-weighing. The dB(A) scale has been selected as it represents the human ear response to sound. Ambient condition readings were also taken without any noise barrier. The recorded observations were then formulated using equations (1) to (5) and the comparative analyses were carried out to determine the materials with best sound absorption capacity.

3. Results and discussion
Figure 2 shows the comparative study of equivalent noise levels inside the room in an ambient condition and the active mode noise source for estimating the noise transmitted to the room with each of the materials as noise barrier at various engine speeds individually.
The comparative study of noise levels as shown in Figure 2 revealed that the noise absorbing capacity is the higher for thermocol and glass sheets when compared to the plastic fiber, coconut fiber and plywood sheets.

Another parameter used for assessing the noise absorption property of the material is the pressure transmission ratio. It is the ratio of pressure incident on materials to the pressure transmitted from the materials. These values of transmission ratio have been obtained from experimental data observations and the average values have been depicted in Figure 3.

The above figure depicts that thermocol has the lowest pressure transmission ratio i.e. thermocol has the best sound absorption capacity followed by glass and plastic fiber sheet. The sound absorption capacity of thermocol is due to its porosity which helps to damp the noise. Coconut fiber has the
the highest transmission ratio. It is due to the fact that the coconut fibers have micro-voids in them which allow noise to pass through.

In order to understand in depth about noise absorbing capacity of each material, the reduction in sound power and sound energy levels have been calculated using the formulas 1 to 5 and presented in Figure 4 (a) and (b) respectively.

Figure 4. (a) Reduction in sound power for each material; (b) Loss of sound energy for each material

Figure 4 indicates that the reduction of sound power and loss of energy is maximum for thermocol barrier followed by glass barrier. Plastic fiber sheet shows the potential to be developed in composite form to be used as a replacement to heavy glass sheets. Another important observation is that although the noise absorption of coconut fiber is low, but it is the most flexible, cheap and easily available material from the enlisted materials. Also, coconut fiber can be used in composite form to improve the noise absorption capacity and provide better results.

4. Conclusion
The study was focused at determining the noise absorbing capacity of various materials. The experiments were performed to record the sound pressure levels and calculations were done to determine the reduction in power and loss of sound energy through each material. The experimental results and the mathematical analysis suggested that the noise absorbing capacity of thermocol and glass sheets was the highest among the considered materials. It was also observed that glass provides better noise damping at higher noise levels whereas thermocol provides better damping at low to medium noise levels. Another interesting observation was the noise reduction due to plastic fiber sheet. The plastic sheet had results comparable to that of glass sheet. Hence it can be said that instead of using heavy glass sheets, a plastic fiber sheet and thermocol can be manufactured in a composite form as a light weight and cheap material which is capable of providing high noise damping. It can also be said that the flexibility and easy availability of coconut fiber can be mixed with porous materials and can be used to develop composites with high noise absorption capacities.

5. References
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