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Article

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DESCRIPTORS OF SOUND INSULATION OF BUILDING STRUCTURES IN RESIDENTIAL BUILDINGS IN UKRAINE AND EUROPE

The object of the research is the descriptors (indices/parameters) of sound insulation of construction structures of residential buildings.

The work presents a brief overview of modern generally accepted construction technologies in Eastern Europe. The most common sources of noise and the consequences of their impact on people's health and life have been studied. An analysis of the levels of airborne sound insulation indicators of building structures in European countries and Ukraine was carried out. Partitions for standard types of housing (private houses, townhouses, multi-story residential buildings) are considered. As a result, a great diversity of sound insulation requirements in different European countries was shown. And this leads to an imbalance and worsens the quality of connections in the construction sector, due to possible confusion and can cause certain problems in trade and exchange of experience. It is also shown that the difference between the numerical indicators of the sound insulation levels of air noise is not entirely appropriate within the EU, since the subjective indicators of the sound insulation of the population have approximately the same data. Comfortable conditions for people from different countries should be the same. Examples of descriptors of air noise sound insulation indicators of 35 European countries are given. Numerical norms of sound insulation levels of EU countries are detailed. General characteristics and differences between states are highlighted.

The paper also examines the diversity of housing types and the relationship between detached, semi-detached (terrace/terraced) and multi-apartment buildings in many countries. This allows for some approximations to calculate the number of neighbors in these countries with adjoining walls and floors in attached housing. Having data on European countries, a conclusion was made with similar characteristics used in Ukraine. On the basis of the obtained data, the strengths and weaknesses of the Ukrainian noise protection regulations were determined, which consist in a small variety of modern types of housing, taken into account in the building regulations, and in a relatively low general level of requirements for sound insulation of building structures. Finally, the quality of life aspect of building occupants and the importance of good design, construction and control are discussed. We hope that the work gained will be used to achieve the goal of creating European-level housing. The already mentioned topic will be of interest to noise and sound insulation specialists, acoustic engineers, ecologists, urban planners and city planners.

Keywords: *architectural acoustics, sound insulation indices, European sound insulation standards, international sound insulation standards, norms of sound insulation levels.*

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1. Introduction

The countries of the European Union (EU) often and thoroughly investigate the issue of sound insulation and the related health status of the population [1, 2]. Thanks to this, we have indicators, according to which it is possible to create a number of standards and rules for the design of residential objects. Some countries deal separately with sound insulation and vibration insulation. For example, in [3, 4], norms and parameters for northern countries (Sweden, Switzerland, etc.) are separately considered, as local weather conditions create their own rules for design and construction. On the other hand, in Ukraine, the standards for sound insulation are partly a copy of the SNIP, which were developed under the USSR and ISO, which were developed as a counterweight to the SNIP. Therefore, Ukrainian norms are not something unique. The only major difference is that the regulatory requirements in Ukraine are somewhat higher than in most European countries. Therefore, it is relevant to analyze and compare the main parameters of sound insulation in European countries and Ukraine, which is considered in this paper.

So, the descriptors (indices/parliaments) of sound insulation of construction structures of residential buildings were chosen as *the object of research*. And *the aim of research* is the structuring and analysis of these parameters between European countries and Ukraine.

2. Research methodology

The research used an empirical method, i. e. a description of the existing phenomenon, in this case – the existing norms for the calculation of sound insulation, and a theoretical method, namely the generalization of the given data in available sources, data classification, analysis of these data and explanations.

3. Research results and discussion

In 2012, the European Union (27 countries of the European Union «EU27») and the rest of Europe accounted for 10–11 % of the world population [1].

To consider the housing stock in Europe in terms of sound insulation, different types of sound transmission and the proportion of residents who may experience sound transmission, it is useful to know the type of housing found in each country. Main types of accommodation [1]:

– separate housing (private houses);
– attached building (townhouse, semi-apartment);
– apartments.

The proportion of the population living in private homes in each country ranges from 6 % (Malta) to 72 % (Croatia) with an average of 41 %, with the relative proportion in each country shown in Fig. 1.

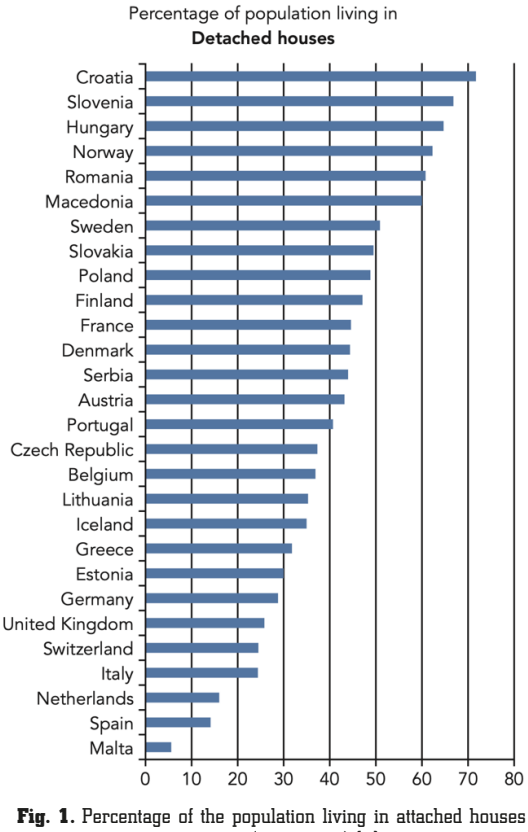

Fig. 1. Percentage of the population living in attached houses in Europe (2013 data) [1]

Fig. 2 shows examples of the variety of townhouses with the involvement of terraced and semi-detached housing. The share of the population living in attached houses varies from 2 % in Romania to 61 % in the Netherlands, with an average of 32 %. The comparison between countries is shown in Fig. 3 [1].

Fig. 2. Examples of buildings: *a, c–h* – a townhouse in a classic form; *b* – duplex townhouse

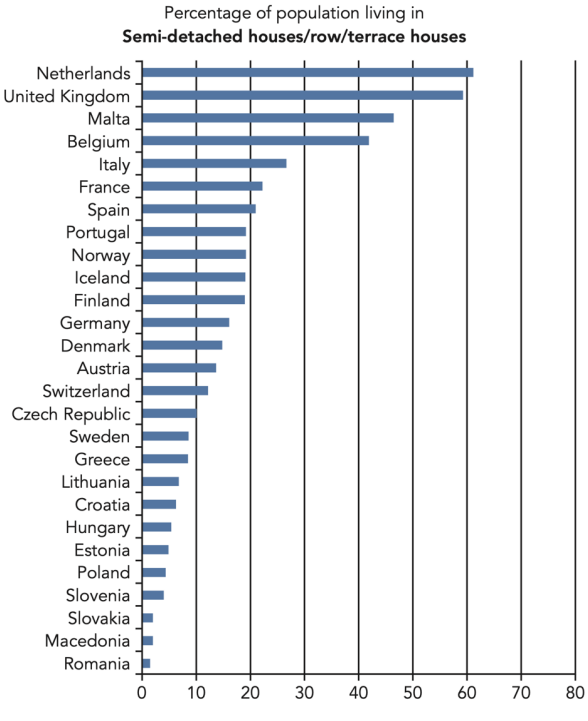

Fig. 3. The percentage of the population living in townhouses in Europe (2013 data) [1]

3.1. Modern generally accepted methods of construction in Europe. During most of the 20th century, methods of

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building new attached housing evolved using new building methods and local materials.

The transition from large solid, monolithic constructions, for some EU countries, to hollow walls took place in the early 1920s and 30s thanks to the improvement of mineral wool, plasterboard, wooden construction, brick and concrete blocks.

In the 1950s, many EU countries started building high-rise apartments with concrete and steel frames. More recently, for Northern European countries, the development and number of multi-apartment light steel and wooden frame buildings has changed significantly [5].

The variety and choice of materials used in European countries is mainly determined by costs.

However, more recently, in the 1980s and 1990s, increased performance requirements such as energy efficiency and sound insulation led to an increased combined focus on cost and building performance [2]. It has also led to an increase in trans-European supply chains and the consolidation of multinational manufacturing companies.

The beginning of the 21st century may be seen in the future as a turning point in terms of increased attention to more sustainable construction. The scale of regulatory change over the past decade has been unprecedented for many EU countries. However, the current two decades (2010–2030) will bring the most comprehensive and complex changes to specifications and materials.

As a result, requirements for technical compatibility between different building codes will be a key factor in the successful implementation of new housing systems and building technology products. The interplay between each country's regulatory and regulatory requirements for structures, energy efficiency, sound insulation and environmental impact will determine the types of materials, systems and structures that are built.

3.2. Classification of the main elements of structures. The classification of modern structural elements (walls) for attached housing in European countries is not unambiguous. For the purposes of this publication and for simplicity, the following categorization may apply:

– Based on blocks – involves the use of structures based on ceramics, aggregates or calcium silicate.

– Timber-based – using timber framing (open and closed panel), post and beam, cross-laminated timber or solid timber elements and engineered timber systems such as load-bearing I-beams or metal beams.

– Steel-based – light steel frame, heavy steel frame with composite concrete deck systems.

– On a concrete base – concrete, prefabricated beams, slabs and panels, formwork made of concrete insulation.

– On a hybrid basis – the involvement of working walls with a beam and a beam floor, block working walls with a wooden floor, steel frame and panels based on wood, concrete or steel frame with insulated metal cladding or load-bearing walls [6].

3.3. Typical ways of sound transmission in housing. In townhouses, each room has separate walls, and for apartments, walls and floors are the separating walls.

«Partition wall» is a wall that separates two separate houses. Apartments may also have one or two partition walls with neighboring apartments, but may also have a partition wall with common areas, entrances or shared stairs.

The term «split floor» or ceiling is used only for apartments. This does not apply to the intermediate floor (second floor) of a house or maisonette (a two- or three-story house for several families).

However, there are additional pathways for sound transmission, known as direct or structural. For example, the construction of a partition wall can be the same for its entire height (from the foundation to the roof). Since the partition wall can be structurally connected to the foundations, floors, internal walls, roof and external walls, each of these joints and their composition affects the soundproofing properties of the wall. Sound that is transmitted between buildings at points of contact is usually called structural sound transmission. This can often have an impact on the sound insulation performance of the partition wall.

Thus, the sound insulation performance of a partition wall between two attached houses can vary at each level due to different structural joints, building materials used, direct and structural noise transmission paths, as shown in Fig. 4.

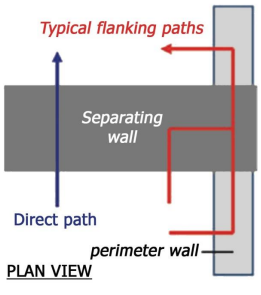

Fig. 4. Ways of noise transmission

The overall noise exposure due to sound transmission from the townhouse can affect the health and well-being of the residents. The degree of impact on health depends on a person's sensitivity, state of health, circumstances and perception of noise or control over it.

3.4. Negative effects of noise on residents. Effects that do not affect hearing and are not derived from direct exposure to household noise can be defined as [7]:

– sleep disturbance;
– irritation;
– disability;
– emotional reaction.

A negative effect, such as sleep disturbance, depends on the stimulus (noise type, intensity, duration, repetition, etc.), on the stage of sleep at which the disturbance occurs, as well as on age or health [7].

The intrusion of noise into the home affects a number of aspects of the resident's home life, and it is therefore very important to design and build homes that can at least attenuate the sounds of normal life activities.

Residents' perception of noise and their reaction to sound transmission from neighboring residential premises varies [8]. The reaction to the noise (sounds) of the neighbors may depend on the type of relationship that already exists between the neighbors. Some residents may accept that it is impossible to prevent all sounds from entering their homes, or may not find it acceptable to hear moderate levels of noise from televisions and radios, conversations and general life.

3.5. The need for sound insulation of housing. Social surveys in several European countries have shown that

residents of high-rise buildings are annoyed by the noise from their neighbors' activities [1]. The World Health Organization (WHO) defines health as «a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity» [7]. Based on this definition, the impact of noise on health should not only be understood as an adverse physical impact due to exposure to noise, but also as a disturbance of well-being, i. e. a psychological impact of noise, which in the long term may lead to adverse physical consequences. WHO has identified a significant number of specific negative health effects caused by environmental noise [9]. These effects can be disease-causing agents, and can also include sleep disturbances, stress, etc.

The relevance of the sound insulation problem is illustrated in Fig. 5 [9] showing the extent of severe noise disorders in national surveys in three EU countries, representing approximately 1/3 of the total EU population. Despite the uncertainties caused by the different methodologies (including questionnaires) used for the surveys, the author of the study [9] concluded that the problem of neighborhood noise in Europe is significant.

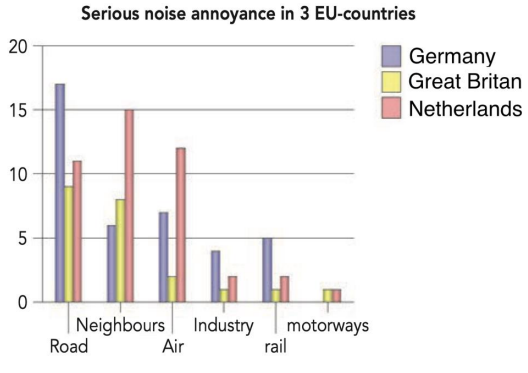

Fig. 5. Sources of annoying noise [9]

The work [10] includes the results of various social surveys and describes the shortcomings due to inconsistent questionnaires in different countries. Neighbor noise was examined in the large pan-European study LARES (Large Analysis and Review of European Housing and Health), coordinated by WHO/Europe. The WHO LARES study covered eight European cities and aimed to assess the impact of housing conditions on health. The results can be found on the WHO website [10].

When ranking annoyance from different noise sources, traffic is the dominant source, followed by noise from neighbors.

Based on population statistics [11] and the results of surveys due to noise irritation [9], more than 50 million Europeans are exposed to neighborhood noise, which negatively affects the quality of life. Citations from the WHO LARES study and more detailed references are given in [12].

For cities to remain a center of concentration of people and jobs, high-rise accommodation must be attractive to different people and offer «quietness». Thus, new housing must meet people's needs and provide comfort. Also, for existing housing, aspects of sound insulation should be taken into account, especially when renovating housing. The problem is huge, and the exchange of knowledge between countries is urgently needed.

Comparative studies of sound insulation descriptors (indices) and regulatory requirements (2008) in Europe are described in [13, 14]. And sound classification schemes are shown in [15, 16]. The high degree of diversity of descriptors, levels of requirements and classification schemes in Europe is an obstacle to the exchange of experience in designing housing and structural details for different levels of sound insulation. The need for unification is emphasized in studies [11, 17] and several research initiatives are proposed.

3.6. Sound insulation standards in Europe. Currently, building acoustic requirements for housing exist in more than 30 European countries. In some countries, national requirements for soundproofing have existed since the 1950s. The requirements for sound insulation are expressed by the norms defined in the standards. Within building acoustics, ISO standards are implemented as European (EN) and national standards.

International standards for the assessment of airborne and impact sound insulation are defined in ISO 717.

A total of 35 European countries use 7 basic descriptors [3, 4, 18] in various variants and recommendations. For high-rise housing, the difference between the indices reaches up to 10 dB. The sound insulation index for townhouse and similar buildings may differ by 10 dB. 8 European countries additionally introduce parameter C to clarify this index. In Sweden, this parameter takes into account only low frequencies. Scotland and Austria have the strictest requirements among European countries. 5 countries have no air noise insulation standards at all.

3.7. Normative levels of sound insulation in Ukraine. Currently in Ukraine, DBN V.1.1-31:2013, introduced in 2013, which replaced SniP II-12-77, which was introduced in 1977, which, in turn, canceled its relevance from June 1, is valid in Ukraine 1978:

– Paragraphs 3.56 and 3.57 of SniP II-L.1-69 «Theatres. Design norms»;
– Instructions on the acoustic calculation of ventilation units (CH 399-69), paragraphs 3.20–3.24;
– Appendix 1 to the chapter of SniP II-L.1-71 «Residential buildings. Design norms»;
– Paragraphs 13.3–13.7 of sanitary standards for the design of industrial enterprises (SN 215-71);
– Paragraph 4.3 of the chapter SniP II-L.16-71 «Clubs. Design norms»;
– Paragraphs 2.21–2.23 and appendix 3 to chapter SniP II-L.2-72 «Public buildings and structures. Design standards. General part»;
– Paragraphs 3.14 and 3.15 of SniP II-73-76 «Cinemas».

This standard specifies the numerical data of the sound insulation index of air noise by inter-apartment partitions, which is $R`w=52$ dB (clause 17, Table 3 of DBN B.1.1-31). This descriptor is indicated empirically and is borrowed from SniP II-12-77. Also, in addition to the current DBN 31, DSTU-NB V.1.1-32 «Instructions for designing protection against noise in premises by means of sound absorption and shielding» were developed and introduced, which provides methods for calculating the reduction of noise levels in premises with noise sources when applying sound-absorbing structures and acoustic screens. Methods of calculating the acoustic efficiency of screens and the required area of sound-absorbing cladding, requirements for the selection and placement of the specified noise reduction means to ensure their most effective use are also displayed.

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DSTU-NB V.1.1-33 «Instructions for the calculation and design of noise protection of agricultural areas», which provides methods for calculating the noise characteristics of traffic flows, tram flows, railway trains and underground trains, water transport flows, air transport and intra-quarter local noise sources. The specified methods of calculating the expected levels of noise from traffic flows on the territory of residential buildings and their necessary reduction, methods of determining the acoustic efficiency of means of protection against traffic noise.

DSTU-NB B.1.1-34 «Instructions for the calculation and design of sound insulation of the enclosing structures of residential and public buildings», which provides methods for calculating the insulation of air noise by internal and external enclosing structures, the isolation of shock noise by floor coverings. Methods for calculating the necessary sound insulation and recommendations for designing sound insulation of enclosing structures are also displayed.

DSTU-NB B.1.1-35 «Instructions for calculating noise levels in premises and on territories», which provides methods for calculating expected noise levels at calculation points of premises in buildings of various purposes, on the territories of industrial enterprises, agricultural and landscape-recreational territories from stationary sources of noise. This DSTU provides methods for determining the necessary reduction of noise levels at calculation points to allowable values for each of the sources under their complex action.

Comparing European and Ukrainian standards, one can observe a striking difference in the number and variety of premises to which these standards apply. For example, in Ukraine, norms have been introduced only for two-story, multi-story buildings, for hotels and dormitories [11], while in European countries there are norms for attached buildings (townhouses, duplexes, etc.) and private houses. There is also a noticeable difference in the numerical values of the sound insulation indices and in the descriptors. Comparing the values of Table 1 with the value of $R`w$ in the standards of Ukraine indicated above, it can be seen that the Ukrainian indicator is somewhat lower than the average indicators for Europe. The difference may be related to climatic conditions, the availability of certain building materials in the countries, and the easy availability of more or less quality materials. It would be absolutely fair to say that these types of housing (cottages, townhouses, etc.) are not so widespread on the territory of Ukraine. It should be noted that recently these types of housing are gaining more and more popularity, especially in the conditions of the growth of large cities, as well as in new areas of cities and on the outskirts of Ukraine.

Also, taking into account the pro-European development vector of Ukraine, it is necessary to expand the norms to the European level in order to fully correspond to the European standard of living.

It would be appropriate to say that, in addition to the variety of norms, the Ukrainian DSTU does not provide for regulatory developments of multi-layer, multi-density structures that are widely used in the modern construction industry. Analytical calculations of such constructions are given in work [17], which is being refined and the final version will be presented in the next research of the authors.

Table 1

Report table for 35 European countries

Country	Description	Multi-storey housing, dB	Townhouses, dB
Austria	*DnT,w*	≥55	≥60
Belgium	*DnT,w*	≥54	≥58
Bulgaria	*R`w*	≥53	≥53
Croatia	*R`w*	≥52	≥52
Cyprus	N/D	N/D	N/D
Czech Republic	*R`w*	≥53	≥57
Denmark	*R`w*	≥55	≥55
England	*DnT,w+C*	≥45	≥45
Estonia	*R`w*	≥55	≥55
Finland	*R`w*	≥55	≥55
France	*DnT,w+C*	≥53	≥53
Germany	*R`w*	≥53	≥57
Greece	*R`w*	≥50	≥50
Hungary	*R`w+C*	≥51	≥56
Iceland	*R`w*	≥55	≥55
Ireland	*DnT,w*	≥53	≥53
Italy	*R`w*	≥50	≥50
Lithuania	*DnT,w/R`w*	≥54	≥54
Luxembourg	N/D	N/D	N/D
Macedonia	N/D	N/D	N/D
Malta	N/D	N/D	N/D
Netherlands	*R`w+C*	≥52	≥52
Norway	*R`w*	≥55	≥55
Poland	*R`w+C*	≥50	≥52
Portugal	*DnT,w*	≥51	≥50
Scotland	*DnT,w*	≥56	≥51
Serbia	*R`w*	≥52	≥56
Slovakia	*DnT,w/R`w*	≥53	≥52
Slovenia	*R`w*	≥52	≥57
Spain	*DnT,w+C*	≥50	≥52
Sweden	*R`w+C50-3150*	≥53	≥53
Turkey	N/D	N/D	N/D
Switzerland	*DnT,w*	≥52	≥55

Note: N/D – no data

As a result, these data can and must be taken into account during design during the development of the «Noise Protection» section, the development of subsequent iterations of state building regulations, and during the process of building or repairing residential premises. The only problem is financial limitations in the selection of materials.

4. Conclusions

In the course of the study, it was shown that Ukrainian norms and descriptors are not lagging behind the European ones, but they require improvement, clarification and the introduction of new algorithms and indicator values (the level of absorption in the room when calculating sound insulation), based on modern construction realities and modern materials. That is, modern construction rules and

methods are not fully regulated by Ukrainian approved norms, namely DBN V.1.1-31 «Protection of territories, buildings and structures from noise». Taking into account all of the above, in order to eliminate these problems, it is necessary to conduct a full-fledged study on the descriptors, starting with audiogram experiments, ending with a review of sanitary regulations on noise protection.

Conflict of interest

The author declares that he has no conflict of interest in relation to this study, including financial, personal, authorship or other, which could affect the study and its results presented in this article.

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Data availability

The manuscript has no associated data.

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