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Investigating the acoustic performance of flexible elastomeric foam insulation in dealing with impact noise

Milad Mehri khalafbadam*, Mohammadsadegh Soleymani,
Mohammadjavad Azizli, Mohammad Hashemi

Linkran industrial group, Gisha, Tehran, Iran.

* *m.mehri@linkran.com*

Abstract

In recent years, significant attention has been devoted to a critical architectural concern, namely, the mitigation of impact noise transmission within building structures. This sound is transmitted to the whole building through the skeleton and is spread in the space by the vibrating surfaces of the building. Particularly in multi-story buildings, the transfer of knocking sound (e.g., noise by walking) from one floor to another significantly impacts the comfort of the building's occupants. Consequently, measures must be taken to minimize the transmission of percussive sounds from the ceiling, effectively enhancing the ceiling's soundproofing capabilities. Therefore, in this research, elastomeric insulation with a closed cell structure with simple roll shapes and egg crate patterns has been used to implement the floating floor. This approach aimed to effectively control and reduce noise resulting from impact events across various frequencies. Based on the investigations, the value of ΔL_W coefficient for insulation cut in the shape of an egg crate patterns with a thickness of 12 mm and simple roll insulation with a thickness of 19 mm is 20 and 22, respectively. These findings underscore the efficacy of both insulation types in significantly reducing impact noise. It's important to note that the performance coefficient of elastomeric egg crate insulation exceeded expectations relative to its thickness.

Keywords: Elastomeric insulation; Impact noise; Frequency; Closed cell foam.

1. Introduction

Human industrialization has caused a person to be in contact with machinery and equipment at times such as when he is at home and also at many other times, and this issue creates various risks for him. Sound is one of the physical harmful factors in many work and residential environments. Sound is one of the physical harmful factors in many working and environmental environments. Control based on insulation is one of the types of sound engineering and technical control methods. Prolonged exposure to noise poses potential health hazards, including the risk of hearing impairment. Furthermore, noisy environments can lead to diminished attentiveness in cognitive tasks, cardiovascular repercussions, disruptions in intellectual work, and difficulties in conversations and comprehension. Sound can emanate from various sources, encompassing human activity within buildings and other external sound sources[1,2]. In industrial settings, in addition to the intrinsic sound generated by the equipment and processes, factors like sound reflection from internal surfaces and sound transmission from other areas can contribute to the overall acoustic environment. Efficiently managing sound reflection and transmission from various sources is essential for curtailing increases in sound pressure levels. The presence of reflective surfaces surrounding sound sources can exacerbate sound pressure levels due to recurrent reflections. Closed-cell elastomeric insulation as a flexible nanocomposite polymer foam, due to the air bubbles in its structure, can act as thermal and cold insulation in the form of sound insulation in addition to its proper performance[3,4].

2. Materials and methods

2.1 Conditions and Equipment Requirements for Impact Sound Testing

Accurate performance of each test requires providing suitable and isolated environmental conditions, using calibrated devices, correct application and accurate implementation of procedures related to performing that test, etc. This research was carried out in the laboratory of the acoustic department of the Road, Housing and Urban Development Research Center.

0It should be noted that this laboratory was built based on the national standard of Iran 1-8568 (international standard ISO 140-1). One section of this laboratory is exclusively devoted to the measurement of sound produced by impact instruments.

2.1.1 *Testing Environment Specifications*

As previously stated, one of the important issues that especially affects the test results is the environmental conditions which the test is conducted The specific test conditions for this research are outlined below:

A) Reception room volume: 100 cubic meters
B) Test floor area: 12.3 square meters

2.1.2 *Measuring equipment*

The instruments employed for assessing the sound insulation of the ceiling against impact noise should be made according to IEC standards. The apparatus used for this purpose encompasses the following:

A) tapping machine (impact sound generation source)
B) Loudspeaker (airborne sound generation source)
C) Microphone (receiver)
D) Sound analyzer device for measuring sound levels
E) Rotating base for microphones (for spatial averaging)

2.1.2.1 Tapping machine Model 3207

This device conforms to ISO 140, DIN 52210, BS 5821, and ASTM 492 standards. It is equipped with five metal hammers, each weighing 500 ± 12 grams, spaced 100 mm apart. These hammers are dropped from a height of 40 mm, striking the surface below the device at various intervals, generating a percussive shock. The torque of each hammer that hits the floor is equal to the free fall torque of an effective mass of 500 grams that falls from a height of 40 mm, so the speed during hitting must be a certain amount. The device features a gear motor, capable of converting the rotary motion into a periodic motion of the five hammers by the tapping machine[5,6].

2.1.2.2 Pulse Measurement System

The pulse measurement and analysis system is equipped with the capability to connect to a computer, allowing for the installation of various acoustic software and hardware locks. Additionally, it is portable, providing the versatility needed to conduct a wide range of laboratory and field acoustic measurements. This includes functions such as time and reading, sound level assessment, airborne wall soundings, as well as impact soundings of ceilings in accordance with ISO 140 standards, which specify methods for measuring sound in buildings and building components. All measured data can be easily retrieved from the pulse device, presented in the form of tables and graphs, and utilized for in-depth analysis[6].

2.1.2.3 Speaker with power amplifier

The sound source utilized for these measurements is the Nor276 dodecahedron speaker. This speaker boasts high power and omnidirectional capabilities, meeting all the requirements specified in the Iranian national standards 6-8568 for laboratory measurements of percussive soundproofing of ceilings, and 8568-7 for field measurements of ceiling percussive soundproofing. It is rated to deliver an output power level of 120 decibels, based on one picowatt for sound. The Nor276 can operate continuously at its highest power for up to one hour.

It's important to note that the Nor276 is designed exclusively for use with a specific power amplifier. Attempting to use other amplifiers may result in damage to the internal system of the device. This amplifier is purpose-built for acoustic measurements, offering half the weight and double the power of standard amplifiers. Furthermore, this model features an internal noise generator and emits a sound power level of 120 decibels across the frequency range of 50 to 5000 Hz when paired with the Nor276 dodecahedron speaker[5].

2.1.2.4 Microphone

The microphone employed for these measurements is the 2.1-inch free field microphone model 4190-L-001, paired with the preamplifier model 2669-L to form the receiving system. This microphone is specifically designed for precise acoustic measurements and meets the Class 1 specifications outlined in the IEC 61672 standard.

2.1.2.5 Rotating base for microphone

This device is designed as an enhancement to building acoustic and sound power measurement equipment, typically mounted on a tripod during testing. It features an adjustable arm, with lengths ranging from 50 to 200 cm. The unit is equipped with a power supply circuit, as well as input and output jacks. The arm's rotation duration can be set to 16, 32, or 64 seconds, and its rotational angle can be finely adjusted in ten-degree increments using a gear clutch.

2.2 Method for sealing soundness against impact noise

The acoustic performance of a floating floor is contingent upon the characteristics of the concrete floor on which it is installed. To account for this, the national standard of Iran 2-8834 has established percussive sound pressure level values for a reference base floor. When measurements are conducted on a standard heavy floor within the acoustics laboratory, a single-digit, weighted normalized impact sound pressure level of 71 dB is obtained. Subsequently, laboratory measurements are performed with the floating floor installed on this base floor, resulting in a single value of the weighted normalized impact sound pressure level for the combined system, denoted as $L_{n,r,w}$.

$L_{n,r,w}$ will be lower than 71 dB. Consequently, the single value of the weighted sound pressure level reduction for the floating floor, ΔL_w, can be calculated using equation 1:

$$\Delta L_W = 71 - L_{n,r,w} \quad (1)$$

For flexible elastomeric foam insulation with egg crate and simple roll shapes, a singular value of weighted sound pressure level reduction can be applied and measured[7,8].

2.2.1 *Measuring percussive sound level transmission from the Ceiling*

To conduct this test, two rooms are stacked one above the other: the upper room, designated as the “source room”, and the lower one as the “receiving room”. These rooms are isolated from each other by a standard floor, onto which the test floor covering is applied. Airborne sound transmission between the source and receiving rooms should be such that the transmission of airborne sound from the source room to the receiving room is at least 10 dB lower than the impact sound transmission level in each frequency band.

The separating floor between these two rooms, where the test covers will be installed, consists of a uniform, reinforced concrete slab with a consistent thickness of 16 cm. The visible floor area from the reception room measures 12.3 square meters.

Four specific points on the test floor are designated for the placement of the tapping machine. It is worth noting that the positioning of the tapping machine adheres to ISO standards, forming the basis for the ensuing measurements. According to Iran's national standard 6-8568 (ISO 140-6), the impact sound should be evaluated from at least four randomly selected positions on the test floor.

When the tapping machine initiates its impact in a given location within the lower room, the percussive sound is transmitted from the ceiling (L_i) by means of a microphone that is placed on a rotating base and connected to the analyzer device for measurement (Figure 1). Then the drum is relocated to other designated spots on the floor, and the corresponding drum sound level is recorded[5,6].

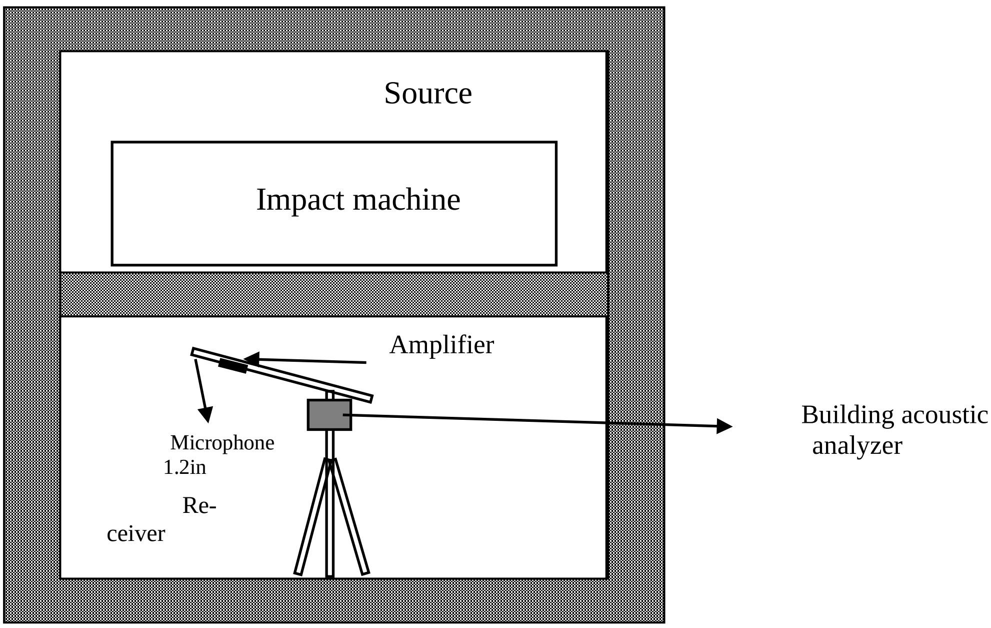

Fig.1 Acoustic Experimental test set-up

The following points are observed in the measurements:

a) The central frequency range of the one-third-octave bands in Hertz is specified as follows:

100	125	160	200	250	315
400	500	630	800	1000	1250
1600	2000	2500	3150	4000	5000

b) The angle between the rotating arm of the microphone and the horizon is set at 20 degrees.
c) The length of the rotating arm of the microphone is set to 120 cm.
d) The level of the impact sound at the measured frequency is determined by one full revolution of the rotating base over a 30-second period.
e) The microphone is positioned at least one meter away from the walls in the test room.
f) The cleaning device is situated at a distance of at least half a meter from the edges of the floor being tested.

2.3 The method of calculating the normalized impact sound pressure level

The normalized impact sound pressure level (L_n) in decibels (dB) is determined using equation 2. The equivalent level of sound absorption in the correction term of relation 2 is derived from equation 3.

$$L_n = L_i + 10 \log \frac{A}{A_0} \tag{2}$$

$$A = \frac{0.16V}{T} \tag{3}$$

In equation 2, A and A0 denote the absorption equivalent level measured in the receiving room (in square meters) and the base absorption equivalent level (in square meters), respectively. Additionally, V represents the volume of the receiving room in cubic meters, and T stands for time in seconds.

As a result, by measuring the impact sound pressure level, along with its duration, and inputting the room's volume, the building acoustic analyzer computes the normalized impact sound level and presents the outcomes for each frequency. It is evident that a lower level of normalized impact sound indicates a higher degree of soundproofing against impact noise for the ceiling[5,6].

2.4 Elastomeric Insulation and Materials

In this research, elastomeric insulations with a closed cell structure, which are in the form of simple roll insulation and egg crate (Figures 1 and 2), have been used. The egg crate insulation boasts a thickness of 12 mm and a volume density of 60 kg/m^3, while the simple roll insulation measures 19 mm in thickness with a volume density of 54 kg/m^3. The installation of the floating floor is carried out on a base floor that is uniformly smooth.

The construction process for the tested floor commences with the application of the specified elastomeric insulation onto the floor. Subsequently, a layer of waterproofing material is added to prevent concrete water vapor from permeating the elastomeric insulation. After that, the floating floor is then concretized. It's important to note that the concrete thickness in this section should not be less than 4 cm. This layer can be executed using a special mortar that doesn't necessitate a mesh network, or with standard concrete that does require one. After a curing period of 14 days for the top layer of concrete, the impact sound pressure level of the floor was evaluated. Figure 2 illustrates the implementation of the floating floor on the concrete base.

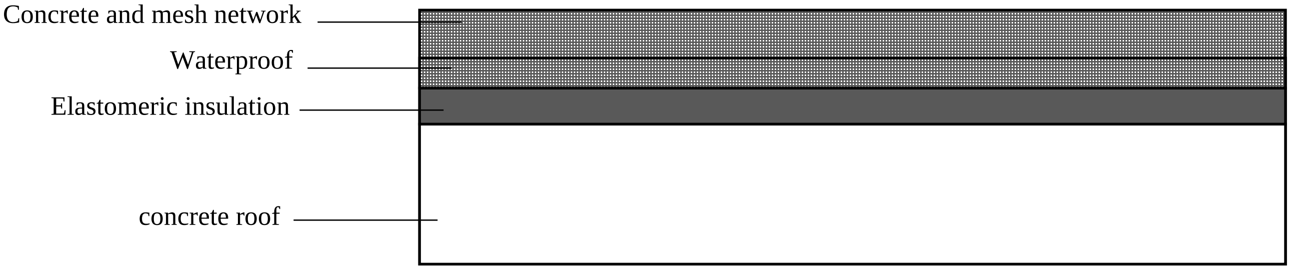

Fig.2 Details of material layers

3. Discussion

3.1 Evaluation of impact sound pressure level reduction

To determine the value of impact sound pressure level reduction (ΔL_W), it is imperative to measure the recorded values of ΔL in relation to a reference base floor. The base floor used in the experiments of this study is composed of a uniform and seamless concrete surface, with a normalized impact sound pressure level equivalent to 71 dB. The reduction in percussive sound pressure level (ΔL) is computed using equation 4.

$$\Delta L = L_{n.r.0} - L_{n.r} \tag{4}$$

In equation 4, $L_{n,r}$ signifies the normalized impact sound pressure level measured on the tested base floor with floor covering. Additionally, $L_{n,r,0}$ and ΔL represent the normalized impact sound pressure level of the base floor and the reduction in the calculated impact sound pressure level, respectively.

Furthermore, the value of impact sound pressure reduction is determined using equation 5.

$$\Delta L_W = L_{n.r.0.w} - L_{n.r.w} \tag{5}$$

In equation 5, $L_{n,r,w}$ stands for the normalized impact sound pressure level of the tested base floor with floor covering, while $L_{n,0,r,w}$ represents the normalized impact sound pressure level of the base floor[7,8].

The outcomes of the investigation and tests performed on flexible elastomeric foam insulation, available in the forms of egg crate and simple roll, are detailed in tables 1 and 2.

Table 1: The results of the experimental measurement of the reduction of impact noise transmission on the egg crate form of flexible elastomeric foam insulation

Reduction of the normalized impact sound of the floating floor (dB)	Normalized impact sound level of the base floor (dB)	The central frequency of the one-third-octave bands in Hertz
0.9	58.0	100
1.4	59.3	125

5.4	61.8	160
7.5	64.9	200
8.4	66.6	250
9.9	67.4	315
11.9	68.7	400
13.3	68.9	500
16.9	69.8	630
19.0	69.4	800
20.9	68.1	1000
23.9	67.4	1250
24.9	66.1	1600
24.5	64.2	2000
26.1	62.5	2500
29.4	61.6	3150
33.2	60.0	4000
40.0	58.1	5000

Table 2: The results of the experimental measurement of the reduction of impact noise transmission on the simple roll form of flexible elastomeric foam insulation

Reduction of the normalized impact sound of the floating floor (dB)	Normalized impact sound level of the base floor (dB)	The central frequency of the one-third-octave bands in Hertz
5.0	60.9	100
5.8	58.4	125
9.6	62.6	160
12.0	64.5	200
13.9	67.8	250
14.9	68.6	315
16.8	69.5	400
16.9	69.9	500
18.4	69.7	630
20.5	69.4	800
21.6	67.7	1000
23.7	66.4	1250
23.4	65.0	1600
23.0	63.9	2000
24.7	62.7	2500
28.2	61.4	3150
31.4	59.5	4000
37.9	58.2	5000

In Table 3, there is a comparison between the test results. As anticipated, the sample with lower density exhibits a notably higher normalized impact sound level reduction due to its greater elasticity when compared to the denser polymer layer. Moreover, the simple roll sample outperforms the egg crate roll sample in lower frequencies.

Upon scrutinizing the test results, it is deduced that for polymer-based materials like elastomeric foams, an increase in density corresponds to a harder and less elastic material, particularly at lower frequencies. Consequently, they demonstrate diminished efficacy in mitigating impact noise. These products exhibit superior performance with reduced density and a tendency towards greater elasticity. It is worth noting that, for the elastomeric insulation in the form of egg crate, the insulation's performance coefficient surpasses its thickness.

Table 3 The measurement results of normalized impact noise level reduction (ΔLW) for floating floor samples

Row	Insulation type	Thickness(mm)	Density(kg/mm^3)	Normalized impact level reduction (ΔLW)
1	Egg crate roll	12	60	20
2	Simple roll	19	54	22

4. Conclusion

Given that, under typical circumstances, the soundproofing of conventional roofs in the country is notably inferior to the standards outlined in Topic 18 of the national building regulations (pertaining to insulation and sound control), adopting the floating floor system emerges as the most viable solution. Accordingly, the results of this study underscore the potential of flexible foam elastomeric insulation as a highly effective elastic material for attenuating the transmission of impact sound within buildings.

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