CSCE Annual Conference

Laval (Greater Montreal)

June 12 - 15, 2019

A PROPOSED USE OF SOUND INSULATION SYSTEMS

ElSaeed, Ali[1], Naguib, George[1], El Mekawy, Ahmed[1], Ghaly, Athnasious[1], El Assaly, Moustafa[1], Abu Ali, Reem[1] and Abou-Zeid, Mohamed[1].
[1] The Department of Construction Engineering, the American University in Cairo, Egypt

Abstract: Acoustic noise pollution represent a major source of pollution particularly in densely populated residential areas. A research conducted in a busy neighborhood in Cairo, concluded that street noise exceeded the permissible limits at three different times of the day. Hence, the introduction of sound insulation materials to residential areas, among others, can help reduce noise without completely muting the exterior noise to maintain a level of awareness of the surrounding environment. The main purpose of this study is to help assess various means of sound insulation systems in structures at different levels of sound frequency intervals. Three different types of materials; natural cork, rockwool and blue foam, were investigated for their performance as a sound insulating material, along with their thermal insulation property. For the purpose of this investigation, a special control room was constructed using conventional cement bricks with conventional plastering mortar. A partition wall was built in the middle of the room to divide it into a source room and a receiving room. The insulation materials were installed on the partition wall; plastered on the side of the source room. The acoustic insulation behavior was tested by monotone sounds at the same amplitude at various frequency intervals covering the human hearing range. The results demonstrated that each material had different acoustic insulation behavior under the various levels of sound frequencies tested. In general, cork has yielded the best sound insulating results while having the lowest conductivity. Recommendations are made on how to improve sound insulation in residential buildings.

1 Introduction

Sound pollution continues to be one of the utmost dilemmas of overpopulated cities such as Cairo. As of today, 96.1 million citizens populate Egypt, while Cairo holds 9.7 million citizens. (CAPMAS) Insufficient and poor public transportation in Egypt has led to the increase of the use of private transportation on Cairene streets, resulting in increased sound pollution. (Werr) A study has also shown that the increase of sound pollution and urbanization are directly proportional to one another making it a prominent factor contributing to the sound pollution issue in Egypt. (El Bardisi) Due to its physical and psychological consequences on the individuals living within the polluted environment, sound insulation is seen as an efficient and effective solution.

"Sound Insulation is the ability of building elements or structures to reduce sound transmission." (Gracey) Sound transmission in buildings is classified in two forms; impact sound and airborne sound. Impact originates from vibrations through walls of a structure due to footsteps or moving furniture for example. Airborne sounds are caused by noise circulating in the atmosphere. Examples of airborne sounds are music, wind, or traffic sounds. This paper will focus on the airborne sounds transmitted into room; it will focus on the experimentation of multiple room-to-room sound insulating materials. The experiment conducted was initiated by building a three-meter squared room, divided in half by a wall. The experiment proceeded by insulating the separating wall of the room, each time with a different material. As initially predicted, results have varied with each material and each material with different sound frequencies; this will be presented subsequently in the results along with the methods and the material used.

2 Literature Review

1) Noise Pollution in Cairo
Egyptian Ministry of Environment

This research was conducted in Corniche El Nile in Maadi, Cairo, Egypt. The study focused on the level of loudness at different times of the day. The study was done on a three-month period. The results showed sound loudness exceeding the permissible limit at all times. The measured sound level averaged at about 75 dB while the permissible limit was 60 dB at day time, 55 dB at evening, and 50 dB at night. The study mentions that the prime cause for environmental noise in Egypt is noise by means of transportation and traffic roads.

	Loudness measured (L_a) at different periods of the day for three months at Corniche Maadi					
	Day (L_a)		Evening (L_a)		Night (L_a)	
Month	Measurement	Permissible Limit	Measurement	Permissible Limit	Measurement	Permissible Limit
Oct-06	75.9	60	75.73	55	74.61	50
Nov-06	76.27	60	75.77	55	74.63	50
Dec-06	75.98	60	75.43	55	74.45	50

Table 1: Loudness Levels

2) Performance of vacuum insulation panels in building energy conservation
Herek, S.J.

Sound insulation materials can possibly contribute to thermal insulation as well. This research was conducted on several buildings to evaluate the performance of vacuum insulation panels. The study showed energy saving of rooms with thermal insulation ranged from 17% to 40%. Energy savings in colder months were significantly greater than warmer months. Although this research was conducted on a different thermal insulator, it can be deducted that thermal insulation can have a significant impact on energy conservation.

3) Effects of thermal insulation characteristics on energy consumption of buildings
Liting Yuan, Yanming Kang, Shuhan Wang, Ke Zhong

This research was conducted on a multi-story office building to assess the effects of thermal insulation of different characteristics (orientation, density, thickness) on energy consumption of buildings with irregularly operated air-conditioning systems. Difference in characteristics affect the thermal resistance of the material (R-value) and consequently, the energy conservation rate of mentioned material. The research concluded that heat dissipation and storage of the wall's inside layer during non-working times are the main reasons affecting the transmission loads of the irregularly operated air-conditioning systems. The energy savings of rooms with inside position was at least 18% higher than that of rooms with outside insulation position. The study also attained a graph that shows the increase of energy conservation rate with R values of the material.

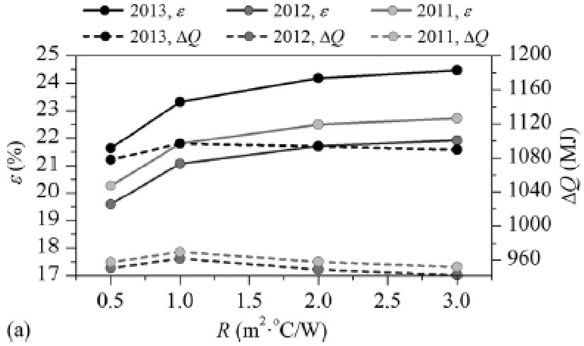

Figure 1: Energy conservation rate versus R

3 Objective and Scope

The objective of the project is to study various means of sound insulation in structures. This work will include limited-experimentation on few potentially-feasible systems that can help reduce excessive sound and noise in Egypt.

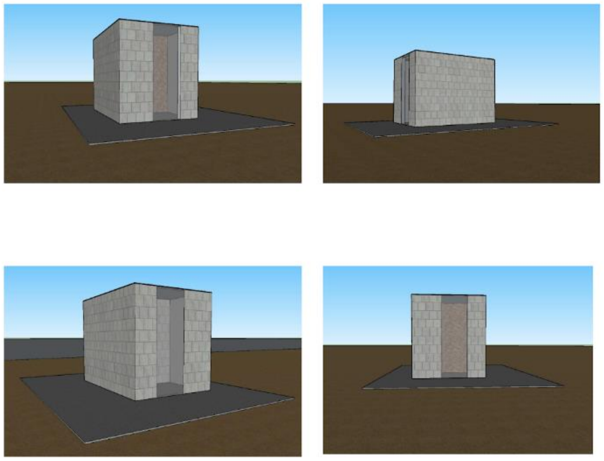

Figure 2: 3D Room Model

In order to achieve this objective, a controlled room was constructed with cement bricks. Moreover, a limited market study was conducted to assess the potentially available systems in the Egyptian market.

A thermal conductivity experiment was carried on one of the systems in the Housing and Building National Research Center. Additionally, a limited feasibility study was conducted to assess the feasibility of the systems experimented on and the direct costs savings on the long term.

4 Experimental Work

Systems experimented on:

Conventional Cement Brick Wall: The partitioning wall was tested as a control experiment for other systems tested.

Blue Polystyrene Foam: The blue foam is typically used as a thermal insulating material. It was tested to observe its behavior as a sound insulator.

Rockwool: The rockwool is used for sound and thermal insulation. It was also experimented on as a sound insulator.

Natural Cork: Natural cork was selected for experimentation for its strong acoustic insulation properties. It was also tested for thermal conductivity at the Housing and Building National Research Center.

4.1 Controlled Room

As mentioned in the scope, a room was constructed for the sound insulation experiments of dimensions 3 meters on both sides. The room was partitioned in half by a cement brick wall. The partitioning wall would be experimented on. The ceiling was constructed using mortar reinforced by steel of diameter 10 mm.

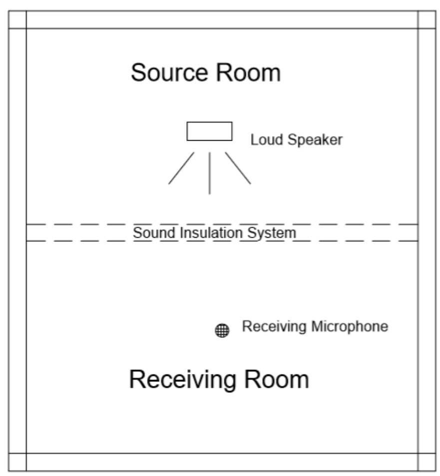

Figure 3: Room Plan

4.2 Experiments

4.2.1 Sound Insulation

A monotone was played at a sound level of 110 dB. Frequency intervals measured on the sound insulation systems were from 100 Hz to 10000 Hz. 100 Hz to 1000 Hz range was measured in 100 Hz intervals. 1000 to 10000 Hz was measured in 1000 Hz intervals. As shown in figure 3, the source room is where the loud speaker plays frequencies. From the receiving room, the sound level is measured using the sound level meter. The partitioning wall was a cement brick wall. Wooden frames were installed from

Figure 4

Figure 5

the receiving end of the wall to fix the materials in them. Previously, the ceiling was constructed of gypsum boards. The gypsum boards did not endure unexpected multiple storms and we opted to using mortar supported by steel bars and net.

3.2.2 Thermal Insulation

A limited thermal conductivity experiment was carried on three natural cork samples at the Housing and Building National Research Center.

4.3 Results and Analysis

4.3.1 Sound Insulation Results

Experimentations showed that the conventional cement brick wall performed the worst in all frequencies. Blue polystyrene performed better than cement brick wall in low frequencies. However, they performed almost the same at 500 Hz. Polystyrene performed better in 600 Hz and 700 Hz and performed the same or slightly better in latter frequencies. The sound level was observantly lower in 9000 Hz and 10000 Hz and the difference in performance between polystyrene and cement brick wall was more vast than lower frequencies. Rockwool performed better than the cement brick wall and polystyrene in all frequencies. The difference in performance increased immensely in higher frequencies. Cork performed the best as an acoustic insulator in almost all frequencies. Rockwool performed better than Cork in 800 Hz. Both materials performed the same at 300 Hz and 500 Hz. In all latter frequencies, cork

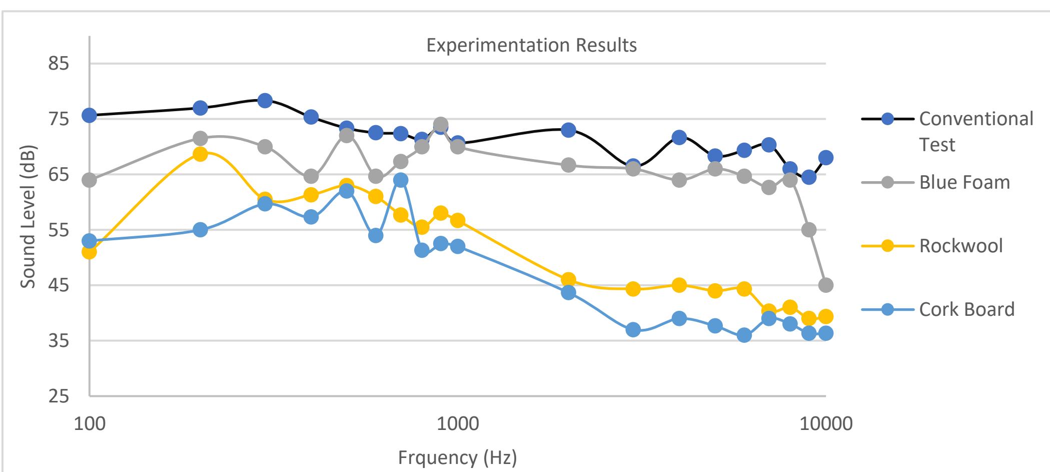

Figure 6

resumed performing better than other materials. After 7000 Hz both materials achieved levels very close to background ambient level.

4.3.2 Thermal Insulation Results

Thermal conductivity of cork board obtained from the housing and building research center was 0.042 W/m.K. Thermal resistance (R value) of rockwool and polystyrene was obtained from their respective online catalogues. Using the graph of the 2017 study of Liting Yuan et al., the relative energy conservation rate ε % was obtained. The thermal resistance of cork was obtained by dividing thickness by thermal conductivity

$$R = \frac{L}{k}$$

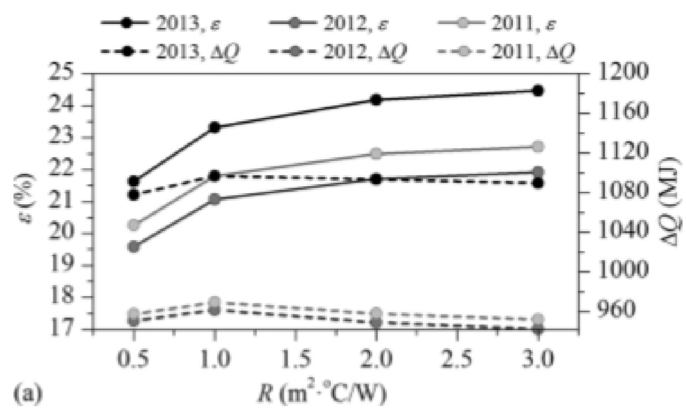

Figure 7

Material	Thickness (cm)	Thermal Resistance (R) [K·m2/W]	Thermal Conductivity (k)[W/m·K]	Relative energy conservation rate ε %
Cement Brick Wall	11.25	0.09	1.2	≈0
Polystyrene	5	1.25	0.04	23.55
Rockwool	5	1.25	0.04	23.55
Cork	5	1.19	0.042	23.45

Table 1

As table 1 shows, the thermal resistance of cement brick wall was negligibly low and thus, relative energy conservation rate was close to zero. The sound insulation materials used in the experiments had very close thermal resistance. The relative energy conservation rate of rockwool and polystyrene was 23.55%. Cork was a close 23.45%.

5 Conclusion

Despite the constraint of time and scope, we were able to conclude the following in light of our experimentations:

- Natural cork had the best acoustic insulation performance in almost all frequencies.
- Polystyrene offers good thermal insulation, however, it offered very slight acoustic improvement over cement brick wall.

- Rockwool performed better in acoustic insulation performance than polystyrene in all frequencies. It performed better in higher frequencies than lower ones.
- Conventional cement brick wall has weak thermal resistance, as opposed to rockwool, polystyrene, and cork, which have high thermal resistances and can contribute immensely to energy consumption
- Smart phone applications were not reliable in field use for acoustic experimentations.

6 Recommendations

For future research:

- After unsuccessful trials, we can conclude that mobile phone applications are not suitable for such experiments, in which a more competent and efficient device would be needed. Therefore, we have decided to use the Sound Level Meter to measure sound levels as accurately as possible.
- Weak points and air gaps have also hindered the results of our experiments, for they need to be taken into consideration when taking the measurements as they are important factors affecting the end results.
- A further study can be done by investigating different densities and thicknesses of the same material used, while observing their effect on sound insulation at different frequencies.
- The investigation of other types of brick walls to widen the scope of the study.
- Conducting a feasibility study to assess the feasibility of insulation materials on the long term versus energy conservation; studying how insulation materials can save energy consumption and hence, cost, on the long run.

For Applicators:

- Ensuring a precise installation of the sound insulation material is essential for gaining an optimal acoustic installation performance.
- It is quite substantial for sound insulation to be introduced in the construction industry, especially for the residential sector as it would improve the quality of life of the residents and would protect them from the harmful effects of sound pollution.

Acknowledgements

Dr. Mohamed Nagib Abou-Zeid, Thesis Advisor, Construction Department, American University in Cairo

Eng. Athnasious Ghaly, Thesis Advisor

Eng. Reem Abo Ali, Thesis Advisor

Eng. Mostafa El-Assaly, Thesis Advisor

References

Canadian masonry for sound buildings. (2017, March 23). Retrieved from https://www.constructioncanada.net/canadian-masonry-for-sound-buildings/

CAPMAS. Central Agency for Public Mobilization and Statistics. Retrieved from http://www.capmas.gov.eg/

El Bardisi, M. *Sources Of Noise In Greater Cairo, Example East Cairo*. Retrieved from http://www.diva portal.org/smash/get/diva2:738612/FULLTEXT01

Glass Rock. Mineral Wool. Retrieved from http://www.glassrock.com.eg/mineral.html

Gracey, B. Acoustic Glossary. Retrieved from http://www.acoustic-glossary.co.uk/sound-insulation.htm

Herek, S. J. (2014). *Performance of vacuum insulation panels in building energy conservation* (Order No. 1566542). Available from ProQuest Dissertations & Theses Global. (1621417215). Retrieved from http://p2048-library.aucegypt.edu.libproxy.aucegypt.edu:2048/login?url=https://search-proquest-com.libproxy.aucegypt.edu/docview/1621417215?accountid=8423

ICB - Insulation Corkboard. (2012, May 14). http://www.corklink.com/wp-content/uploads/2012/09/expanded-cork-technical-data.pdf

Ministry of Environment. (2006). Noise Pollution (Tech.). Retrieved from http://www.eeaa.gov.eg/portals/0/eeaaReports/SoE2007En/air/02-Noise-FENG.pdf

Sound Insulation. Retrieved from http://personal.cityu.edu.hk/~bsapplec/sound4.htm

Werr, P. (2017, April 19). *Egypt's public transport a matter of real urgency.* Retrieved from https://www.thenational.ae/business/egypt-s-public-transport-a-matter-of-real-urgency-1.47911

Yuan, L., Kang, Y., Wang, S., & Zhong, K. (2017). Effects of thermal insulation characteristics on energy consumption of buildings with intermittently operated air-conditioning systems under real time varying climate conditions. Energy and Buildings, 155, 559-570.