Assessing the sound performance of common building materials used as outer walls[1]

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Abstract
Unprecedented population growth along with the development of science and technology in mega cities has brought about various problems for the inhabitants if these cities. One of the biggest such problems is the environmental pollution. In this respect, noise pollution can be considered one of the biggest ones. Noise pollution as one of the biggest environmental problems is responsible for a large part of the pollution in our big cities. There is a mutual relation between noise pollution on the one hand and industrial technology on the other hand. In other words, as technology improves further each day, various aspects of noise pollution start appearing in our society. Noise pollution can be also considered as a big issue in buildings. What keeps the inhabitants away from the outer space and the noise pollution is the outer walls in a building. Thus, this layer should be made in a way that provides tranquility and relaxation including acoustic tranquility for the inhabitants of the building. In this paper, first, we introduce the modern types of outer walls in buildings. Then, considering the site we have chosen in our study, these materials will be considered. It should be mentioned here that we have used ODEON software in order to determine the acoustic performance of various materials used in the study. We hope that the result from the current study will be able used by experts and engineers in designing buildings which are more resistant against noise pollution.
Key words: *Noise pollution, building's outer wall, common building materials, ODEON software*

Introduction

Housing is one of the most important sections closely related to people's life. Thus, it is extremely important to design and build houses according to the standards of our modern world. What separate the inhabitants of the building from the outer space are the walls. Thus, the walls in the building should be designed in ways that act as keeping the temperature well within the building, the noise pollution outside the building and provide comfort for the inhabitants of the building. Thus, according to what has been said, the choice of standard and insulating walls becomes extremely important for the building. Since there are various types of material today used for designing and making the walls of the building, deciding which type of material to be used must be done with great care. In this study, first, we have collected information regarding various types of separating building walls in the city through questionnaires, which have then been examined further.

Theoretical or applied research

Research can be generally divided into two types, the theoretical resarch and the applied research. The theoretical research is concerned with producing the body of knowledge for futher inderstanding of the world phenomena. The applied research, on the other hand, is concerened with producing knowledge for being used in industy. Applied research draws on the body of knowledge obtained through theoretical research in order to find and design new appraoches to be used in for developing human's life. On other words, the theoretical research is in touch with more conceptual issues while the applied research is more

[1] The current paper has been extracted from the writer's M.A thesis, "an evaluation of temporal, acoustic behavior of common building materials in residential buildings of Mashhad" in August, 2014

closely related with social and practical issues [1 and 2].Based on what has been refered to above, the cuurent paper can be considered and aplied study because it aims at facilitating the apropruate structural materials in order ti facilitate the economy, provide further facilities for people, and improve the social welfare within the socity.

Research methodology

Since various types of research are being used in constructing buldings today, first, we have made a comprehensive lsist of the types of modern materials being used in buildings.

To do this, we have provided questionnaires and distributed it among all these professions closely related with construction, such as university professors, civil engineers, officials, contracters, mnagers, councelors, etc.

Since collecting information from all the popukation of those professions mentionned above was not easy, we have used the Cochran formula in order to decide an appropriate volume for out questionnaire respondents. We have also used the Cronbach Alpha in order to obtain the reliability of the questionnaire. Thus, the number 75 has been obtined as the appropriate size of our questionnaure. Thus, it can be claimed that the the questionnaire used in this study has reliability.

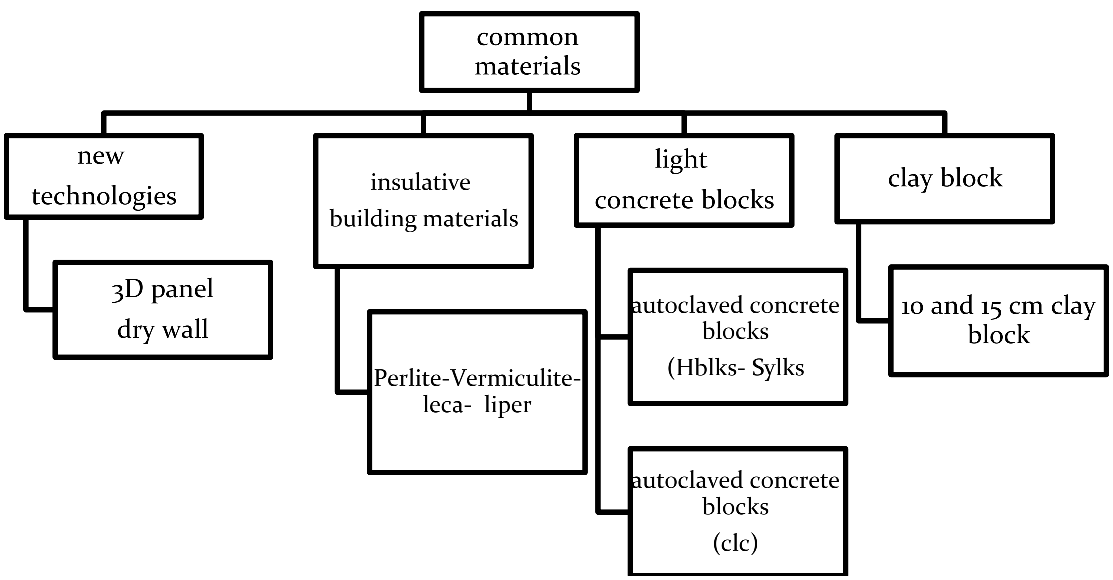
Questionniare analysis

After the responses from the questionniares had been collected, the constructon materials were ranked and scored. First, the items without any response were removed from our analysis. Hten, scores from 1 to 5 were given to responses “very little”, “little” , “medium”, “plenty” and “a lot” respectively. Thus, based on the scores obtained from the questionnaire, the materials were ranked in such way that the higher the score of each type of wall, the more importance was given to it and the higher its rank will be in our hierarchy. Finally, the results obtained through questionaires were clasified into four sections as indicated in table 1 along with the index in each section.

The results of the questionnaire

In this paper, the most common types of materials used as outer walls in buildings have been divided into 4 sections.

Table 1: classification of the most common materials examined in this study



The most important parameter for evaluating noise resistance of walls against airborne has been reduction of volume’s weigh (Rw). The higher this coefficient, the better is the performance of the separating wall to reduce the amount of nose transmitted inside the building. For instance, if the noise source produces sounds as severe as 80dB with Rw separator as much as 50dB, only as much as 30dB will be heard on other side of the wall. What has been investigated in this section is the noise index. Because of the difficulties of investigating sound and its index in laboratory, we have used a new approach by means of acoustic software.

Model selection approach

In this study, a five story building in one of the residential areas of the city has been considered as the site for the study. Since the site for the study is neighboring with such sound sources as surface source (school), line source (street) and point source (school speakers), it is a complete example for investigating the effect of sound. The amount of acoustic pressure of these sources has been measured by audiometer, which has then been defined for the software in the form of data as will be explained below. It must be mentioned here that a number of other variables affect this index as coating on walls, windows and joints. Yet, since the aim of our study has been investigating the effect of building materials on sound resistance, such elements have not been taken into account in this paper and have thus been considered constant in all out experiments.

Modeling approach with ODEON

First, the intended site for designing has been modeled in ODEON. As it can be seen in the picture, the intended site is situated next to an educational building (high school) and a street with high traffic load.

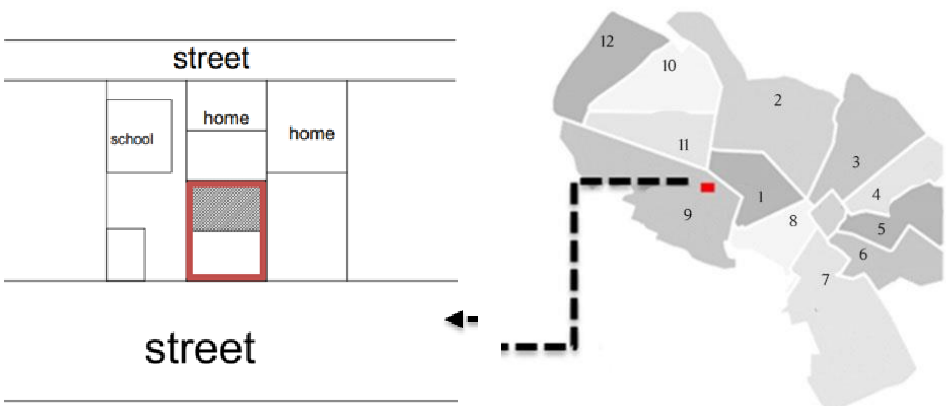


Figure 1: the situation of intended site

Two streets situated in the north and south of the building have 85 and 80 decibel of sound severity each. Also, school is considered as a source of noise with 75 decibel, which has been defined in the software. The site has been defined with dimensions of 100, 100, and 60. Also, sound receivers have been installed inside the residential building to receive the amount of sound coming inside the building.

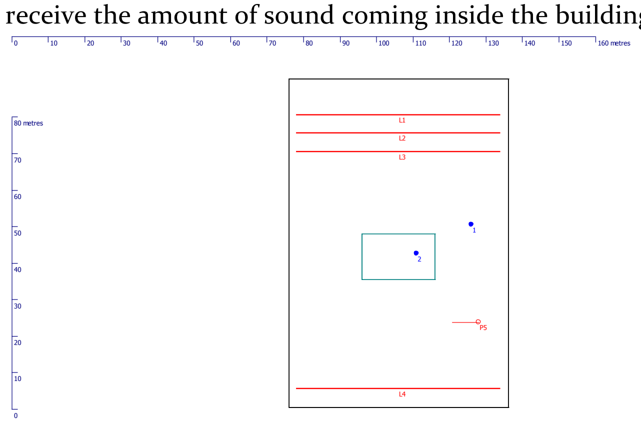


Figure 2: designed model in software

Introducing Octave Bands

In order to examine, evaluate, order and perform other technical computations related to sound insulators and sound phenomena, not only the surface of the sound is important, but the sound's frequency distribution is also important.

In order to analyze he frequency, first, the frequency range should be divided into smaller intervals. This can be performed in two ways; in the first approach, the length of the intervals is equal. For instance, the length of the intervals is 10 and the frequency range will be divided into for instance [-10], [0, -10Hz], [19990, 20000], etc. in the second approach, the ratio of the big number to the small number of the interval is equal, for instance, always the large number (upper limit) of the interval is twice as big as the small number (lower limit) of the interval. So the interval will be divided as follows: [90,180], [180,360], [360,720], etc. If the ratio of the upper limit of the interval to the lower limit of the interval is 2, such interval is called Octave bands. Dividing frequency interval into Octave Band approaches is good for human's hearing capabilities. The most common octave is octave 1/3 (one third) in which the ratio of the higher limit to the lower limit is the third order root (about 1.26). Octaves 1.12 and 1.24 are also used in the frequency analysis. In this software, the range of frequency of octave band 1.3 is as follow;

Table 2: band 1.3 of octave

100	**125**	**160**	**200**	**250**	**315**	**400**	**500**
630	800	1000	1250	1600	2000	2500	**3150**

Noise performance of the most common materials for building wall

Clay brick block

The following diagram indicates the distribution of received energy from each source in various frequencies when the mode's walls are lay block. In this diagram, colors red, yellow and blue indicate energy received from 30 meter street, color blue indicates energy received from 10 meter street and color white shows the energy received from school. As it can be seen, the biggest problem concerns the frequency range of 250-1000. In this section, the performance of clay blocks will be investigated.

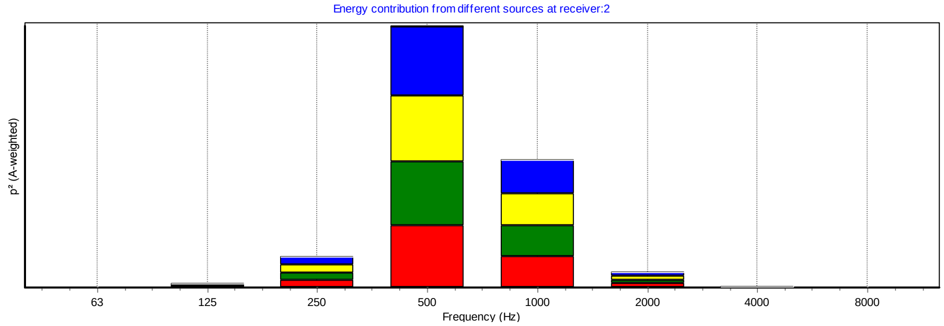


Figure 3: received energy distribution diagram for each source for clay block

In the diagram below, sound pressure level found within each frequency inside the building has been shown. As it was mentioned, sound severity level is a criterion for measuring human's perception of the sound severity. If we consider the permissible sound severity for each building as 35 decibel, it can be claimed that clay blocks have a weak performance in frequency range of 63 to 100 Hz, particularly at 500 Hz.

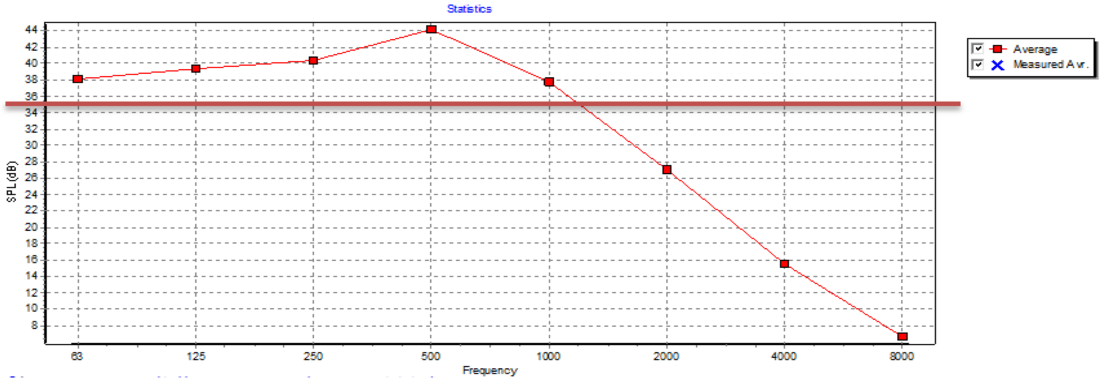


Figure 3: sound pressure level diagram for clay blocks

Sound pressure level for each frequency can be seen clay in the below diagram. According to the data, sound pressure level can be obtained in A weight network which equals 43.2 dB.

Table 2: sound pressure level for clay brick wall

Band (Hz)	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
SPL (dB)	38.1	39.3	40.4	44.2	37.7	27.0	15.5	**6.6**
SPL (A) = 43.2 (dB)								

hbleks block

In the following diagram received energy distribution from each source within different frequencies when model walls are made with clay bricks have been indicated in which colors red, yellow and green all indicate energy received from 30 meter street, color blue indicates energy from 10 meter street and color white shows energy received from the school. As it can be observed, our biggest problem concerns frequency range of 250 to 1000 Hz. In the following section, we will examine the performance of clay blocks in this frequency range. The following diagram indicates the received energy distribution when walls are made of hbleks. As it can be observed, like clay blocks, the highest amounts are in frequency range of 250 to 1000 Hz. The difference is that the maximum has a frequency of 500 Hz.

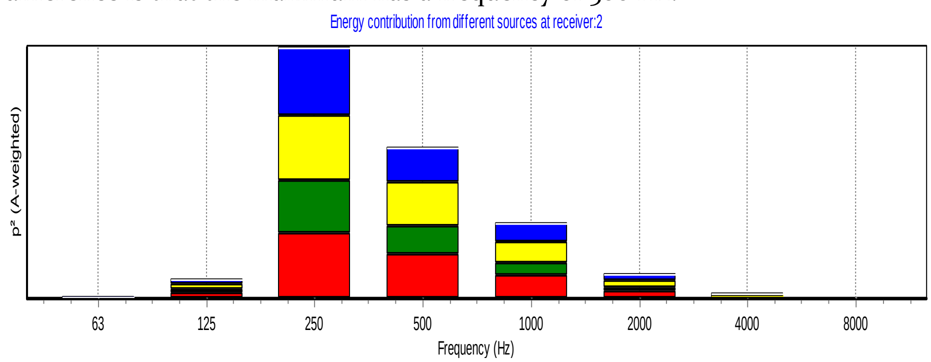


Figure 5: diagram of sound pressure level for Hbleks block

Sound pressure diagram for hbleks block has been indicated below where the weakness is only in 250 Hz frequency, which can be considered a good performance compared with other clay blocks. Figure 6: sound pressure level diagram for hbleks block. According to what has been obtained from sound level pressure in each frequency; we can consider sound level pressure in weight network A for hblks blocks as 31.4 dB

Table4: sound pressure level for hblks block walls

Band (Hz)	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
SPL (dB)	32.6	33.4	36.7	29.3	22.8	16.4	10.3	**3.4**
SPL (A) = 31.4 (dB)								

Perlite block

The received energy distribution diagram for each source for perlite blocks is similar to those of hbleks blocks. As it can be seen, the highest amount for this is 250 Hz.

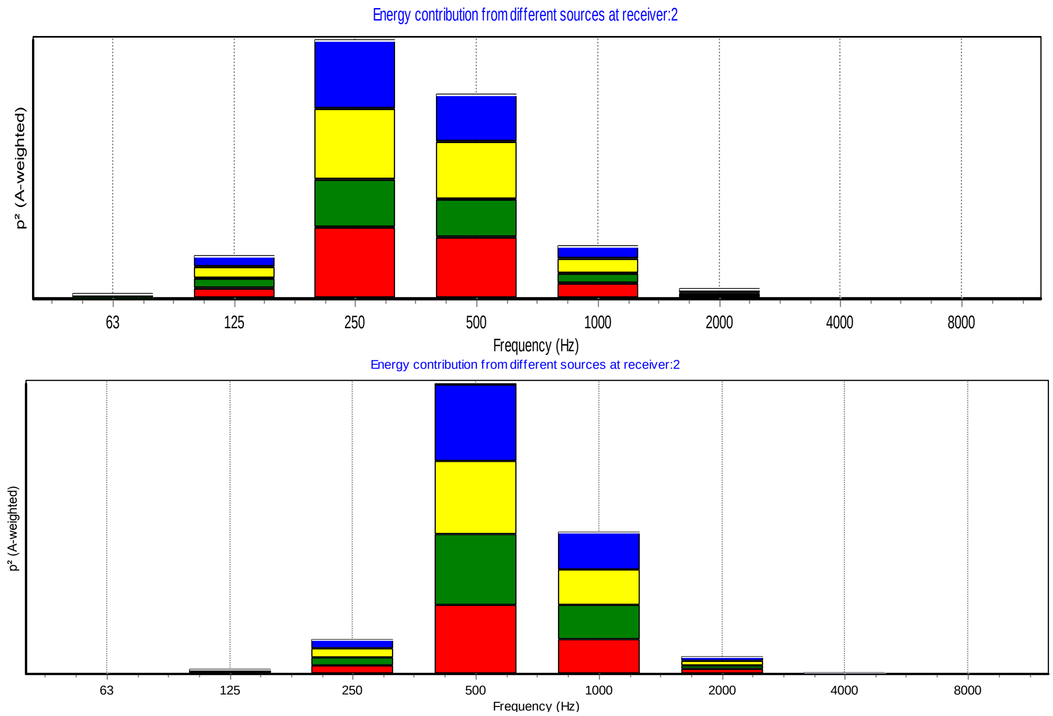


Figure 7: received energy distribution diagram from each source for perlite block

In the following diagram, the highest amount of sound pressure level is within 63-125 Hz. Yet, such extremes are within frequencies where received energy distribution diagram has the lowest amount. Thus, it can be concluded that such blocks have satisfactory sound performance.

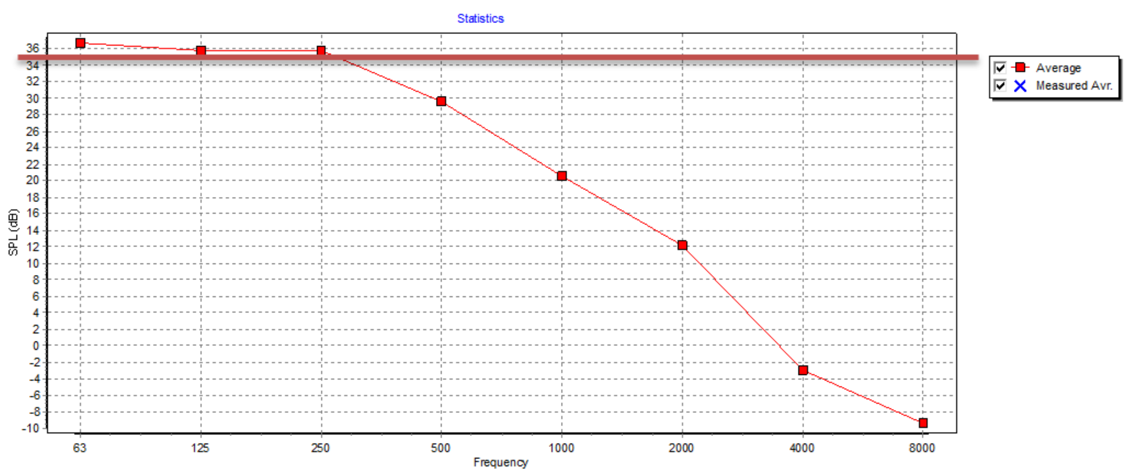


Figure 8: sound pressure level diagram for perlite block

Sound pressure level in weight network A for perlite blocks equal 30.8 dB

Table 5: sound pressure level for perlite block wall

Band (Hz)	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
SPL (dB)	36.7	35.8	35.8	29.6	20.6	12.1	-2.9	-9.4
SPL (A) = 30.8 (dB)								

Leca block

Leca blocks have a diagram similar to received energy distribution diagram for perlite and clay blocks with highest amount frequency between 250 to 500 Hz.

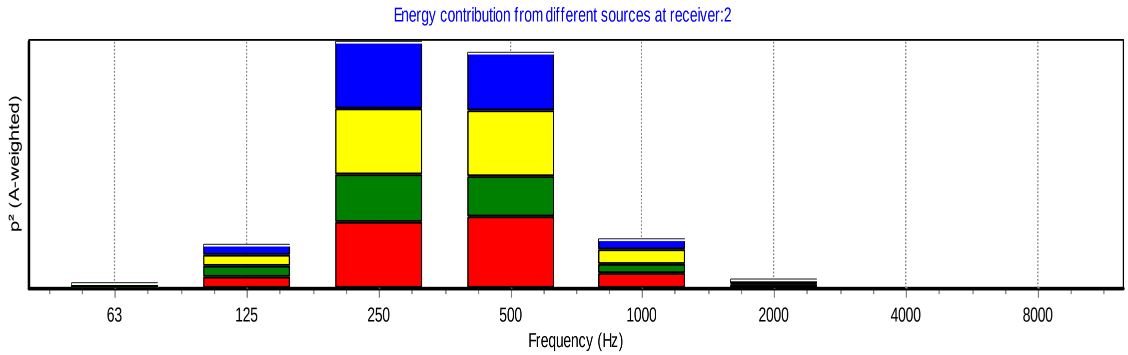


Figure 9: received energy distribution diagram from each source for leca block

It can be understood from sound pressure level diagram of leca block that such blocks are weak against frequency range of 63-250 Hz. Since the maximum of received energy distribution of the source is within frequency of 250, thus a solution must be presented for this frequency.

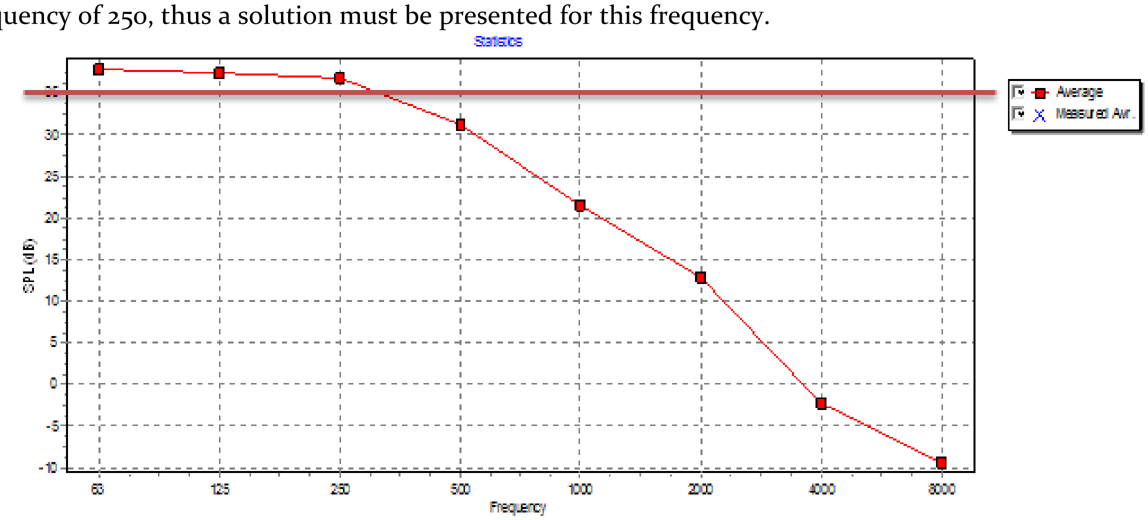


Figure 10: sound pressure level distribution diagram for leca block

Sound pressure level in weight network A for leca blocks equals 32.1 dB.

Table 6: sound pressure level for leca block wall

Band (Hz)	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
SPL (dB)	37.9	37.4	36.9	31.3	21.5	12.8	-2.2	**-9.4**
SPL (A) = 32.1 (dB)								

Received energy distribution diagram for each wall when walls are made with 3D panel have been shown in the following diagram. As it can be seen, the highest amounts are within the 500-1000 frequency range.

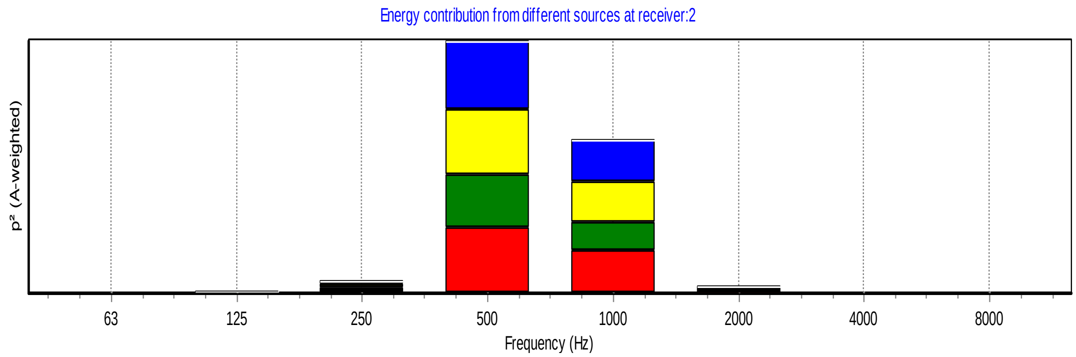


Figure 11: received energy distribution diagram from each source for 3D panel

In the sound pressure level diagram for 3D panel, in frequency of 500 Hz, the sound pressure level is 35.7 decibel, which s situated on the border line. This is a frequency where the highest received energy takes place.

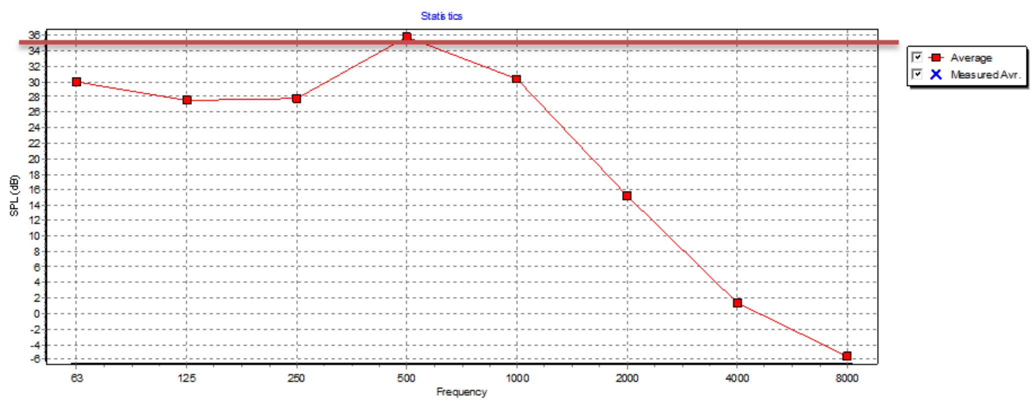


Figure 12: sound pressure level diagram for 3D panel

Sound pressure level in weight network A for 3D panel equals 34.8 dB.

Table 7: sound pressure level for 3D panel

Band (Hz)	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
SPL (dB)	30.0	27.5	27.9	35.7	30.3	15.2	1.4	**-5.6**
SPL (A) = 34.8 (dB)								

Light steel structure

Received energy distribution diagram for walls made of light steel structures are as follow:

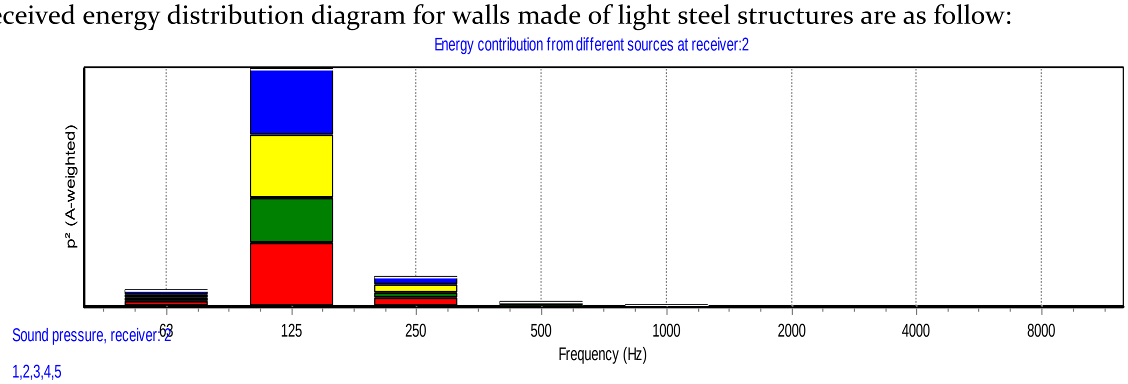


Figure 13: received energy distribution diagram from each source for light steel structure

As it can be seen in the sound pressure level diagram foe the walls, these walls have acceptable performance in high frequency. Thus, their only weakness is in frequency of 125 Hz.

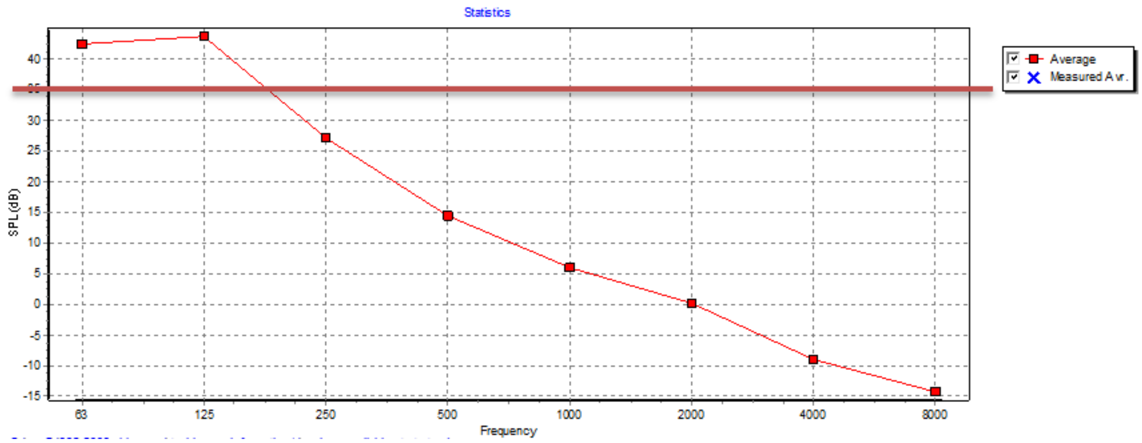


Figure 14: sound pressure level diagram for light steel structure

Sound pressure level in weight network A for light steel structure is 28.5 dB, which is lower than the other type of materials.

Table 8: sound pressure level for light steel structure

Band (Hz)	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
SPL (dB)	42.4	43.7	27.2	14.5	6.0	0.2	-8.9	**-14.2**
SPL (A) = 28.5 (dB)								

Conclusion

The current study examines the sound resistance capability of the most common materials used today in the outer walls of the building. First, a list of the most common of such non-traditional materials were collected through information we obtained by questionnaires. In the next stage, the sound behavior of such materials was investigated through ODEON without considering such factors as density, which might reduce the sound affect. Summarizing through figure 15, it can be claimed that light steel structures were the most efficient types of materials in this study on the condition that a number of problems with such materials is obviated. Next, perlite blocks had a satisfactory performance, which make them more economically efficient than light steel structure.

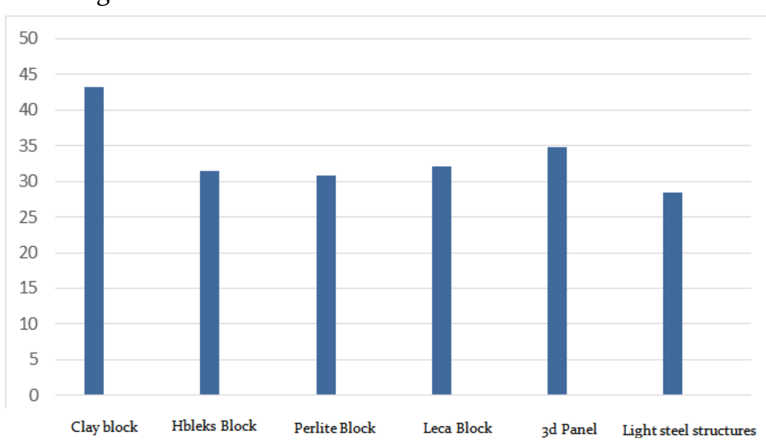


Figure 15: Comparison of sound performance of modeled materials

In the following table, a summary of sound pressure level in weight network A has been modeled. It must be mentioned that the outer walls in a building are not often made from a single material bur rather from a combination of different materials. The existence of various sections such as doors and windows on the wall can reduce or weaken each wall's resistance against sound. In order to solve this problem, the transmittance reduction of materials used in the wall must be almost within the same range so that the walls performance will be higher.

Table 9: sound pressure level in weight network A

SPL (A) Wall material	Sound pressure level in weight network A
Clay block	**43.2**
hbleks	**31.4**
perlite	**30.8**
leca	**32.2**
3D panel	**34.8**
Light steel structure	**28.5**

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