E3S Web of Conferences **533**, 01005 (2024) https://doi.org/10.1051/e3sconf/202453301005
FORM-2024

Sound insulation properties of materials and methods used in civil engineering

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Abstract. The issue of sound insulation in enclosing structures continues to be extremely prevalent in both newly constructed and exploited buildings. Standard fencing solutions frequently employ contemporary wall materials without the additional sound insulation that is required. This study investigates the materials applied to soundproofing in various residential buildings and evaluates the extent to which they assist in reducing noise levels indoors. The research suggests measurement techniques to assess how effectively certain building materials and architectural layouts perform in terms of acoustics when used during the construction. The results of the study expand knowledge of noise absorption materials used in the context of urban development and provide recommendations for construction regulations and architectural designs to improve living environments while minimizing noise-related complaints.

Key words: sound insulation, sound waves, noise level, decibel, sound absorption, materials.

1 Introduction

As for the present day, an extensive number of considerations ought to be taken into account in the design of residential structures in order to guarantee suitable conditions for living. The conditions for providing insolation, sufficient natural lighting, air and vapor permeability, and thermal efficiency are the primary variables and are taken into consideration initially, in accordance with modern requirements. However, it's crucial to keep in mind sound insulation, particularly for structures with comfortable conditions [1].

The normalized parameters of sound insulation of internal enclosing structures of residential buildings are the air noise insulation indices of enclosing structures R_w and the indices of the impact noise level L_{nw}. The following indicators vary based on categories of buildings, such as category A (highly comfortable conditions), category B (comfortable conditions), and category C (the maximum permissible conditions). The building category is determined by the design specification [2]. In this particular instance, the distinctive features of category B buildings with comfortable conditions are taken into account.

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Individuals who reside or work in buildings frequently experience serious concerns about the sound insulation of the walls and floors. In addition to residences, it is particularly relevant to structures such as workplaces, hospitals, and schools. For an extremely long time, standards and research have been conducted regarding sound insulation in structures. The sources of noise have expanded in frequency and intensity, and it's conceivable that the tenants' demands have grown as well [3]. Concurrently, there is a gradual development and modification of construction materials and methods [4-5]. Therefore, throughout the initial stages of building, it is crucial to comprehend the additional aspects of sound insulation [6].

According to information gathered by the World Health Organization (WHO), it negatively impacts 1.3 billion people, 10% of whom, according to specialists, have health issues that are incurable. Above 85 dB, excessive noise not only deteriorates hearing and can lead to diseases, but it also shortens lifespan [7]. The European Environment Agency estimates that at least one in five EU citizens is exposed to long-term noise levels and excessive noise-related deaths have caused almost 12,000 premature deaths in the EU [8].

Nowadays, in Kazakhstan, residents who are living in large metropolitan areas are well aware of the issue of noise pollution. A person typically stays indoors due to the variety of sounds surrounding them, including music, commercials, ambulance and police signals, and announcements. They are unable, however, to escape from the increased sound pressure levels, even inside. Large cities, including Astana and Almaty, are home to residents who primarily complain about all the noises coming from neighboring flats, the commercial residences, and the construction cranes. Nevertheless, considering the wide range of factors that contribute to noise in buildings, even well-defined regulations are ineffective.

Generally, this investigation is devoted to the analysis of the materials applied to soundproofing in several various residential buildings and evaluating the extent to which they assist in reducing noise levels indoors. The study combines a measurement technique to assess how effectively certain building materials and architectural layouts perform in terms of acoustics when used during the construction of these structures. The results of the study expand knowledge of noise absorption materials used in the context of urban development and provide recommendations for future building regulations and architectural designs that improve living environments while minimizing noise-related complaints.

Noisy environments are often caused by hard, flat surfaces reflecting sound most effectively. It is possible to create a more serene and tranquil indoor atmosphere with the use of materials that are effective in absorbing and blocking sound waves. For the purpose of absorbing sound waves and decreasing the transmission of noise, sound insulation has been diligently used in the construction process. It is a great option for soundproofing a residence because it is denser and thicker than standard thermal insulation [3].

A particular kind of measure that prevents sound waves from seeping in is sound insulation. The sound transmission loss, which is measured as the decibel variance between the incident and penetrated sounds, serves as a prime instance of it [9]. Sound insulation is divided into two categories: airborne sound insulation, where the noise source is in the air inside or outside the building, and structure-borne sound insulation, where the noise source is located at a building structure. The most prevalent causes of airborne noise in a building are people chatting, televisions and musical instruments. These sources are currently considerably louder and cover a greater range compared to how they were when the building standards for sound insulation emerged [10].

For sound insulation, it is preferable to use heavy, dense materials such as steel plate, reinforced concrete, and clay brick. Implementing the disconnected structure is the most efficient way to minimize the sound carried by solids. This refers to filling in the elastic liner between the wall and the spandrel girder, as well as between the wallboard and the building frame. Rubber, cork, felt, and elastic carpet are alternatives for the elastic liner.

Material that absorbs sound ought not to be mistaken for material that insulates sound. It should be highlighted that sound-absorbing materials are porous, light, and loose [9].

The "BI Group" company has continued to develop noise insulation advancements since 2017. Due to consumer complaints about the rising levels of noise and in order to improve insulation measures without contributing to the increase in load on the building frame, Acoustic Pro sound-absorbing inter-apartment partitions and "floating floor" technologies were implemented. This design idea makes applications for Acoustic Pro technology, which was developed through a partnership with Daewoo E&C, a Korean enterprise. The structure uses a double layer of drywall and a sound-absorbing mineral plate to encase an aerated concrete block on each side of the inter-apartment walls. Moreover, as a result of the "floating floor" system, impact noise cannot be transmitted [11].

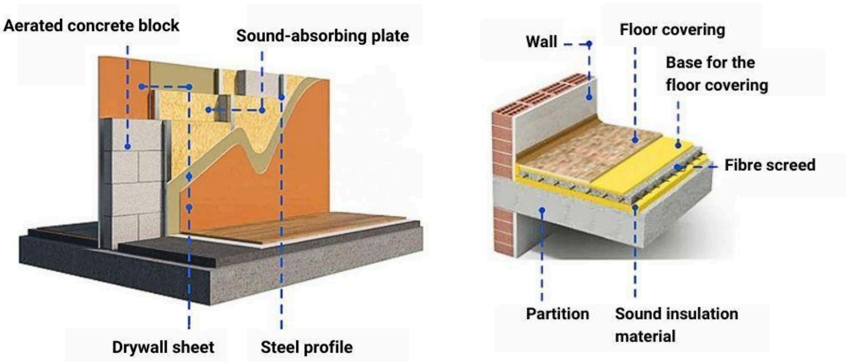

Fig. 1. The compositions of Acoustic Pro and "floating floor" systems [11].

2 Methods

Apart from the material's additional characteristics, thickness, and surface conditions, the incident angle and frequency of the sound waves possess an influence on the material's ability to absorb sound. The sound absorption coefficient varies at six distinct frequencies in order to accurately represent the sound-absorbing characteristics of a material [12].

There are basic requirements for the selection of materials for sound absorption. The ability to absorb sound will be enhanced if the open pores are situated near the adjacent ones. It is preferable to position sound-absorbing materials above the height of the wall protection plate in order to prevent damage. The resulting expansion and shrinkage must be taken into account since materials that absorb sound efficiently absorb heat. The distinctions between sound-absorbing material and sound-insulating barriers should be recognized [12]. To execute the mentioned requirements, the following constructive measures are recommended for the purpose of enhancing the sound insulation of double walls and partitions: increasing the thickness of the gap between the elements of the double structure and eliminating the rigid connection between the elements of the double structure, as well as with structures adjacent to walls and partitions [13]. Point fastening of sheets with a span of at least 300 mm to the frame is provided in the construction of frame-sheathing partitions. Two layers of sheathing sheets ought not to be glued together. It is advised to leave a minimum of 600 mm between the horizontal elements of the frame racks and their span. Independent frames are advised for panels to improve sound insulation. Two or three-layer sheathing should be placed on either side of the partition [13].

Internal walls and partitions composed of brick, ceramic, and cinder blocks should be designed with full-thickness seam filling and non-shrink plaster applied on both sides. Internal walls between built-in and residential rooms, which are subject to more rigid air noise isolation regulations, should be designed twice, with their components completely isolated from one another and from adjacent structures. It will prevent indirect sound waves from traveling along close by walls and ceilings and entering the isolated room [14].

Determining the existing noise levels in residential construction and identifying problem areas can be achieved mostly by conducting a noise insulation survey, which entails conducting measurements of sound levels both within and outside the building, analyzing the data gathered, and formulating solutions for enhancing noise absorption. The aforementioned data may be applied to develop an action plan [15].

A system-structural approach that was based on the building materials and the insulation science methodology within the system was used to carry out the experimental research. Modern research methods, standard methodologies that provide sufficient precision of the results, and experimental work employing research and testing equipment with sufficient methodology of research results together ensure a high degree of reliability.

For the following experimental research, the digital sound level meter is used to measure the sound insulation ability of the monolithic, brick, and modular building structures—particularly the bearing walls, partitions, and floor slabs. The sound level meter operates on the following principle: vibrations can be detected and recorded using the built-in microphone and converted into an electrical signal. This signal subsequently passes through a number of filters and is displayed on the device's indicator after getting amplified. Ultimately, the collected and measured data will be displayed on the panel. The following are the characteristics of a digital sound level meter: sound pressure accuracy: ±1,5 dB (sound pressure standard, 94 dB - 1 kHz); sound pressure frequency response: 30 Hz - 8 KHz, measurement scope: 30-130 dBA, 35-130 dBC; dynamic range of sound pressure: 50 dB; microphone: polarized capacitive microphone [16]. A portable wireless speaker is used as an instrument to measure sound insulation by acoustically increasing sound levels in the premises and later measuring the noise absorption of the structures.

3 Results

The study was carried out in buildings with varying structures and materials to compare and assess the effectiveness of certain building materials and architectural layouts in terms of acoustics when used during the construction. It was envisaged to determine the noise level value of the structure elements, such as the bearing wall, partition, and floor slab.

In order to obtain the noise level value, the normative documents on the sound insulation properties of residential buildings and the characteristics and operation principles of noise meters were studied using existing regulatory documents and taking into account the technical requirements. The sound insulation measurement devices applied for determining the sound insulation level during experimental research are listed in Table 1.

Table 1. Sound insulation measuring instruments.

№	Denomination of measuring instruments	Manufacturers' number	Information about verification
1	Digital sound level meter MS6708	MS6708	Verification certificate CE / ETL / RoHS
2	Portable wireless speaker DS26	190050.35/2	-
3	Acoustic type calibrator AK-1000 №1098	№1098	-

4	Microphone preamplifier P200	№196283	Verification date 28.10.2019
5	Standard impact machine УМ-10	№190035	Certificate № A/37 dated 11.12.2019

The sound insulation properties of modular, brick, and monolithic buildings, as well as architectural elements such as floor slabs, bearing walls, and partitions, are displayed in Table 2. The values of the sound meter level that were obtained during experimental research are presented in the following table.

Table 2. The sound insulation characteristics of various structures and elements.

Type of structure	**Monolithic structure**				**Brick structure**				**Modular structure**			
Type of a building element	Bearing wall		Floor slab		Bearing wall		Floor slab		Bearing wall		Floor slab	
Actual and normal values of indexes	R_w (A)	R_w (N)	L_{nw} (A)	L_{nw} (N)	R_w (A)	R_w (N)	L_{nw} (A)	L_{nw} (N)	R_w (A)	R_w (N)	L_{nw} (A)	L_{nw} (N)
The noise level value, dB	42	50	66	60	37	50	64	60	41	50	65	60

Where: $R_{w\,(A)}$ - an actual value of air noise isolation index; $R_{w\,(N)}$ - a normal value of air noise isolation index; $L_{nw\,(D)}$ - an actual value of impact noise insulation index; $L_{nw\,(N)}$ - a normal value of impact noise insulation index.

The design and normative values of the noise level of different structures and their elements varied substantially, according to the analysis of the data collected throughout the experiment. The values of the air noise isolation indexes were measured with the help of a portable wireless speaker, while the values of the impact noise insulation indexes were measured using the standard impact machine, both of which were applied as sound sources.

The bearing wall of any structure ought to have a normal noise level of 50 dB, and according to the noise meter's results, a sufficient level of 42 dB is determined by actual measurements. Comparable outcomes can be discovered for the brick-bearing wall's sound insulation level, which correspondingly revealed a low noise level of 37 dB in comparison to the normative value of 50 dB. In contrast, the bearing wall of the modular structure has a slightly less noise level than the monolithic structure. Also, at 41 dB, this value does not exceed the normative range, indicating that the structure's sound absorption is sufficient. Upon comparing the noise level measurements for all three structures, it can be observed that the monolithic construction has the lowest ability to absorb sound because of its demonstrated higher noise level compared to brick structure.

Nevertheless, in comparison to the normative value, the floor slabs' ability to provide insulation over sound in both structures indicates a substantially greater noise level value. The actual floor slab noise level of the brick construction in the current experiment was 64 dB, the modular structure's was 65 dB, and the monolithic structure had a noise level of 66 dB compared to the standard measurement of 60 dB, demonstrating the absence of a sound insulation layer in the floor slab's manufacturing. Furthermore, the examination of floor slabs also demonstrated the higher noise level in monolithic structures compared to modular and brick structures.

The results indicated in Table 2 are visually represented in the diagram in Figure 2. The diagram effectively demonstrates the previously indicated variations in the noise level values of distinct structures and their individual components.

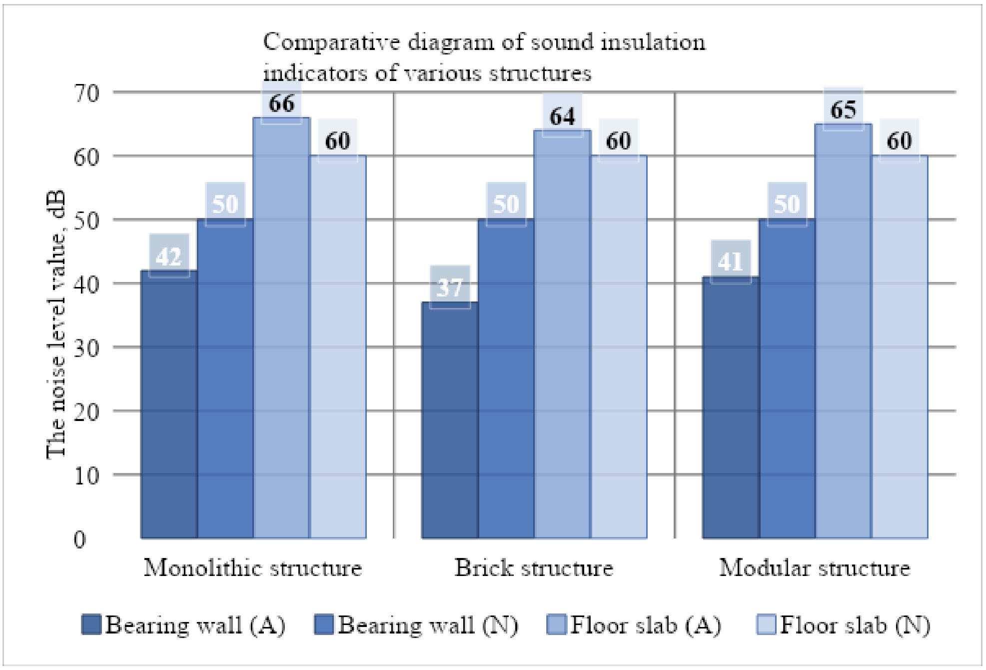

Fig. 2. Comparative diagram of sound insulation indicators of various structures.

4 Discussion

The research work combined an analysis of the materials applied to soundproofing in several various residential buildings with an assessment of how effectively certain building materials and architectural layouts perform in terms of acoustics when used during the construction of these structures. The investigation determined that the noise level was fully comprehensible during the floor slab testing and that the floor slabs were not sufficiently soundproofed. The high decibel level was particularly apparent in monolithic and modular structures, which are commonly used in the building of multi-story residential buildings. The significance of the following results resides in their evidence of the absence of sound insulation in floor slabs, as demonstrated by indicators exceeding the normative values established by regulatory standards. There's a substantial likelihood that residents on one level will experience disturbances due to excessive noises that might come from apartments on the upper or lower level. Taking into consideration the current results of the evaluation, it is required to provide recommendations for future building regulations and architectural designs that will minimize noise-related complaints.

The following recommendations for the design of sound insulation for enclosing structures are based on the examination of investigation and regulatory sources [17-18]. For the improvement of sound insulation of floor slabs, it is suggested to use the "floating" floor system on the sound-isolating layer. A floating concrete floor base or screed requires contour separation from walls and other building structures by 1-2 cm-wide gaps filled with a material that absorbs the sound, such as a soft fiberboard, molded products made of expanded polyethylene, etc. While designing a floor that comprises a monolithic floating screed for the base and gaskets made of mineral wool, glass wool slabs, or mats, the sound insulation layer should be placed along with a solid waterproofing layer such as parchment, roofing material, waterproofing, etc. at the joints, with at least 20 centimeters of overlap. The joints between sound-absorbing boards ought not to include cracks or spaces [14].

On the contrary, it is recommended to construct fence components using materials with a solid framework that does not contain open pores in the walls. Additionally, the structures that enclose them must be built to ensure that there are no apparent fractures during construction or execution, not even minor cracks in the joints, as any minor defects might permit sound to travel through those crevices [19-20]. After they are examined, cracks that occur during construction must be repaired using preventative measures and completely sealed with non-drying sealants and other materials [14]. In particular circumstances, it is advisable to add additional cladding to the frame of a wall or partition constructed of reinforced concrete, concrete and brick in order to enhance the insulation from outside noise. Plasterboard sheets, solid fiberboard, and other comparable sheet materials can be used as cladding if they are attached to the wall with wooden slats and linear or point beacons formed of gypsum mortar. It is recommended to leave a 40–50 mm thick air gap between the wall and the cladding, which is then required to be filled with a mild substance that absorbs sound, such as mineral wool or fiberglass plates, textiles, etc. [14].

5 Conclusions

The analysis work integrated an evaluation of the acoustical efficiency of specific building materials and engineering layouts with an examination of the materials used for soundproofing various residential buildings. The investigation concludes that the floor slabs are not effectively soundproofed and that the noise level during the floor slab assessment was entirely explicable. The monolithic and modular constructions, which are regularly used in the construction of multi-story residential complexes, were particularly susceptible to the high decibel level.

In general, it should be pointed out that the implementation of a "floating" floor system, the prevention of joint cracks and spaces, and the use of sound-absorbing materials such as soft fiberboard, molded expanded polyethylene products, fiberglass plates, textiles, etc. represent a few great examples of effective sound insulation solutions.

In consideration of the evaluation's current outcomes, several recommendations for sound insulation of floor slabs as well as exterior and interior walls that are capable of being implemented into practice in the modern construction industry are recommended to minimize noise-related issues and complaints.

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