



**DETERMINATION OF ACOUSTIC PERFORMANCE CRITERIA IN
RESIDENTIAL BUILDINGS ACCORDING TO NATIONAL REGULATION**

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BY

Ahsen İNCE

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ETHICAL STATEMENT

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Ahsen İNCE

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DETERMINATION OF ACOUSTIC PERFORMANCE CRITERIA IN RESIDENTIAL
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(M. Sc. Thesis)

Ahsen İNCE

GAZİ UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

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ABSTRACT

Residential buildings are noise-sensitive places where users spend most of their time. In the literature, unwanted sounds from inside and outside the building are referred to as "noise," and they have a negative impact on users' physical, physiological, psychological, and performance. In this thesis, by using literature data, noise types affecting residential buildings and noise control methods are included. In this context, to provide acoustic comfort conditions, national regulations as well as German, British, and American legislation have been examined comparatively. Acoustic performance criteria have primarily been established according to national regulations. In case the performance criteria were not defined in the national regulation, the regulations of Germany, England, and America were applied, respectively. In the light of these criteria, calculations were made for an existing residential building using the Insul (v9.0.24) simulation program, and the acoustic report for this unit was created by analyzing the current situation within the scope of the regulation. In the light of these analyses, the sound insulation values of the building elements located in an independent part of the residential building were determined. If these values do not comply with the limit values defined in the regulation, recommendations for improvement were presented.

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ULUSAL MEVZUATA GÖRE KONUT BİNALARINDA AKUSTİK PERFORMANS KRİTERLERİNİN BELİRLENMESİ

(Yüksek Lisans Tezi)

Ahsen İNCE

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ÖZET

Konut binaları kullanıcıların zamanlarının büyük bir bölümünü geçirdikleri gürültüye karşı hassas mekanlardır. Yapı içinden ve yapı dışından kaynaklanan istenmeyen sesler, literatürde gürültü olarak tanımlanmış olup kullanıcılar üzerinde fiziksel, fizyolojik, psikolojik ve performansa yönelik olumsuz etkiye sahiptir. Bu tezde; literatür verilerinden yararlanılarak, konut binalarını etkileyen gürültü türleri ve gürültü kontrol yöntemlerine yer verilmiştir. Bu bağlamda akustik konfor koşullarını sağlayabilmek amacıyla ulusal yönetmelikler ile birlikte Almanya, İngiltere ve Amerika mevzuatları karşılaştırmalı olarak incelenmiştir. Öncelik ulusal yönetmeliklerde olacak şekilde akustik performans kriterleri oluşturulmuştur. Performans kriterinin ulusal yönetmelikte tanımlı olmaması durumunda ise sırasıyla Almanya, İngiltere ve Amerika mevzuatlarına başvurulmuştur. Bu kriterler ışığında mevcut bir konut binası için Insul (v9.0.24) simülasyon programı kullanılarak hesaplamalar yapılmış ve yönetmelik kapsamında mevcut durum analizi yapılarak bu birimin akustik raporu oluşturulmuştur. Bu analizler ışığında konut binasının bağımsız bir bölümünde yer alan yapı elemanlarının ses yalıtım değerleri tespit edilmiştir. Bu değerlerin yönetmelikte tanımlı olan sınır değerlere uygun olmaması durumunda ise iyileştirmeye yönelik öneriler sunulmuştur.

Bilim Kodu : 80101
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SYMBOLS AND ABBREVIATIONS

In this study, the used symbols and abbreviations are explained below. Akustik Terimler Sözlüğü was used to create definitions of terms (2022). When symbols and abbreviations were not found in the reference, literature data was used.

Symbols	Definition
C	Spectrum adaptation term for internal noise
Cl	Spectrum adaptation term for impact noises
C_{tr}	Spectrum adaptation term for traffic noise
dB	Desibel
dBA	A-Weighted sound pressure level
D_{nT}	Standardized level difference
D_{nT,A}	$D_{nTw} + C$
D_{nT,A,tr}	$D_{nTw} + C_{tr}$
D_{n,Tw}	Weighted standardized level difference
L_{Aeq}	A weighted eq. continuous sound pressure level
L_{Amax}	Maximum A-weighted sound pressure level
L_{den}	Day-evening-night sound level
L_{eq}	Equivalent continuous sound pressure level
L_{night,h}	Night sound level
L_{n,w}	Weighted normalized impact sound pressure level
L_{n,Tw}	Weighted standardized impact sound pressure level
L'_{n,Tw}	W. standardized impact sound pressure level (in situ)
R'	Apparent sound reduction index
R_w	Weighted sound reduction index
R'_w	Weighted apparent sound reduction index
s	Second
T	Reverberation Time (s)
T₀	Reference reverberation time (s)

Abbreviation	Definition
AHU	Air Handling Unit
BS	British Standard
COST	European Cooperation in Science and Technology
DEGA	Deutsche Gesellschaft für Akustik
DIN	Deutsches Institut für Normung
EN	European Standards
FHA	Federal Housing Administration
HVAC	Heating, Ventilation and Air Conditionig
IIC	Impact Insulation Class
ISO	International Organization of Standardization
NC	Noise Criteria (curves)
NR	Noise Rating Curves
NRC	Noise Reduction Coefficient
Regulation	Regulation on Protection of Buildings Against Noise
RC	Room Criteria
STC	Sound Transmission Class
TL	Sound Transmission Loss
WHO	World Health Organization

1. INTRODUCTION

Nowadays, the development of technology has necessitated the provision of appropriate physical environmental conditions in buildings, such as thermal insulation, lighting, and ventilation, as well as acoustic performance, due to the increasing comfort level required by users. The spaces that people need with acoustic comfort can be achieved by constructing suitable structures at the design stage and finding solutions to acoustic problems that will adversely affect people's health and activities and affect working performance. Residential buildings are one of the living spaces where users can spend most of their lives and should be comfortable. With the development of technology and changing needs, housing construction systems have also changed. Due to the lightening of the building elements over time, it has become difficult to control the noise. With the development of technology and the increase in the number of electrical appliances used in homes, the diversity of noise has increased, and the control of noise has become much more important. For this reason, noise, which is considered unwanted sound, should be removed from the building or controlled to create a comfortable environment during the design stage (Özkartal, 2011; Şentop, 2013; Tekinbaykal, 2016).

In order to provide the necessary acoustic environment in residential buildings, criteria for environmental noise, background noise of volumes, and insulation of building elements are explained in the regulations of various countries using international standards and indicators. In this context, ISO standards and European Standards (EN) are widely used international standards (Rasmussen, 2010; Tekinbaykal, 2016).

The "Regulation on Protection of Buildings Against Noise" regarding noise control, which has recently gained importance in our country, was published on May 31, 2017. With the amendment made on May 31, 2018, the "Amendment to Regulation on Protection of Buildings Against Noise" entered into force. The values specified in the regulation were created within the scope of the COST Action TU0901 (2014) study prepared for residences with the theme "Integrating and harmonizing sound insulation aspects in sustainable urban housing constructions." This study covers a wide area by including the sound insulation of the facade of the house and the sound insulation of the dividers separating the house from the other volumes. With the "Regulation on Protection of Buildings Against Noise," which

came into force in our country, it is aimed at providing acoustic comfort by making it compulsory to meet acoustic criteria in many building types, such as residential buildings. Defined limit values are determined within the framework of acoustic performance classes from A (best) to F (worst). The minimum acoustic performance class to be achieved is determined as C for new buildings and D for existing buildings. Various limit values and standards are defined in the regulation to ensure these performance class conditions (Regulation on Protection of Buildings Against Noise, 2017).

Research problem

There are studies on the control of noise in residential buildings, mostly in terms of the subjective aspect of noise and the calculation of sound transmission in residential buildings. However, there is no study that includes acoustic performance criteria within the scope of the current regulation (Regulation on Protection of Buildings Against Noise). In this context, it is necessary to determine the acoustic performance criteria in residential buildings in accordance with the regulation, and from the planning stage of the building regarding the measures to be taken in this respect, architects have important duties in noise control while designing.

Purpose and scope

The purpose of this study is to establish and improve acoustic performance criteria for residential buildings within the scope of the Regulation on Protection of Buildings Against Noise, which is our current regulation. For this purpose, the types of noise in residential buildings and the measures to prevent noise have been analyzed with all their components. During the design phase, solutions were presented to reduce the noise problem in residential buildings and improve the acoustic environment. At the same time, in the study, national and international legislation on noise control was examined in terms of residential buildings, and performance criteria were established. In this context, it is aimed to create a study that can guide designers and architects who can provide acoustic comfort in residential buildings by compiling and arranging the data in the literature.

Method

For the purpose of the thesis, first of all, other studies in the literature related to noise control are briefly mentioned. In this process, external and internal noise sources affecting residential buildings were determined, and the effects of these sources on users were examined. The aforementioned data were collected by conducting a literature search on how to prevent these noises. Then, the regulations on noise control were examined in terms of residential buildings, and performance criteria were established. These design criteria were examined in accordance with the regulations, and improved acoustic performance criteria for residences were presented. In establishing the criteria, in addition to national legislation, German, British, and American legislation were applied for international legislation. Reason for consulting German legislation: a classification similar to the acoustic performance classes defined in our national regulation has been made, and the data is handled in more detail for the performance classes. In the event that information was not included in the German legislation, the data in the England legislation was used. Finally, the data in the America legislation was preferred. Since we are heading towards the European Union and the indicators used in America (TL, STC, and IIC) are different from the indicators defined in our regulation (R, R_w , and L_{nw}), the data in the America legislation has generally remained in the analysis stage.

The method applied in the thesis study is given in Figure 1.1 as a flow chart.

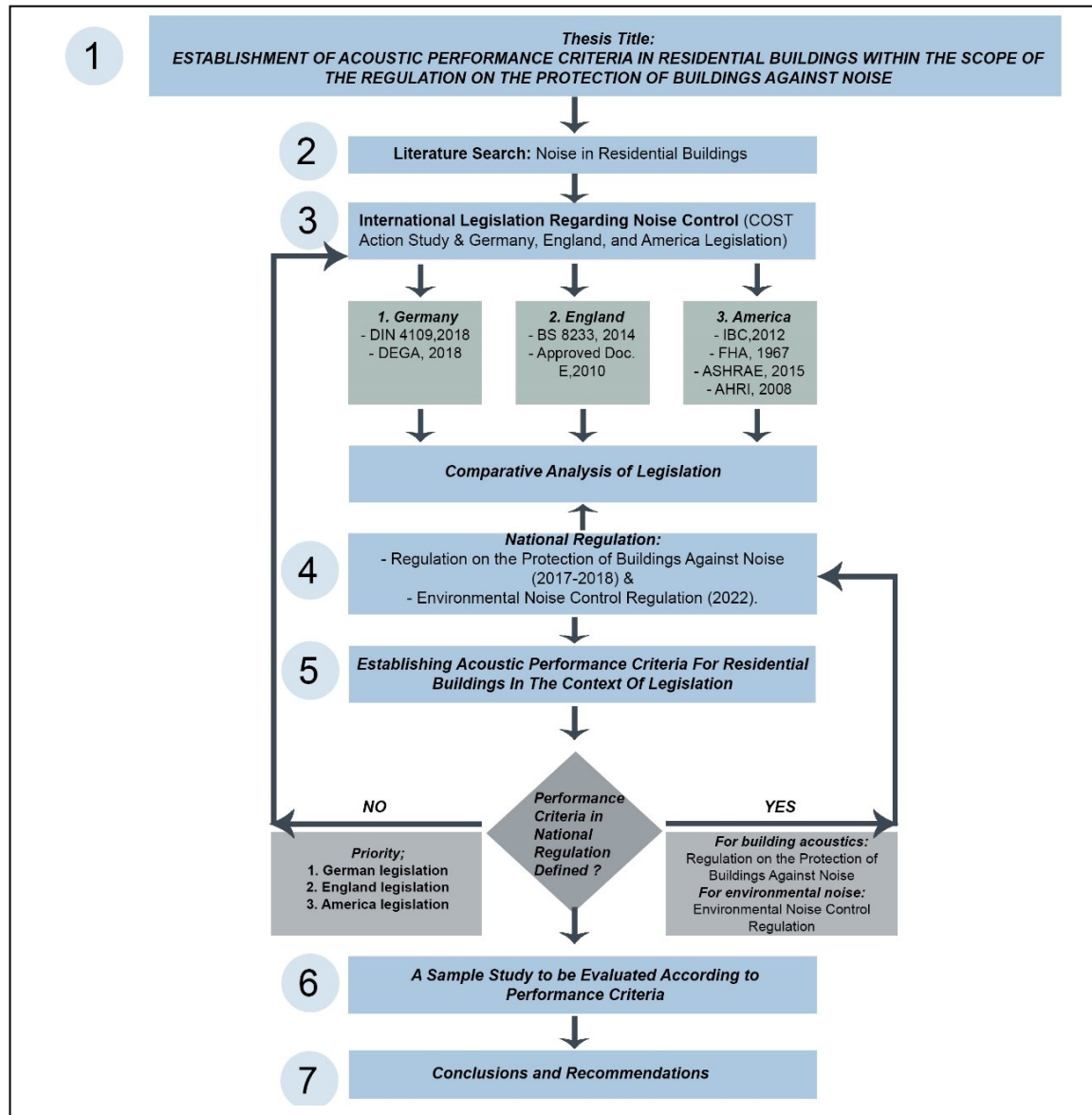


Figure 1.1. Flow chart of the method applied in the thesis study

Limitations

The limitation of the thesis is residential buildings, which are among the building types specified in the Regulation on Protection of Buildings Against Noise. Building types other than residential buildings are excluded from the scope of the study. In addition to national regulations, in the analysis of international legislation, German, England, and America legislation were used. Other countries' legislation is out of scope.

2. NOISE IN RESIDENTIAL BUILDINGS

According to the definition by the World Health Organization (WHO), being healthy requires feeling physically, mentally, and socially comfortable as well as not being sick or disabled (Berglund, Lindvall, and Schwela, 1999: 21). Exposure to noise, which causes environmental pollution, creates physiological and psychological disturbances. It has become important to consider the acoustics of a residential building and its effects on occupants in order to reduce unwanted noise and therefore provide a more comfortable environment (Adhikari and Thapa, 2020).

2.1. Sound and Noise Concept

As stated by Moorhouse (2010), noise and sound must be cautiously differentiated. Sound is used to define wave-like changes in air pressure, while noise is specified as the unwanted sound that expresses a response to sound. Özgüven (2008) defines "noise" as the sum of complex sounds with sudden or continuous high pressure without a harmonic relationship. For this reason, noise is accepted as a type of environmental pollution that must be controlled. According to Kurra (2021), the term "environmental noise" primarily refers to sounds coming from sources outside the building. These noises can cause health and comfort problems in the short, medium, and long terms. As stated by Dunn et al. (2018), for these reasons, the aim in residential buildings is to achieve good acoustic comfort.

Acoustic comfort is defined as:

- Lack of unwanted sound
- Existence of sound of the desired level and quality

Requirements for acoustic activities:

- do not disturbing other people
- not to be heard by other people (Rindel and Rasmussen, 1995).

2.2. Effects of Noise on Humans

Loudness is a subjective intensity that describes the sound a person perceives. The human ear, by nature, cannot perceive sound with its real physical properties (Kurra, 2021: 102). The assessment of what is "undesirable" varies from person to person, depending on the type of sound (Mehta, Johnson and Rocafort, 1999: 87). Therefore, "noise" depends on the physical aspects of the sound as well as the human response, which includes many complex psychological and other factors (Moorhouse, 2010: 8). These factors can be demographic: personal or behavioral factors such as an individual's age, gender, and socioeconomic status; or attitudinal: determinants of occupation, physical activity, and psychosocial health (Figure 2.1) (Eriksson, Nilsson, and Pershagen, 2013: 17).

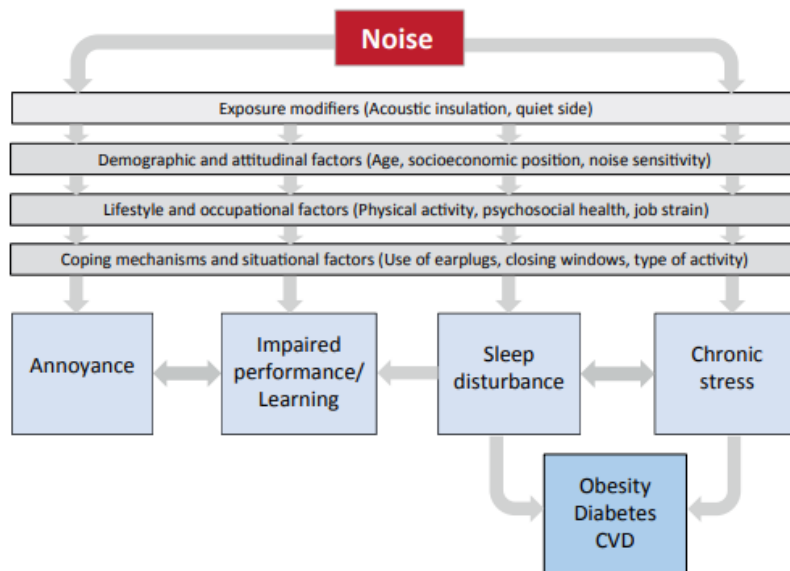


Figure 2.1. Effects of noise on health (Eriksson et al., 2013: 17)

2.2.1. Effects of noise on human health and performance

The adverse effects of noise are defined by the World Health Organization (WHO) as "a change in the morphology and physiology of an organism (Kurra, 2021: 610). The negative effects of noise are given under the following headings:

- a) **Physical effects:** Hearing impairment and noise-induced hearing loss can result in threshold shifts. Hearing impairment is defined as an increase in the hearing threshold. This situation negatively affects the person's work performance and daily life.

- b) Physiological effects: changes in body activities, increased blood pressure, irregular heartbeat, change in respiratory rhythm, sleep disturbances, etc. Uninterrupted sleep is essential for a healthy person to have a good physiological and spiritual structure. The sleeping disorder causes an increase in the feeling of fatigue, poor performance, and changes in mood and movements.
- c) Psychological effects: behavioral changes, headache, fatigue, depression, etc. Environmental noises may not directly affect human health but may increase existing mental illnesses.
- d) Performance effects: decreased speech intelligibility, concentration disorder, decreased work performance or productivity, etc. (Kurra, 2021; Kulak Kayıkçı ve Genç, 2004). If speech is blocked, the level of speech is 30 dB above the normal value (45–50 dB). This situation can cause effects such as the deterioration of human relations and stress. In addition, in complex tasks that require concentration, comprehension problems arise due to noise. Although noise does not affect the amount of work done, it does affect the accuracy of the work (Kurra, 2021: 611; Yılmaz Demirkale, 2007: 192-200). Figure 2.2 shows the effects of noise on people.

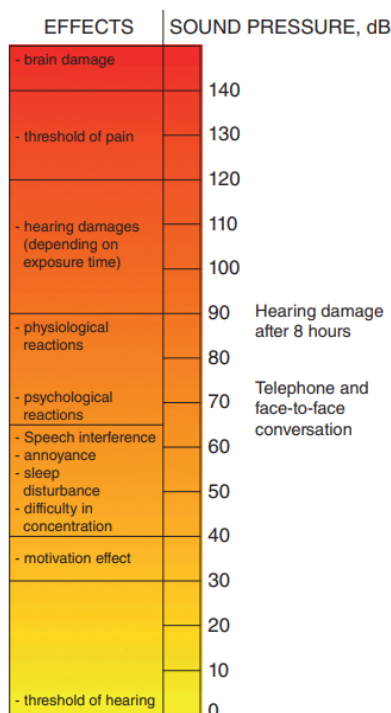


Figure 2.2. Disturbances caused by noise (Kurra, 2021: 611)

2.2.2. Variables affecting noise discomfort

The discomfort caused by the noise does not only depend on the acoustic character of the noise. Apart from these factors, social and economic factors are also effective in determining the degree of discomfort (Yılmaz Demirkale, 2007: 200). The variables that affect the discomfort caused by noise can be classified as follows:

- a) Acoustic factors: Discomfort depends on the various acoustic properties of the noise source, such as sound pressure level, background noise levels, etc.
- b) Source-related factors: The characteristics of the noise source have a direct or indirect effect on the disturbance.
- c) Environmental Factors: Meteorological factors in the environment, green areas, noise barriers, etc.) and physical properties have a direct effect on the increase or decrease of noise levels. The characteristics of the built-up areas, the layout of the buildings, and the sound insulation properties of the building facades are associated with noise disturbance.
- d) Temporal and situational factors: The degree of discomfort may vary depending on the duration of the activity and the impact of external and internal noise sources.
- e) Individual factors: It depends on factors such as the psychological state of the person, sensitivity to noise, the person's current activity, gender, age, health, and education (Kurra, 2021: 633-634). (Table 2.1).

Table 2.1. Factors affecting the subjective assessment of noise (Kurra, 2021: 626)

Evaluation	Concept	Basic factors	
Loudness	Perception	Acoustic factors	Sound intensity (sound energy) Sound frequency
		Individual factors	Hearing physiology Health Age
Noisiness	Unwantedness due to auditory factors	Acoustic factors	Sound pressure level Time Spectrum (tonal content) Temporal variation of sound
		Individual factors	Adaptation Meaning of sound
Annoyance	Unwantedness due to auditory and non-auditory factors	Acoustic factors	Type of noise source Sound pressure level Duration of exposure Tonal components Temporal variation of sound (steady, intermittent, impulse, etc.) Background sound level
		Environmental factors	Land use (residential, mixed, etc.) Urban-suburban Type of building Physiography and climate Transportation facilities
		Individual factors	Physiological Psychological Social and educational status Economic status
		Other factors	Meaning of sound Personality and likeness Expectations Motivation
		Temporal factors	Day-time, evening, and night-time Seasons Weekday and weekend, holidays

2.2.3. Studies on noise discomfort

The World Health Organization (WHO) regards neighbor noise as a health risk. From 2002 to 2003, the Large Analysis and Review of European Housing and Health Status (LARES) project conducted a large survey of eight European cities. 24 percent of all residents surveyed reported that exposure to noise at night was the main cause of sleep disturbance. The main cause of sleep disturbance was traffic noise, while the second was the sounds of

neighbors. They observed that noise from neighbors had different effects on patients with hypertension, depression, and migraine (Figure 2.3) (Rindel, 2018: 396).

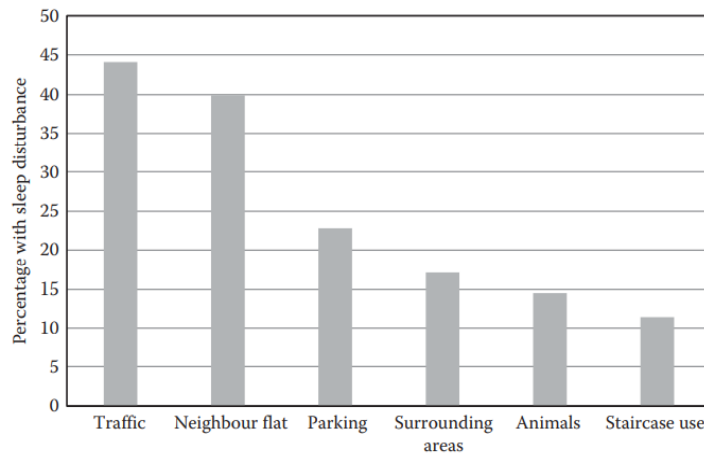


Figure 2.3. The main sources of sleep disturbance in adult residents (Rindel, 2018: 397).

Another survey was conducted in Norway to examine complaints about poor sound insulation in residential buildings. According to the results of this research, the most disturbing noise types are: traffic noise; footsteps on the floors; music, television, and radio; designated as doors (Rindel, 2018: 401). (Figure 2.4).

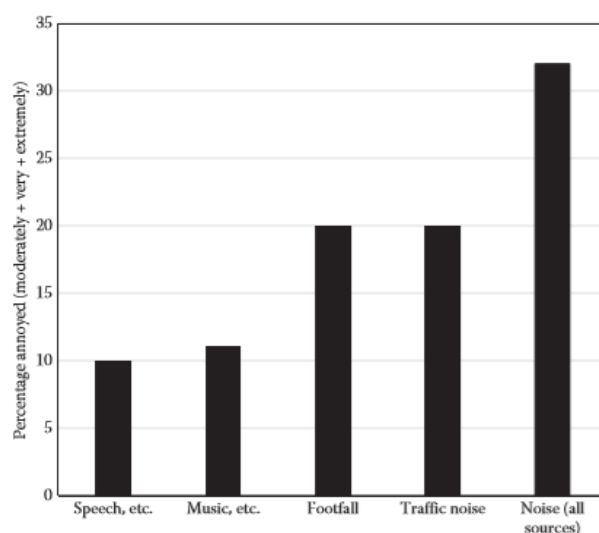


Figure 2.4. The percentage of people who are irritated by noises (Rindel, 2018: 401).

In addition, in these surveys, it has been determined that people are uncomfortable with the thought of disturbing their neighbors. These findings show the effects of noise caused by inadequate sound insulation on residents (Figure 2.5) (Rindel, 2018: 401).

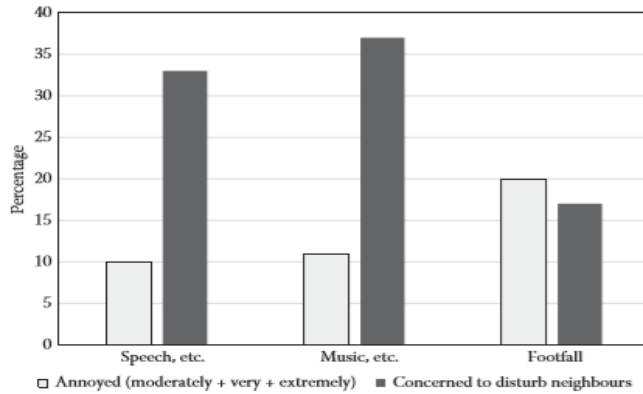


Figure 2.5. Percentage of people who are disturbed by noise sources and think they will disturb their neighbors (Rindel, 2018: 402)

2.3. Types of Noise Affecting Residential Buildings

Environmental noise can be divided into two classes: external and internal noise, according to the location of the source and receiver and the noise propagation paths (Kurra, 2009). Residential buildings are affected by both these external and internal noise sources (Rindel, 2018). While external noise consists of sounds such as transportation, industry, construction, commercial activities, and entertainment, internal noise consists of sounds such as human and animal sounds, home vehicle noises, circulation systems, and mechanical device sounds (Figure 2.6) (Türk Akustik Derneği Sertifika Notları, 2021).

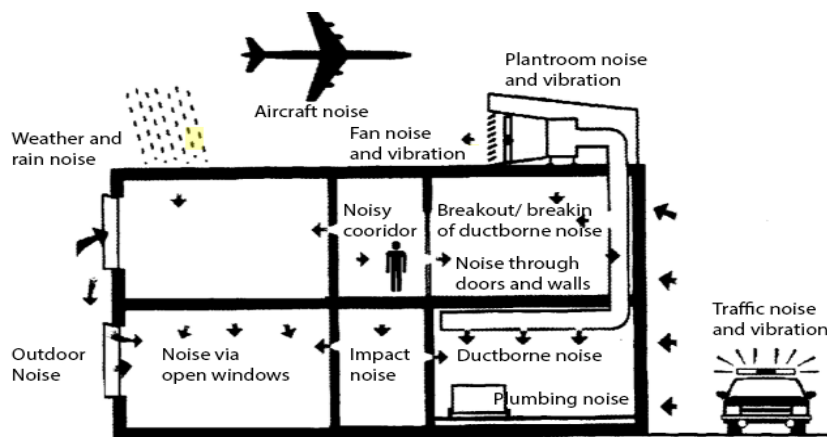


Figure 2.6. Typical sources of noise affecting buildings (Hassan, 2009: 78)

2.3.1. Types of external noise affecting residential buildings

Environmental noise sources can be classified as follows:

Transportation noise sources: Motor vehicle traffic, railway traffic, air traffic, and water transport (or ship traffic).

Industrial noise sources: Mechanical systems, equipment; fans, HVAC units, chillers, energy generators, etc.

Construction noise sources: Demolition, installation, assembly, etc. Road and building construction sites using equipment such as machinery and heavy vehicles.

Sources of noise related to outdoor human activities: Noise-producing electrical and electronic equipment, public announcements and emergency systems, religious sounds, recreational activity areas such as sports fields, children's playgrounds, animal sounds, and loud human voices, etc. (Kurra, 2021: 172).

In our country, Environmental Noise Control Regulation (2022) was entered into force in 2022 by the Republic of Turkey Ministry of Environment and Urbanization. This regulation is prepared in place of the " Environmental Noise Assessment and Management Regulation," which was published in 2010 and repealed in 2022. The purpose of this regulation is to prevent the negative effects of environmental noise and to ensure environmental noise control. Within the scope of this regulation, environmental noise limit values have been determined for environmental sources such as roads, airports, and industrial facilities for noise control in areas where residential buildings are located. According to this regulation, noise maps are prepared in these areas. Considering the results of this map, action plans are being prepared to control the noise, especially in areas where the environmental noise level is harmful to human health.

2.3.2. Types of internal noise affecting residential buildings

Noise sources in buildings can produce continuous, intermittent or impulsive sounds:

Neighbor noises: Loud conversations, TV/radio, footsteps, noises from household appliances and appliances, falling and pulling sounds, etc.

Mechanical devices and installation sounds: Airborne and structural noises and mechanical vibrations from HVAC systems equipment such as boilers, air conditioning units, fans, ducts, plumbing, water flowing through pipes, water pumps, siphons, etc.

Electrical system sounds: Sounds from generators, lighting devices, etc.

Vertical circulation sounds: Elevator, stairs, elevator machine rooms, elevator cabin doors, etc.

Specific noises: Other noises related to building type and use.

In addition to the above resources, mechanical and electrical service rooms in multi-story residences contain a wide variety of equipment. Systems such as machinery, plumbing, etc. each create a different type of noise source to consider (Kurra, 2021: 172-174).

For noise control in buildings in our country, the Regulation on Protection of Buildings Against Noise (2017) and Amendment to Regulation on Protection of Buildings Against Noise (2018) are in force. These regulations, T.C. It has been published by the Ministry of Environment and Urbanization and includes limit values for the control of various noises that users are exposed to indoors.

Sources of airborne noise in a building often include people talking, stereos, televisions, and musical instruments (Rindel, 2018: 1). Structure-borne sounds are produced by the effect of building elements such as walls, floors, and roofs. This impact allows sound to travel through the building elements by vibrating them; because they are related to the impact, they are also known as impact sounds (Mehta et al., 1999: 143).

Sounds such as walking, falling objects, pulling objects, and slamming doors create impact sounds, which are irregular. As indicated in the drawing, the impact on the ground radiates directly downward. In addition, these sounds can be transmitted horizontally and spread to distant places. For this reason, it is necessary to prevent the formation of impact (structure-borne) sound (Figure 2.7) (Egan, 2007: 246).

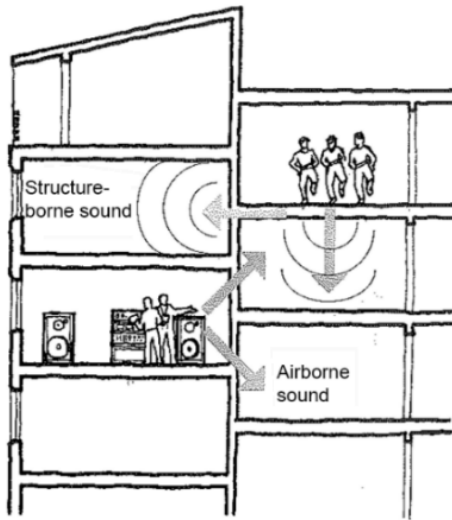


Figure 2.7. Noise sources in a multi-family residential building (Mehta et al., 1999: 171)

2.4. Noise Control in Residential Buildings

In today's architecture, as a result of the construction techniques consisting of high-rise buildings and light construction elements, which increase with the development of technology, acoustic problems with complex solutions arise in buildings. Acoustic measures to be taken in a space to ensure acoustic comfort;

- Prevention of noise from indoor and outdoor sound sources that adversely affect comfort
- Ensuring speech privacy in units such as bedrooms in residential buildings
- It is in the form of obtaining good sound perception in the places where the hearing function is present (Bayazıt ve Aşçıgil, 2007).

In order to solve the noise problem by meeting these demands, respectively,

- The problem must be analyzed,
- The most economical and functional solution possible should be determined,
- This solution should be applied according to noise reduction principles (Bayazıt ve Aşçıgil, 2007).

When designing a system for noise reduction, acoustic criteria need to be determined for the existing physical condition. Considering these criteria, the negative effects of noise can

be minimized by the arrangement of the space and the design of the building elements and components (Kurra, 1997).

Methods of noise control

As Mehta, Johnson, and Rocafort (1999) stated; "All noise, whether interior or exterior, is subject to a three-way control mechanism: at the source, along the path, and at the receiver" (p. 160). Actually, source-path-the-receiver is a fundamental principle that applies to all noise control (Figure 2.8).

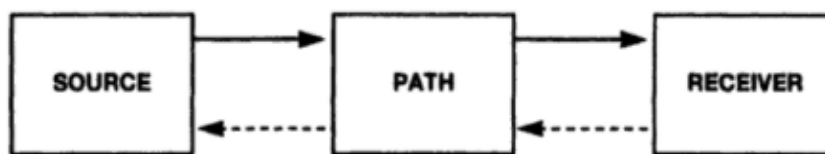


Figure 2.8. Interaction between key components of the noise control (Hassan, 2009: 84)

Noise control at the source is possible through decisions such as shortening the exposure time or designing, maintaining, and repairing the source. Noise control can be achieved by taking architectural and structural measures on the road between the source and the receiver (Figure 2.9) (Kurra and Bayazit, 1995).

The following measures can be taken to prevent noise:

- The sound insulation properties of building elements such as walls, floors, ceilings, windows, and doors can be improved.
- Sound transmission can be prevented by using materials with different acoustic properties in the transmission path.
- The gaps between the source and the receiver should be closed to prevent sound transmission.
- Proper positioning and orientation of buildings and room layout are necessary to reduce noise control measures (Dunn et al., 2018:120)

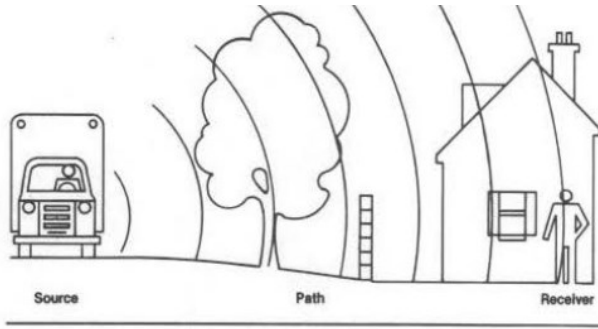


Figure 2.9. Noise control components (The Noise Guidebook, 2009)

2.4.1. Control at source

Reducing the noise level in areas where noise sources are present in the building is of great importance. In these places, which constitute the installation centers of the buildings, a significant noise reduction can be achieved by partially or completely enclosing the source in the cell. Partial ceiling is generally better than noise curtains placed in front of the source but less effective than a well-designed full cell. The surfaces of the partial cells facing the noise source should be covered with absorbent material (Figure 2.10) (Bayazıt ve Aşçıgil, 2007).

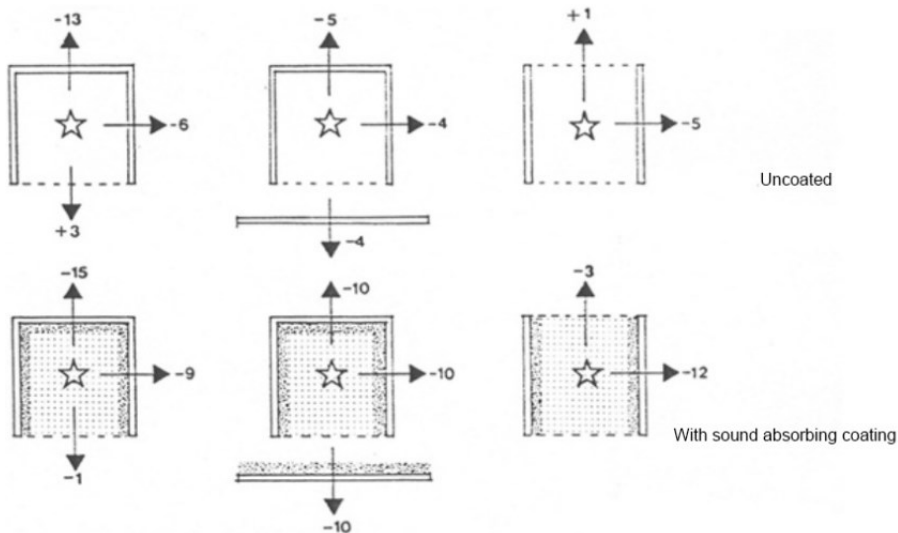


Figure 2.10. Partial noise cell examples (all values are valid for 500–4000 Hz) (Templeton and Saunders, 1987; as cited in Bayazıt ve Aşçıgil, 2007)

These measures, in which noise sources are planned by considering technology and structure, are called active noise protection measures. These are the most economically viable and cheapest ways to combat noise. If these measures are insufficient, passive sound

protection measures can be considered in terms of sound transmission; because active noise protection measures can only be implemented in a few cases during planning and construction that involve construction techniques, passive noise protection measures that can be implemented on transmission routes form the foundation of noise protection for buildings (Özer, 1979: 74).

2.4.2. Control in the transmission path

In many cases, it may not be possible to change the properties of the resource. In this case, a more convenient solution is to switch one or more transmission paths between the source and the receiver (Bies and Hansen, 2009).

Architectural measures that can be taken to control path noise can be examined under three main headings: The first are the measures that can be taken at the settlement scale. Second, volume layouts can be considered at the building scale. Finally, it can be handled at the structure scale level through building element design and detailing (Figure 2.11) (Şentop, 2013).

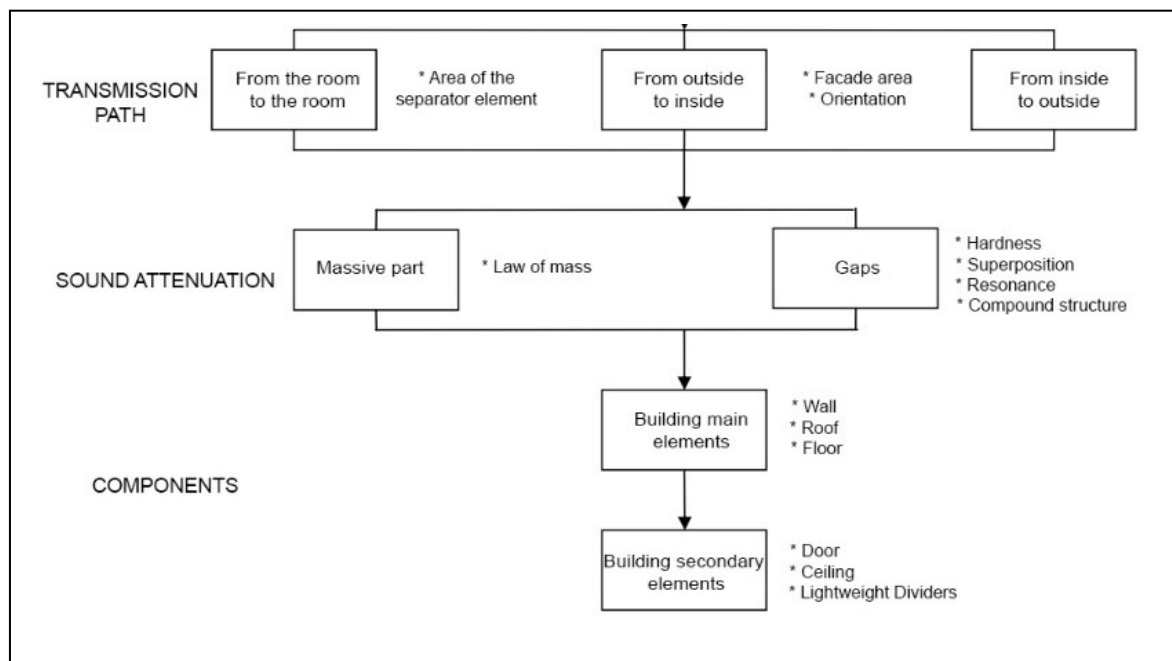


Figure 2.11. Sound insulation in the design process (Templeton, 1993; as cited in Bayazıt ve Aşçıgil, 2007)

2.4.3. Control at the receiver

When control measures at the source or transmission path fail, control measures at the receiver can be used. This control can only be achieved through ear protectors (Bies and Hansen, 2009).

4.2.2. a) Principles of noise control at the settlement scale

The factors affecting the propagation of sound can be specified as follows;

- Distance Factor
- Meteorological Factors (Temperature, wind, air absorption)
- Air Absorption Factor
- Ground Factor
- Barrier Factor (Yılmaz Demirkale, 2007: 40).

Effect of the distance factor on sound transmission

The sound level from the sound source to the receiver point far away decreases as a function of distance due to wave deflection (Figure 2.12) (Yılmaz Demirkale, 2007: 40).

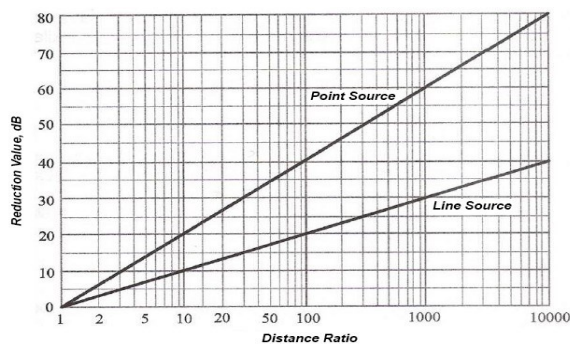


Figure 2.12. Effect of the distance factor on the propagation of sound (Parkin and Humphreys, 1958; as cited in Yılmaz Demirkale, 2007: 41)

Effect of meteorological factors on sound transmission

Sound rays propagating in the air are bent downward in the direction of the wind and curved upward against the wind. The curvature of the rays is inversely proportional to the

wind speed. Wind speed and temperature vary with height above ground level, causing the speed of sound to vary with height. When the temperature increases with altitude, the sound waves bend the ground (downward), increasing the sound pressure levels, and no shadow zones are formed. In this case, sounds can be heard from long distances (Kurra, 2021: 109-111 ; Yılmaz Demirkale, 2007: 42-45). (See Figures 2.13, 2.14, and 2.15).

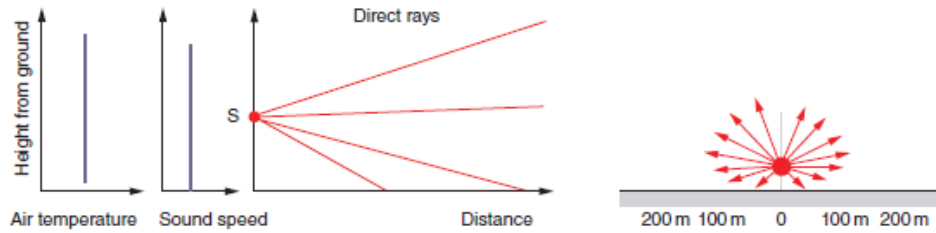


Figure 2.13. Sound distribution in the absence of temperature exchange between the ground and the air (Kurra, 2021: 111)

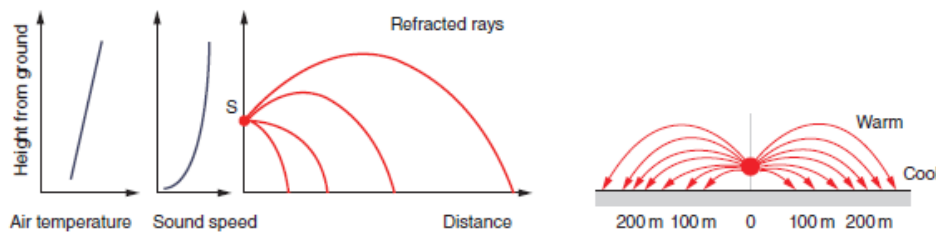


Figure 2.14. Sound distribution when the floor is cooler than the air (Kurra, 2021: 111)

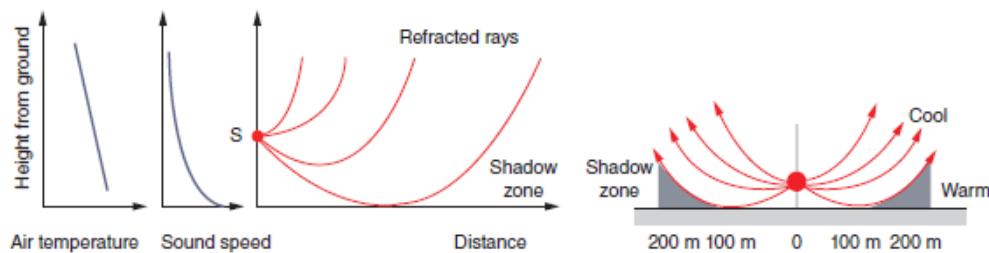


Figure 2.15. Sound distribution when the floor is warmer than the air (Kurra, 2021: 111)

By considering meteorological factors, especially temperature changes and the effects of winds on sound propagation, the boundaries of shadow zones can be determined for suitable areas for settlement. As a general principle, in the presence of prevailing winds affecting the terrain, the settlement in the upper wind belt provides significant noise control (Yılmaz Demirkale, 2007: 47).

Sound transmission and the air absorption factor

In the absorption of air, air temperature, humidity, frequency of sound waves, and distance are effective (Yılmaz Demirkale, 2007: 50).

Ground factor influence on sound transmission

The ground effect, which plays a role in the sound level, varies depending on different factors. It depends on the source-receiver height, the airflow resistance in the pores of the floor, the reflection angle of the sound and the height angle of the sound beam, the type of floor covering, and the distance of the receiver from the source (Yılmaz Demirkale, 2007: 52).

Effect of the barrier factor on sound transmission

Outdoor barriers are the most common way to provide environmental noise control (Long, 2006). (Figure 2.16).

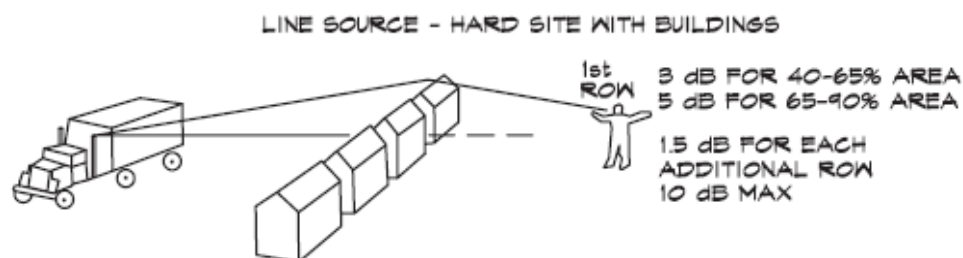


Figure 2.16. Reducing highway noise (Long, 2006: 169)

Obstacles should be placed as close to the receiver as possible and designed to block the view between the source and the receiver. In the case of sound reflections, the barriers should be bent so that they are not parallel, and sound absorbers should be used (Figure 2.17) (Ermann, 2015: 210)

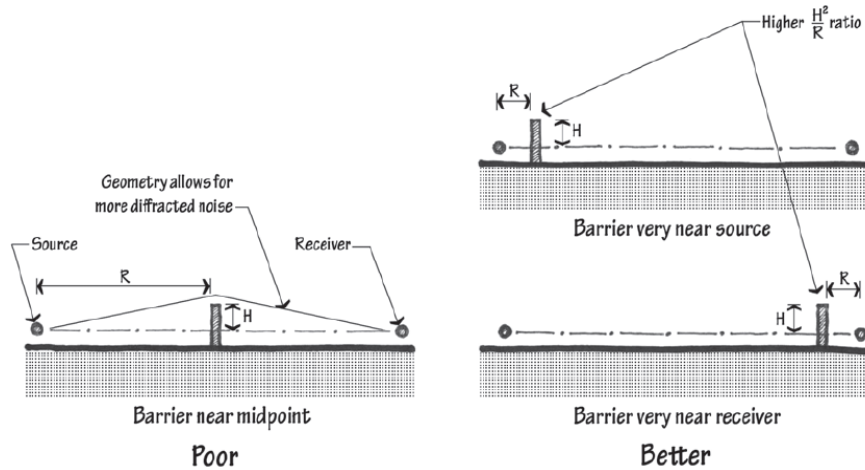


Figure 2.17. Use of barriers in external noise control (Ermann, 2015: 212)

Earth berms are natural-looking man-made hills created using fill materials such as rocks and stones (Kurra, 2021: 150). If it is covered with grass or other sound-absorbing plants, it can reduce the noise by 5–10 dB. At the same time, the effectiveness of the ground surface can be reduced with reflective surfaces such as asphalt, concrete, and soil (Figure 2.18) (Yılmaz Demirkale, 2007: 78).

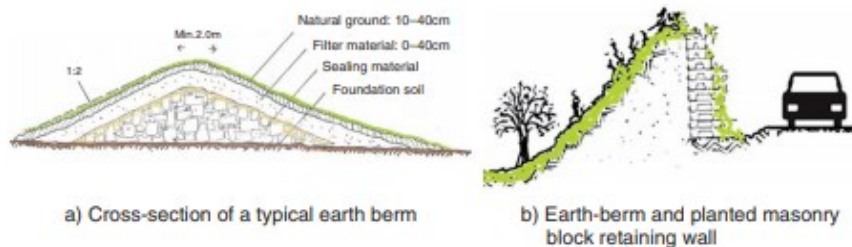


Figure 2.18. Use of earth berms in external noise control (Kurra, 2021: 152)

Single or multiple barriers, also called *wall barriers* or *sound walls*, are constructed along highways and can be found around elevated structures. Additional attenuation is provided by sound absorption on roadside surfaces (Figure 2.19) (Kurra, 2021: 151).

In order to use barriers effectively

- The barrier should be non-porous, dense, and airtight.
- It is necessary to position the obstacle close to the sound source or receiver.
- It is necessary to increase the obstacle's height.
- For mutual barriers, sound-absorbing material or a slope are required (Yılmaz Demirkale, 2007: 82).

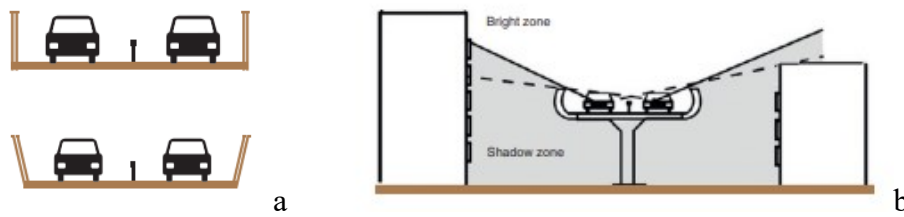


Figure 2.19. a) Noise curtains along the road b) Barrier on the raised road structure (Kurra, 2021: 152)

Many rows of trees are not as effective as sound control barriers, but they provide a psychological sense of privacy and can be used aesthetically in a sound barrier arrangement. The reduction provided by trees depends on the branches and leaves of the tree. While dense trees and bushes at least 30 m wide provide a reduction of 7 to 10 dB, in winter, evergreen trees can provide 2 to 4 dBA attenuation in noise control if tall enough (Figure 2.20) (Long, 2006: 166 Yılmaz Demirkale, 2007: 78).



Figure 2.20. Providing noise control with many heavy tree rows (Long, 2006: 169)

2.4.2. b) Noise control principles at building scale

Building orientation: The building's orientation and the building's relationship to the surrounding buildings can affect the reflections and angular variables of sound and cause acoustic imperfections such as reverberation. In this context, the number of floors, spaces, and relative positions of the building and surrounding buildings is important. Parallel and facing walls, as well as courtyards facing the noise, should be avoided. Noise control can be achieved by angling buildings (Figure 2.21) (Egan, 2007: 270).

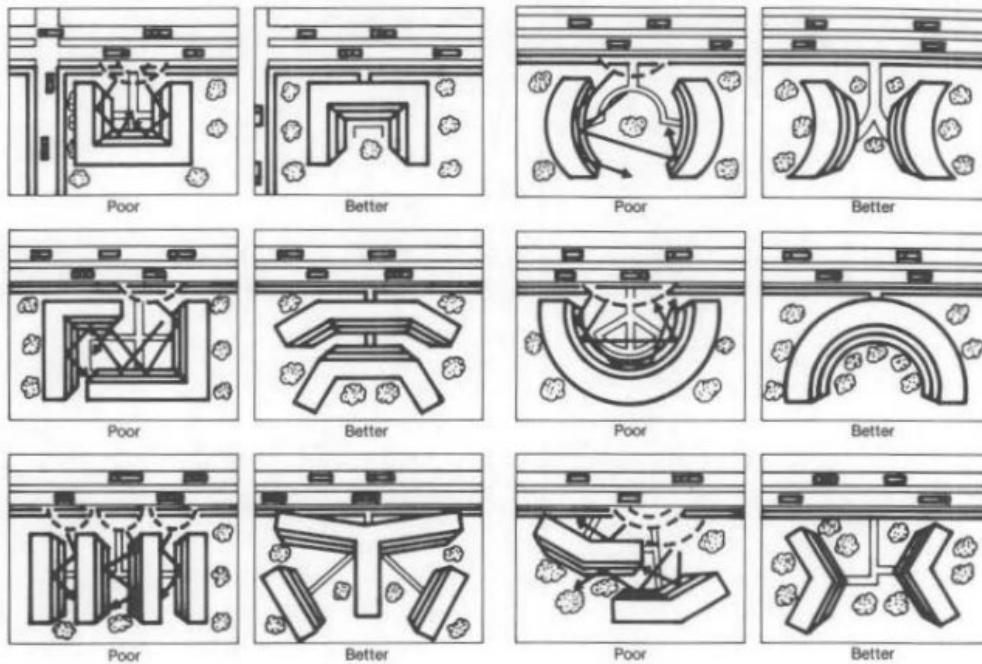


Figure 2.21. Acoustic problems and solutions related to building orientation (The Noise Guidebook, 2009)

Building form: A self-protecting building has elements around it that act as a barrier against noise sources. Acoustically weak elements such as windows and doors can be protected in this way (Figure 2.21) (Egan, 2007: 259).

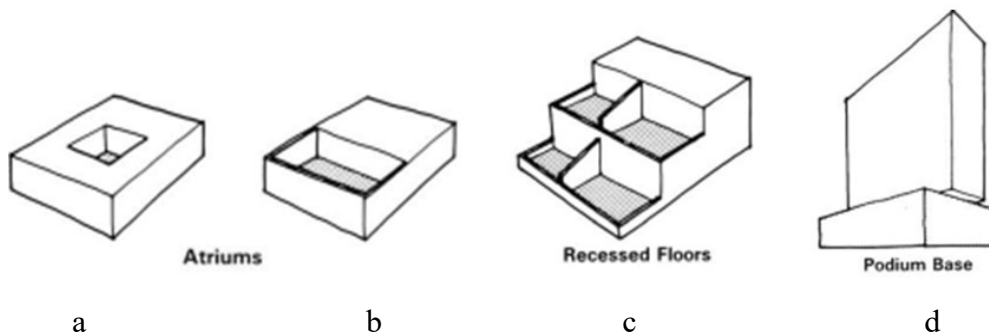


Figure 2.22. Noise-protected settlements: Different facade forms (a, b) courtyard type, (c) embedded terrace type, (d) podium type (Egan, 2007: 259)

The sound level of the facade can be reduced by covering the lower surfaces of exterior elements such as balconies and sills with sound-absorbing material (Figure 2.23) (Üstüner & Demirel, 2021).

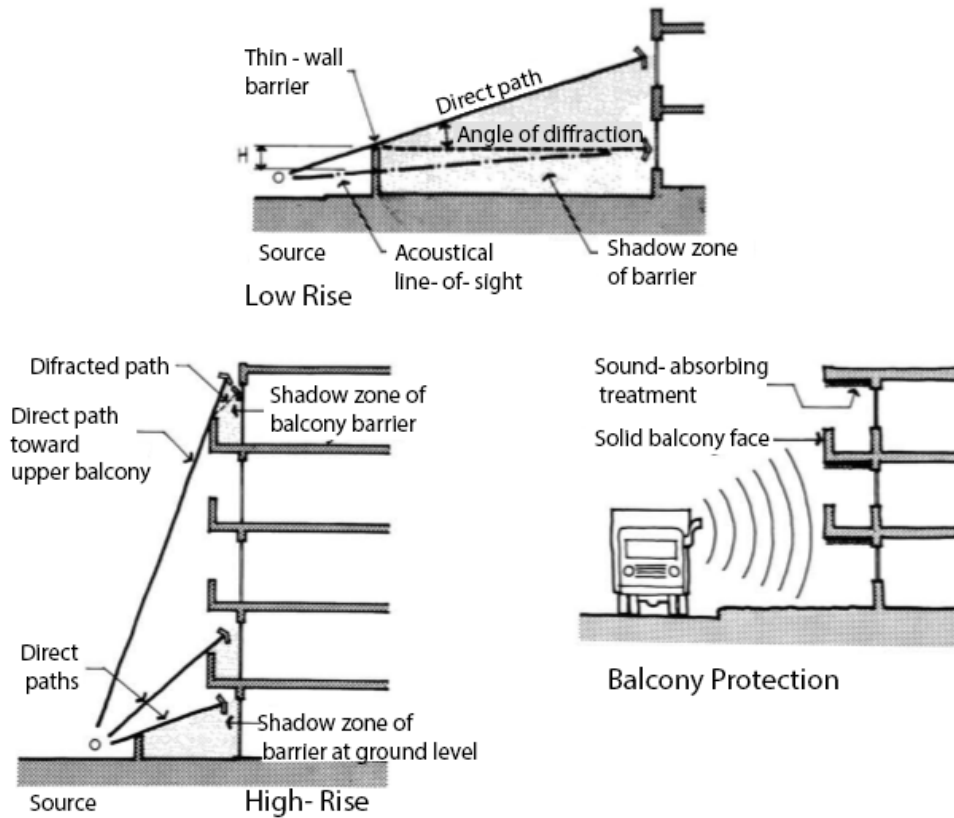


Figure 2.23. Sound reflection from balcony soffits (Egan, 2007: 260)

Volume Layout (Reducing Sound Transmission Through Layout and Design)

Indoor spaces can be divided into four categories in terms of noise control:

- Noise-sensitive areas (bedrooms and living rooms, private workspaces, etc.)
- Moderately sensitive areas (corridors, etc.)
- Insensitive areas (e.g., kitchens).
- Noise source areas (plumbing centers, garages, etc.) (Bayazıt ve Aşçıgil, 2007).

It is generally good practice to locate noise-sensitive activities away from noisy activities. As an example of this application, in Figure 2.24, quiet areas in the residences are located around the bedroom and positioned away from the stairwell; cabinets and double-entry lobbies are used to reduce the noise coming from the stairwell (Buxton, 2007: 180).

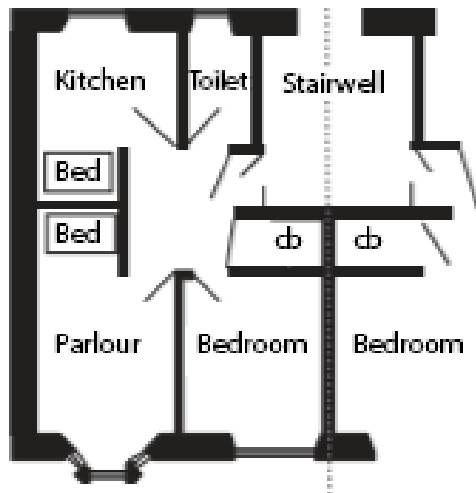


Figure 2.24. Glasgow 1890 traditional tenement flat layout (Buxton, 2007: 180)

To reduce the noise problem in buildings, the following points should be considered:

- Noise-sensitive rooms should not be placed next to rooms with high levels of noise.
- Loud noise-producing rooms should not be placed above quiet rooms.
- Fire doors in common corridors should be located away from the entrance doors of residences or noise-sensitive rooms.
- Rooms with high occupancy rates should not be placed at the ends of corridors with noise-sensitive rooms along the corridor (Buxton, 2007: 180).

Residential buildings are exposed to noise in areas close to the traffic boundary. Therefore, places that do not need protection from noise should be placed in these noisy areas. In the planning of residential areas, the design should be based on the regional separation of noisy and silent functions (Figure 2.25) (Özer, 1979: 75-76).

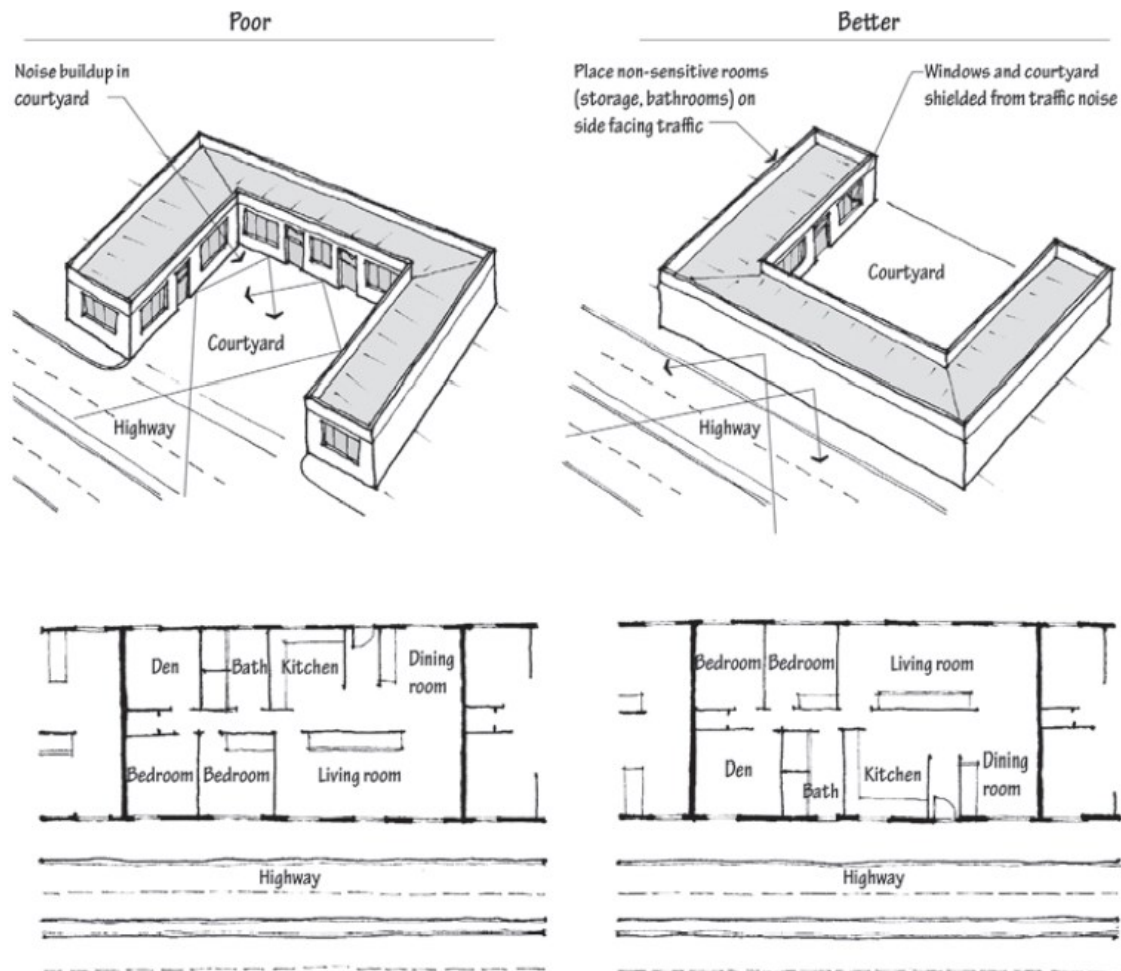


Figure 2.25. Architectural acoustic design to be implemented for noise control (Ermann, 2015: 203)

If traffic noise cannot be prevented in residences with such measures, it will be necessary to use building elements with high sound insulation properties, such as windows. When planning the building in terms of noise control, it is necessary to determine which functions and for what purpose it will be used. The separation of these functions should be considered both horizontally and vertically. For example, in skyscraper-type, high-rise buildings, bedrooms that require high levels of silence should not be planned on floors just below or above the installation floors. Otherwise, a special sound insulation construction should be made on the ceiling and floor of the installation floor. In residences, care should be taken not to place bathrooms and kitchens adjacent to bedrooms and living rooms of foreign apartments, as the plumbing may cause discomfort in adjacent rooms. It is beneficial to plan the apartments symmetrically (Özer, 1979). Measures to be taken regarding installation noise will be discussed under the heading 2.4.2 d).

2.4.2. c) Noise reduction principles at the structural scale

In order to control the sound, it is necessary to examine the propagation of the sound. According to the sound transmission paths, airborne sounds can be classified as structure-borne (impact) sounds and sounds transmitted through openings. Sound insulation includes all measures taken to reduce the level of sound transmitted from building elements (Yılmaz Demirkale, 2007: 287-288).

To ensure acoustic comfort in a building, certain requirements regarding airborne and impact sound insulation and the noise level from traffic and building services must be met (Eriksson *et al.*, 2013). Sound insulation is especially necessary when designing multi-room buildings where noise is not desired, such as apartment blocks. For this reason, the sound insulation properties of building elements such as walls, floors, ceilings, doors, and windows that cause sound to pass from one room to another will be emphasized.

Airborne sound insulation

Airborne noises occur due to open windows, gaps, discontinuity at the points where the plumbing systems meet the building elements, and the transmission of the sound to another space in a divider (Yılmaz Demirkale, 2007: 288). Airborne sound transmission between rooms or outside the building consists of sounds such as people talking, and equipment sounds. Sound energy spreads from the air to the wall surface and from the wall to other building elements (Ermann, 2015: 140).

In terms of the airborne sound insulation properties of building elements, it is necessary to look at the sound absorption properties of the walls, ceilings, doors, windows, and shell elements surrounding the volume. Single-layer building elements are structural elements that vibrate as a whole. These elements can be reinforced concrete floors, pure brick walls, perforated brick walls, or lightweight multi-layered building materials. Multi-layer building elements consist of independent vibrating layers. These are double-glazed windows, double-deck walls, and ceilings with floating floors (Özer, 1979: 135).

Classification of walls according to wall layers

Sound insulation can be considered to be the sound insulation of single-layer, double-layer, multi-layer, and composite walls (Yılmaz Demirkale, 2007).

Transmission of airborne sound in single-layer building elements

Sound insulation is provided by a dividing element that separates the environment where the sound source is located from the receiving environment. Sound waves in the air hit the dividing element and pass from the source medium to the receiving medium as a result of the vibration of the element. The intensity of the transmitted sound depends on the sound transmission loss (TL or R) of the element (Figure 2.26) (Yılmaz Demirkale, 2007: 291).

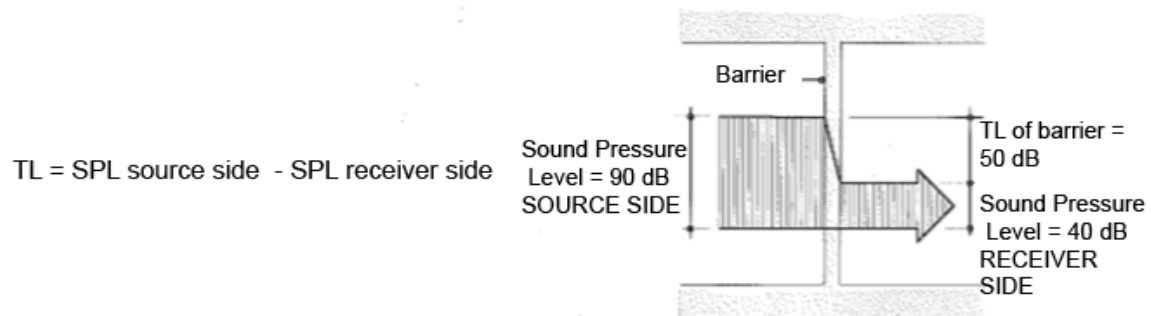


Figure 2.26. Loss of sound in a component (Mehta et al., 1999: 90)

However, the behavior of the sound wave in solid media varies depending on the properties and frequency of the material. In Figure 2.27, the behavior of the wave and which properties of the material are effective are indicated in the sound transmission-frequency graph (Yılmaz Demirkale, 2007: 293).

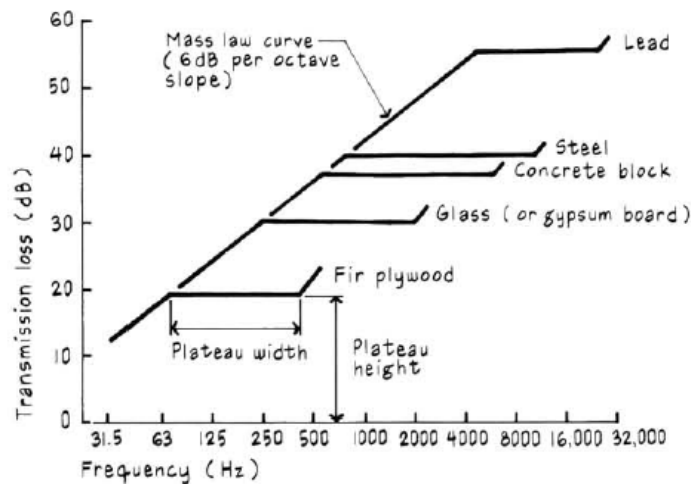


Figure 2.27. Sound transmission loss values of different materials for single walls (Egan, 2007: 181)

The sound wave behavior can be investigated in three frequency regions: low, medium, and high. The hardness of the material is effective at low frequencies. The movement of the sound wave on the wall is controlled by the dimensions of the building element, the surface density, and the hardness of the material used. Sound transmission loss (TL) at medium frequencies depends on the mass of the material (Yılmaz Demirkale, 2007: 294).

There is a resonance region between the region where the behavior of the sound wave is controlled by the material stiffness and the region controlled by the material mass. The sound loss in the region between the resonance region and the critical frequency is calculated using mass law (Yılmaz Demirkale, 2007: 295-296).

Mass law

The airborne sound insulation of single-layer building elements is strengthened in parallel with the increase in mass and frequency, depending on the area. This relationship is known as the law of mass or Berger's law. It is used to determine the sound insulation levels of light and single-layer walls. The law of mass states that when the frequency or area-dependent mass is doubled, the sound insulation scale increases by 6 dB (Özer, 1979: 143).

In addition, the thickness of the material has a role in mass, flexibility resistance, and sound insulation because the increase in thickness of the building element means an increase in mass, which improves the sound insulation level. However, increasing the

thickness above the specified limit value provides deterioration rather than improvement because the thickness effect and the elastic resistance effect balance each other (Özer, 1979: 148).

As indicated in Figure 2.28, it is seen that heavier materials provide better sound insulation (STC: Sound Transmission Class). Therefore, the mass law is the fundamental principle of soundproofing for architectural acoustics (Egan, 2007: 177).

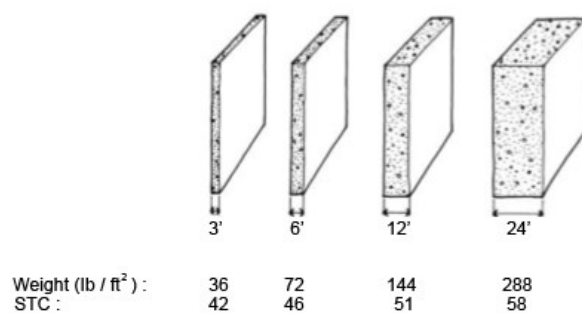


Figure 2.28. Mass-law effect (Egan, 2007: 179)

Sound loss within the mass law region:

- increases by 6 dB for every twofold increase in frequency and surface density (Figure 2.29).

According to the law of mass, the sound transmission loss (TL) and the sound transmission class rating (STC) for homogeneous building elements (glass, wood, concrete, etc.) increase by 5 dB with an increase of 2 times the surface weight (Yılmaz Demirkale, 2007: 297-298).

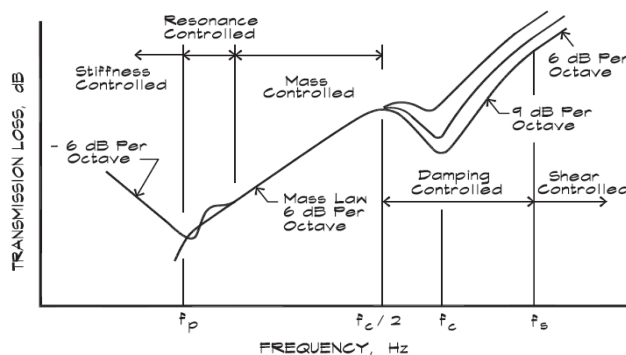


Figure 2.29. Loss of sound - frequency graph (Long, 2006: 331)

Double-layer constructions should be used to ensure a high level of sound transmission loss. A wide gap should be left between these two layers, and gypsum boards should be placed between the metal channels. These elements reduce the stiffness of the sound barrier. The ideal soundproofing construction should be heavy, soft, and airtight. (Yılmaz Demirkale, 2007: 304).

Sound Transmission in two-layer structural elements

Single-layer building elements include simple application technology both in the manufacturing phase and in the assembly stage. Multi-layer building elements are required for a high sound insulation requirement. However, it is more expensive and more difficult to assemble than single-layer building elements. In addition, the detailed construction of multi-layer building elements can cause construction and design errors. Sound leakages that may occur between two floors of walls or between a floating floor and ceiling can often eliminate its superiority compared to a single-layer structure. Incorrect sizing may cause the sound insulation effect to be worse than that of a single-layer building element of the same weight (Özer, 1979: 135,143). When a second wall is placed in front of a wall at certain intervals, it is not possible to add the sound insulation values of the two walls to each other because, as indicated in Figure 2.30, sound transmission paths formed in double-layer building elements are included. These transmission paths significantly reduce the sound insulation level (Özer, 1979: 153).

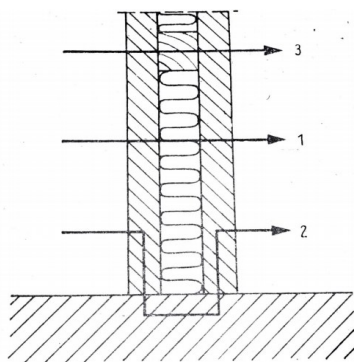


Figure 2.30. Sound transmission ways for double- storey building elements
1- Air gap or insulation material 2- Edge joint 3- Sound bridges (Özer, 1979: 154)

In double-layer walls with air gaps, the frequency range of the wall with sound transmission loss depends on the properties of the wall layers, the way the layers are

connected to each other, and the width of the air gap between them (Yılmaz Demirkale, 2007: 308). Therefore, the following elements must be known in order to prevent sound transmission.

The importance of separating the layers of the building construction; Even when the wall layers are not connected to each other, the layers of the air layer between them act as a union, and the width of the air layer becomes important in this connection. Therefore, multiple layers should not be interconnected. *Importance of wide cavity depth;* In a 2-layer structural element with a very narrow air gap left between the materials, the sound transmission loss performance may be worse than in a single-layer panel. This situation is due to the resonance pit formed by the cavity. If there is an air gap between two walls, the sound transmission loss value of the composite wall depends on the width of the air gap between them. *The importance of using porous sound absorbing materials in a gap;* It is necessary to put a porous sound-absorbing material, such as fiberglass or open-pore plastic foam, into the cavity. Fiberglass should be placed to cover the width and length of the gap. *Cavity insulation density;* The density of fibrous, air-gapped insulation affects the sound insulation value of a wall. The increase in the thickness of the insulation also has an effect. *Importance of using different structure layers;* To be adequate in terms of airborne sound insulation, the resonance frequency of the double-layered building components should be as low as possible. In order to achieve better sound insulation by using different building layers:

- The weight of the layers and the width of the air layer in between should be increased.
- The air layer can be filled with fibrous insulation materials, provided that the material is very soft and flexible.
- The two panels must have different surface weights.
- The cavity must contain sound-absorbing material.
- There should be no air bridges between the panels.
- Panels should not be connected to each other by construction methods.
- If the panels need to be connected to each other by providing a resistance mismatch, it is necessary to use light bonds with heavy plates and heavy bonds with light plates (Yılmaz Demirkale, 2007: 311-315).

Sound transmission in multilayer structural elements

The explanations regarding the two-layer building elements are also valid for three- or more-layer structures. In two-layer constructions, larger floor openings and greater mass provide more positive results than multi-layer building elements (Özer, 1979: 159).

Three or more layers of different materials can be used to increase the sound transmission loss values of building constructions. However, problems such as cost, weight, and location are limiting the use of different materials. Therefore, its use is rare (Yılmaz Demirkale, 2007: 320).

In this case, the conditions to be complied with in multi-story building elements are as follows:

- The total weight should be as high as possible.
- The separation between layers must be continuous.
- A maximum distance should be left between layers.
- Sound-absorbing materials should be placed in the air gap.
- The layers must be of different materials or made of the same materials but of different thicknesses.
- Layers should be connected flexibly.
- Gaps that may cause sound transmission should be avoided (Yılmaz Demirkale, 2007: 320).

Heavy double walls are also used to isolate particularly noisy areas. For example, if the elevator shaft and transformer room are adjacent to the bedrooms and living rooms, it is very important to make the separators double-layer in order to prevent sound transmission (Özer, 1979: 188-189).

Sound transmission in composite walls

In a building, walls can contain multiple components, such as doors and windows. Since the sound transmission loss values of building elements such as doors and windows are

lower than those of the solid wall, the sound transmission loss value of the entire wall will approach the low value (Cavanaugh, Tocci, and Wilkes, 2010: 17).

Since sound waves hitting building elements such as walls, floors, and ceilings create movement. The magnitude of this movement or vibration is determined by the mass of the structural member. The greater the mass of the structural elements, the greater their resistance to movement and the less noise they transmit (Figure 2.31) (Egan, 2007: 174).

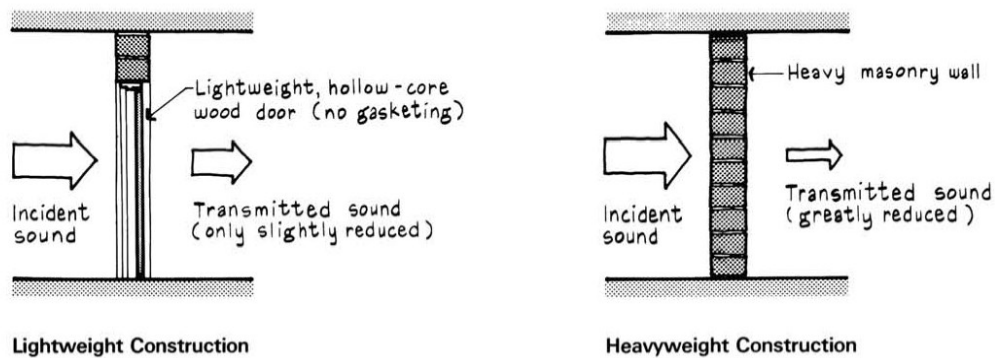


Figure 2.31. Comparison of light construction and heavy construction (Egan, 2007: 174)

Walls according to the material

The greater the mass of the material used and the more massive the material, the greater the sound insulation. An equal thickness of solid concrete will provide better sound insulation than solid wood, and a thicker concrete wall will be more effective at soundproofing than a thinner concrete wall. Sound insulation can be improved by adding plasterboard layers to the exterior surfaces (Figure 2.32) (Ermann, 2015: 149).

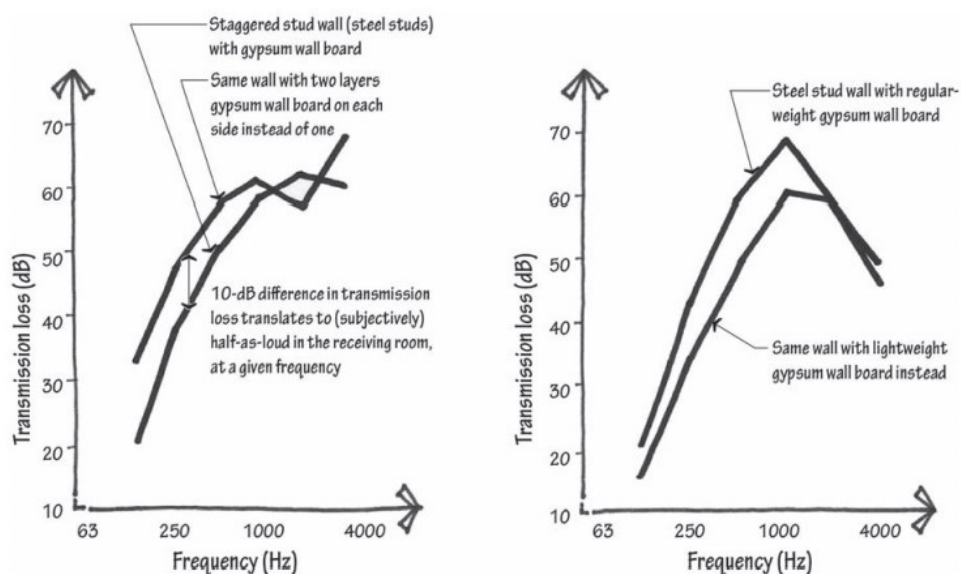


Figure 2.32. Mass effect on sound insulation (Ermann, 2015: 149)

Using plaster on both sides of the wall increases the sound transmission loss (TL) of the wall. The increase in sound insulation (STC) as the wall thickness doubles is indicated in Figure 2.33 (Everest and Pohlmann, 2009: 298).

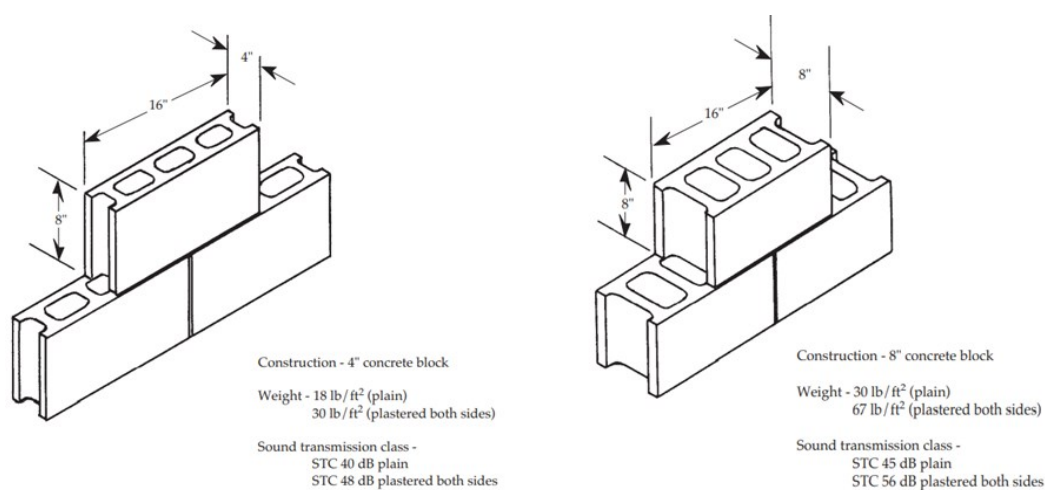


Figure 2.33. Different wall constructions (Everest and Pohlmann, 2009: 297-298)

Concrete walls

The performance of concrete walls can be improved by increasing the wall thickness, plastering one or both surfaces, or filling the gaps with sand or well-anchored concrete, all of which increase the wall mass. To further improve performance (STC: sound transmission class), it is necessary to add a second block wall with an air gap. To achieve the highest sound transmission loss (TL) value, all joints of the partition must be filled with an acoustic sealant (Figure 2.34) (Ballou, 2008: 77).

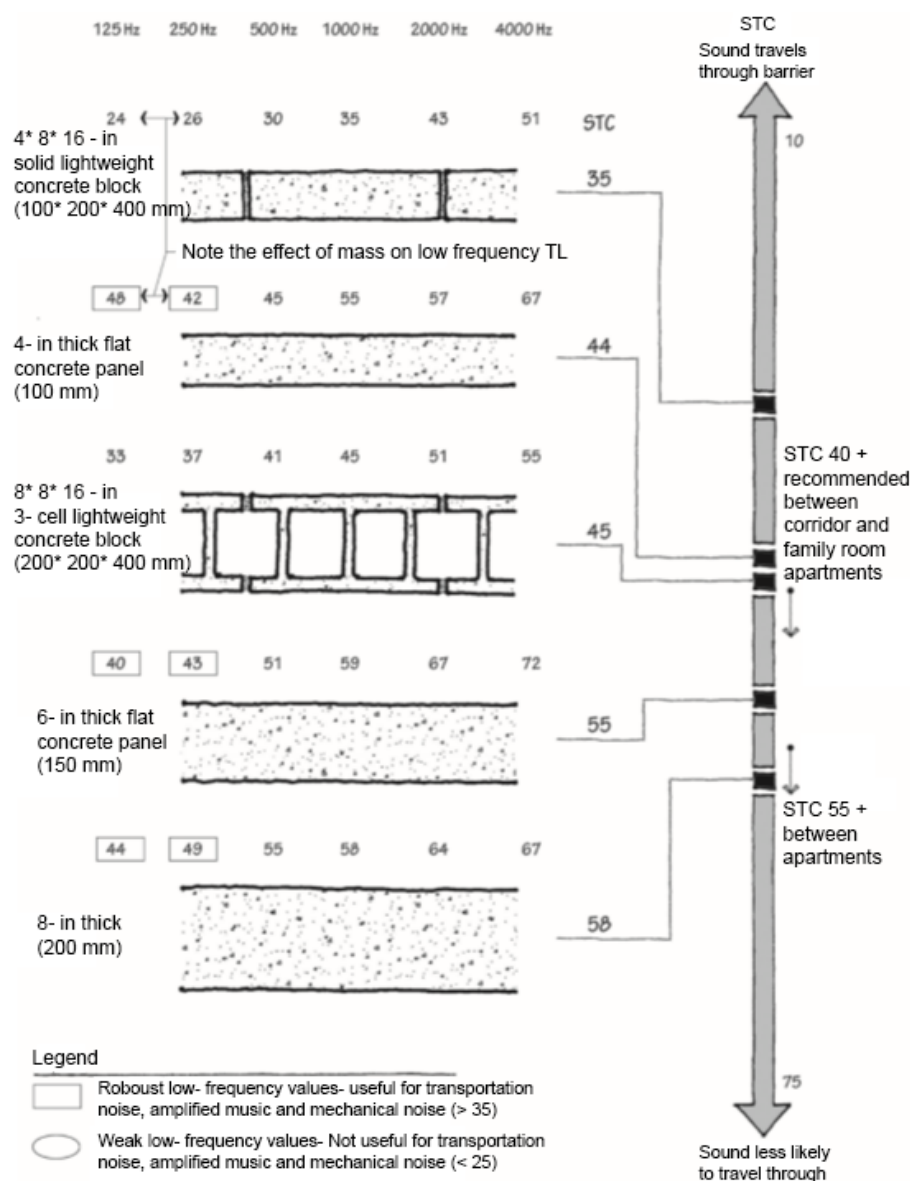


Figure 2.34. Recommendations for improving sound insulation in a concrete wall (Ermann, 2015: 165)

Masonry walls

Masonry walls can be considered single-layer, double-layer, or coated masonry walls.

Sound insulation in single-layer masonry walls

Masonry walls are composites as they consist of components such as mortar, brick, and stone. In this system, the mortar that connects the blocks, the porous structure of the blocks, or the holes in the middle of the blocks adversely affect the sound transmission loss. Mortar and block joints can create weak areas in sound transmission (Yılmaz Demirkale, 2007: 353).

The most important factor separating a masonry wall from a solid concrete wall or floor is air leakage from the masonry mortar joints. Due to the porous structure of the lightweight concrete blocks and the air leakage caused by the space between them, the sound transmission in the building element will increase. In systems using bricks, sound transmission is low as the mortar spreads over the entire surface. Therefore, a brick wall of similar thickness and weight is more airtight than a block wall (Figure 2.35) (Mehta et al., 1999: 118).

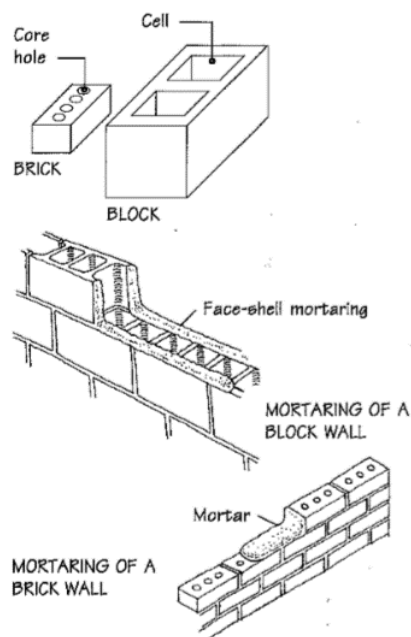


Figure 2.35. Masonry wall samples (Mehta et al., 1999: 118)

Sound insulation in double-layer masonry walls

Cavity masonry walls have better sound transmission loss than a single wall of the same weight. In this increase, the degree of separation between the layers is effective. The use of porous, sound-absorbing materials in the air gap and increasing the air gap increase the separation of the layers (Figure 2.36) (Mehta et al., 1999: 120; Yılmaz Demirkale, 2007: 354).

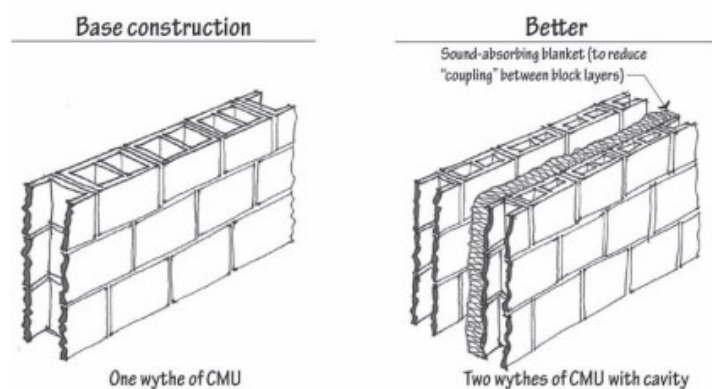


Figure 2.36. Separation of layers and use of porous material in the cavity wall (Ermann, 2015: 138)

Maximum insulation is achieved when there is no connection between the two layers. The layers are structurally independent of each other, as shown in (Figure 2.37) (Mehta et al., 1999: 120).

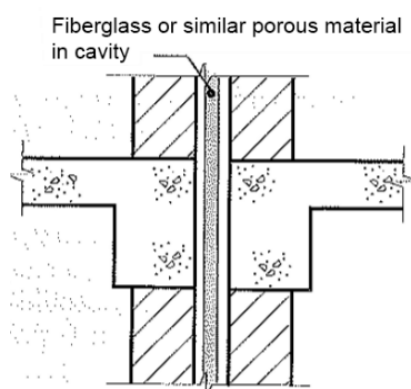


Figure 2.37. Structurally independent two-layer cavity wall (Mehta et al., 1999: 120)

However, due to cost and other factors, this method is not widely used. The masonry wall system shown in Figure 2.38, usually connected by metal ties, shares common support at the top and bottom (Mehta et al., 1999: 121).

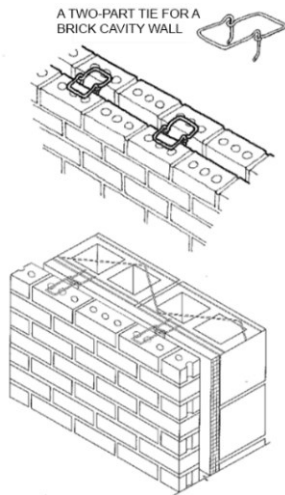


Figure 2.38. Connecting masonry walls with metal ties (Mehta et al., 1999: 121)

Therefore, the sound insulation provided by a conventional hollow wall connected by metal bonds in Figure 2.39 is much lower than that provided by the wall in (Figure 2.37) (Mehta et al., 1999: 121).

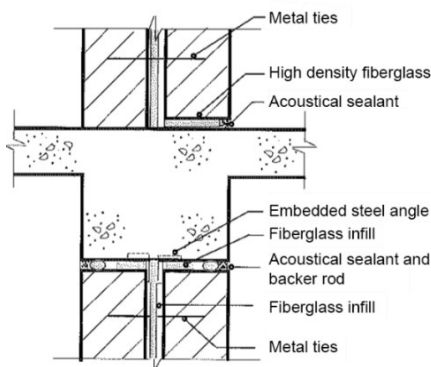


Figure 2.39. A traditional masonry cavity wall detail (Mehta et al., 1999: 121)

Sound insulation in coated masonry walls

The sound insulation of the masonry wall can be increased by combining metal or wooden fasteners with gypsum panels attached to the masonry walls. Further insulation is provided by using fiberglass in the intermediate space or by using the flexible joint between the

drywall and the wall. If the gypsum panels are transported to a separate wooden or metal carrier system without being mounted on the masonry wall, a higher sound insulation value is obtained since two independent systems will be formed. However, it should not be added from the inside, because this creates a channel that can create a sound bridge inside (Yılmaz Demirkale, 2007: 355).

For improvement in multi-layer wall applications made of gypsum boards:

- Heavy gypsum boards should be used.
- The sound transmission path formed on both sides of the wall can be cut by using staggered wooden studs, placing a double row of wooden studs, or leaving a flexible channel on one side of the stud.
- At least 5-cm-thick sound-absorbing covers should be placed in the gaps.
- Sealing must be ensured by insulating between the other building elements where the insulated wall is joined (Yılmaz Demirkale, 2007: 363-364).

Insulation principles in masonry walls

The example structures shown below show an 8-inch-thick brick wall. Insulation can be improved in two ways: Method-1: It can be improved by dividing the wall into two separate pieces (two layers of 4-inch-thick bricks separated by 4-inch airspace) (Figure 2.40) (Egan, 2007: 207).

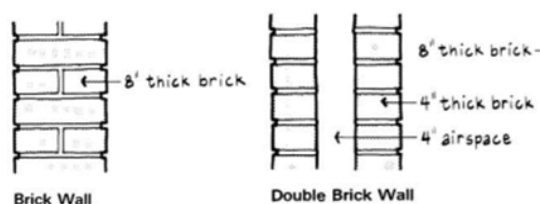


Figure 2.40. Method (1) of brick wall improvement (Egan, 2007: 207)

Method 2: This can be enhanced by flexibly adding a 1/2-inch-thick layer of drywall to the original 8-inch-thick wall (Figure 2.41) (Egan, 2007: 207).

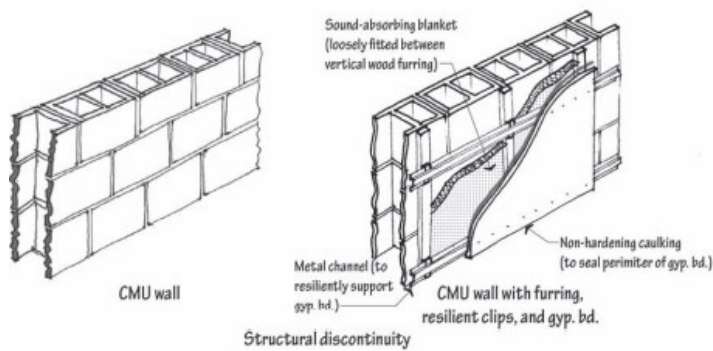


Figure 2.41. Method (2) of brick wall improvement (Ermann, 2015: 138)

However, according to Figure 2.42, Method 1 provides a better insulation value (Egan, 2007: 207).

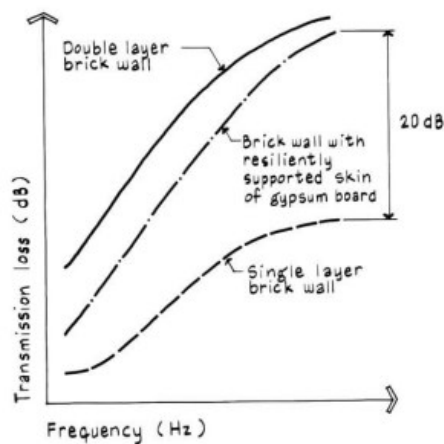


Figure 2.42. Masonry walls' sound-isolating effectiveness (Egan, 2007: 207)

Lightweight drywall installations

Attaching gypsum board to metal studs with screws provides a higher sound transmission loss value than adhesive attachment. This situation is caused by screws that provide point addition instead of a continuous line. Sound insulation values can be greatly increased by placing flexible channels on one side of the nails in the wooden strut structure. Therefore, short drywall screws can be used to maintain flexibility, or the panels should only be fixed between the uprights (Figure 2.43) (Egan, 2007: 211).

Resilient Channel Supports

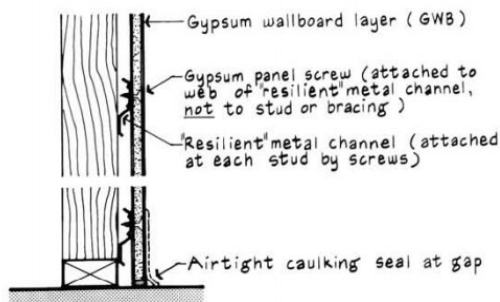


Figure 2.43. Resilient channel support (Egan, 2007: 211)

Heavier gypsum board layers increase the sound transmission loss (TL) value. Wider studs will cause more transmission loss at lower frequencies. In addition, adding double-nailed wooden studs that separate the screws, or flexible conduits will improve sound insulation (STC: Sound Transmission Class) (Figure 2.44 and Figure 2.45) (Egan, 2007: 211).

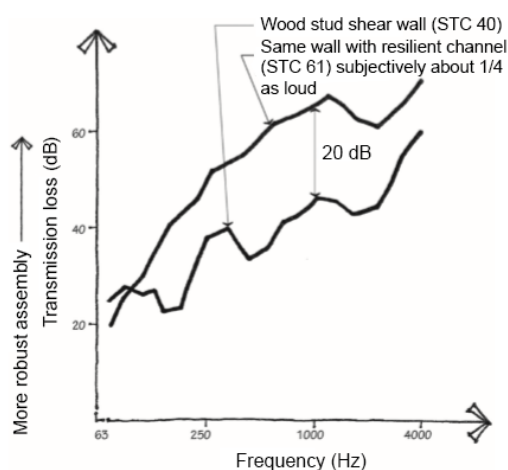


Figure 2.44. Effect of resilient channel (Ermann, 2015: 200)

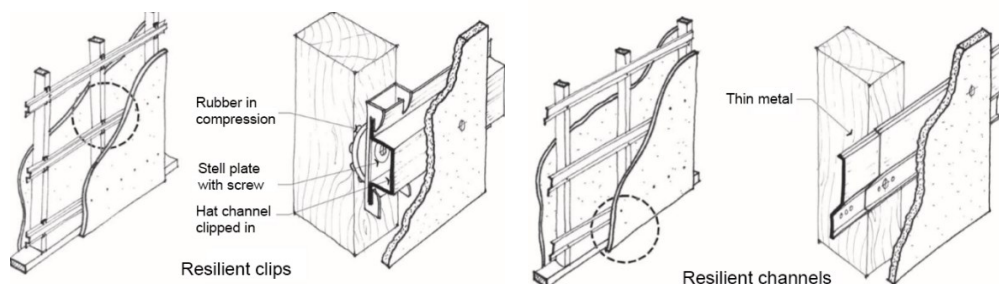


Figure 2.45. Resiliently mounted room surfaces (Ermann, 2015: 197)

Covering the air gap surface of the partition wall with a sound-absorbing material increases the sound transmission loss (TL) (Rindel, 2018). (Figure 2.46) In addition, the sound bridge that will occur due to the air gap between the insulation and the opposite layer will be prevented (Egan, 2007).

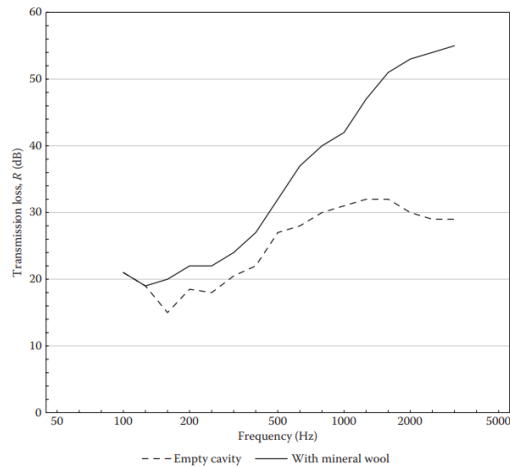


Figure 2.46. Transmission loss of a gypsum board (Rindel, 2018: 121)

Wall constructions for mechanical installation rooms

For mechanical fields, the greater the mass of the structure, the more resistant it is to airborne sound. Recommendations for increasing the sound insulation efficiency of concrete block wall structures are shown below. Lightweight hollow concrete blocks, plasterboards, and other structures should be avoided since these structures have poor transmission loss performance at low frequencies (Figure 2.47) (Egan, 2007: 313).

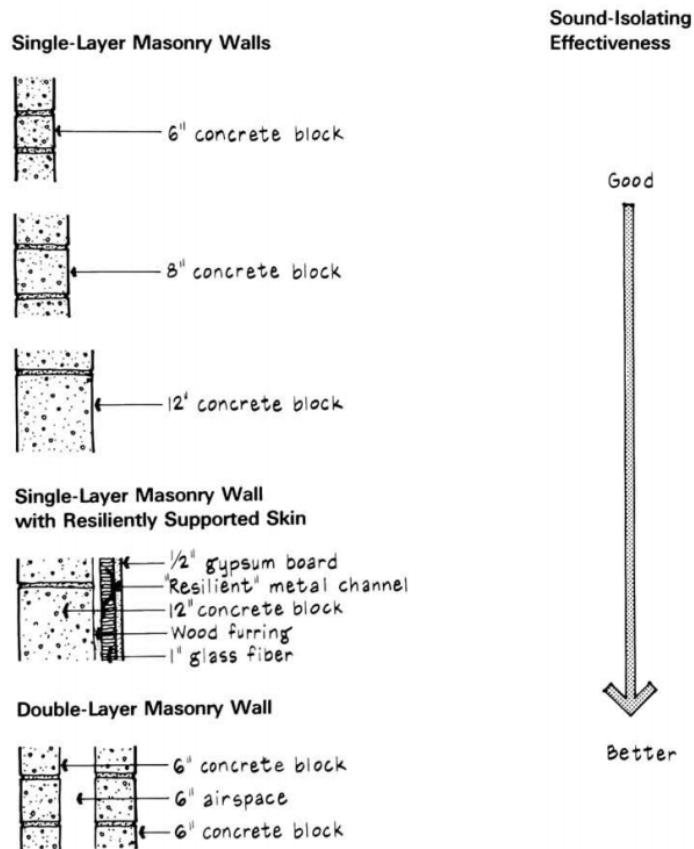


Figure 2.47. Sound insulation efficiency of brick walls (Egan, 2007: 313)

Windows

Doors and windows are considered weak elements because their mass per unit area is lower than other materials around them and they provide sound transmission (Yılmaz Demirkale, 2007: 453). Leaks in openable windows cause poor sound insulation (Figure 2.48) (Rindel, 2018: 130).

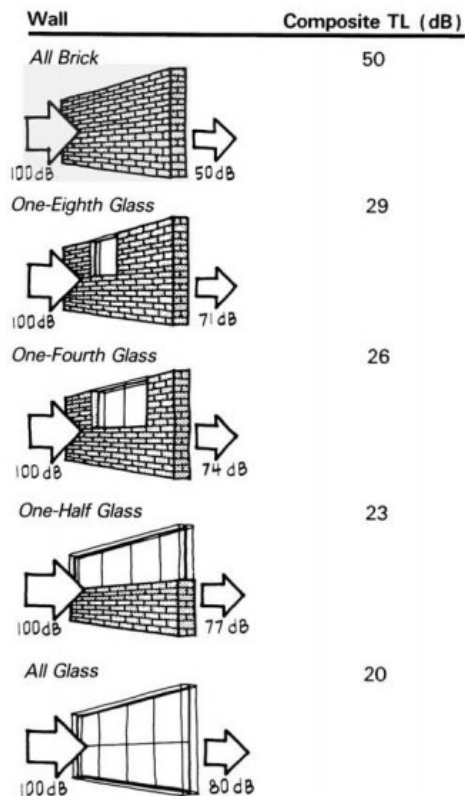


Figure 2.48. The effect of window surfaces on sound insulation (Egan, 2007: 188)

High-transmission-loss windows (sound insulation windows) are required in buildings located in environments with high outdoor noise. It is a thermal field with a plastic binder (usually high-strength polyurethane) between two parts of the aluminum frame of a thermally efficient window. Thus, the thermal insulation divides the aluminum window frame into two parts, one facing outward and the other inward. An energy-efficient window can also control air leakage. Air leakage control not only improves the energy efficiency of the window but also improves the sound insulation (Figure 2.49) (Mehta et al., 1999: 134).

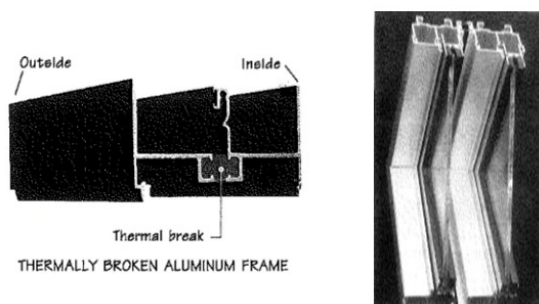


Figure 2.49. A thermal break splits the window into parts (Mehta et al., 1999: 134-135)

To prevent air leakage, applying a soft sealant around both glass surfaces of windows will increase the sound transmission loss (TL) and provide better sound insulation than covering a single glass perimeter of the window (Figure 2.50) (Rindel, 2018).

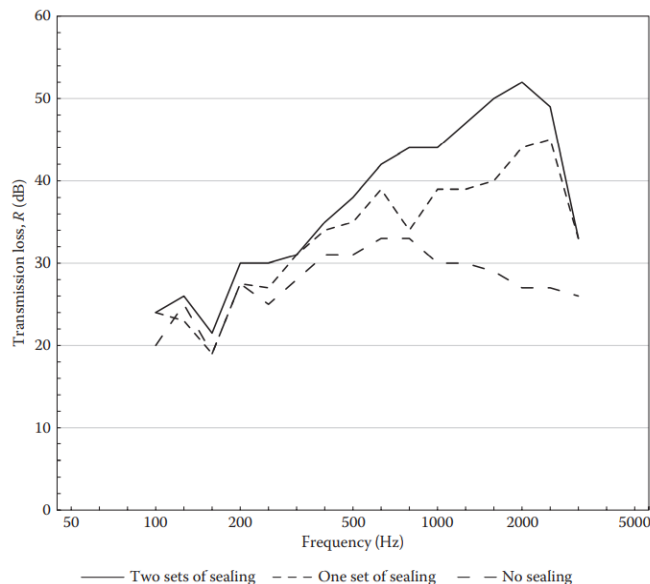


Figure 2.50. Effect of sealing in an openable double window (Rindel, 2018: 133)

Another important aspect of a soundproof window is the thickness of the glass. The greater glass thickness creates a greater mass and therefore better sound insulation. The use of two glass panels with an air gap between them increases the insulation of the window (Figure 2.51) (Mehta *et al.*, 1999: 135).

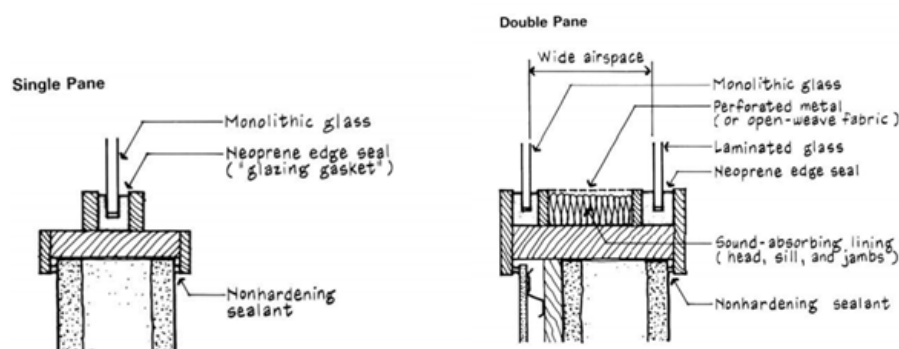


Figure 2.51. Window construction types (Egan, 2007: 224)

It is better to prefer glasses of different thicknesses in terms of sound insulation. A very high level of sound insulation cannot be achieved with a single-layer frame (Özer, 1979: 232).

Doors

For a door to be effective as a sound barrier, it must be heavy and sealed on all sides. Louvers or undercut doors cannot be used as sound barriers because they allow air leakage (Egan, 2007: 220). Figure 2.52 shows improvement recommendations for the sound insulation of the doors.

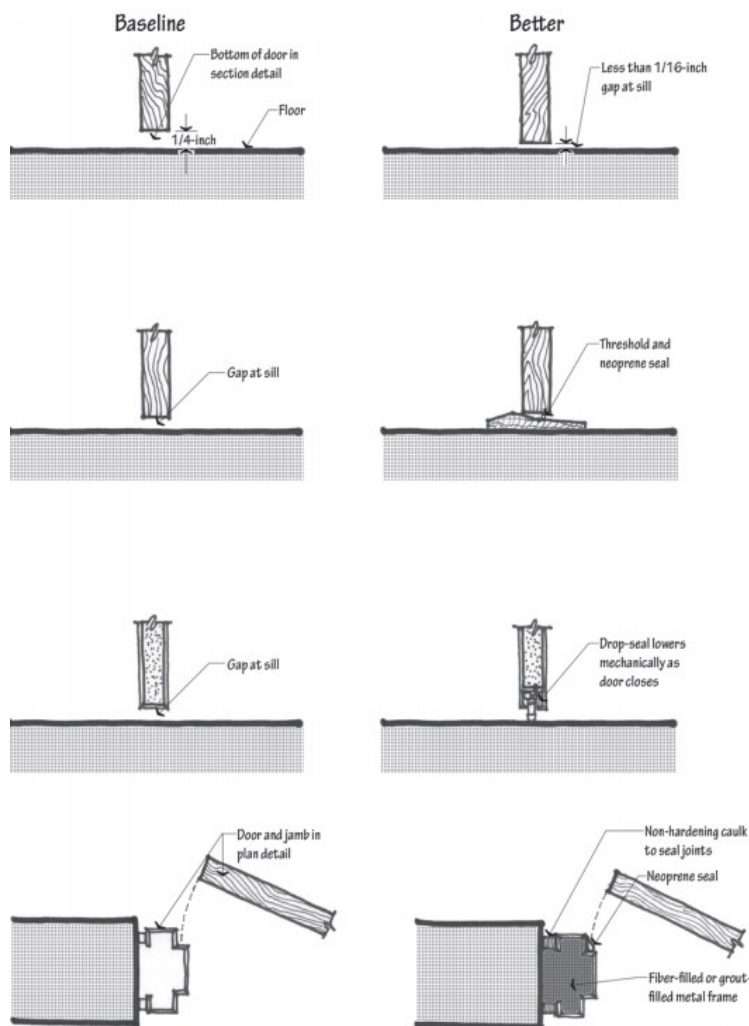


Figure 2.52. Improving door thresholds and seals for sound insulation (Ermann, 2015: 183)

Transmission loss is the loss of sound pressure level caused by sound passing through the panel (Mehta et al., 1999: 90). The figure below shows the audio transmission loss for "leaky" doors. The sound transmission loss in the gaps and thresholds on the door surface is 0 dB. Therefore, these sound leaks seriously reduce the insulation value of the doors (Figure 2.53) (Egan, 2007: 184).

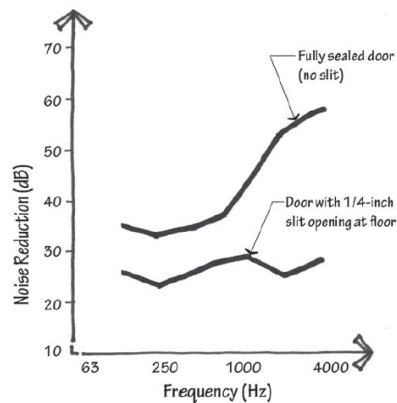


Figure 2.53. Noise reduction in doors (Ermann, 2015: 148)

Sealed hollow metal doors filled with dense loose materials such as fibrous materials, sheet lead, or lead-loaded vinyl have higher insulating performance than solid wood doors with the same weight seal (Egan, 2007: 184). Doors with better sound insulation are shown in Figure 2.54.

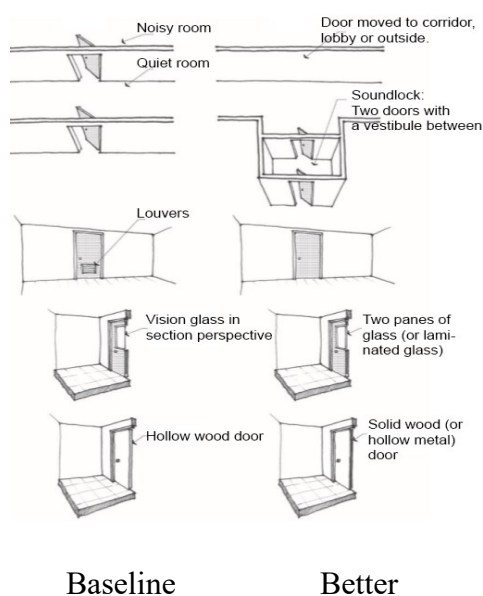


Figure 2.54. Sound insulating doors (Ermann, 2015: 182)

Single-layer door panels are made from wood chipboards, thatch and reed chipboards, or glass. Acoustically, custom-made doors are mostly multi-layered. The gaps between the door layers are filled with insulation material. An improvement of 5–10 dB in the sound insulation level can be achieved. Care should be taken so that the sealing strips on the doors are not rendered ineffective as a result of the painting process (Özer, 1979: 222-223).

Fundamentals of impact noise isolation

Impact noise is a difficult situation to prevent in multi-family residential buildings. These sounds are mostly furniture movements, running sounds, walking sounds, falling objects, etc. It annoys users due to the irregularity of the sounds. With the floor-ceiling interaction, sounds originating from this structure can be transmitted to every point of the room. With the floor-ceiling arrangement aiming to reduce airborne noise, although the impact noise caused by the structure cannot be completely prevented, it contributes to the prevention of airborne noise (Ermann, 2015: 185).

Structure-borne / impact noises can be controlled by:

- Using soft, flexible surfaces
- Using floating floor systems
- Using the suspended ceiling system (Yılmaz Demirkale, 2007: 425).

In Figure 2.55, there are recommendations to prevent impact noise.

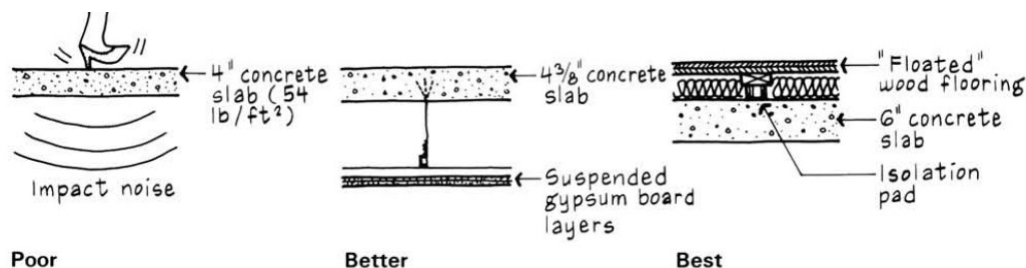


Figure 2.55. Recommendations to avoid impact noise (Egan, 2007: 246)

Using soft flexible surfaces

Weakening the impact at its source is one of the most effective ways to heal a floor against impact noise. Therefore, applying soft flooring such as foam underlayment or carpet across the surface is an excellent way to improve impact soundproofing (Mehta et al., 1999: 146).

Floating floor

The best way to block the sound transmission path in structure-borne sound is the separation of one structure from another. The floating floor is separated from the structural floor by being raised by an additional floor. The floating floor can be made of wood or concrete and insulated from the structural floor with springs, insulation blocks, or other elements. A well-built floating floor (especially a floating concrete slab) can provide a high insulation value. Thanks to the floating floor, low-frequency noise and vibration can be reduced. However, it should be noted that there are no sound bridges in these systems (Figure 2.56) (Everest and Pohlmann, 2009: 306 ; Yılmaz Demirkale, 2007: 425-426).

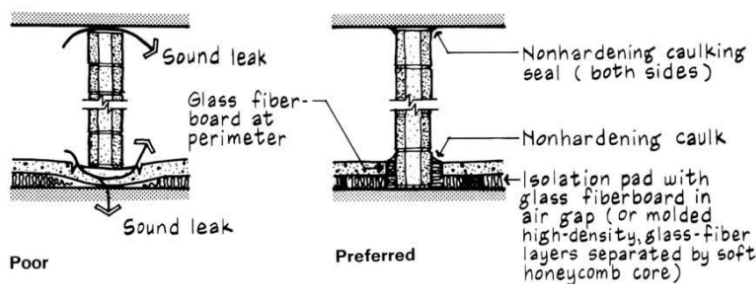


Figure 2.56. Sound leakage in floating floor (Egan, 2007)

Floating floor on a conventional wood floor

Due to its low cost and simple structure, it is mostly used in residences and apartments, but the disadvantage of such a floor is that it transmits low-frequency impact noise due to its lightweight. A floor covering such as a carpet will increase the sound transmission class (STC) and impact insulation class (IIC) values (Figure 2.57) (Mehta et al., 1999: 148).

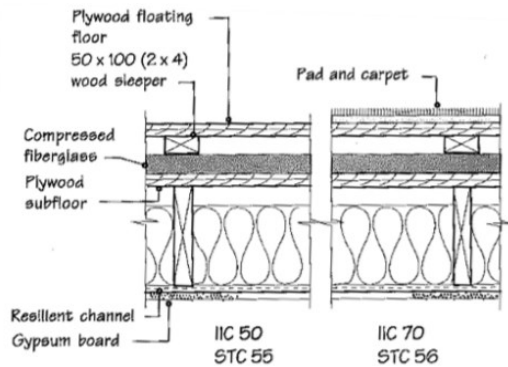


Figure 2.57. Plywood floating floor on conventional wood floor (Mehta et al., 1999: 148)

Another disadvantage of a light floor is that it creates more noise in the area where it is located. On a light floor, using a layer of Portland cement or gypsum concrete instead of plywood provides the necessary weight, improving low-frequency insulation (Figure 2.58) (Mehta *et al.*, 1999: 148).

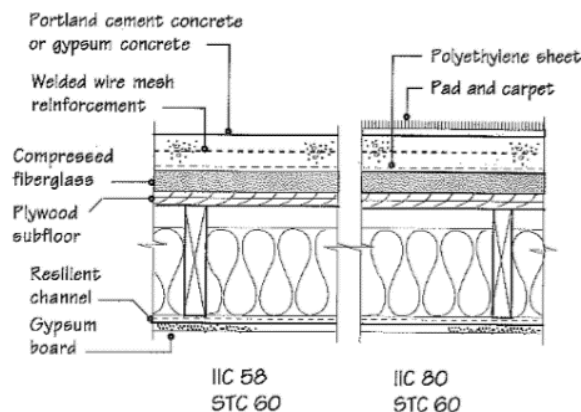


Figure 2.58. Concrete floating floor on a conventional wood floor (Mehta et al., 1999: 149)

Wood floating floor over concrete structural floor

A floating wooden floor on a concrete structural floor is ideal for especially high-rise apartments on suspended concrete slabs, etc. Although there are different versions, Figure 2.59 shows a typical wooden floating floor on a reinforced concrete structural floor. Impact absorption is provided by high-density fiberglass blocks (Mehta *et al.*, 1999: 150).

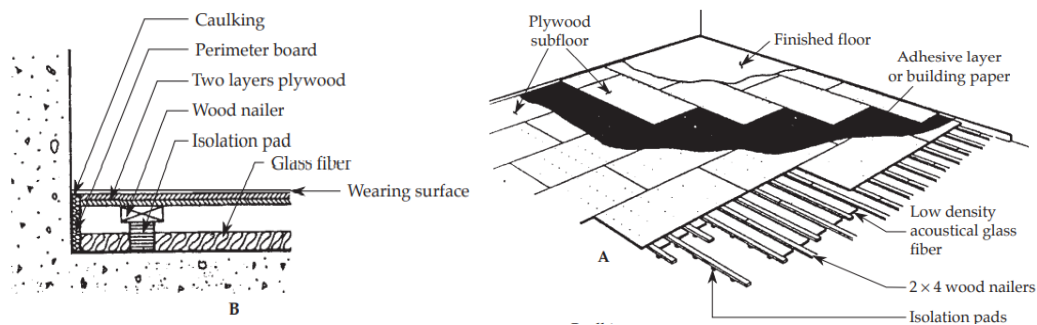


Figure 2.59. Wood floating floor on a reinforced concrete structural floor (Everest and Pohlmann, 2009: 308)

In Figure 2.60, there are recommendations on how to improve the insulation performance class against impact sound (Impact Insulation Class / IIC) in wooden structures.

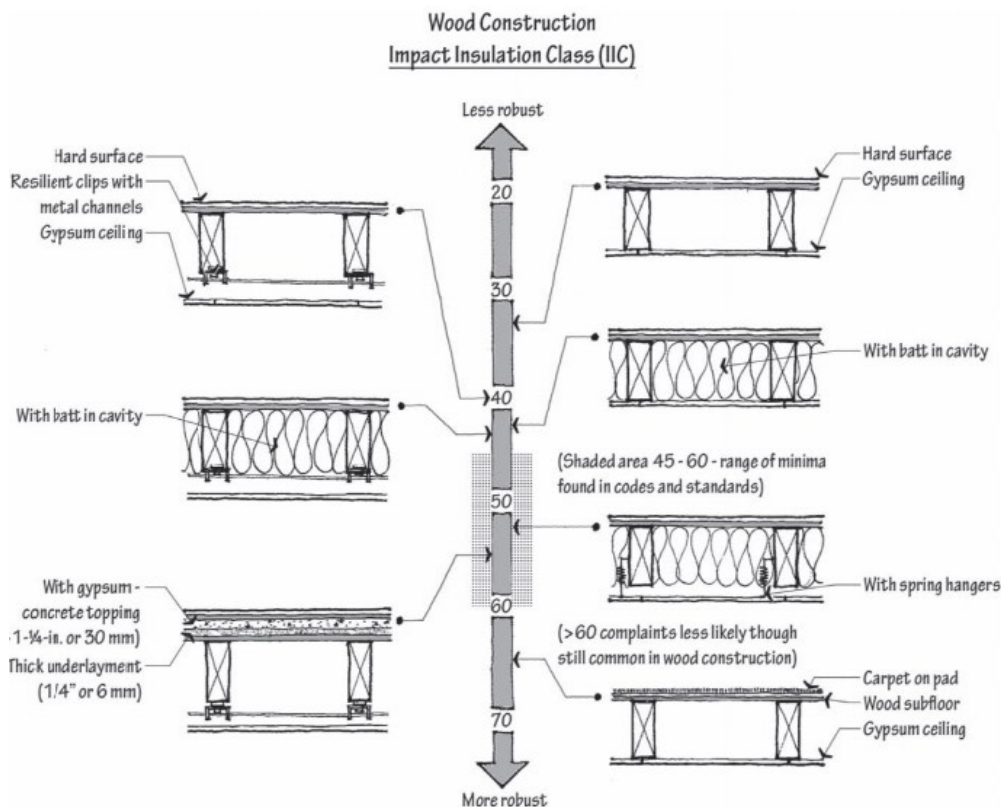


Figure 2.60. Improving impact insulation in wooden construction (Ermann, 2015: 189)

Floating concrete slab over concrete structural floor

A concrete-covered floating floor is similar to a wooden floating floor. Plywood panels over fiberglass blocks act as a permanent form for the floating concrete slab, and the air

gap between the floating concrete slab and the structural floor is filled with low-density fiberglass (Figure 2.61) (Mehta *et al.*, 1999: 151).

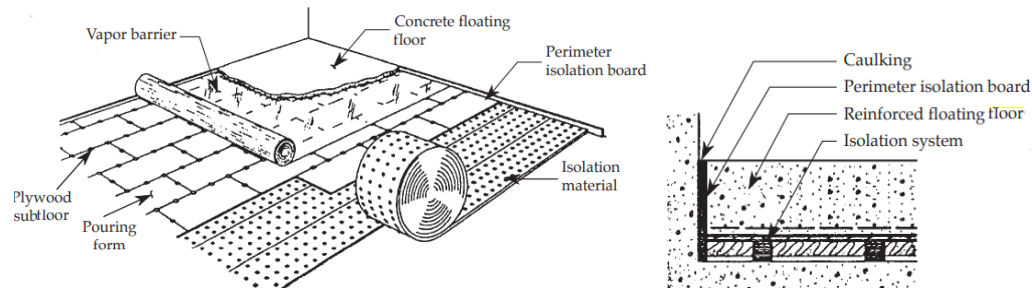


Figure 2.61. Components of a concrete floating floor (Everest and Pohlmann, 2009: 307)

This type of floor is commonly found in residential buildings and performs well in terms of impact sound. Carpet covering will increase impact sound insulation (IIC: Impact Insulation Class) (Everest and Pohlmann, 2009: 307). Additionally, in Figure 2.62, there are recommendations on how to improve the insulation performance class against impact sound (Impact Insulation Class/ IIC) in concrete structures.

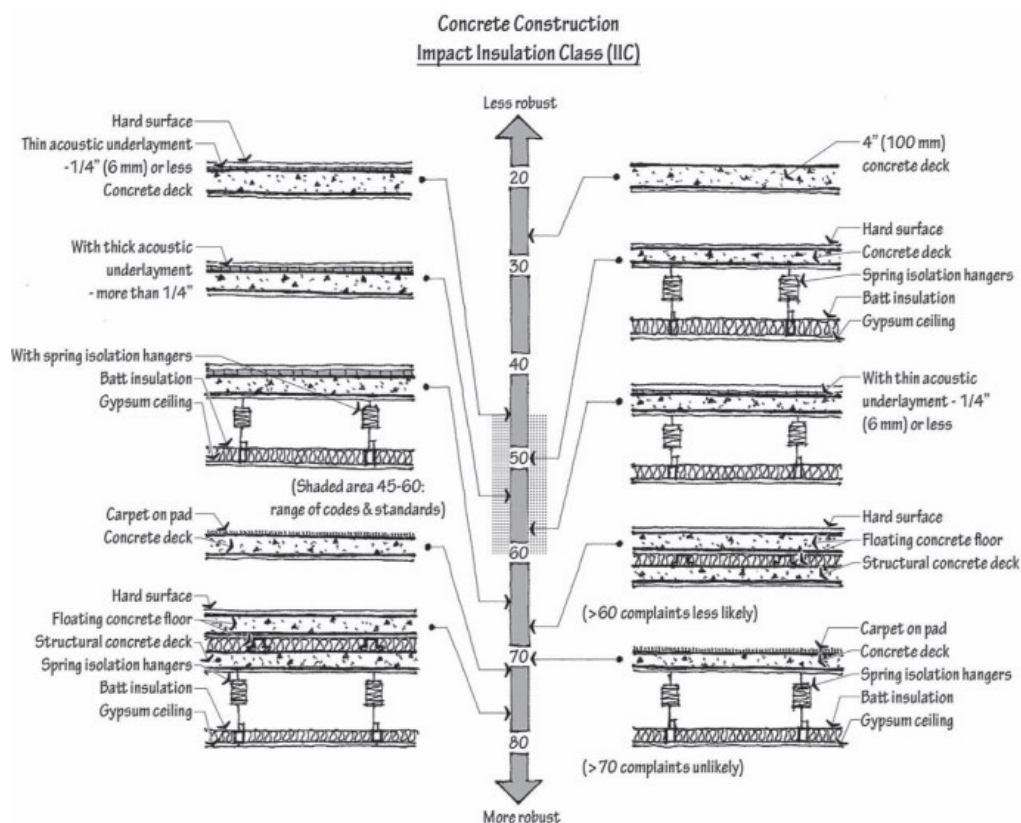


Figure 2.62. Improving impact insulation in concrete construction (Ermann, 2015: 188)

There are some points to consider when making floating floors:

- In the construction of reinforced concrete floating floors, soft cushions should be placed under the molds where the floors will be poured.
- The entire perimeter should be covered with cork strips or fiberglass material so that there are no gaps at the joints of floating floors and walls.
- The elements used in the ceiling and wall construction should have a high sound transmission loss.
- It is necessary to increase the air gap between the ceiling and the floor, where the pipes that cause vibration can be found, and to use soundproof insulation covers in this area. Therefore, the noise caused by airborne and impact sounds can be controlled with well-designed flooring systems (Yılmaz Demirkale, 2007: 434).

Flexible ceiling system

As with the walls, the material should not be homogeneous in terms of density, sound transmission from side roads should not be possible, and the sound insulation effect should not be reduced by the insulation board fixed to the ceiling surface with concrete or plaster. Ceilings with uneven mass distribution are considered bad for sound insulation. This is because the ceiling mass gathers at certain points, creating areas with higher sound permeability in other places (Özer, 1979: 205).

Suspended ceiling constructions, suspended from the structural floor with wire or flexible hangers, are used to prevent sound from spreading to the ceiling due to impacts from the floor. Thanks to these ceilings, noise from both air and impact sounds is reduced (Figure 2.63) (Ginn. M., 1978: 77).

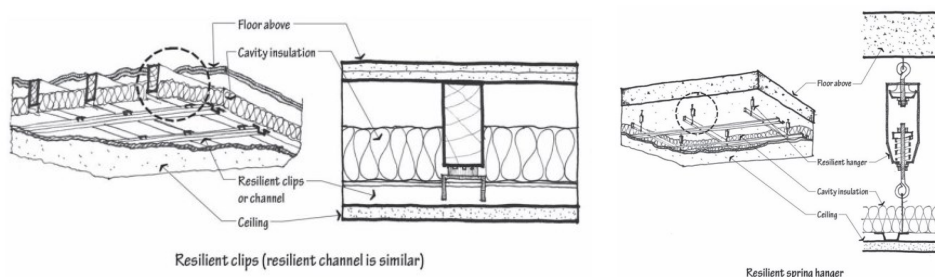


Figure 2.63. A method of suspending a ceiling that gives a great improvement in the insulation rating (Ermann, 2015: 199)

It is very important to reduce the impact sound in concrete floor-ceiling installations where extra air space is provided with hangers (preferably the cavity is filled with acoustic insulation material) (Ermann, 2015: 200). All joints and openings that may occur in the ceiling structure must be tightly closed. (Figure 2.64) (Egan, 2007: 218).

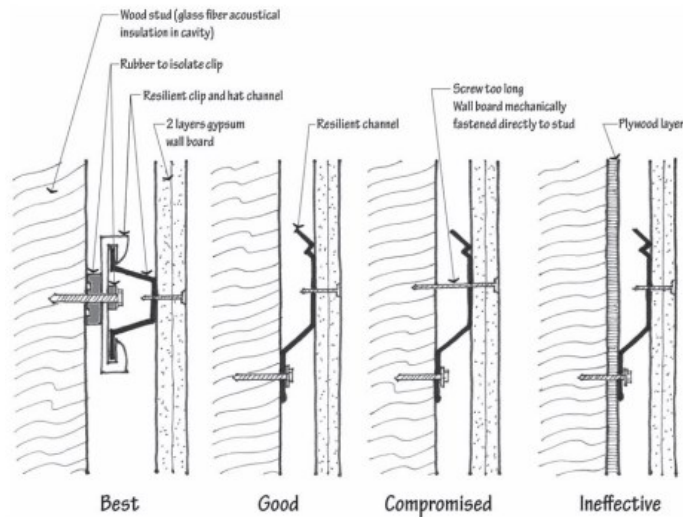


Figure 2.64. Insulation in the ceiling (Ermann, 2015: 201)

When a suspended ceiling is tested alone or in combination (suspended ceiling and floating floor), as shown in Figure 2.65, using them together appears to be even more effective (Rindel, 2018: 300).

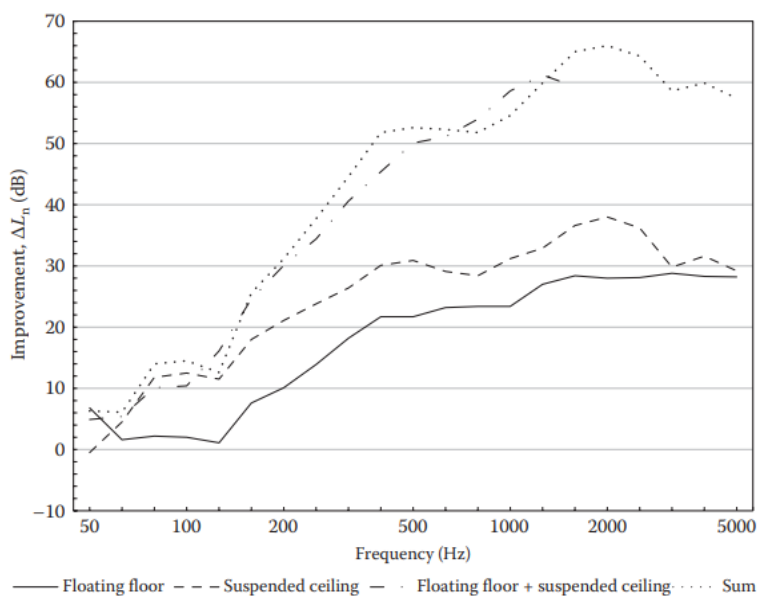


Figure 2.65. Impact sound attenuation of a floating floor (Rindel, 2018: 302)

However, low-frequency sounds can also be transmitted through structures with these surfaces. Suspended ceilings and floating floors in concrete structures can achieve high impact insulation values across the entire frequency range (Figure 2.66) (Egan, 2007: 247).

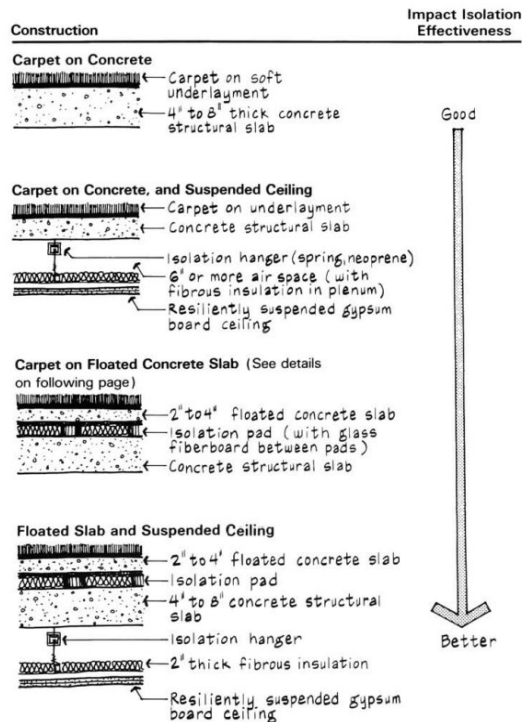


Figure 2.66. Methods to improve impact insulation (Egan, 2007: 247)

Sounds transmitted through gaps

Flanking Transmission Performance at the weakest point in sound transmission determines the overall effectiveness of an assembly. Therefore, a small leak will weaken the entire barrier (Figure 2.67) (Ermann, 2015: 135).

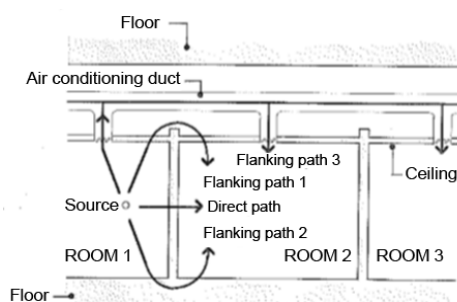


Figure 2.67. A cross-section showing the direct and flanking sound transmission paths (Mehta et al., 1999: 107)

Consideration should be given to transmission paths when designing or selecting structures to reduce the transmission of airborne sound. Typical transmission paths include mostly walls and connections between ceilings, floors, or other walls; openings in doors and windows, mechanical or electrical service equipment; and openings (Figure 2.68) (Cavanaugh et al., 2010: 18).

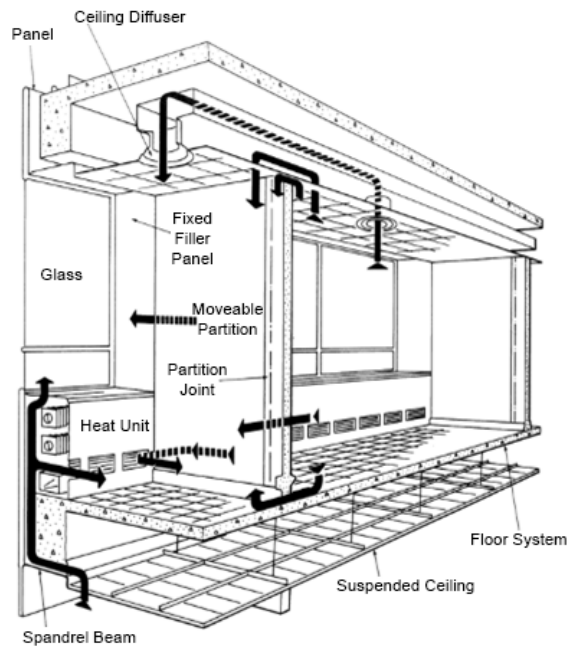


Figure 2.68. Some examples of sound leaks (Cavanaugh et al., 2010: 19)

To prevent flanking sound transmission

1. The presence of a discontinuity in flexible components causes sound transmission. The only way to reduce the transmission of structure-borne sound along the road is to ensure continuity on the floor and ceiling. Therefore, joints between a resiliently supported ceiling and the wall must be insulated using a sound-absorbing material (Figure 2.69) (Mehta *et al.*, 1999: 155).

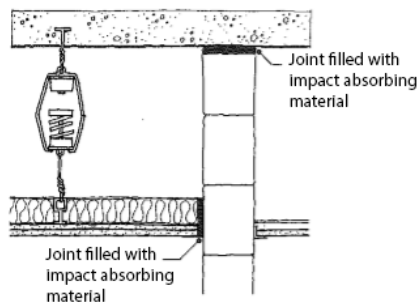


Figure 2.69. Joint between the suspended ceiling and the wall (Mehta et al., 1999: 155)

A floating floor must also be isolated from the adjacent structure. This is because the flexible connections under a floating floor provide structural discontinuity. For this reason, the wall separating the floating floor from other spaces must be insulated with sound-absorbing material (Figure 2.70) (Mehta *et al.*, 1999: 155).

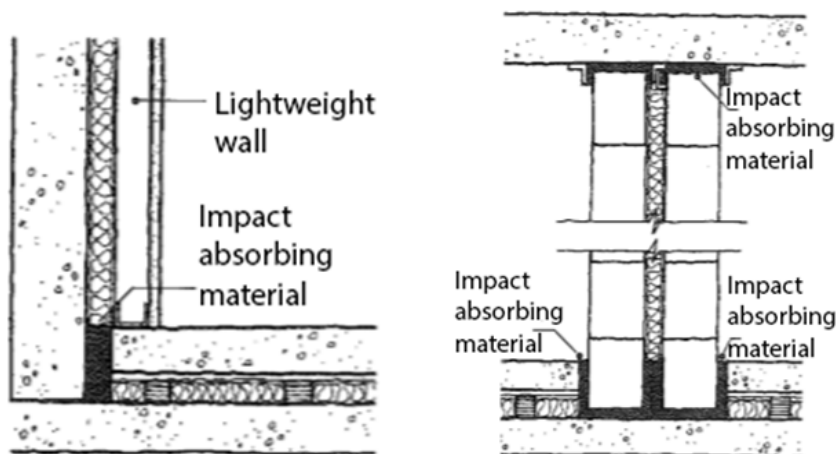


Figure 2.70. Joints between wall and floor (Mehta et al., 1999: 155)

2. Electrical outlets, wired wall sockets, etc. should not use the same spacing with similar indentations on the same side (Ermann, 2015: 133). (Figure 2.71).

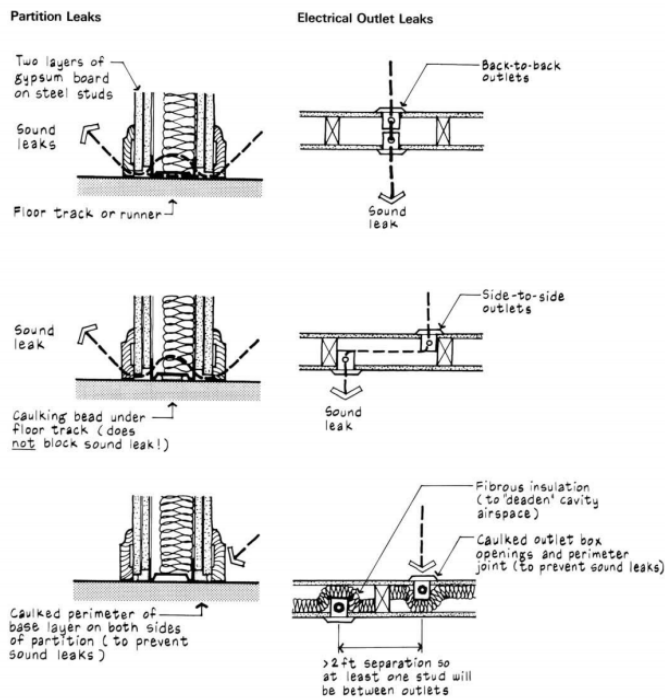


Figure 2.71. Measures to avoid sound flanking (Egan, 2007: 183)

3. Louvered doors should not be used in all sound-sensitive rooms (Ermann, 2015: 135).
4. Partitions should extend up to the structural deck above the ceilings. An acoustic ceiling floor is effective at absorbing sound in a room as it prevents sound from being transmitted to different rooms (Figure 2.72) (Ermann, 2015: 135).

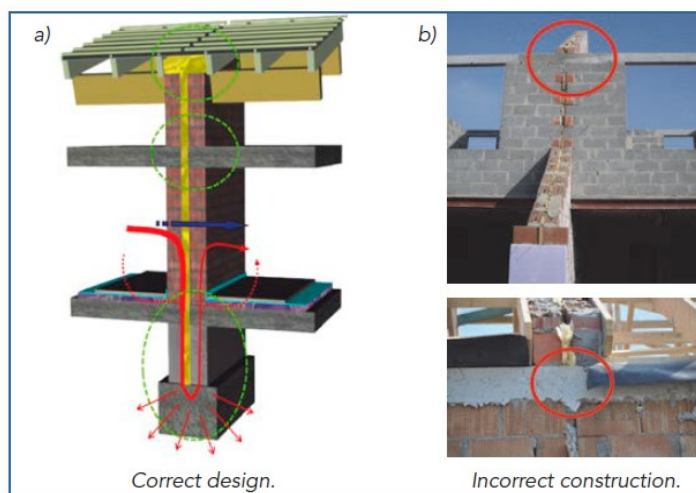


Figure 2.72. Preventing sound bridges that may occur in row houses (COST Action TU0901, 2014: 199)

- a) For good workmanship in row houses, separation walls should be structurally and acoustically separate. The walls should be continuous from the foundation to the roof and should not transmit sound.
- b) It is an example of poor workmanship since the mortar connects the two layers of the wall. Sound bridges caused by poor workmanship can result in a 3 dB to 12 dB reduction in sound insulation (COST Action TU0901, 2014: 199).

For this reason, in order to prevent airborne noise, the gaps that will cause sound transmission in the building elements should be improved. Expanding structural elements should be avoided, and connections between different building elements should be reduced by placing them on a floor surface (Ermann, 2015: 135). (Figures 2.73 and 2.74).

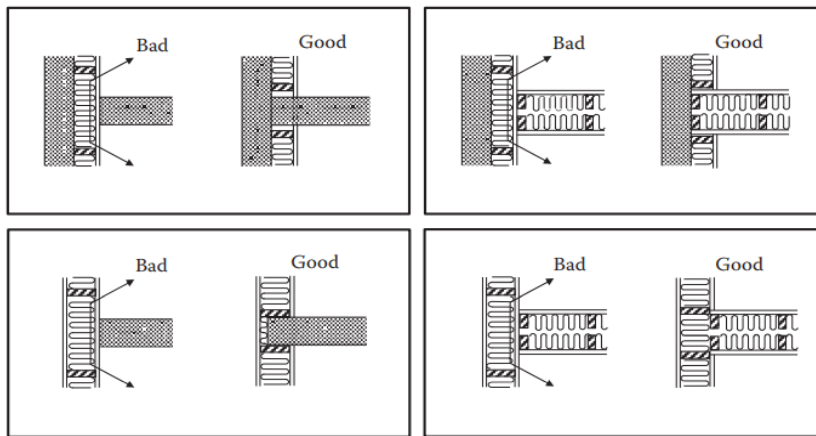


Figure 2.73. Examples of junctions between external and internal walls (Rindel, 2018: 134)

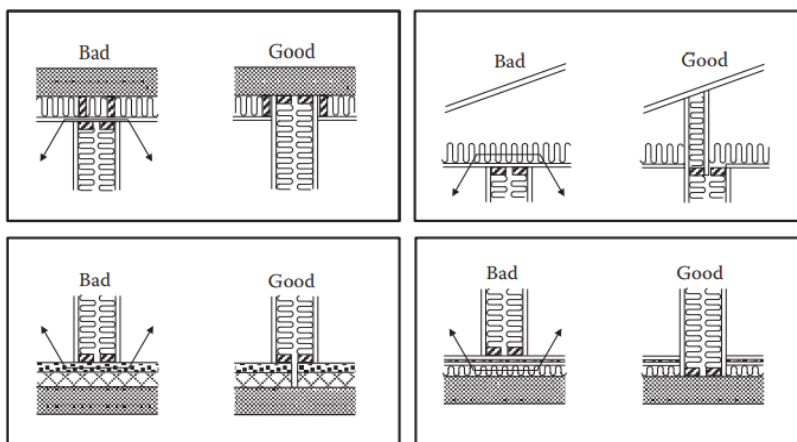


Figure 2.74. Examples of junctions between the roof and internal wall and between the floor and internal wall (Rindel, 2018: 135)

In Figure 2.75, the current state of the building is given in the example on the left, and the sound insulation performance of the building elements as a result of the improvement process is given in the example on the right.

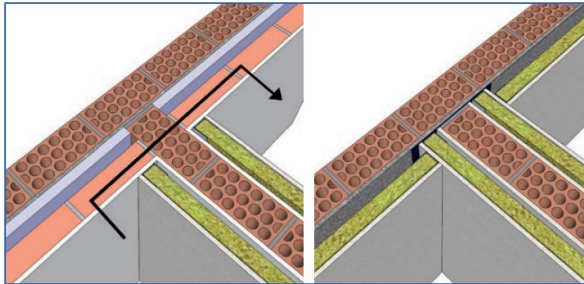


Figure 2.75. Sound insulation performance examples in the partition wall (COST Action TU0901, 2014: 188)

Transmission occurs from the inner wall in the existing brick on the left. Sound insulation: $D_{nT,w} + C = 48$ dB. After the facade improvement on the right, the sound insulation is $D_{nT,w} + C = 54$ dB (COST Action TU0901, 2014: 188).

5. Tight connections between single floors of multi-layer building elements cause a significant deterioration in the sound insulation level since they cause sound transmission. This deterioration can even fall below the value provided by a single-layer building element. For audio bridges, the dot-shaped connection provides a higher level of improvement than the line-shaped connection. This separating gap must be covered with acoustic mastic (Özer, 1979).

Transmission of impact sound horizontally and diagonally

In residential buildings that are not protected from impact sound, noise disturbance problems arise in living rooms, study rooms, and bedrooms in neighboring apartments. Therefore, in order to provide noise control, diagonal and horizontal directional impact sound transmission should be considered in places such as corridors, kitchens, attics, and stairwells (Özer, 1979: 271).

Stairs: Step noise protection measures are not required on stairs and stairwells unless there are rooms or partitions directly adjacent to the stairwell where there is a demand for step noise protection. In dual structures where two flats are opened in the stairwell, it is

necessary to take precautions against impact sound. A soft floor can be used for this measure. An insulating opening can be provided if the landing is not positioned against the back wall of the stairwell. Even if the gap is closed with lightweight wood construction boards, sufficient sound insulation can be achieved (Figure 2.76) (Özer, 1979: 273-274).

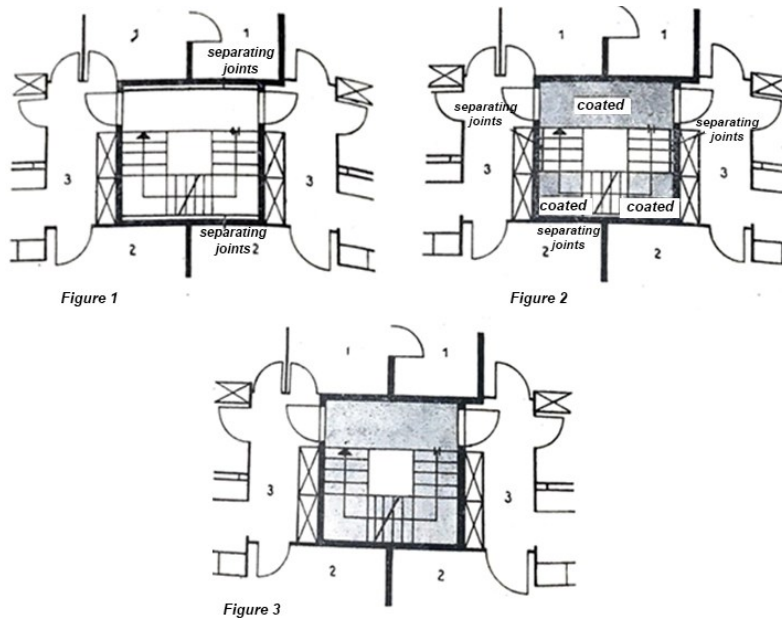


Figure 2.76. 3 examples that provide an adequate insulation on a stair (Özer, 1979: 274).

1- Children's Room 2- Living Room 3- Corridor

Figure 1: Stairs and landings are uncoated, while the sides of the sitting and children's rooms have separating joints.

Figure 2: Coated landings, stair sides with separating joints

Figure 3: Stairs and landings are coated; there is no separation joint.

One of the main sources of disturbance caused by noise in residential buildings is noise from technical equipment and installations. This noise should be taken into account, especially in multi-layer residences. In this section, situations that can create noise are included. Solution recommendations are presented for the problems that may occur.

Elevator installation

It occurs as a result of the transmission of noise from the engine room to the surrounding rooms and from the compartments to the adjacent rooms. In addition to vibration isolation,

measures to reduce airborne sound transmission should be decided by considering the noise of the elevator type, the construction style of the engine room, and the location of the elevator inside the building. With regard to the positioning of the engine room with respect to the nearest living rooms, the three cases outlined in figure 2.77 are evaluated. These rules are applicable when it comes to heavy building structures (Özer, 1979: 289).

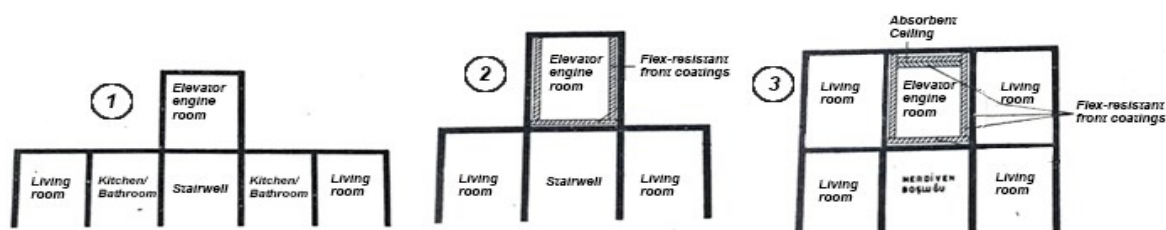


Figure 2.77. Measures that must be taken based on the elevator engine room's location within the building (Özer, 1979).

1. If the engine room is above the stairwell, there is no need to take additional measures if there is no room in horizontal and diagonal situations.
2. Due to the ability to transmit sound diagonally to the living rooms, front coatings that are resistant to flexing should be used on the walls of the engine room.
3. In addition to the prevention in Figure 2, it is necessary to apply the absorbent ceiling (Özer, 1979: 289-290)

Noises from the elevator shaft

Protection measures in the elevator shaft are taken according to the location of the elevator in the building. It will be sufficient to apply a single-layer building system without disrupting the functions of the elevator shaft. Elevator shafts passing right next to the living rooms should be constructed as a double-deck structure consisting of two heavy walls equipped with a separation gap (Özer, 1979: 290).

Hydrophore installation

Water pressure-increasing installations are used in cases where the normal water main pressure is not sufficient for all apartments, such as in high-rise residential buildings, and

where the water comes without pressure. However, this creates a noise problem. Flex-resistant face layers should be used to prevent noise. In addition, the propagation of the sound from the pump and compressor elements to the pipe network should be prevented with flexible intermediate elements, especially in important places (Özer, 1979: 309).

Sound transmission from chimneys in residential buildings

In the kitchens and bathrooms that are not located on the exterior of the residences, since there are no windows, air shafts equipped with ventilation mechanisms are required. In terms of acoustics, these chimney structures must meet two requirements. First, the sound insulation between the rooms to which they are connected on the upper floor should not fall below the required minimum. Second, it must be ensured that the noise from the ventilation device transmitted through the chimneys does not exceed the maximum sound pressure levels set for living rooms. In this case, the size of the silencer to be used is determined by the type of ventilation installation and the rooms most exposed to adverse effects. It is beneficial to place the silencers in a separate room. If a very high sound pressure level appears in the room:

- Using a silencer element or other means to reduce the sound level in the duct.
- It is necessary to increase the sound insulation scale of the duct wall by increasing the separation area density or using double-layer structures (Özer, 1979: 290).

Sound can travel through chimneys, chimney holes, chimney walls, or the floor edge of the chimney entrance. The greater the sound absorption degree of the chimney wall and the greater the distance between the two chimney sections, the greater the sound insulation in the longitudinal direction. Changing the chimney cross-section and direction causes a significant reduction in sound transmission. Having the chimney mouths in the middle of the wall instead of on the wall edge will reduce the sound input to the chimney and the sound insulation level coming from the chimney section (Özer, 1979: 291). In Figure 2.78, types of chimney construction for residential buildings are given.

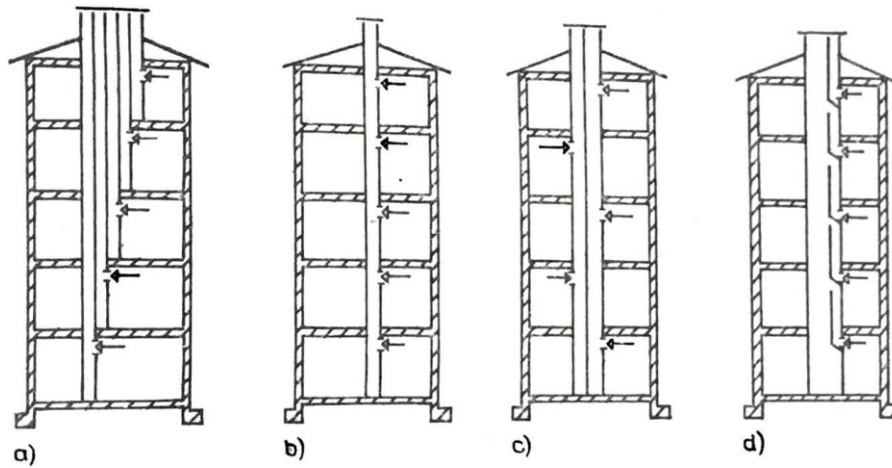


Figure 2.78. Types of chimney construction for residential buildings (Özer, 1979: 291)

- single chimney facility for each flat
- collection chimney facility with a single chimney
- two chimney collection chimneys
- side chimney collection chimney facility

a) In single-chimney construction (a) a different chimney is determined for each room. This application is very suitable in terms of acoustics, since sound transmission from the chimney cross-section is eliminated. But such structures require more material, which takes up more space.

b) Chimney constructions that are common in a single chimney where all sections are opened (b) do not take up space and require very little expense and effort. However, the required minimum sound insulation level cannot be reached without additional measures.

c) If two chimneys are used instead of a single chimney, (c) chimney walls must be porous.

d) An acoustically viable solution is to use common chimney structures (d) with common side ducts. Sound insulation will be higher due to the many direction and cross-section changes. In addition, the use of sound-absorbing materials such as glass fiber in the construction of the chimney is acoustically good (Özer, 1979: 290-292).

Positioning of machines to isolate impact sound

Impact sound penetrates the internal structure of buildings with machine vibrations. This sound can even spread to distant rooms, causing discomfort. The transmission path of the impact sound should be cut off at the location of the machine. For this, the machines should be installed on a springy floor, as seen in (Figure 2.79) (Özer, 1979: 285).

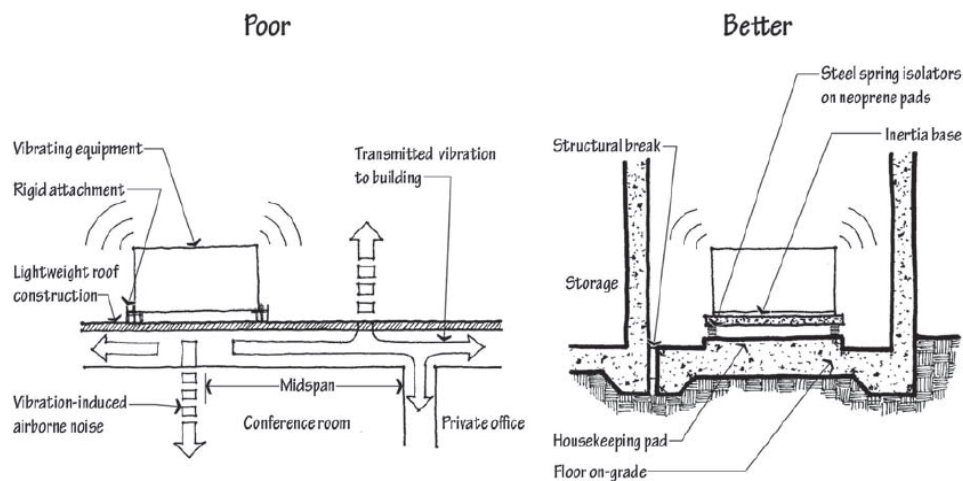


Figure 2.79. Placing the machine on the spring-loaded floor (Ermann, 2015: 230)

In this way, the sound of the machine can be isolated by placing it on the subfloor with springs made of steel, rubber, or cork. In order to minimize vibration, the springs should be placed in as wide an area as possible. In addition, care should be taken that there is no connection with the ground to prevent the formation of sound bridges (Özer, 1979: 287).

Sound propagation in installation noises

In every area connected to the building elements, the sound is transmitted to another area. Sand-filled mufflers, sound-absorbing mass, water sound silencers, or rubber pipes can be used to reduce noise in the pipe transmission system. However, one of the most effective solutions is to cut the pipeline with a flexible connector such as rubber (Özer, 1979: 307-308). Figure 2.80 offers recommendations for providing sound insulation to pipes.

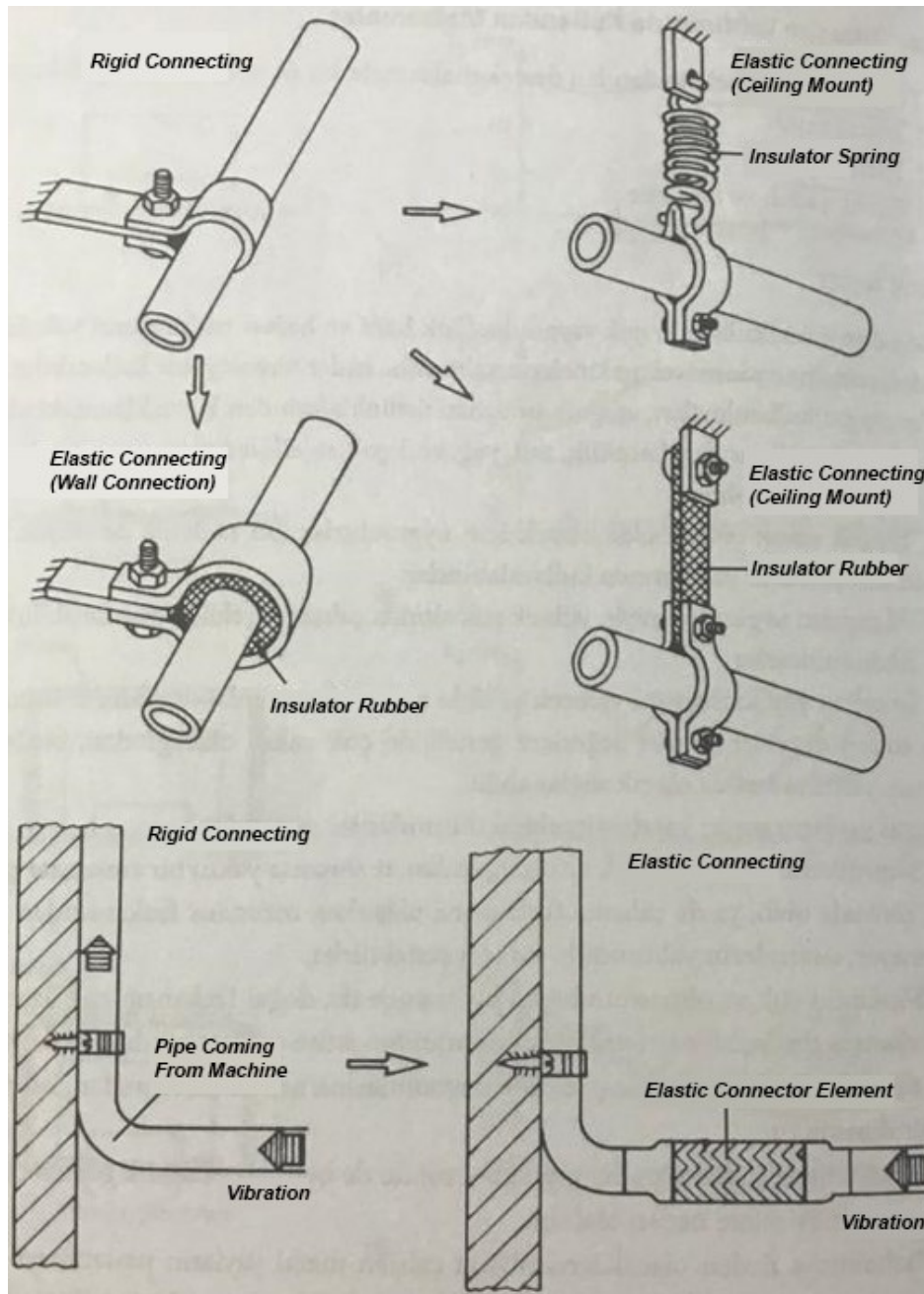


Figure 2.80. Examples of fasteners that can be used to insulate pipes from the wall to which they are connected (B&K, 1982; as cited in Özgüven, 2008)

Another solution for sound insulation is to make the right planning solutions in terms of building acoustics. Faulty solutions are cases where fixtures or pipelines are fixed to the walls that separate the room that needs to be protected from noise (Figure 2.81 a). No plumbing tools or parts should be placed on the walls of the room that needs to be protected from sound for proper planning (Figure 2.81 b) (Özer, 1979: 307).

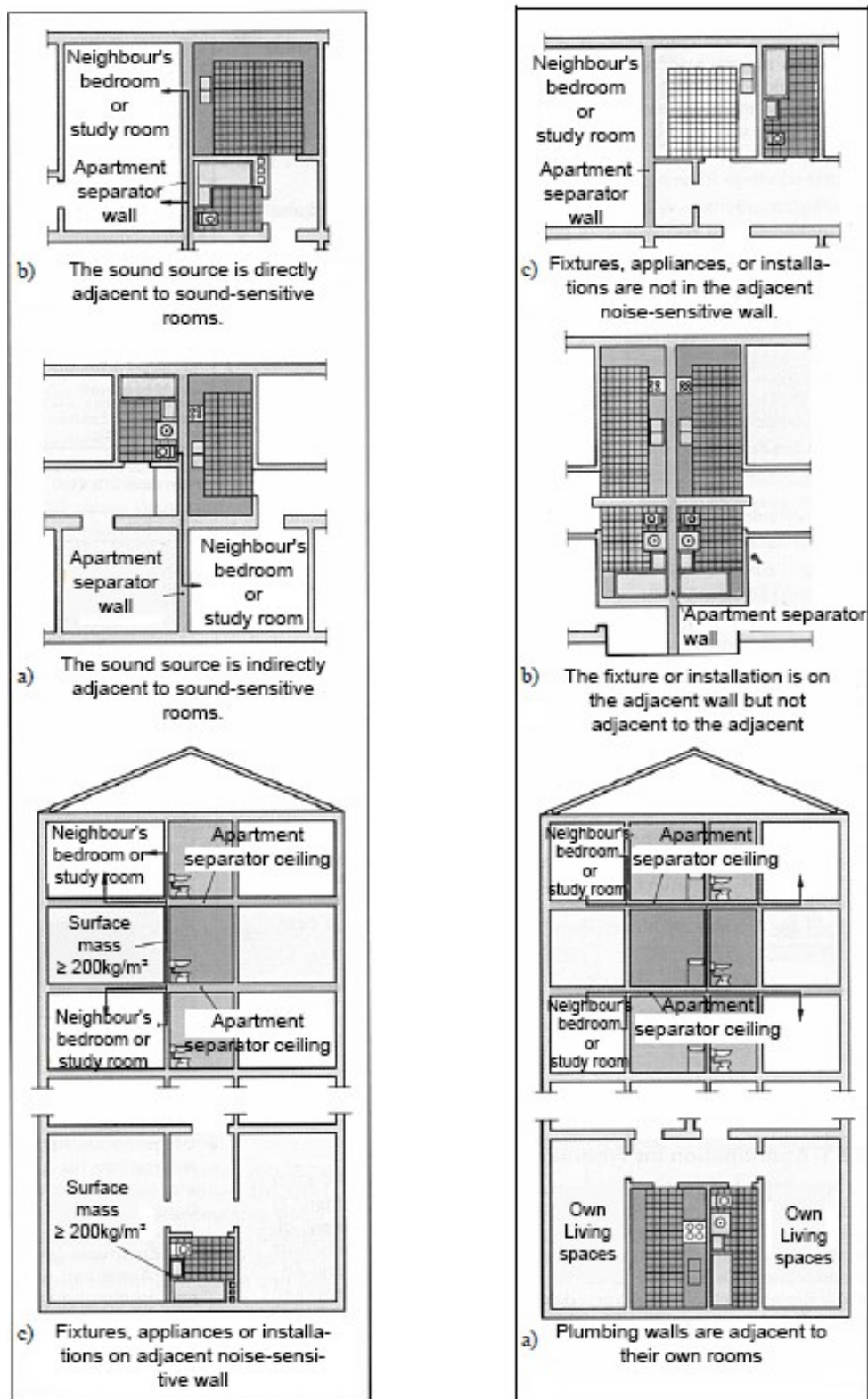


Figure 2.81. a) An example of negative planning in terms of building acoustics
 b) An example of positive planning in terms of building acoustics
 (Schoemaker ve Bıdı, 1999).

3. INTERNATIONAL LEGISLATION AND NATIONAL REGULATIONS ON NOISE CONTROL IN RESIDENTIAL BUILDINGS

Due to the increase in living units in urban areas, designs for the construction of high-density apartments create noise-related disturbances. The main reasons for noise complaints are the preference for lightweight buildings, ignoring the acoustic design, faulty workmanship, high-rise apartment blocks, and insufficient education in the field of acoustics. Noise disturbance was a major factor in the earlier adoption of noise control requirements in European building codes due to the presence of high-density apartments (FHA, 1967).

Analysis of National Regulations and International Legislation

In this part of the thesis, national regulations and international legislation will be mentioned only by name, and the COST TU0901 (2014) study will be discussed under the title of international legislation. In the section of Thesis 3.3, the following legislation will be examined comparatively in the context of acoustic performance criteria in residential buildings.

The acoustic comfort conditions to be provided in residential buildings will be evaluated within the scope of the following regulations and legislation.

- National regulations (Regulation on Protection of Buildings Against Noise, 2017–2018; Environmental Noise Control Regulation, 2022),
- Germany legislation (DIN 4109, 2018; DEGA-Empfehlung 103, 2018),
- England legislation (BS 8233, 2014; Approved Document E, 2010), and
- America legislation (IBC, 2018; FHA, 1967; ASHRAE, 2015; AHRI, 2008).

3.1. Analysis of International Legislation

For many years, neighbor noise has been a major issue for both existing and new homes. For this reason, building regulations in most countries in Europe specify sound insulation requirements for residential buildings. Requirements are expressed by identifiers defined in

the standards. ISO standards and European (EN) standards are widely applied in building acoustics (Rasmussen, 2010).

However, in the findings obtained from comparative studies on sound insulation for this purpose, European requirements and classification schemes, soundproofing descriptors, and legal requirements cause a lot of variation (COST Action TU0901, 2014).

Therefore, COST Action TU0901 (2014), "Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions," is aimed to initiate and support a process towards this framework by creating a common language between countries in the creation of acoustics in Europe. The main purpose of this study is to define acoustic quality classes and create an acoustic classification scheme for residences. This work, initiated at COST TU0901 (2014), aims to create quieter European dwellings.

The secondary objectives of the COST Action TU0901 study are;

- To understand interdisciplinary variations and to examine the knowledge and differences of cultures on an international/interdisciplinary basis.
- Establishing an interdisciplinary approach by collecting and reanalyzing sound field data
- To ensure harmonization and development of the foundations for future European/international standards, including review and harmonization of existing methodologies (COST Action TU0901, 2014).

Standardized soundproofing field descriptors

In Tables 3.1 and 3.2, the findings of the studies conducted in 2008 investigating the legal requirements for sound insulation between residences are given. As a result of the comparison, significant differences such as descriptors, frequency range, and requirement level were observed (Rasmussen, 2010).

In Table 3.1, the valid international descriptors for airborne sound and impact sound insulation are defined in ISO 717: 1996. Identifiers in ISO 717:

Table 3.2 shows that each of the 24 nations has separate descriptors. Given the diversity, it is hoped that the number of descriptors will be reduced and descriptors will be harmonized for further discussion in order to stem the increasing diversity in Europe and facilitate the exchange of information and experience, but harmonization of sound insulation requirements appears unrealistic due to the wide variety (Rasmussen and Rindel, 2010).

Taking into account the updated sound insulation values specified in Figures 3.1 and 3.2 of COST TU 0901 (2014), a joint EU project carried out between 2009 and 2013, the criteria values specified in the regulation on insulation descriptors caused significant inconsistency among European member states. These graphs are organized following the legislation of 35 nations after converting the original insulation descriptors $D_{nT,w}$ for airborne noise insulation and $L'_{nT,w}$ for impact sound insulation, respectively. (Figures 3.1 and 3.2) (COST TU0901, 2014; Rasmussen, 2019).

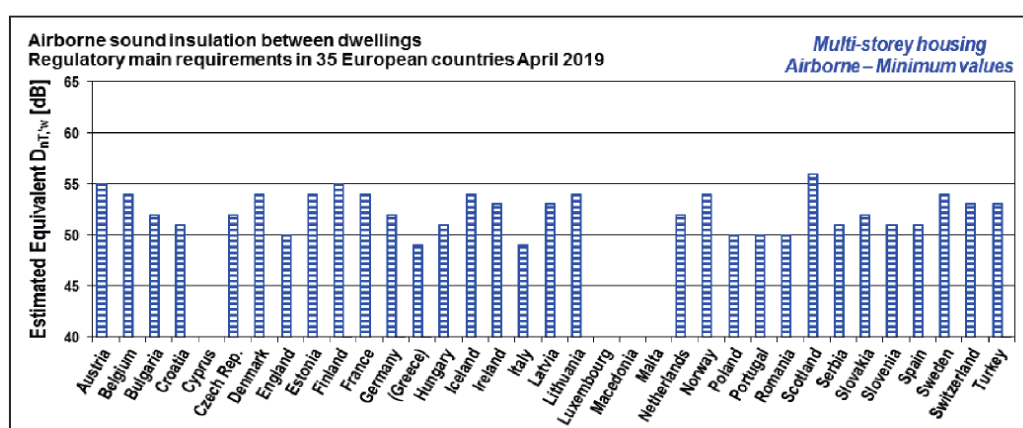


Figure 3.1. Overview of information on airborne sound insulation between dwellings: main requirements in 35 European countries (Rasmussen, 2019)

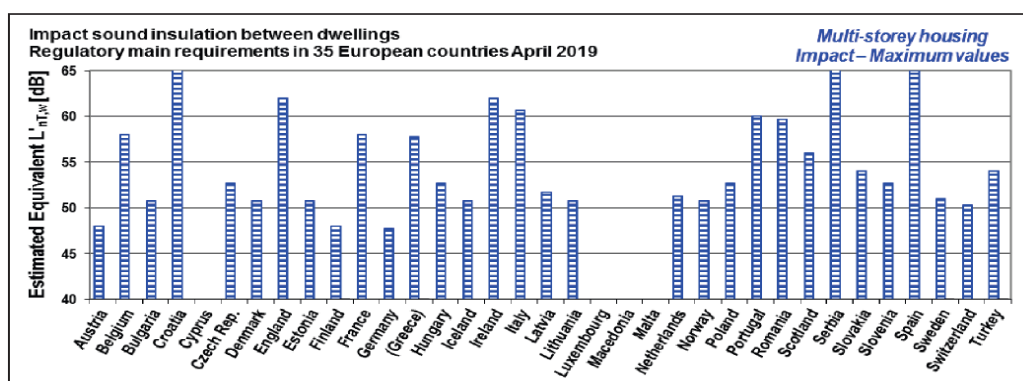


Figure 3.2. Overview of information on impact sound insulation between dwellings: main requirements in 35 European countries (Rasmussen, 2019)

Figures 3.1 and 3.2 contain diagrams showing airborne and impact sound insulation requirements, respectively. When the figures are analyzed, it can be seen that the impact sound requirements in particular differ considerably across Europe. It is thought that this difference may be a combination of traditional structural techniques and the culture of that country (COST TU0901, 2014).

3.2. Analysis of National Regulations

Due to the negative effects of noise on human health in our country, two regulations have entered into force to ensure noise control. The first of these regulations is the Environmental Noise Control Regulation, which entered into force in 2022 with the last update. The second is the Regulation on Protection of Buildings Against Noise, published in 2017, which is the main subject of the thesis, and the Amendment to Regulation on Protection of Buildings Against Noise, which entered into force in 2018.

Environmental noise control regulation, 2022

The "Environmental Noise Control Regulation," which came into force in 2022, is a regulation prepared in place of the "Environmental Noise Evaluation and Management Regulation," which was published in 2010 and repealed in 2022. The goal of this regulation is to prevent the negative effects of environmental noise on the environment and human health through the development of noise maps and noise action plans, the implementation of noise control measures to reduce environmental noise, and the dissemination of environmental noise management studies to the public (Environmental Noise Control Regulation, 2022).

While the Environmental Noise Control Regulation is based on the control of environmental noise, in order to provide sound insulation against indoor and outdoor sounds in buildings, the Regulation on Protection of Buildings Against Noise (2017) is in force in the official gazette dated May 31, 2017 and numbered 30082, prepared by the Ministry of Environment and Urbanization. Furthermore, on May 31, 2018, Amendment to Regulation on Protection of Buildings Against Noise in Official Gazette No. 30437 entered into force.

Regulation on protection of buildings against noise, 2017-2018

The *purpose* of the Regulation on Protection of Buildings Against Noise (2017) is the determination of the rules that will minimize the negative effects of the noises originating from outside or inside the buildings, which people will be exposed to in all kinds of structures, buildings, facilities, and businesses, on the physical and mental health of the people.

Within the scope of the Regulation on Protection of Buildings Against Noise (2017), it covers the basic rules regarding the measures to control the external environmental noises that people are exposed to indoors in all kinds of official and private buildings, facilities, and businesses to be built in and outside the borders of the municipality and the adjacent area, and the mechanical vibrations emitted from the devices and the indoor noises.

The *provisions* of this regulation (2017) After the regulation enters into force, it is also applied in the evaluation of buildings and facilities whose intended use will be changed partially or completely and in important repair and renovation projects. The regulation will be applied when obtaining the building permit and occupancy permit. According to the regulation, construction permits are not given to projects that do not comply with the conditions specified in this regulation in terms of noise prevention, as well as other legal regulations.

In the *implementation* of the provisions of this regulation (2017), administrations authorized to issue building permits, investor organizations, building owners, architects and engineers responsible for design and implementation, contractors and manufacturers, building acoustics experts involved in the construction and use of the building, and building evaluation and operation officials are in charge, authorized, and responsible.

The process to be applied to protect the buildings specified in the regulation from noise is given in Figure 3.3 (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

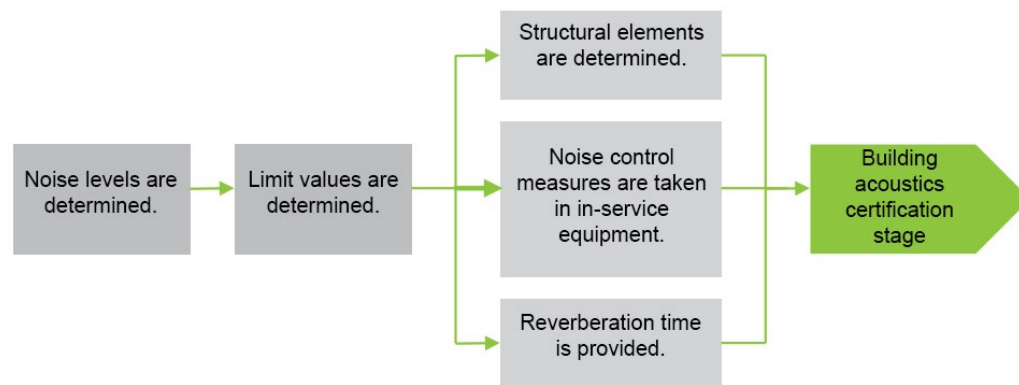


Figure 3.3. The process required to protect the buildings from noise (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018)

3.2.1. Determination of noise levels

In the Regulation (2017), the lowest sound insulation values to be provided for the facade elements are given depending on the external noise level affecting the facade. Therefore, first of all, the external noise level (environmental noise level) should be determined. Environmental noise level can be determined by using noise maps, acoustic measurements to be made according to ISO 1996-1 and ISO 1996-2 international standards, or by a calculation method according to the limit values of the Environmental Noise Control Regulation (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

3.2.2. Determination of limit values

In the regulation, four different acoustic performance criteria are taken as the basis for ensuring noise control in buildings. To determine limit values,

- The highest acceptable noise levels in spaces
- Sound insulation values for airborne and impact sounds in exterior and interior building elements
- Acceptable noise level from building installation and service equipment in usable indoor spaces

- The upper limits of reverberation times in the locations used should be determined. These performance criteria and the factors they depend on are given in Figure 3.4 (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

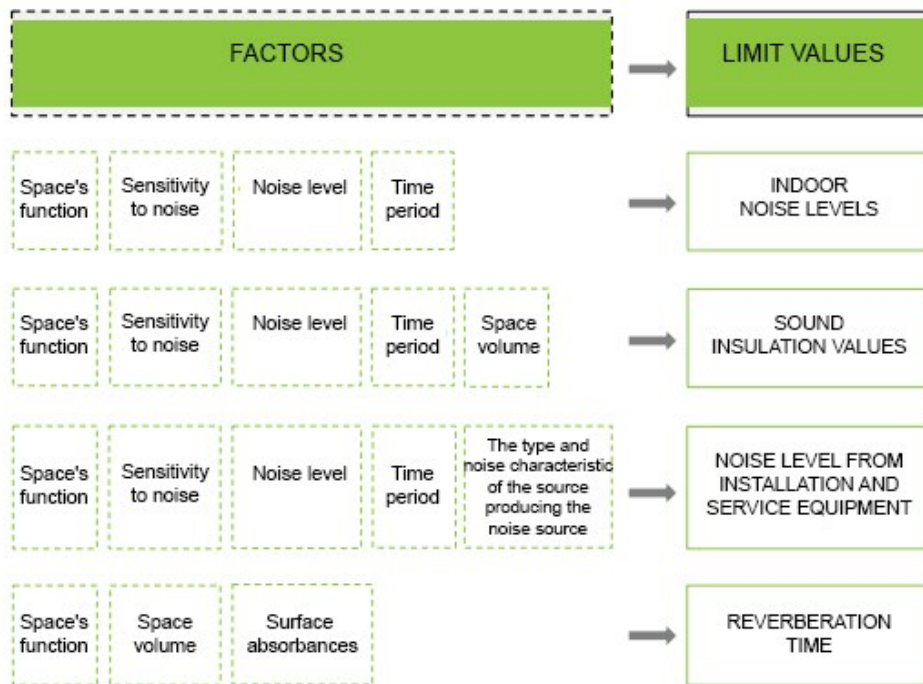


Figure 3.4. Acoustic performance criteria and its dependent factors (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018)

The following methods will be applied to determine the limit values:

Targeted acoustic performance class

Since the limit values given in the regulation are determined according to the acoustic performance classes, the targeted acoustic performance class should be selected first.

The acoustic performance classification system depends on:

- interior noise levels;
- sound insulation values of building elements;
- levels of indoor noise from plumbing and service equipment
- reverberation times.

Sound insulation limit values

After the targeted acoustic performance class is determined, the sensitivity of the spaces to noise and the degree of noise are evaluated. According to this evaluation, limit values are determined for airborne sound insulation for facade elements, airborne sound insulation for partition elements, and impact sound insulation. A simple method or calculation method is applied to determine the lowest airborne sound insulation values required from the building elements. The simple method is to determine the limit values from the tables given in the regulation, taking neighborhood relations into account. However, in special noise conditions, if the spectrum values of the noise source are known, the calculation method can be used by the acoustics expert (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

a) Determination of sound insulation limit values with a simple method

The methods for determining the sound insulation values required from the building elements are given below.

Determination of airborne sound insulation limit values for exterior building elements

The noise sensitivity levels of the volumes facing the façade will be determined using Table 3.4. In Table 3.4, the sound insulation values ($D_{nT,A,tr}$) required from the exterior building elements are given depending on the outdoor noise levels and sensitivity levels to noise (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.4. Noise sensitivity and noise levels in residential buildings (Regulation, 2017)

ON BUILDING SCALE			ON SPACE SCALE			1 Circulation area: It refers to common areas such as corridors, stair halls, and entrance halls. NOISE SENSITIVITY LEVELS .I - high sensitivity II - moderate sensitivity III - low sensitivity NOISE LEVELS YG - High noise generation OG - Moderate noise generation DG - Low noise generation
BUILDING FUNCTION	RESOURCE SITUATION	RECEIVER SITUATION	SPACE	RESOURCE SITUATION	RECEIVER SITUATION	
	Noise levels	Noise sensitivity levels		Noise levels	Noise sensitivity levels	
Residential Buildings	Moderate noise generation (OG-In Turkish)	I	Bedrooms	Moderate noise generation (OG)	I	
			Living Spaces	Moderate noise generation (OG)	II	
			Kitchen or Bathroom	Moderate noise generation (OG)	III	
			Circulation Spaces ¹	Moderate noise generation (OG)	III	
			Technical Rooms	High noise generation (YG)	III	

The limit value is determined according to Table 3.5, according to the determined receiver room sensitivity level.

Table 3.5. The lowest sound insulation values to be provided according to external noise levels and noise sensitivity ($D_{nT,A, tr 1,2}$, dB) (Regulation, 2017)

Sensitivity of the Receiver Room	ACOUSTIC PERFORMANCE CLASS ^{3,4}					
	A	B	C	D	E	F
I: high sensitivity	$L_{den}-14$	$L_{den}-18$	$L_{den}-22$	$L_{den}-26$	$L_{den}-30$	$L_{den}-34$
II: moderate sensitivity	$L_{den}-17$	$L_{den}-21$	$L_{den}-25$	$L_{den}-29$	$L_{den}-33$	$L_{den}-37$
III: low sensitivity	$L_{den}-20$	$L_{den}-24$	$L_{den}-28$	$L_{den}-32$	$L_{den}-36$	$L_{den}-40$

¹ $D_{nT,A, tr} = D_{2m,nT,w} + C_{tr}$
² In cases specified in Article 10, $D_{2m,nT,50} = D_{2m,nT,w} + C_{tr,50-3150}$ value can also be used.
³ L_{den} values are levels measured at least 2m away from the building, excluding facade reflections.
⁴ For A, B, C, and D classes, in addition to the values in this table, the criteria for a minimum sound insulation value of 30 dB will be sought.

Determination of airborne sound insulation limit values for partition elements

Adjacent volumes separated both horizontally by internal partition walls and vertically by floors are evaluated. In Table 3.6, the lowest sound insulation values ($D_{nT,A}$) that interior building elements should provide according to typical neighborhood relations are given (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.6. The lowest airborne sound insulation values to be provided between adjacent volumes in residential buildings ($D_{nT,A 1,2}$, dB) (Regulation, 2017)

Building Function	ADJACENT RELATION		ACOUSTIC PERFORMANCE CLASS ³					
	Source Room	Receiver Room	A	B	C	D	E	F
RESIDENTIAL BUILDING	Commercial Use Technical Room	Independent unit	68	64	58	54	50	46
	Independent unit Common Area	Independent unit Common Area	62	58	52	48	44	40
	Bedroom Living Areas Kitchen / Bathroom	<i>Located in the same independent unit; Bedroom Living Areas</i>	54	50	44	40	36	32

¹ $D_{nT,A} = D_{nT,w} + C$
² In cases specified in Article 10, $D_{nT,50} = D_{nT,w} + C_{50-3150}$ value can also be used.
³ For building elements containing doors: the sound insulation value provided with the door is allowed to be 14 dB lower than the limit values specified in the Regulation

If there is no neighborhood relationship specified in Table 3.6, the noise and sensitivity levels of the spaces will be determined using Table 3.4. After determining the noise and sensitivity levels of the spaces, the lowest desired airborne sound insulation value will be found according to Table 3.7 (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.7. The lowest airborne sound insulation values to be provided according to the source and receiver room characteristics ($D_{nT,A}$ 1,2,dB). (Regulation, 2017)

SOURCE ROOM NOISE LEVEL	SENSITIVITY OF THE RECEIVER ROOM	ACOUSTIC PERFORMANCE CLASS ^{3,4}					
		A	B	C	D	E	F
High Level Noise (YG) $L_{AF,max} > 75$ dB	I	68	64	58	54	50	46
	II	65	61	55	51	47	43
	III	62	58	52	48	44	40
Moderate Level Noise (OG) $75 \geq L_{AF,max} > 55$ dB	I	62	58	52	48	44	40
	II	59	55	49	45	41	37
	III	56	52	46	42	38	34
Low Level Noise (DG) $L_{AF,max} \leq 55$ dB	I	56	52	46	42	38	34
	II	53	49	43	39	35	31
	III	50	46	40	36	32	28

1 $D_{nT,A} = D_{nT,w} + C$

2 In cases specified in Article 10, $D_{nT,50} = D_{nT,w} + C_{50-3150}$ value can also be used. In this case, the limit values will be reduced by 4 dB.

3 For building elements containing doors: the sound insulation value provided with the door is allowed to be 14 dB lower than the limit values specified in the Regulation.

4 Regulation Appendix-3- Table 3.4 will use for partitioning elements within independent units in residential buildings.

Determination of impact sound insulation limit values for partition elements

In Table 3.8, the highest impact sound transmission values ($L'_{nT,w}$) required from floors in residences are given. Impact sound transmission to the lower floor must not exceed the values given (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.8. Highest impact sound levels in residential buildings source room floors ($L'_{nT,w}$ ¹, dB) (Regulation, 2017)

Building Function	ADJACENT RELATION	ACOUSTIC PERFORMANCE CLASS					
	Source Room (Upper Floor)	A	B	C	D	E	F
RESIDENTIAL BUILDINGS	Independent unit	46	50	54	58	62	66
	Common Area						
	Commercial Use	40	44	48	52	56	60
	Technical Room, Rooftop equipment Floors inside the same dwelling	54	58	62	66	70	74

1 In cases specified in Article 14, the value $L'_{nT,50} = L'_{nT,w} + C_I$, 50-2500 can also be used.

If the source room is not defined for the spaces not included in Table 3.8, the noise level, potential impact sources, and usage intensity will be determined, and the highest allowed pulse sound transmission values will be determined according to Table 3.9 (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.9. Highest impact sound levels to be provided based on source and receiver room characteristics ($L'_{nT,w1}$, dB) (Regulation,2017)

SOURCE ROOM NOISE LEVEL	ACOUSTIC PERFORMANCE CLASS ²					
	A	B	C	D	E	F
High Level Noise (YG)	40	44	48	52	56	60
Moderate Level Noise (OG)	46	50	54	58	62	66
Low Level Noise (DG)	50	54	58	62	66	70

¹ In cases specified in Article 14, the value $L'_{nT,50} = L'_{nT,w} + CI$, 50-2500 can also be used. In this case, the limit values will be increased by 4 dB.

² Regulation Appendix-3- Table 3.5 will use for partition elements in independent units in residential buildings.

b) Determination of limit values by the calculation method

Depending on the noise level of the environment where the noise source is located, the maximum allowable noise level in the receiving environment, and the reverberation time, the desired standardized level difference [D_{nT}] can be calculated using this formula according to TS EN ISO 16283-1 as follows:

$$D_{nT} = L_{\text{source}} - L_{\text{criterion}} + 10 \log \frac{T}{T_0}$$

(3.1)

D_{nT} : Standardized level difference, dB

L_{source} : The noise level resulting from the measurement made according to ISO 1996-1 and ISO 1996-2 in the environment where the noise source is located, dB. The highest measured value of the source noise ($L_{F\text{max}}$) should be used in the calculations.

$L_{\text{criterion}}$: The highest allowable noise level in the receiving environment, dB. NR curves will be used to arrive at the spectral values of the allowable internal noise limit value (L_{eq}).

T : Reverberation time in the receiving environment, s.

T_0 : Reference reverberation time, s. (0.5s should be taken for residences and other furnished volumes, 1.5s should be taken for unfurnished volumes) (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

The calculation is repeated for all frequencies in the octave or 1/3 octave band between 100-3150 Hz, and the odd-numbered DnT,w value, and the C spectrum adaptation term are calculated according to TS EN ISO 717-1. By summing these values, $DnT_{100} = DnT_w + C$ value is obtained. The same operations are repeated for the facade elements, and the result is shown as $D2m,nT_{100} = D2m,nT_w + C_{tr}$. However, if the tonal components dominate the noise, the calculations should start at 50 Hz. In these cases, the insulation indicators are $DnT_{50} = DnT_w + C_{50-3150}$ and $D2m,nT_{50} = D2m,nT_w + C_{tr, 50-3150}$ (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Indoor noise level limit values

The highest allowed indoor noise levels in residential buildings are given in Table 3.10.

Table 3.10. Maximum permissible internal noise levels depending on the acoustic performance class, dB (Regulation, 2017)

BUILDING FUNCTION	AREA	TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00	Indoor Noise Level, L_{Aeq}^1					
			ACOUSTIC PERFORMANCE CLASS					
			A	B	C	D	E	F
Residential Buildings	Bedroom	Night	26	30	34	38	42	46
	Living Areas	24 hours	31	35	39	43	47	51
	Kitchen	24 hours	31	35	39	43	47	51

¹ If there are sudden sounds, sounds with low-frequency components, singular noise events, and tonal components in the internal noise characteristic, evaluations will be made by applying corrections according to TS 9315 ISO 1996-1.

These values show the A-weighted values of the sound pressure levels transmitted to the space from outside, excluding the user noise inside the space. The NR (Noise Evaluation) criterion curves defined in BS:8233 are used in calculations based on the internal noise level, taking into account the spectral structure of the noise. Table 3.11 shows NR curves and A-weighted sound pressure levels (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.11. Octave band sound pressure levels and dB(A) NR curves (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Sound Pressure Level (dB)										dB(A)
NR Curve	Frequency (Hz)									
	31.5	63	125	250	500	1000	2000	4000	8000	
NR 0	55.4	35.5	22	12	4.8	0	-3.5	-6.1	-8	6
NR 5	58.8	39.4	26.3	16.6	9.7	5	1.6	-1	-2.8	11
NR 10	62.2	43.4	30.7	21.3	14.5	10	6.6	4.2	2.3	16
NR 15	65.6	47.3	35	25.9	19.4	15	11.7	9.3	7.4	21
NR 20	69	51.3	39.4	30.6	24.3	20	16.8	14.4	12.6	26
NR 25	72.4	55.2	43.7	35.2	29.2	25	21.9	19.5	17.7	31
NR 30	75.8	59.2	48.1	39.9	34	30	26.9	24.7	22.9	36
NR 35	79.2	63.1	52.4	44.5	38.9	35	32	29.8	28	41
NR 40	82.6	67.1	56.8	49.2	43.8	40	37.1	34.9	33.2	46
NR 45	86	71	61.1	53.6	48.6	45	42.2	40	38.3	51
NR 50	89.4	75	65.5	58.5	53.5	50	47.2	45.2	43.5	56
NR 55	92.9	78.99	69.8	63.1	58.4	55	52.3	50.3	48.6	61
NR 60	96.3	82.9	74.2	67.8	63.2	60	57.4	55.4	53.8	66
NR 65	99.7	86.8	78.5	72.4	68.1	65	62.5	60.5	58.9	71
NR 70	103.1	90.8	82.9	77.1	73	70	67.5	65.7	64.1	76
NR 75	106.5	94.7	87.2	81.7	77.9	75	72.6	70.8	69.2	81

Limit values for internal noise from installation and service equipment

Internal noise levels caused by the highest permitted installation and service equipment in residences are given in Table 3.12 for noise sources that produce continuous noise and in Table 3.13 for noise sources that produce intermittent noise. These values are determined to be 5 dB less than the highest allowed indoor noise levels (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.12. Highest allowable internal noise levels due to constantly noisy service equipment ($L_{Aeq,nT}$) (Regulation, 2017)

BUILDING FUNCTION	AREA	TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00	Service equipment noise level, $L_{Aeq,nT}$ ¹					
			ACOUSTIC PERFORMANCE CLASS					
			A	B	C	D	E	F
Residential Buildings	Bedroom	Night	22	26	30	34	38	42
	Living Areas	24 hours	27	31	35	39	43	47
	Kitchen	24 hours	27	31	35	39	43	47

¹ It is calculated by subtracting 4 dBA from the internal noise levels given in Regulation Appendix-4-Table 4.1.

Equipment that produces continuous noise, such as ventilation ducts, air conditioning units (AHU), generators, and boiler noise, is a device whose sound pressure level is constant or slightly variable within a certain period of time. While the noise of the ventilation ducts is

evaluated for the room it is in, the noise of the devices in the mechanical room is evaluated in the neighboring volumes (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Table 3.13. Highest allowable internal noise levels due to other plumbing and service equipment ($L_{AF,max,nT}$) (Regulation, 2017)

RECEIVER AND NOISE SOURCE	Service equipment noise level, $L_{AF,max,nT}$					
	ACOUSTIC PERFORMANCE CLASS					
	A	B	C	D	E	F
Service equipment with intermittent noise	26	30	34	38	42	46

Installation and service equipment that produces intermittent noise is defined as devices that have a sound that repeats at regular or irregular intervals and lasts for at least 5 seconds. These equipments are devices such as siphons, faucets, elevators, and garage doors. These noise sources are evaluated at adjacent volumes, not where they are under normal conditions (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

Reverberation time limit values and surface absorbances

The maximum reverberation time values in residential buildings are given in Table 3.14.

Table 3.14. The highest reverberation times to be achieved according to the acoustic performance class (Regulation, 2017)

BUILDING FUNCTION	Area	ACOUSTIC PERFORMANCE CLASS	¹ The given limit value is the arithmetic average of the values at frequencies 250, 500, 1000, 2000 Hz. ² For other performance classes, the international limit values will be examined and the acoustic expert will decide on the limit values. ³ Circulation area: It refers to common areas such as corridors, stair hall, entrance hall.
		C - D ²	
Residential Buildings	Circulation areas ³	1.2	
	Bedroom	0.5	
	Living areas, kitchen	0.8	

In accommodation function volumes such as residential buildings, reverberation is low due to a large amount of furniture. For this reason, there is usually no need to take any precautions (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

3.2.3. Determination of appropriate building elements

According to the construction technique and materials of the partition elements separating the spaces in the architectural project, the sound insulation values should be determined and compared with the limit values (Figure 3.6). The method to be followed for this is defined in Article 16 of the Regulation (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

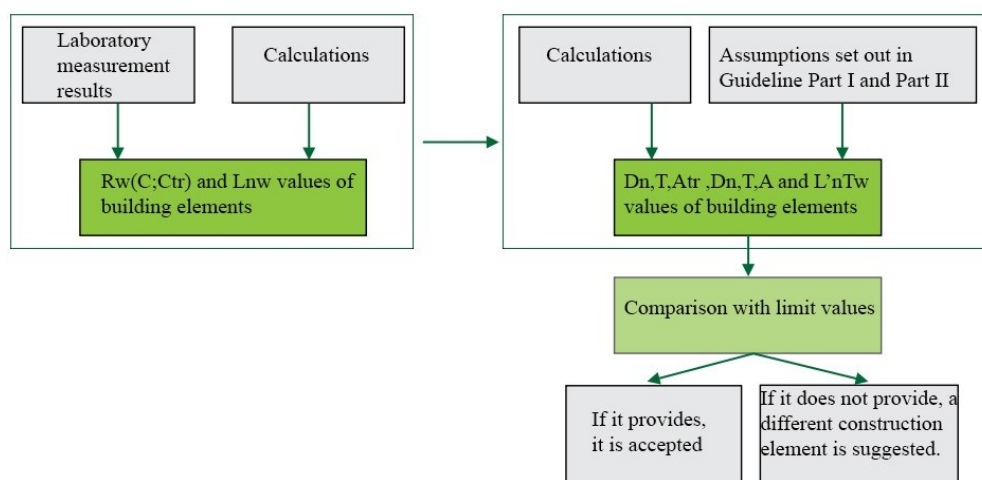


Figure 3.6. Determination of building elements in the regulation (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018)

Rw (C,Ctr) and Lnw values of the building elements that will provide the desired values; It is determined as a result of calculations or by choosing from catalogs based on reports measured in accredited laboratories. Area performance values (DnT,A,tr ,DnT,A, and L'nTw) are determined according to the volumes of the spaces separated by the building elements, the interior acoustic properties, and the characteristics of the junction points of the elements (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

The value found is compared with the desired sound insulation values. It is expected that the airborne sound insulation value result will be higher than the lowest permissible insulation value and the impact sound transmission value result will be lower than the highest allowable impact sound transmission value. However, considering the errors that may arise from the calculations or that may occur in detailing and application, it is necessary to target a positive situation of +2 dB for airborne noises and -2 dB for impact

noise from the limit values. In order for the performance of the structural element to be close to the laboratory measurement values, attention should be paid to avoid the formation of weak points and sound bridges in detailing (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

3.2.4. Control of noise from plumbing and service equipment

The noise control measures that can be taken in the installation and service equipment are given in Appendix 8 of the Regulation. Plumbing equipment, valves, taps, sinks, bathtubs, shower trays, and accessories, clean and waste water pipes, connections, and indoor individual heating, cooling, and ventilation units will be evaluated within this scope (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

- If there are noisy devices in the area, sound insulation measures such as selecting the appropriate device or enclosing the device in a sheath should be implemented to ensure that the operating noise of these devices does not exceed the limit values.
- When determining ducts and pipes and connecting them to building elements, noise control measures should be implemented by following the rules and checklists outlined in Appendix 8 of the Regulation.
- In the connection of equipment that emits vibrations to the ground, vibration-dampening insulating materials are utilized.
- Necessary noise control measures are taken by closing the elevator machine room and mechanical, ventilation, and elevator shafts with absorbent material.
- The proximity of mechanical centers, elevator shafts, and trash chimneys to areas sensitive to noise should be avoided, or essential noise control measures should be taken.
- Sound transmission (AHU, boilers, etc.) is calculated for locations that are extremely sensitive and sensitive to noise, such as those adjacent to a mechanical apartment or roof equipment. It has been determined that the sum of these sound levels does not surpass the internal noise levels produced by the installation and service equipment authorized at that location.

If there is roof equipment or outdoor equipment, the noise emission of these devices to the environment is evaluated, and the noise reduction effect is calculated by developing

acoustic solutions such as cabins, insulated rooms, and noise curtains (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

3.2.5. Indoor noise control

As long as sound insulation, noise control from service equipment, and reverberation conditions are provided in buildings, it is expected to reach internal noise levels. In the acoustic project prepared by the acoustic specialist, the internal noise level is calculated where the noise level is critical and compared with the highest allowed internal noise level, and necessary measures are taken to ensure that it does not exceed this value. Indoor noise level: the noise level due to the service equipment calculated in that place, the noise level transmitted from the facade, and the sum of the sounds transmitted from the neighboring place where sound amplifier systems are used, if any, are calculated (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

3.2.6. Ensuring the reverberation limit

Reverberation time calculation

The formula that can be used to calculate the reverberation time [T] is given in Figure 3.7:

T	Reverberation time, sec (calculated based on frequencies)
V	Volume (m ³)
A _{total}	Equivalent total absorption area
S ₁	Area covered with type 1 material (m ²)
α_1	Absorption coefficient of type 1 material
S ₂	Area covered with type 2 material (m ²)
α_2	Absorption coefficient of type 2 material

(3.2)

Figure 3.7. Reverberation time formula (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018)

3.2.7. Acoustic performance certificate

The Acoustic Performance Certificate is a mandatory document for buildings targeting Acoustic Performance Classes A and B, providing assessment and certification of the acoustic conditions presented by a building with evaluation classes from A to F.

Acoustic Performance Certificate:

- Indoor noise levels are equal to or below the maximum allowable values;
- The airborne sound reduction values of the façade elements are equal to or above the lowest desired value;
- The airborne sound reduction values of the interior partition elements are equal to or above the lowest desired value;
- The impact sound transmission values of the floors are equal to or below the highest desired value;
- The level of internal noise from installation and service equipment is equal to or below the maximum allowable values;
- It certifies with measurements that reverberation times are equal to or below the maximum allowable values.
- An acoustic performance certificate can be arranged for the whole building or issued for a single independent unit within the building. An acoustic performance certificate is issued after the post-construction inspections. The measurement and sampling conditions specified in the post-construction inspections section must be met.
- In order to assign an acoustic performance class to the entire building or +0.15 s. to an individual unit, all measurement results must meet the specified limit values. No value should differ more than 2 dB (negatively) from the limit values of that class. The maximum allowed deviation "limit" for the reverberation time is +0.15s. If different apartments, rooms, or acoustic properties indicate different classes, the lowest class value obtained will be displayed as the result value.

The acoustic performance certificate loses its validity in the event of a change in building construction or external noise levels. In the event of such a change, a new quality class should be determined with calculations. In the case of a maximum difference of 2 dB, the acoustic performance class does not change. If there is no change in building construction or external noise levels, the validity period of the acoustic performance certificate is 10 years. Figure 3.8 shows the acoustic performance certificate (Preparation of the Descriptive Implementation Guideline for the Regulation, 2018).

ACOUSTIC PERFORMANCE CERTIFICATE

Project title : _____

Issued for : ☐ Building / ☐ Unit

Function : _____

Year of construction : _____

Floor area : _____

City block, Parcel : _____

Address : _____

Building / Unit Owner

Name surname : _____

Address : _____

Photo of the building

Acoustic Performance Class

Descriptions for acoustic quality classes:

A : A quiet atmosphere with a high level of protection against sound

B : Under normal circumstances a good protection without too much restriction to the behaviour of the occupants

C : Protection against unbearable disturbance under normal behaviour of the occupants

D : Regularly disturbance by noise even in case of comparable behaviour of occupants

E : Hardly any protection is offered against intruding sounds

F : No protection is offered against intruding sounds

		Number of repeated measurements	Number of samples / Total	Max - Min values among samples	Acoustic Performance Class
ASSESSMENT CRITERIA	1 Indoor background noise level (L_{Aeq})				A B C D E F
	2 Façade elements insulation ($D_{nT,A,n}$)				A B C D E F
	3 Interior partitions Airborne sound ($D_{nT,A}$)				A B C D E F
	4 Insulation impact sound ($L'_{nT,w}$)				A B C D E F
	5 Mechanical noise ($L_{Aeq,nT}$ - $L_{Aeq,max,nT}$)				A B C D E F
	6 Reverberation time (T)				A B C D E F
Overall					A B C D E F

Statements

Certificate

Number : _____

Date : _____

Date of validity : _____

Issuing Authority

Name Surname : _____

Company : _____

Address : _____

Signature

Figure 3.8. Acoustic performance certificate (Bayazıt *et al.*, 2016 ; as cited in Kurra, 2021)

3.3. Comparative Analysis of Legislation and Regulations

National regulations

Information on the Regulation on Protection of Buildings Against Noise (2017-2018), which is our national regulation for noise control, is given in detail in Section 3.2. In the comparative analysis, the Environmental Noise Control Regulation (2022) was applied for the criteria related to environmental noise.

International legislation

Residential buildings were examined within the framework of the legislation of three countries: Germany, England and America. The method followed in the thesis is discussed in detail in Table 1.1. A comparative analysis of national regulations and international

legislation in the context of acoustic performance criteria in residential buildings is shown in Table 3.15. The main headings of the table are given below.

1. General Information / Sensitivity to Noise
2. Design Criteria for Outdoor Noise and Planning of New Residential Areas
3. Explanations on Subjective Perceptibility of Common Noises from Neighboring Settlements
4. Limit Values for Acoustic Performance Classes in Buildings
 - 4.1. Requirements Regarding Sound Insulation Limit Values
 - 4.1.1. Lowest sound insulation values to be provided according to external noise levels and receiver sensitivity degree ($D_{nT,A,tr}$, dB)
 - 4.1.2. Lowest airborne sound insulation values according to source and receiver room characteristics ($D_{nT,A}$, dB)
 - 4.1.3. Highest impact sound levels to be provided based on source and receiver room characteristics ($L'_{nT,w}^1$, dB)
 - 4.1.4. Lowest airborne sound insulation values to be provided between adjacent volumes in different building types ($D_{nT,A}$, dB)
 - 4.1.5. Highest impact sound levels for source room floors in different building types ($L_{nT,w}$, dB)
 - 4.2. Permissible Indoor Noise Levels in Spaces
 - 4.3. Limit Values for Internal Noise Originating from Installation and Service Equipment
 - 4.3.1. Highest permissible internal noise levels due to continuous noise service equipment
 - 4.3.2. Highest permissible internal noise levels due to intermittent noise service equipment
 - 4.3.3. Noise Levels from Elevators
 - 4.4. Limit Values for Reverberation Time

5) Installation and Service Equipment Noise Control Measures

5.1. Noise Control in Ventilation Ducts

5.2. Control of Equipment Noise

5.2.1. Fans- fancoils

5.2.2. Combi devices

5.2.3. Acoustic louvers

5.2.4. Chillers

5.2.5. Noise control principles for roofing equipment

5.2.6. Noise control principles for plumbing and other mechanical, electrical service equipment

5.3. Noise and Vibration Control in Mechanical Centers

6. Design Criteria and Noise Control Measures for Indoor Noise

7. Acoustic Performance Class and Certification

- In Table 3.15, National regulation (Regulation on Protection of Buildings Against Noise) data is given in this table by specifying its appendices and articles. These tables will be mentioned in detail in the formation of acoustic performance criteria

Table 3.15. Comparison of the legislation for residential buildings

TOPIC/TITLE	TURKEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)
Sensitivity To Noise	Article 4 (rr): "Buildings that are very sensitive to noise" (Regulation, 2017)	BS 8233 (2014) standard is designed for existing noise-sensitive buildings, including residential buildings, in areas where noise sources are present.	In addition to the sound insulation requirements of DIN 4109 (2018), the DEGA recommendation (2018) contains sound insulation recommendations for residential buildings that are very sensitive to noise, offering multi-level requirements with seven noise protection classes, from A* (the best) to F (the worst).	FHA (1967) is a guide to noise control for noise-sensitive residential buildings.
1.GENERAL INFORMATION				
2.DESIGN CRITERIA FOR OUTDOOR NOISE AND PLANNING OF NEW RESIDENTIAL AREAS	According to the Environmental Noise Control Regulation (2022), it is necessary to provide the limit values specified in the aforementioned regulation's Appendix-2 Table 1 in residential areas.	According to BS 8233 (2014), in gardens and terraces, it is desirable that the outdoor noise level not exceed 50 dB LAeq,T. In louder environments, the upper limit value is 55 dB LAeq,T. In BS 5228-1, which is based on noise and vibration control in construction and open areas, a number of criteria for ambient noise level changes are presented. Limits offered: -70 dB (A) for noise in rural, suburban, and urban areas away from main road traffic and industrial areas; -It is 75 dB(A) in urban areas near major roads and heavy industry areas (BS 5228-1; 2009, 2014).	The outside noise level must be taken into account when constructing residential buildings in Germany. The calculation method of façade sound insulation in DIN 4109 (2018) provides an average indoor noise level of 35 dB during the day and 25 dB at night. The level differences between day and night are due to fluctuations in traffic density (DIN 4109, 2018; as cited in Körper, 2019).	Three classes of acoustic environments have been defined in order to determine appropriate criteria for different factors in the FHA (1967). <u>Grade I</u> applies primarily to suburban and surrounding suburban residential areas that can be considered "quiet" locations. Outside noise levels at night can be around 35–40 dB (A) or less. The permissible indoor noise environment is defined by the NC 20-25 noise criteria. <u>Grade II</u> applies to urban and suburban areas in residential areas considered to have an "average" noise environment. At night, outside noise levels can reach 40–45 dB(A), and the permissible indoor noise environment should not exceed NC 25-30. <u>Grade III</u> criteria should be considered as minimum recommendations and may be applied in some urban areas that are generally considered "noisy" places. Outside noise levels at night can be 55 dB (A) or higher. It is recommended that indoor noise environments do not exceed NC-35 (FHA, 1967).

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE	TUR KEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)																								
Planning Of New Residential Areas		For the noise levels to be measured from the façade, the following limit values must be provided. Typical traffic noise levels measured at a distance of approximately 1 m from the façade (BS 8233, 2014).	<u>Positioning of Buildings According to External Noise Conditions</u> The location of a building and the orientation of the residential units to be considered play an important role in the classification of acoustic quality. This area definition can be defined by external noise sources from road, rail, water and air traffic, commercial and recreational noise. Regional characters are given in the table below. Existing field characteristics according to performance classes (DEGA-Empfehlung 103, 2018).																									
		<table><tr><td></td><td>dB $L_{Aeq,16h}$</td></tr><tr><td>At 20 m from the edge of a busy motorway carrying many heavy vehicles; average traffic speed 100 km/h; intervening ground turfed</td><td>78</td></tr><tr><td>At 20 m from the edge of a busy main road through a residential area; average traffic speed 50 km/h; intervening ground paved</td><td>68</td></tr><tr><td>On a residential road parallel to a busy main road and screened by the houses from the main road traffic; free flowing traffic</td><td>58</td></tr></table>		dB $L_{Aeq,16h}$	At 20 m from the edge of a busy motorway carrying many heavy vehicles; average traffic speed 100 km/h; intervening ground turfed	78	At 20 m from the edge of a busy main road through a residential area; average traffic speed 50 km/h; intervening ground paved	68	On a residential road parallel to a busy main road and screened by the houses from the main road traffic; free flowing traffic	58	<table><tr><td></td><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td>A*</td></tr><tr><td>current field character</td><td>GI (Industrial Area)</td><td>GE / MU (Commercial / Urban Area)</td><td>MI / WB (Mixed, Private Residential Area)</td><td>WA (General Residential Area)</td><td>WR (Entirely Residential Area)</td><td></td><td></td></tr></table>		F	E	D	C	B	A	A*	current field character	GI (Industrial Area)	GE / MU (Commercial / Urban Area)	MI / WB (Mixed, Private Residential Area)	WA (General Residential Area)	WR (Entirely Residential Area)			
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current field character	GI (Industrial Area)	GE / MU (Commercial / Urban Area)	MI / WB (Mixed, Private Residential Area)	WA (General Residential Area)	WR (Entirely Residential Area)																							
			The noise level range and external noise level according to the quality classes are given in the table below. According to DIN 4109: 2018-01, External noise level and noise level range in dB (A) (DEGA-Empfehlung 103, 2018:11)																									
			<table><tr><td></td><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td>A*</td></tr><tr><td>Noise level range</td><td>VI</td><td>V</td><td>IV</td><td>III</td><td>II</td><td>I</td><td></td></tr><tr><td>External noise level [dB(A)]</td><td>≥ 76</td><td>71 to 75</td><td>66 to 70</td><td>61 to 65</td><td>56 to 60</td><td>up to 55</td><td></td></tr></table>		F	E	D	C	B	A	A*	Noise level range	VI	V	IV	III	II	I		External noise level [dB(A)]	≥ 76	71 to 75	66 to 70	61 to 65	56 to 60	up to 55		
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2.DESIGN CRITERIA FOR OUTDOOR NOISE AND PLANNING OF NEW RESIDENTIAL AREAS																												

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE		TURK EY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)																																													
Lowest Sound Insulation Values to be Provided According to External Noise Levels and Receiver Sensitivity Degree		Article 11: Appen dix -3 - Table – Table 3.1 (Regul ation, 2017).	According to BS 8233 (2014), in gardens and terraces, it is desirable that the outdoor noise level not exceed 50 dB LAeq,T. In louder environments, the upper limit value is 55 dB LAeq,T.	Recommended sound insulation values on the façade of residential buildings (DIN 4109, 1989; as cited in Özçetin, 2011)	Required sound insulation values on the façade, according to FHA 1967) are given in the table below.																																													
				<table><tr><td>L_{Aeq} ≤ 55</td><td>R_w 30</td></tr><tr><td>56 ≤ L_{Aeq} ≤ 60</td><td>R_w 30</td></tr><tr><td>61 ≤ L_{Aeq} ≤ 65</td><td>R_w 35</td></tr><tr><td>66 ≤ L_{Aeq} ≤ 70</td><td>R_w 40</td></tr><tr><td>71 ≤ L_{Aeq} ≤ 75</td><td>R_w 45</td></tr><tr><td>76 ≤ L_{Aeq} ≤ 80</td><td>R_w 50</td></tr><tr><td>L_{Aeq} > 80</td><td>Special precautions must be taken.</td></tr></table>	L _{Aeq} ≤ 55	R _w 30	56 ≤ L _{Aeq} ≤ 60	R _w 30	61 ≤ L _{Aeq} ≤ 65	R _w 35	66 ≤ L _{Aeq} ≤ 70	R _w 40	71 ≤ L _{Aeq} ≤ 75	R _w 45	76 ≤ L _{Aeq} ≤ 80	R _w 50	L _{Aeq} > 80	Special precautions must be taken.	<table><tr><td colspan="2">Sound insulation values recommended to be provided on the facade of residential buildings</td></tr><tr><td>NC 20-25</td><td>Grade I : STC ≥ 55</td></tr><tr><td>NC 25-30</td><td>Grade II : STC ≥ 52</td></tr><tr><td>NC 30-35</td><td>Grade II : STC ≥ 48</td></tr></table>	Sound insulation values recommended to be provided on the facade of residential buildings		NC 20-25	Grade I : STC ≥ 55	NC 25-30	Grade II : STC ≥ 52	NC 30-35	Grade II : STC ≥ 48																							
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Lowest Airborne Sound Insulation Values According to Source and Receiver Room Characteristics		Article 11: Appen dix -3 - Table 3.2 (Regul ation, 2017).	For separating walls, floors, and stairs, which have a divider function in residences and flats performance standards (Approved Document E, 2010).	Requirements for sound insulation in apartments and mixed-use buildings (E DIN 4109-1; as cited in Lein, 2013).	For <i>airborne sound</i> , separating residential units from each other or from public or service areas must have a sound transmission class of not less than 50 or, if field-tested, not less than 45 per ASTM E90. For <i>impact sound</i> , walls, partitions, and floor-ceiling assemblies separating residential units. Partitions and floor-ceiling assemblies for floor-to-ceiling assemblies between residential units, or between a public or utility area within the structure, should have a sound transmission class of at least 50, or 45 if field tested, for <i>impact sound</i> . In accordance with ASTM E90 (IBC, 2018).																																													
Highest impact sound levels to be provided based on source and receiver room characteristics		Article 11: Appen dix -3 - Table 3.3 (Regul ation, 2017).	<table><tr><th>Wall Floors and stairs</th><th>Airborne Sound Insulation D_{A,T,w}+C_{tr} dB (Min. Values)</th><th>Impact Sound Insulation n L_{n,T,w} dB (Max. Values)</th></tr><tr><td colspan="3">Purpose built dwelling</td></tr><tr><td></td><td>45</td><td>-</td></tr><tr><td></td><td>45</td><td>62</td></tr><tr><td colspan="3">Dwelling – houses and flats formed by material change of use</td></tr><tr><td></td><td>43</td><td>-</td></tr><tr><td></td><td>43</td><td>64</td></tr></table>	Wall Floors and stairs	Airborne Sound Insulation D _{A,T,w} +C _{tr} dB (Min. Values)	Impact Sound Insulation n L _{n,T,w} dB (Max. Values)	Purpose built dwelling				45	-		45	62	Dwelling – houses and flats formed by material change of use				43	-		43	64	<table><tr><th>Line</th><th>Components</th><th colspan="2">Requirements in dB</th></tr><tr><td></td><td></td><th>Required R_w</th><th>Required L_{n,w}</th></tr><tr><td>1</td><td>Apartments dividing ceilings and ceilings between third-party work rooms or comparable usage units</td><td>54</td><td>50</td></tr><tr><td>2</td><td>Apartment partitions and walls between other people's work rooms</td><td>53</td><td>-</td></tr><tr><td>3</td><td>Staircases and landings</td><td>-</td><td>53</td></tr><tr><td>4</td><td>Doors leading from hallways or stairwells into hallways and apartment hallways</td><td>R_w 27</td><td>-</td></tr></table>	Line	Components	Requirements in dB				Required R _w	Required L _{n,w}	1	Apartments dividing ceilings and ceilings between third-party work rooms or comparable usage units	54	50	2	Apartment partitions and walls between other people's work rooms	53	-	3	Staircases and landings	-	53	4	Doors leading from hallways or stairwells into hallways and apartment hallways	R _w 27	-	Adjacent detached and multi-family homes should have a minimum STC rating of 55 for sidewalls. Acoustic sealant must be used all sidewall penetrations, and floor/ceiling assemblies must have a minimum STC and IIC rating of 55. The table summarizes the essential criteria for airborne and impact-borne sound insulation (FHA, 1967).
			Wall Floors and stairs	Airborne Sound Insulation D _{A,T,w} +C _{tr} dB (Min. Values)	Impact Sound Insulation n L _{n,T,w} dB (Max. Values)																																													
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Lowest Airborne Sound Insulation Values to be Provided between Adjacent Volumes in Different Building Types	Article 11: Appendix -3 - Table 3.4 (Regulation, 2017).	In rooms for accommodation purposes; performance standards for separating walls, floors, and stairs with a divider function (Approved Document E, 2010).	<table><tr><th>Airborne Sound Insulation L_{n,T,w} on D_{n,T,w}⁺ C_{tr} dB (Min. Values)</th><th>Impact Sound Insulation L_{n,T,w} dB (Max. Values)</th></tr><tr><td>Purpose built rooms for residential purposes</td><td></td></tr><tr><td>Wall Floors and stairs</td><td>43 45</td></tr><tr><td>Rooms for residential purposes formed by material change of use</td><td></td></tr><tr><td>Wall Floors and stairs</td><td>43 43</td></tr></table>	Airborne Sound Insulation L _{n,T,w} on D _{n,T,w} ⁺ C _{tr} dB (Min. Values)	Impact Sound Insulation L _{n,T,w} dB (Max. Values)	Purpose built rooms for residential purposes		Wall Floors and stairs	43 45	Rooms for residential purposes formed by material change of use		Wall Floors and stairs	43 43	Airborne sound requirements (DEGA-Empfehlung 103, 2018).	Criteria for Airborne Sound Insulation of Dwelling Wall Partitions (FHA, 1967).																																																																																	
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Requirements Regarding Sound Insulation Limit Values			Impact sound requirements (DEGA-Empfehlung 103, 2018).	Airborne and Impact Sound Insulation Criteria for Floor-Ceiling Assemblies Between Dwelling Units (FHA, 1967).																																																																																																																											
	4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS		<table><tr><th></th><th>F</th><th>E</th><th>D</th><th>C</th><th>B</th><th>A</th><th>A*</th></tr><tr><td>Ceiling [L'n,w]</td><td>> 60 dB¹⁾</td><td>≤ 60 dB¹⁾</td><td>≤ 50 dB</td><td>≤ 45 dB¹⁾</td><td>≤ 40 dB¹⁾</td><td>≤ 35 dB</td><td>≤ 30 dB</td></tr><tr><td>Balconies , loggias, terraces, [L'n,w]</td><td>> 63 dB¹⁾</td><td>≤ 63 dB¹⁾</td><td>≤ 50 dB²⁾</td><td>≤ 48 dB¹⁾</td><td>≤ 43 dB¹⁾</td><td>≤ 38 dB</td><td>≤ 33 dB</td></tr><tr><td>Stairs, hallways [L'n,w]</td><td>> 63 dB¹⁾</td><td>≤ 63 dB¹⁾</td><td>≤ 53 dB³⁾</td><td>≤ 48 dB¹⁾</td><td>≤ 43 dB¹⁾</td><td>≤ 38 dB</td><td>≤ 33 dB</td></tr></table> Notes:1) Replaceable floor covering can be taken into account (calculated only with tested Lw) 2) For balconies requirement L'n,w ≤ 58 dB 3) For hallways, requirement L'n,w ≤ 50 dB		F	E	D	C	B	A	A*	Ceiling [L'n,w]	> 60 dB ¹⁾	≤ 60 dB ¹⁾	≤ 50 dB	≤ 45 dB ¹⁾	≤ 40 dB ¹⁾	≤ 35 dB	≤ 30 dB	Balconies , loggias, terraces, [L'n,w]	> 63 dB ¹⁾	≤ 63 dB ¹⁾	≤ 50 dB ²⁾	≤ 48 dB ¹⁾	≤ 43 dB ¹⁾	≤ 38 dB	≤ 33 dB	Stairs, hallways [L'n,w]	> 63 dB ¹⁾	≤ 63 dB ¹⁾	≤ 53 dB ³⁾	≤ 48 dB ¹⁾	≤ 43 dB ¹⁾	≤ 38 dB	≤ 33 dB	<table><tr><th>Partition Function Between Dwelling</th><th>Grade I STC, IIC</th><th>Grade II STC, IIC</th><th>Grade III STC, IIC</th></tr><tr><td>Apt. A Apt. B</td><td></td><td></td><td></td></tr><tr><td>Bedroom above Bedroom</td><td>55</td><td>55</td><td>52</td></tr><tr><td>Living room above Bedroom^{1,2}</td><td>57</td><td>60</td><td>54</td></tr><tr><td>Kitchen³ above Bedroom^{1,2,4}</td><td>58</td><td>65</td><td>55</td></tr><tr><td>Family room above Bedroom^{1,2,5}</td><td>60</td><td>65</td><td>56</td></tr><tr><td>Corridor above Bedroom^{1,2}</td><td>55</td><td>65</td><td>52</td></tr><tr><td>Bedroom above Living room⁶</td><td>57</td><td>55</td><td>54</td></tr><tr><td>Living room above Living room</td><td>55</td><td>55</td><td>52</td></tr><tr><td>Kitchen above Living room^{1,2,4}</td><td>55</td><td>60</td><td>52</td></tr><tr><td>Family r. above Living r.^{1,2,5}</td><td>58</td><td>62</td><td>54</td></tr><tr><td>Corridor above Living room^{1,2}</td><td>55</td><td>60</td><td>52</td></tr><tr><td>Bedroom above Kitchen^{1,4,6}</td><td>58</td><td>52</td><td>55</td></tr><tr><td>Living room above Kitchen^{1,4,6}</td><td>55</td><td>55</td><td>52</td></tr><tr><td>Kitchen above Kitchen⁴</td><td>52</td><td>55</td><td>50</td></tr><tr><td>Bathroom above Kitchen^{1,2,4}</td><td>55</td><td>55</td><td>52</td></tr><tr><td>Family r. above Kitchen^{1,2,4,5}</td><td>55</td><td>60</td><td>52</td></tr><tr><td>Corridor above Kitchen^{1,2,4}</td><td>50</td><td>55</td><td>48</td></tr><tr><td>Bedroom above Family room^{1,6}</td><td>60</td><td>50</td><td>56</td></tr><tr><td>Living r. above Family room^{1,6}</td><td>58</td><td>52</td><td>54</td></tr><tr><td>Kitchen above Family room^{1,6}</td><td>55</td><td>55</td><td>52</td></tr><tr><td>Bathroom above Bathroom⁴</td><td>52</td><td>52</td><td>50</td></tr><tr><td>Corridor above Corridor⁷</td><td>50</td><td>50</td><td>48</td></tr></table>	Partition Function Between Dwelling	Grade I STC, IIC	Grade II STC, IIC	Grade III STC, IIC	Apt. A Apt. B				Bedroom above Bedroom	55	55	52	Living room above Bedroom ^{1,2}	57	60	54	Kitchen ³ above Bedroom ^{1,2,4}	58	65	55	Family room above Bedroom ^{1,2,5}	60	65	56	Corridor above Bedroom ^{1,2}	55	65	52	Bedroom above Living room ⁶	57	55	54	Living room above Living room	55	55	52	Kitchen above Living room ^{1,2,4}	55	60	52	Family r. above Living r. ^{1,2,5}	58	62	54	Corridor above Living room ^{1,2}	55	60	52	Bedroom above Kitchen ^{1,4,6}	58	52	55	Living room above Kitchen ^{1,4,6}	55	55	52	Kitchen above Kitchen ⁴	52	55	50	Bathroom above Kitchen ^{1,2,4}	55	55	52	Family r. above Kitchen ^{1,2,4,5}	55	60	52	Corridor above Kitchen ^{1,2,4}	50	55	48	Bedroom above Family room ^{1,6}	60	50	56	Living r. above Family room ^{1,6}	58	52	54	Kitchen above Family room ^{1,6}	55	55	52	Bathroom above Bathroom ⁴	52	52	50	Corridor above Corridor ⁷	50	50
	F	E	D	C	B	A	A*																																																																																																																								
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				See FHA (1967) for footnotes (pp. 10–12).																																																																																																																											

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE	TUR KEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)																							
Requirements Regarding Sound Insulation Limit Values			Noises from restaurants, businesses, etc. (DEGA-Empfehlung 103, 2018).	- The placement of living units adjacent to mechanical equipment rooms, either vertically or horizontally, should be avoided as far as possible. In such cases, the recommended airborne sound insulation criteria between mechanical equipment rooms and sensitive area residences should be $STC \geq 65$, $STC \geq 62$, and $STC \geq 58$ for Grades I, II, and III, respectively. Similarly, the recommended criteria for mechanical equipment rooms and less sensitive areas in residential buildings are, respectively. $STC \geq 60$ for Grades 1, $STC \geq 58$ for Grades 2, and $STC \geq 54$ for Grades 3. Where living units are located above noisy areas, double wall construction is often necessary, as airborne sound insulation is important (FHA, 1967). - The placement of residential units adjacent to business areas, either vertically or horizontally, should be avoided as much as possible. In such cases, the recommended airborne sound insulation criteria between work areas and sensitive living areas are, respectively, $STC \geq 60$ for Grade 1, $STC \geq 58$ for Grade 2, and $STC \geq 56$ for Grade 3 (FHA, 1967). If the living areas are above the work areas, the impact insulation criteria of $IIC \geq 60$, $IIC \geq 58$, and $IIC \geq 56$ must be met, but if the relevant positions are reversed, the impact insulation criteria values should be increased by at least 5 points. If noise levels in mechanical equipment rooms or work areas exceed 100 dB on a standard sound level meter, the airborne insulation criteria given above should be increased by 5 points (FHA, 1967). Criteria for airborne sound insulation within a dwelling unit (FHA, 1967)																							
	4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS			<table><tr><th></th><th>F</th><th>E</th><th>D</th><th>C</th><th>B</th><th>A</th><th>A*</th></tr><tr><td>Day time [Lr,n] [LAF, max,n]]</td><td>> 35 dB(A) > 45 dB(A)</td><td>≤ 35 dB(A)) ≤ 45 dB(A)</td><td>≤ 30 dB(A)) ≤ 40 dB(A)</td><td>≤ 25 dB(A)) ≤ 35 dB(A)</td><td>≤ 25 dB(A)) ≤ 35 dB(A)</td><td></td><td>not permitted</td></tr><tr><td>night [Lr,n] [LAF, max,n]]</td><td>> 25 dB(A)) > 35 dB(A)</td><td>≤ 25 dB(A)) ≤ 35 dB(A)</td><td>≤ 20 dB(A)) ≤ 30 dB(A)</td><td>≤ 15 dB(A)) ≤ 25 dB(A)</td><td>≤ 15 dB(A)) ≤ 25 dB(A)</td><td></td><td>not permitted</td></tr></table> Notes : The class F values exceed the immission guideline values of the TA-Lärm (Technical instructions with explanations for noise protection). Notes : The deviation of the values from the TA noise in level D results from the coordination with the noise from building services systems. The sound pressure level is 30 dB (A) according to DIN 4109-1 and DEGA recommendations; 35 dB (A) is permissible at night according to TALärm. This hesitation has been resolved, and the requirements for the technical buildings systems according to DIN 4109-1 have been adjusted because the residents' need for protection is paramount, making noise is not permitted to be louder than other noises from building services systems when in operation or water installations. The values for the rating levels were also adjusted accordingly and customized.		F	E	D	C	B	A	A*	Day time [Lr,n] [LAF, max,n]]	> 35 dB(A) > 45 dB(A)	≤ 35 dB(A)) ≤ 45 dB(A)	≤ 30 dB(A)) ≤ 40 dB(A)	≤ 25 dB(A)) ≤ 35 dB(A)	≤ 25 dB(A)) ≤ 35 dB(A)		not permitted	night [Lr,n] [LAF, max,n]]	> 25 dB(A)) > 35 dB(A)	≤ 25 dB(A)) ≤ 35 dB(A)	≤ 20 dB(A)) ≤ 30 dB(A)	≤ 15 dB(A)) ≤ 25 dB(A)	≤ 15 dB(A)) ≤ 25 dB(A)	
	F	E	D	C	B	A	A*																				
Day time [Lr,n] [LAF, max,n]]	> 35 dB(A) > 45 dB(A)	≤ 35 dB(A)) ≤ 45 dB(A)	≤ 30 dB(A)) ≤ 40 dB(A)	≤ 25 dB(A)) ≤ 35 dB(A)	≤ 25 dB(A)) ≤ 35 dB(A)		not permitted																				
night [Lr,n] [LAF, max,n]]	> 25 dB(A)) > 35 dB(A)	≤ 25 dB(A)) ≤ 35 dB(A)	≤ 20 dB(A)) ≤ 30 dB(A)	≤ 15 dB(A)) ≤ 25 dB(A)	≤ 15 dB(A)) ≤ 25 dB(A)		not permitted																				

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE	TURKEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)																				
4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS	Permissible Indoor Noise Levels in Spaces	Article 12: Appendix -4 - Table 4.1 (Regulation, 2017). <table><tr><td>Maximum Permissible Indoor Noise Levels Based on Acoustic Performance Class, dB</td><td>Activity</td><td>Location</td><td>07:00 to 23:00</td><td>23:00 to 07:00</td></tr><tr><td></td><td>Resting</td><td>Living Room</td><td>35 dB L_{Aeq, 16 hour}</td><td>-</td></tr><tr><td></td><td>Dining</td><td>Dining Room/ Area</td><td>40 dB L_{Aeq, 16 hour}</td><td>-</td></tr><tr><td></td><td>Sleeping (Daytime resting)</td><td>Bedroom</td><td>35 dB L_{Aeq, 16 hour}</td><td>30 dB L_{Aeq, 8 hour}</td></tr></table> According to the legislation, an indoor noise level of 35 dB LAeq,T during the day for fixed external noise sources is suitable for resting conditions in living rooms and bedrooms. The level of 40 dB LAeq,T is appropriate for dining rooms. During the night, a 30 dB LAeq,T noise level is recommended in bedrooms (BS 8233, 2014).	Maximum Permissible Indoor Noise Levels Based on Acoustic Performance Class, dB	Activity	Location	07:00 to 23:00	23:00 to 07:00		Resting	Living Room	35 dB L _{Aeq, 16 hour}	-		Dining	Dining Room/ Area	40 dB L _{Aeq, 16 hour}	-		Sleeping (Daytime resting)	Bedroom	35 dB L _{Aeq, 16 hour}	30 dB L _{Aeq, 8 hour}	DIN 4109 specifies an indoor noise level of 35 decibels during the day and 25 decibels at night (DIN 4109, 2018; as cited in Körper, 2019).	FHA (1967) recommends 40 dB during the day and 35 dB at night in the kitchen, and a 25 dB indoor noise level at night in bedrooms.
	Maximum Permissible Indoor Noise Levels Based on Acoustic Performance Class, dB	Activity	Location	07:00 to 23:00	23:00 to 07:00																			
	Resting	Living Room	35 dB L _{Aeq, 16 hour}	-																				
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	Sleeping (Daytime resting)	Bedroom	35 dB L _{Aeq, 16 hour}	30 dB L _{Aeq, 8 hour}																				
Limit Values for Internal Noise Originating from Installation and Service Equipment	Article 13: Appendix -5 - Table 5.2 can be consulted. However, there is no special article for elevators in the regulation (Regulation, 2017). <table><tr><td>Noise Levels from Elevators</td><td>Room</td><td>Max. Noise Level (dB LAmax,F)</td></tr><tr><td></td><td>Bedroom</td><td>25</td></tr><tr><td></td><td>Living Room</td><td>30</td></tr><tr><td></td><td>Other Areas</td><td>35</td></tr></table> NOTE These figures relate solely to lift noise levels and do not account for any other noise sources. These values include noise from the lifts irrespective of the transmission mechanism, i.e. they include both airborne and structure-borne noise. The above-mentioned values for recommended maximum noise levels in the residential unit should be considered as upper guideline values and should be considered in the design of each elevator system and component. Noise and vibration must be minimized at the source for lower levels to occur in practice (BS 8233, 2014). In order not to exceed the maximum noise levels given in the legislation, the elevator motor and related equipment should be installed in a suitable place. Elevators should be located in such a way as to minimize disturbances caused by noise. Elevator doors should work silently and acoustically. Signals announcing the arrival of the elevator should not be heard in the residences (BS 8233, 2014). <i>Elevator lobbies:</i> Elevator operating noise and any occupancy level in any part of the elevator loop, including announcements, must not exceed 55 dB LAmax, F (BS 8233, 2014).	Noise Levels from Elevators	Room	Max. Noise Level (dB LAmax,F)		Bedroom	25		Living Room	30		Other Areas	35	No up-to-date information could be obtained.	Heavy-duty motors associated with freight or service lifts must be vibration-isolated to avoid serious noise problems. To isolate residential units from elevator equipment noise, elevator shafts should be surrounded by storage areas that act as buffer zones. (FHA, 1967).									
Noise Levels from Elevators	Room	Max. Noise Level (dB LAmax,F)																						
	Bedroom	25																						
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Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE		TURK EY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)																												
Highest Permissible Internal Noise Levels Due to Continuous Noise Service Equipment	Article 13: Appen dix -5 - Table 5.1 (Regul ation, 2017).	To ensure good acoustic conditions, noise levels in living rooms and bedrooms should not exceed LAeq,T 30 dB for residential mechanical systems (Acoustics Ventilation And Overheating Residential Design Guide, 2020). Indoor noise levels from mechanical services (Acoustics Ventilation And Overheating Residential Design Guide, 2020).	<table><tr><th>Ventilation condition</th><th>Possible system or design solution</th><th>Desirable internal ambient noise levels from mechanical services</th></tr><tr><td>ADF – Whole Dwelling Ventilation</td><td>System 3: Continuous mechanical extract (MEV), minimum low ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum low ventilation rates</td><td>Bedrooms Living Rooms $\leq L_{w, 26}$ or 30 dB (max=1) $\leq L_{w, 30}$ dB</td></tr><tr><td>ADF – Extract Ventilation</td><td>System 1: Intermittent extract fans System 3: Continuous mechanical extract (MEV), minimum high ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum high ventilation rates</td><td>Bedrooms Living / Dining Rooms Bathroom / W/C / Kitchen $\leq L_{w, 26}$ or 30 dB $\leq L_{w, 35}$ dB $\leq L_{w, 45}$ dB</td></tr><tr><td>ADF – Purge Ventilation</td><td>Manually controlled fan exchanging a minimum 4 air changes per hour</td><td>No desirable noise levels are currently proposed based on the lack of evidence of acceptable noise levels when providing purge ventilation for the purpose of rapidly diluting indoor pollutants.</td></tr></table>	Ventilation condition	Possible system or design solution	Desirable internal ambient noise levels from mechanical services	ADF – Whole Dwelling Ventilation	System 3: Continuous mechanical extract (MEV), minimum low ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum low ventilation rates	Bedrooms Living Rooms $\leq L_{w, 26}$ or 30 dB (max=1) $\leq L_{w, 30}$ dB	ADF – Extract Ventilation	System 1: Intermittent extract fans System 3: Continuous mechanical extract (MEV), minimum high ventilation rates System 4: Continuous mechanical supply and extract with heat recovery (MVHR), minimum high ventilation rates	Bedrooms Living / Dining Rooms Bathroom / W/C / Kitchen $\leq L_{w, 26}$ or 30 dB $\leq L_{w, 35}$ dB $\leq L_{w, 45}$ dB	ADF – Purge Ventilation	Manually controlled fan exchanging a minimum 4 air changes per hour	No desirable noise levels are currently proposed based on the lack of evidence of acceptable noise levels when providing purge ventilation for the purpose of rapidly diluting indoor pollutants.	Noise requirements from plumbing, building service systems, and user noise (DEGA-Empfehlung 103, 2018). <table><tr><th></th><th>F</th><th>E</th><th>D</th><th>C</th><th>B</th><th>A</th><th>A*</th></tr><tr><td>Noise requirements from plumbing, building service systems, and user noise [LAF,max,n]</td><td>> 35 dB (A)</td><td>$\leq$ 35 dB (A)</td><td>$\leq$ 30 dB (A)</td><td>$\leq$ 27 dB (A)</td><td>$\leq$ 24 dB (A)</td><td></td><td></td></tr></table> Notes: Bonus points are awarded in the noise protection certificate if there are no low-frequency noise components. This is acceptable if the difference between the C and A-weighted total levels according to DIN 45 680 is less than 20 dB. The requirements also apply to heating and ventilation systems in your area.		F	E	D	C	B	A	A*	Noise requirements from plumbing, building service systems, and user noise [LAF,max,n]	> 35 dB (A)	$\leq$ 35 dB (A)	$\leq$ 30 dB (A)	$\leq$ 27 dB (A)	$\leq$ 24 dB (A)			
Ventilation condition	Possible system or design solution	Desirable internal ambient noise levels from mechanical services																															
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Noise requirements from plumbing, building service systems, and user noise [LAF,max,n]	> 35 dB (A)	$\leq$ 35 dB (A)	$\leq$ 30 dB (A)	$\leq$ 27 dB (A)	$\leq$ 24 dB (A)																												
Limit Values for Internal Noise Originating from Installation and Service Equipment	Article 13: Appen dix -5 - Table 5.2 (Regul ation, 2017).																																
4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS																																	

Table 3.15. (continue) Comparison of the legislation for residential buildings

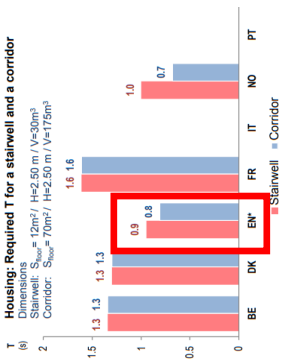
TOPIC TITLE	TURKEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)																																								
Allowed Reverberation Times in Buildings	Article Appendix Table (Regulation, 2017).	Estimated reverberation time in a residential block's stairwell and corridor (Teresa and Rasmussen, 2018; Approved Document E, 2010) Housing: Required T for a stairwell and a corridor Dimensions Stairwell: $S_{stair}=12m^2$ / $H=2.50\text{ m}$ / $V=30m^3$ Corridor: $S_{corr}=70m^2$ / $H=2.50\text{ m}$ / $V=175m^3$  <table><tr><th>Country</th><th>Stairwell T</th><th>Corridor T</th></tr><tr><td>BE</td><td>1.3</td><td>1.3</td></tr><tr><td>DK</td><td>1.3</td><td>1.3</td></tr><tr><td>EN*</td><td>0.9</td><td>0.8</td></tr><tr><td>FR</td><td>1.6</td><td>1.6</td></tr><tr><td>IT</td><td>1.0</td><td>0.7</td></tr><tr><td>NO</td><td>1.0</td><td>0.7</td></tr><tr><td>PT</td><td>1.0</td><td>0.7</td></tr></table>	Country	Stairwell T	Corridor T	BE	1.3	1.3	DK	1.3	1.3	EN*	0.9	0.8	FR	1.6	1.6	IT	1.0	0.7	NO	1.0	0.7	PT	1.0	0.7	A / V (equivalent suction area/volume) ratio recommendation in stairways and corridors of multi-story residential buildings in general (DEGA-Empfehlung 103, 2018). <table><tr><th></th><th>F</th><th>E</th><th>D</th><th>C</th><th>B</th><th>A</th><th>A*</th></tr><tr><td>A/V</td><td>No actions</td><td>No actions</td><td>No actions</td><td>s</td><td>$\geq 0,10$</td><td>$\geq 0,20$</td><td>or no common staircase</td></tr></table> Notes: An A/V ratio of 0.10 usually results in a reverberation time of around 1.4 to 1.8 s.		F	E	D	C	B	A	A*	A/V	No actions	No actions	No actions	s	$\geq 0,10$	$\geq 0,20$	or no common staircase	There is no special provision on this subject.
Country	Stairwell T	Corridor T																																										
BE	1.3	1.3																																										
DK	1.3	1.3																																										
EN*	0.9	0.8																																										
FR	1.6	1.6																																										
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PT	1.0	0.7																																										
	F	E	D	C	B	A	A*																																					
A/V	No actions	No actions	No actions	s	$\geq 0,10$	$\geq 0,20$	or no common staircase																																					
Limit Values for Reverberation Time		Estimated A/Floor ratio in a residential block stairwell and corridor (Teresa and Rasmussen, 2018; Approved Document E, 2010). Housing: Required A/S_{floor} for a stairwell and a corridor Dimensions Stairwell: $S_{stair}=12m^2$ / $H=2.50\text{ m}$ / $V=30m^3$ Corridor: $S_{corr}=70m^2$ / $H=2.50\text{ m}$ / $V=175m^3$  <table><tr><th>Country</th><th>Stairwell A/S_{floor}</th><th>Corridor A/S_{floor}</th></tr><tr><td>BE</td><td>0.30</td><td>0.30</td></tr><tr><td>DK</td><td>0.30</td><td>0.31</td></tr><tr><td>EN*</td><td>0.43</td><td>0.25</td></tr><tr><td>FR</td><td>0.50</td><td>0.25</td></tr><tr><td>IT</td><td>0.40</td><td>0.25</td></tr><tr><td>NO</td><td>0.40</td><td>0.25</td></tr><tr><td>PT</td><td>0.40</td><td>0.25</td></tr></table>	Country	Stairwell A/S_{floor}	Corridor A/S_{floor}	BE	0.30	0.30	DK	0.30	0.31	EN*	0.43	0.25	FR	0.50	0.25	IT	0.40	0.25	NO	0.40	0.25	PT	0.40	0.25																		
Country	Stairwell A/S_{floor}	Corridor A/S_{floor}																																										
BE	0.30	0.30																																										
DK	0.30	0.31																																										
EN*	0.43	0.25																																										
FR	0.50	0.25																																										
IT	0.40	0.25																																										
NO	0.40	0.25																																										
PT	0.40	0.25																																										
4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS																																												

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE		TURKEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)																						
Ventilation Ducts	Noise Control in Ventilation Ducts	It is designed to provide the minimum noise levels given in Appendix 8 and Appendix 5.1 (Regulation, 2017).	Flexible assemblies should be installed where ventilation fans and similar equipment generate building noise (BS 8233, 2014). In order to prevent sound transmission in ventilation ducts passing close to sensitive areas, the gaps in the ducts should be closed (BS 8233, 2014).	No up-to-date information could be obtained.	Design guidelines for HVAC-related background sound in rooms (ASHRAE, 2015) <table><tr><th colspan="4">Design Guidelines for HVAC Related Background Sound In Rooms</th></tr><tr><th></th><th>Octave Band Analysis</th><th>Approximate Overall</th><th>Sound Pressure Level</th></tr><tr><td>Room Types</td><td></td><td></td><td>dBA</td><td>dBc</td></tr><tr><td rowspan="2">Residences, Apartments, Condominiu ms</td><td>Living Areas</td><td>30</td><td>35</td><td>60</td></tr><tr><td>Bathrooms, Kitchens, Utility Rooms</td><td>35</td><td>40</td><td>60</td></tr></table>	Design Guidelines for HVAC Related Background Sound In Rooms					Octave Band Analysis	Approximate Overall	Sound Pressure Level	Room Types			dBA	dBc	Residences, Apartments, Condominiu ms	Living Areas	30	35	60	Bathrooms, Kitchens, Utility Rooms	35	40	60
Design Guidelines for HVAC Related Background Sound In Rooms																											
	Octave Band Analysis	Approximate Overall	Sound Pressure Level																								
Room Types			dBA	dBc																							
Residences, Apartments, Condominiu ms	Living Areas	30	35	60																							
	Bathrooms, Kitchens, Utility Rooms	35	40	60																							
Fans-Fancoils	Control of Equipment Noise	Necessary measures are taken to ensure the values are given in Appendix -8 and Appendix -5. (Regulation, 2017).	There should be sufficient duct distance to reduce fan noise. Generally, larger and slower fans are quieter. Vibration isolation is required in mountings to reduce structural vibration in the housing, fan, and drive motors. The fan may need to be isolated from the duct, often using a case and flexible connectors. In addition, the duct can be supported with flexible hangers (BS 8233, 2014).	No up-to-date information could be obtained.	Design guidelines for HVAC systems in unoccupied spaces (AHRI, 2008) <table><tr><th colspan="2">Design Guidelines for HVAC System Noise in Unoccupied Spaces</th></tr><tr><th>Space</th><th>RC (N)</th></tr><tr><td>Residences, Apartments, Condominiums</td><td>25 to 35</td></tr></table> Rooftop installations of ventilation systems, and fan noise causes many complaints. Such installations must be isolated from the roof and building structures by means of flexible mountings. Noise control must be double-walled or acoustically coated or provided with prefabricated silencers or baffles (FHA, 1967).	Design Guidelines for HVAC System Noise in Unoccupied Spaces		Space	RC (N)	Residences, Apartments, Condominiums	25 to 35																
Design Guidelines for HVAC System Noise in Unoccupied Spaces																											
Space	RC (N)																										
Residences, Apartments, Condominiums	25 to 35																										
Combi Devices		It is selected to provide the minimum noise levels given in Appendix 8 and Appendix 5 (Regulation, 2017).	There is no special provision on this subject.	No up-to-date information could be obtained.	Equipment should be selected to produce low noise (FHA, 1967).																						
5. INSTALLATION AND SERVICE EQUIPMENT NOISE CONTROL MEASURES																											

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE	TURKEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)								
Acoustic Louvers	The test report determined by measurements according to the standards specified in Appendix 8 and Appendix 1 is required (Regulation, 2017).	There is no special provision on this subject.	No up-to-date information could be obtained.	There is no special provision on this subject.								
Chillers	There is no special provision on this subject.	If chillers are located near sensitive areas due to high noise and vibration generation, they should be located in a sheltered area. Air gaps that will cause sound transmission should be avoided. Flexible assemblies are often required in plumbing. In all pipelines, chillers, clips, or hangers are held insulated (or insulated), and the pipes pass through the sleeves lined with a flexible liner (BS 8233, 2014).	No up-to-date information could be obtained.	Noise in cooling towers can be avoided by using equipment with large diameters, low-speed fans, sound-absorbing baffles, and vibration isolation feet. Top mounting should be done on the roof of the highest wing or section of the building, preferably in an uninhabited area (FHA, 1967).								
Noise Control Principles for Roofing Equipment	The requirements specified in 8.2.4 in Appendix 8 must be met (Regulation, 2017).	Roofs and mansards generally have lower sound insulation than masonry facades. The performance of various roof types is given in Table 3.27. Roof windows should be avoided as precipitation noise can be a problem on light roofs (BS 8233, 2014). Sound insulation on roofs (BS 8233, 2014). <table><thead><tr><th>Roof Type</th><th>Weighted sound reduction index R_w dB</th></tr></thead><tbody><tr><td>Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling</td><td>43</td></tr><tr><td>100 mm flat concrete roof (230 kg/m²)</td><td>52</td></tr><tr><td>Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation</td><td>45</td></tr></tbody></table>	Roof Type	Weighted sound reduction index R _w dB	Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling	43	100 mm flat concrete roof (230 kg/m ²)	52	Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation	45	No up-to-date information could be obtained.	Equipment should not be placed on the roof or mezzanine level, especially in multi-story buildings with light frame construction. In cases where the equipment is located on the roof, the equipment must be isolated from the roof and building structures using flexible mountings and flexible connectors. The ductwork must be double-walled, acoustically coated, or provided with prefabricated sound silencers or baffles (FHA,1967).
Roof Type	Weighted sound reduction index R _w dB											
Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling	43											
100 mm flat concrete roof (230 kg/m ²)	52											
Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation	45											
Control of Equipment Noise												
5. INSTALLATION AND SERVICE EQUIPMENT NOISE CONTROL MEASURES												

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE		TURKEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)
5. INSTALLATION AND SERVICE EQUIPMENT NOISE CONTROL MEASURES	Noise Control Principles for Plumbing and Other Mechanical, Electrical Service	Noise control measures that meet the values in Appendix 8 and Appendix 5.2 (Regulation, 2017) are implemented.	Any partition separating the WC from a noise-sensitive room must have airborne sound insulation of at least 40 dB Rw (BS 8233, 2014). To reduce noise caused by the structure, flexible pipe connections and flexible fixings should be used in pipe transitions. Where piping penetrates walls and floors, air gaps must be sealed to reduce noise so that noise from the structure is not transmitted. These gaps can be closed with mineral wool or non-hardening mastic (BS 8233, 2014).	No up-to-date information could be obtained.	Construction fittings for piping penetrations or openings, electrical appliances, walk-in closets, bathtubs, or heating, ventilation, or exhaust ducts shall be sealed, lined, or insulated to maintain required ratings. Although this requirement does not apply to entrance doors, such doors must fit tightly to the frame and sill (IBC, 2018). Electrical circuit equipment should be placed in surface-mounted vibration-isolated boxes on a heavy wall (FHA, 1967).
	Control of Equipment Noise	The requirements specified in Appendix 8's 8.2.5 must be met (Regulation, 2017).	Detailed design advice for building services is outside the scope of this British report (BS 8233, 2014). It may take advice from an acoustic consultant for noise control in these centers.	No up-to-date information could be obtained.	The placement of living units adjacent to mechanical equipment rooms, either vertically or horizontally, should be avoided as far as possible. Where living units are located above noisy areas, double wall construction is often necessary to provide adequate acoustic privacy, as airborne sound insulation is important (FHA, 1967).
	Noise and Vibration Control in Mechanical Centers				

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE	TURKEY	ENGLAND (BS 8233; Approved Document E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)
In order to reach the acoustic performance values specified and defined in the legislation, it is necessary to take noise control measures in the interior design. These measures are specified in the legislation as follows: 6. DESIGN CRITERIA AND NOISE CONTROL MEASURES FOR INDOOR NOISE	Noise control measures for indoor noise are included in The Guideline on Acoustical Design, Installation, and Inspection of Buildings and regulation (2017) appendices on a principal scale.	According to BS 8233 (2014) and Approved Document E (2010), <i>To minimize the noise disturbance produced indoors:</i> - Building services in housing should be kept away from bedrooms. - Precautions should be taken when placing noise-sensitive rooms, such as bedrooms, next to stairs. - Care should be taken when placing bedrooms next to the elevator, and circulation areas should be created where less sensitive rooms are used as buffers. - Residences, apartments, and accommodation rooms should be designed and constructed in such a way as to provide reasonable resistance to sound from other parts of the same building and from adjacent buildings. - Common interiors of buildings containing residential flats or rooms should be designed and built in such a way that reverberation is minimized around common parts (this only applies to stairs, corridors, and entrance halls providing access to a residential flat or room). - Creating and repeating the same house plans can help to improve compatibility between rooms in adjacent houses. - Sound-absorbing materials should be applied to the ceiling surfaces of common corridors and stairwells to reduce noise propagation throughout the building. Carpet and other flexible floor coverings can be used to reduce noise transmission from footsteps on stairwells, corridors, and landings (BS 8233, 2014; Approved Document E, 2010).	No up-to-date information could be obtained.	According to the Federal Housing Administration (1967); <i>To minimize the noise disturbance produced indoors:</i> - The placement of living units adjacent to mechanical equipment rooms, either vertically or horizontally, should be avoided as much as possible. - Where living units are located above noisy areas, double wall construction is often necessary to provide adequate acoustic privacy, as airborne sound insulation is important. - The placement of vertically or horizontally adjacent residential units to business areas such as restaurants, and bars should be avoided as much as possible (FHA,1967).

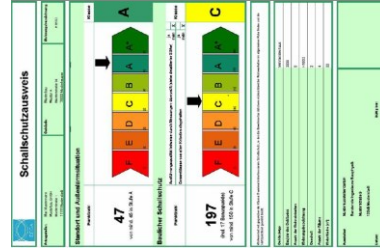
Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE	TUR KEY	ENGLAND (BS 8233; App.Doc.E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)		
				Sound sources, transmission paths, and recommended noise reduction methods (ASHRAE, 2015).		
Design criteria for indoor noise				Sound Source		
				Circulating fans;grilles;registers;diffusers;unitary equipment in room		Path No. 1
				Induction coil and fan-powered VAV mixing units		1,2
				Unitary equipment located outside of the room served;remotely located air-handling equipment, such as fans,blowers,dampers,duct fittings, and air washers		2,3
				Compressors, pumps, and other reciprocating and rotating equipment (excluding air-handling equipment)		4,5,6
				Cooling towers;air-cooled condensers		4,5,6,7
				Exhaust fans;window air conditioners		7,8
				Sound transmission between rooms		9,10
				Noise Reduction Methods		
				No. Transmission Paths		
				1. Direct sound radiated from sound source to ear Reflected sound from walls, ceiling, and floor	Direct sound can be controlled only by selecting quiet equipment Reflected sound is controlled by adding sound absorption to rooms to equipment location	
				2. Air-and structureborne sound radiated from casings and through walls of ducts and plenums is transmitted through walls and ceiling into room	Design duct and fittings for low turbulence; locate high-velocity ducts in noncritical areas; isolate ducts and sound plenums from structure with neoprene or spring hangers.	
				3. Airborne sound radiated through supply and return air ducts to diffusers in room and then to listener by Path 1	Select fans for minimum sound power; use ducts lined with sound-absorbing material; use duct silencers or sound plenums in supply and return air ducts.	
				4. Noise transmitted through equipment room walls and floors to adjacent rooms	Locate equipment rooms away from critical areas; use masonry blocks or concrete for mechanical equipment room walls; use floating floors in mechanical rooms	
				5. Vibration transmitted via building structure to adjacent walls and ceilings, from which it radiates as noise into room by Path 1	Mount all machines on properly designed vibration isolators; design mechanical equipment room for dynamic loads; balance rotating and reciprocating equipment.	
				6. Vibration transmission along pipes and duct walls	Isolate pipe and ducts from structure with neoprene or spring hangers; install flexible connectors between pipes, ducts, and vibrating machines.	
				7. Noise radiated to outdoors enters room windows	Locate equipment away from critical areas; use barriers and covers to interrupt noise paths; select quiet equipment.	
				8. Indoor noise follows Path 1	Select quiet equipment.	
				9. Noise transmitted to an air diffuser in a room, into a duct, and out through an air diffuser in another room	Design and install duct attenuation to match transmission loss of wall between rooms; use c-osstalk silencers in ductwork.	
				10. Sound transmission through, over, and around room partition	Extend partition to ceiling slab and tightly seal all around; seal all pipe, conduit, duct, and other partition penetrations.	

Table 3.15. (continue) Comparison of the legislation for residential buildings

TOPIC TITLE	TURKEY	ENGLAND (BS 8233; App.Doc.E)	GERMANY (DIN 4109; DEGA)	AMERICA (IBC ; FHA)
Acoustic Performance Certification	Appendix-10 Acoustic Performance Determination Method (Regulation, 2017)	There is no special provision on this subject.	The DEGA (2018) recommendation defines seven noise protection classes for residential units. Class A*: A very well-soundproofed residential unit with high sound insulation in semi-detached and terraced houses, allowing for almost uninterrupted living. Class A: A very well-soundproofed residential unit that provides undisturbed living, offering increased sound insulation in semi-detached and terraced houses. Class B: A residential unit with good sound insulation, offering high sound insulation in apartments and normal sound insulation in semi-detached and terraced houses. It allows neighbors to live quietly while maintaining a great deal of privacy. Class C: A well-soundproofed residential unit in which users should be mindful of soundproofing. Class D: soundproof enclosure unit that meets the requirements of DIN 4109-1: 2018-01. In order to protect the health of users in apartments, study rooms, and common rooms, they must be protected from the outside and against unreasonable disturbances caused by sound transmission from other residential areas. This situation requires users to avoid unnecessary noise. Class E: It is a soundproof enclosure unit that does not meet the requirements of DIN 4109-1: 2018-01. There are disturbances caused by sound transmission from other settlements and outside. Precaution is necessary . Class F: It is a residential unit with poor soundproofing, well below the DIN requirements. It creates discomfort due to sound transmissions inside and outside the residence; privacy cannot be expected in the spaces (DEGA-Empfehlung 103, 2018).	There is no special provision on this subject.
7. ACOUSTIC PERFORMANCE CLASS AND CERTIFICATION				

Sound protection certificate example (DEGA-Empfehlung 103, 2018)



4. ESTABLISHING ACOUSTIC PERFORMANCE CRITERIA FOR RESIDENTIAL BUILDINGS IN THE CONTEXT OF LEGISLATION

National and international legislations for residential buildings have been examined, and since the scope of the thesis is our national legislation, the performance criteria have been established, with priority given to the Regulation on Protection of Buildings Against Noise and the Regulation on Environmental Noise Control. The performance criteria determined as a result of the examinations are tabulated. The data used in the phrases specified as "National*" and "International" in the created table are defined in our national regulation; the data are primarily taken from our national legislation. If there are additional performance criteria other than the data in our national legislation, international legislation has been applied. Since our national regulation is based on European standards, the regulations of Germany and England, which are developed European countries, are included in this study. In addition to European countries, American standards are also included in the thesis due to their deep-rooted history. In international legislation, the order of priority is determined as being Germany, England, and America. First of all, the reason for referring to the German data is: A classification similar to the acoustic performance classes defined in our national regulation is made, and the data is handled in more detail for the performance classes. In the event that information was not included in the German legislation, the data in the England legislation was used. Finally, the data in the America legislation was preferred. Since we are heading towards the European Union and the indicators used in America are different from the indicators defined in our regulation, the data in the America legislation has generally remained at the analysis stage. Table 4.1 has been prepared within the scope of this legislation, and the main headings are given in Figure 4.1.

1. General Information
2. Design Criteria for Outdoor Noise and Planning of New Residential Areas
3. Determination of Noise Sensitivity and Degree of Noise, as well as Explanations of Subjective Perceptibility of Common Noises from Neighboring Settlements
4. Limit Values for Acoustic Performance Classes in Buildings

- 4.1 Requirements Regarding Sound Insulation Limit Values
- 4.2 Permissible Indoor Noise Levels in Spaces
- 4.3 Limit Values for Internal Noise Originating from Installation and Service Equipment
- 4.4 Limit Values for Reverberation Time
- 5. Installation and Service Equipment Noise Control Measures
 - 5.1 Noise Control in Ventilation Ducts
 - 5.2 Control of Equipment Noise
 - 5.3 Noise and Vibration Control in Mechanical Centers
- 6. Design Criteria and Noise Control Measures for Indoor Noise
- 7. Acoustic Performance Class and Certification

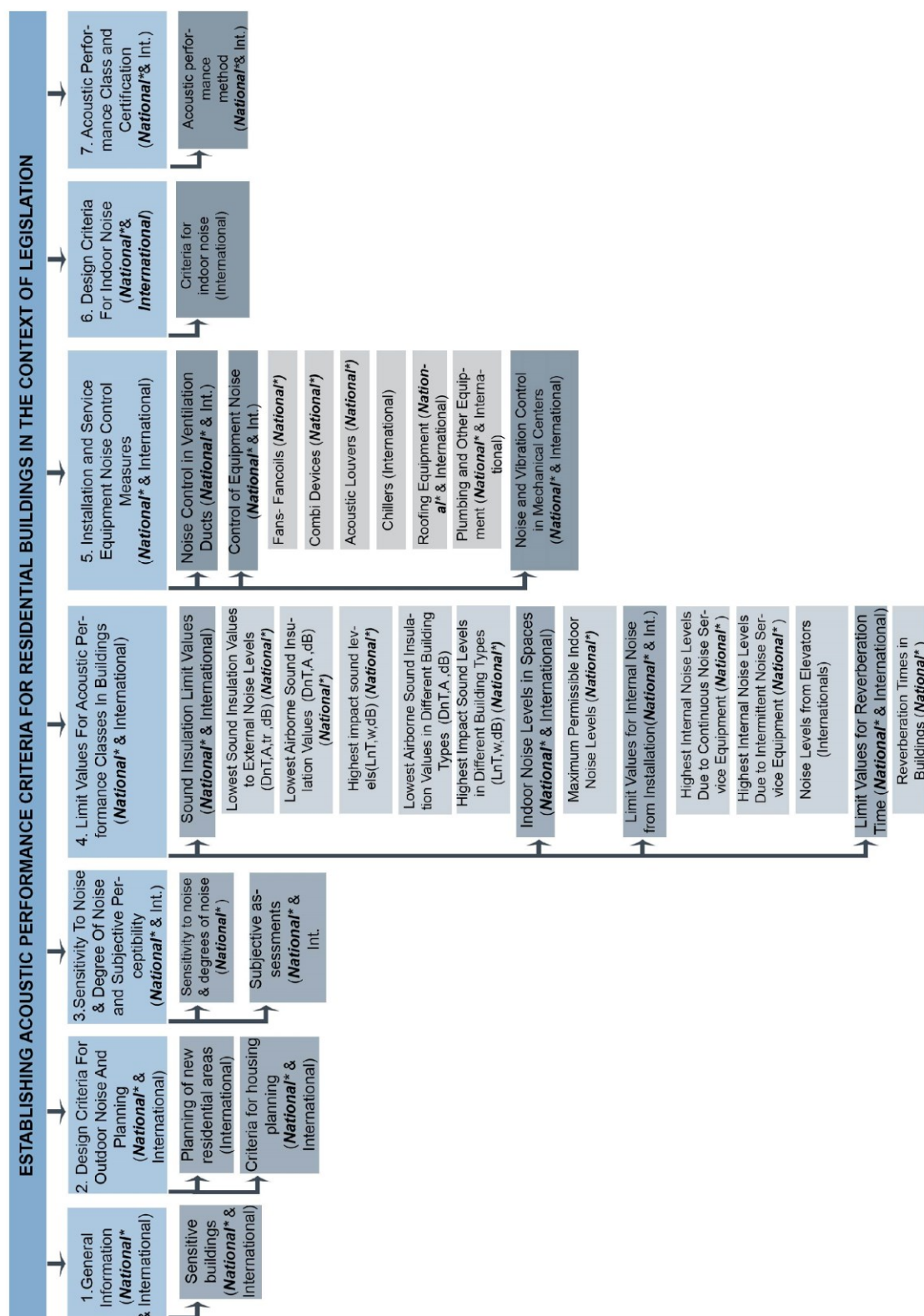


Figure 4.1. Establishment of acoustic performance criteria for residential buildings in the context of legislation

The national legislation, the Regulation on Protection of Buildings Against Noise, is expressed as a regulation in the tables.

Table 4.1. Establishment of acoustic performance criteria for residential buildings

I. GENERAL INFORMATION	Sensitivity to Noise	1. "Buildings that are very sensitive to noise" (Regulation / Article 4-rr).																																								
2. DESIGN CRITERIA FOR OUTDOOR NOISE AND PLANNING OF NEW RESIDENTIAL AREAS	Planning of New Residential Areas	2. In the Environmental Noise Control Regulation (2022), the environmental noise level limit values are given in Appendix 2. In addition to these data, German regulations were also taken into account in the planning of the new housing areas specified in Tables 4.2 and 4.3. <i>According to German legislation</i>, the location of a building and the orientation of residential units play an important role in acoustic performance classification. (DEGA-Empfehlung 103, 2018). Table 4.2. Existing field characteristics according to performance classes (DEGA-Empfehlung 103, 2018) <table><tr><td></td><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td>A*</td></tr><tr><td>current field character</td><td>GI (Industrial Area)</td><td>GE / MU (Commercial / Urban Area)</td><td>MI / WB (Mixed, Private Residential Area)</td><td></td><td>WA (General Residential Area)</td><td></td><td>WR (Entirely Residential Area)</td></tr></table> Table 4.3. According to DIN 4109: 2018-01, External noise level and noise level range in dB (A) (DEGA-Empfehlung 103, 2018:11) <table><tr><td></td><td>F</td><td>E</td><td>D</td><td>C</td><td>B</td><td>A</td><td>A*</td></tr><tr><td>Noise level range</td><td>VI</td><td>V</td><td>IV</td><td>III</td><td>II</td><td colspan="2">I</td></tr><tr><td>External noise level [dB(A)]</td><td>≥ 76</td><td>71 to 75</td><td>66 to 70</td><td>61 to 65</td><td>56 to 60</td><td colspan="2">up to 55</td></tr></table>		F	E	D	C	B	A	A*	current field character	GI (Industrial Area)	GE / MU (Commercial / Urban Area)	MI / WB (Mixed, Private Residential Area)		WA (General Residential Area)		WR (Entirely Residential Area)		F	E	D	C	B	A	A*	Noise level range	VI	V	IV	III	II	I		External noise level [dB(A)]	≥ 76	71 to 75	66 to 70	61 to 65	56 to 60	up to 55	
		F	E	D	C	B	A	A*																																		
	current field character	GI (Industrial Area)	GE / MU (Commercial / Urban Area)	MI / WB (Mixed, Private Residential Area)		WA (General Residential Area)		WR (Entirely Residential Area)																																		
		F	E	D	C	B	A	A*																																		
	Noise level range	VI	V	IV	III	II	I																																			
External noise level [dB(A)]	≥ 76	71 to 75	66 to 70	61 to 65	56 to 60	up to 55																																				
	Design Criteria for Outdoor Noise	3. The criteria to be complied with in housing planning according to the Environmental Noise Control Regulation (2022) are given in table 4.4. Table 4.4. According to the Environmental Noise Control Regulation (2022), criteria to be followed in housing planning <table><tr><th rowspan="2">Noise Source</th><th rowspan="2">Measured Parameter</th><th colspan="3">Environmental Noise Level</th></tr><tr><th>Day</th><th>Evening</th><th>Night</th></tr><tr><td>Industrial facilities, transportation resources</td><td>L_{Aeq,5min}</td><td>65 dB(A)</td><td>60 dB(A)</td><td>55 dB(A)</td></tr><tr><td>Businesses that broadcast music ⁽¹⁾</td><td>L_{Aeq,63-250Hz}</td><td>60 dB(A)</td><td>55 dB(A)</td><td>50 dB(A)</td></tr><tr><td>Businesses ⁽²⁾</td><td>L_{Aeq,5min}</td><td colspan="2">Background +5 dB(A)</td><td>Background +3 dB(A)</td></tr><tr><td>In case of multiple businesses ⁽³⁾</td><td>L_{Aeq,5min}</td><td colspan="2">Background +7 dB(A)</td><td>Background +5 dB(A)</td></tr><tr><td>All resources</td><td>L_{Cmax}</td><td colspan="3">100 dB(C)</td></tr></table> ⁽¹⁾ These limit values are valid as of 31.12.2023. These limit values are provided in every 1/3 octave band of the determined frequency range. In the acoustic reports prepared until this date, environmental noise measurement results and the measures determined as a result of the measurement result are included. ⁽²⁾ Businesses that broadcast music and marine vessels are included. ⁽³⁾ Each workplace that contributes to the background noise level is co-responsible for ensuring this limit value. Each workplace takes the necessary measures according to the contribution rates to noise.	Noise Source	Measured Parameter	Environmental Noise Level			Day	Evening	Night	Industrial facilities, transportation resources	L _{Aeq,5min}	65 dB(A)	60 dB(A)	55 dB(A)	Businesses that broadcast music ⁽¹⁾	L _{Aeq,63-250Hz}	60 dB(A)	55 dB(A)	50 dB(A)	Businesses ⁽²⁾	L _{Aeq,5min}	Background +5 dB(A)		Background +3 dB(A)	In case of multiple businesses ⁽³⁾	L _{Aeq,5min}	Background +7 dB(A)		Background +5 dB(A)	All resources	L _{Cmax}	100 dB(C)									
Noise Source	Measured Parameter	Environmental Noise Level																																								
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In case of multiple businesses ⁽³⁾	L _{Aeq,5min}	Background +7 dB(A)		Background +5 dB(A)																																						
All resources	L _{Cmax}	100 dB(C)																																								

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

3.DETERMINATION OF NOISE SENSITIVITY AND DEGREE OF NOISE, AS WELL AS EXPLANATIONS OF SUBJECTIVE PERCEPTIBILITY OF COMMON NOISES FROM NEIGHBORING SETTLEMENTS

Determination of Noise Sensitivity And Degree of Noise

Explanations of Subjective Perceptibility of Common Noises From Neighboring Settlements

4. Table 2.1 of Appendix-2 (Regulation/Article 11-1) determines the sensitivity to noise based on the functions of the spaces used in the residential building, if they are a source of noise, their degree of noise, and if they are a receiver of noise, their sensitivity to noise. (Table 4.5).
Table 4.5. Sensitivity to noise & degrees of noise in residential buildings (Regulation, 2017).

ON BUILDING SCALE			ON SPACE SCALE		
BUILDING FUNCTION	RESOURCE SITUATION	RECEIVER SITUATION	SPACE	RESOURCE SITUATION	RECEIVER SITUATION
	Noise levels	Noise sensitivity levels		Noise levels	Noise sensitivity levels
Residential Buildings	Moderate noise generation (OG-In Turkish)	I	Bedrooms	Moderate noise generation (OG)	I
			Living Spaces	Moderate noise generation (OG)	II
			Kitchen or Bathroom	Moderate noise generation (OG)	III
			Circulation Spaces ¹	Moderate noise generation (OG)	III
			Technical Rooms	High noise generation (YG)	III

1 Circulation area: It refers to common areas such as corridors, stair halls, and entrance halls.

NOISE SENSITIVITY LEVELS
I - high sensitivity
II - moderate sensitivity
III - low sensitivity

NOISE LEVELS
YG - High noise generation
OG - Moderate noise generation
DG - Low noise generation

5. The acoustic performance class that the residential building should have is determined according to national regulation. For subjective evaluations provided by acoustic performance classes in airborne sound insulation and impact sound insulation: Appendix-2 Table 2.2 is taken into account (Regulation/Article 11-2). (Table 4.6).

Table 4.6. Subjective evaluations on which the acoustic performance classification of places is based (Regulation, 2017)

NOISE SOURCE		ACOUSTIC PERFORMANCE CLASSIFICATION						
		High		Moderate		Low		
		A	B	C	D	E	F	
NOISE LEVEL OF THE SOURCE	SPEECH VOICE	Very loud sound	barely audible but incomprehensible	audible but barely understandable	slightly understandable	understandable	easily understandable	
		Talking loudly	barely audible	slightly audible but never understandable	audible but barely understandable	slightly understandable	understandable	easily understandable
		Normal speech	inaudible	barely audible	slightly audible but never understandable	barely understandable	slightly understandable	understandable
	MUSICAL SOUNDS	Very loud music party	slightly audible	audible	easily audible	very easily audible		
		Loud music	inaudible	slightly audible	audible	easily audible	very easily audible	
		Normal music	inaudible		slightly audible	audible	easily audible	very easily audible
	IMPACT SOUNDS	Step sound	inaudible	barely audible	slightly audible	audible	easily audible	very easily audible
		Playing child	barely audible	slightly audible	audible	easily audible	very easily audible	
		Dragging and dropping objects	inaudible	barely audible	slightly audible	audible	easily audible	very easily audible
	General Definitions at Evaluation of Different Classes		Very good protection against noise, no disturbance in all conditions	Good protection against noise, no disturbance when neighbor noise is normal	Moderate protection against noise, occasional disturbance when neighbor noise is normal	Little protection against noise, often disturbing when neighbor noise is normal	Very little protection against noise, generally disturbing when neighbor noise is normal	Unprotected against noise, constant disturbance while neighbor noise is normal
	The rate of characterization of sound insulation as poor		less than 5%	around 5%	around 10%	around 20%	around 35%	50% or more

Note: Audibility of the sources does not depend only on the construction.

6. New buildings must have at least C-class acoustic performance. If the purpose of use of an existing building changes, at least D acoustic performance class is provided for the affected independent units and at least D for the affected structural elements in the case of major renovations. The sound insulation of all building elements, including transparent components such as windows, is subject to this assessment. It is allowed that the sound insulation value provided with the door in the building elements containing the door is 14 dB lower than the limit values specified in this Regulation (Regulation/Article 11-3).

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS	Requirements Regarding Sound Insulation Limit Values	Lowest Sound Insulation Values to be Provided According to External Noise Levels and Receiver Sensitivity Degree ($D_{nT,A,tr}$,dB)	7. The lowest airborne sound insulation requirements to be taken as a basis for the exterior structural elements of the spaces whose noise sensitivity levels are determined are given in Appendix 3 Table 3.1 (Regulation/Article 11-4). (Table 4.7). Table 4.7. The lowest sound insulation values according to the external noise levels and the sensitivity of the receiver room ($D_{nT,A,tr}^{1,2}$, dB) (Regulation, 2017) <table><tr><th rowspan="2">Sensitivity of the Receiver Room</th><th colspan="6">ACOUSTIC PERFORMANCE CLASS ^{3,4}</th></tr><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td>I: high sensitivity</td><td>$L_{den}-14$</td><td>$L_{den}-18$</td><td>$L_{den}-22$</td><td>$L_{den}-26$</td><td>$L_{den}-30$</td><td>$L_{den}-34$</td></tr><tr><td>II: moderate sensitivity</td><td>$L_{den}-17$</td><td>$L_{den}-21$</td><td>$L_{den}-25$</td><td>$L_{den}-29$</td><td>$L_{den}-33$</td><td>$L_{den}-37$</td></tr><tr><td>III: low sensitivity</td><td>$L_{den}-20$</td><td>$L_{den}-24$</td><td>$L_{den}-28$</td><td>$L_{den}-32$</td><td>$L_{den}-36$</td><td>$L_{den}-40$</td></tr></table> 1 $D_{nT,A,tr} = D_{2m,nT,w} + C_{tr}$ 2 In cases specified in Article 10, $D_{2m,nT,50} = D_{2m,nT,w} + C_{tr,50-3150}$ value can also be used. 3 L_{den} values are levels measured at least 2m away from the building, excluding facade reflections. 4 For A, B, C, and D classes, in addition to the values in this table, the criteria for a minimum sound insulation value of 30 dB will be sought.	Sensitivity of the Receiver Room	ACOUSTIC PERFORMANCE CLASS ^{3,4}						A	B	C	D	E	F	I: high sensitivity	$L_{den}-14$	$L_{den}-18$	$L_{den}-22$	$L_{den}-26$	$L_{den}-30$	$L_{den}-34$	II: moderate sensitivity	$L_{den}-17$	$L_{den}-21$	$L_{den}-25$	$L_{den}-29$	$L_{den}-33$	$L_{den}-37$	III: low sensitivity	$L_{den}-20$	$L_{den}-24$	$L_{den}-28$	$L_{den}-32$	$L_{den}-36$	$L_{den}-40$																																												
		Sensitivity of the Receiver Room	ACOUSTIC PERFORMANCE CLASS ^{3,4}																																																																														
			A	B	C	D	E	F																																																																									
I: high sensitivity	$L_{den}-14$	$L_{den}-18$	$L_{den}-22$	$L_{den}-26$	$L_{den}-30$	$L_{den}-34$																																																																											
II: moderate sensitivity	$L_{den}-17$	$L_{den}-21$	$L_{den}-25$	$L_{den}-29$	$L_{den}-33$	$L_{den}-37$																																																																											
III: low sensitivity	$L_{den}-20$	$L_{den}-24$	$L_{den}-28$	$L_{den}-32$	$L_{den}-36$	$L_{den}-40$																																																																											
Lowest Airborne Sound Insulation Values According to Source and Receiver Room Characteristics ($D_{nT,A}$,dB)	8.The minimum airborne sound insulation requirements to be taken as a basis for the vertical and horizontal elements separating the spaces for which the noise and sensitivity levels are determined are given in Appendix 3 Table 3.2 (Regulation/Article 11-5). (Table 4.8). Table 4.8. The lowest airborne sound insulation values to be provided according to the source and receiver room characteristics ($D_{nT,A}^{1,2}$, dB) (Regulation, 2017). <table><tr><th rowspan="2">SOURCE ROOM NOISE LEVEL</th><th rowspan="2">SENSITIVITY OF THE RECEIVER ROOM</th><th colspan="6">ACOUSTIC PERFORMANCE CLASS ^{3,4}</th></tr><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td rowspan="3">High Level Noise (YG) $L_{AF,max} > 75$ dB</td><td>I</td><td>68</td><td>64</td><td>58</td><td>54</td><td>50</td><td>46</td></tr><tr><td>II</td><td>65</td><td>61</td><td>55</td><td>51</td><td>47</td><td>43</td></tr><tr><td>III</td><td>62</td><td>58</td><td>52</td><td>48</td><td>44</td><td>40</td></tr><tr><td rowspan="3">Moderate Level Noise (OG) $75 \geq L_{AF,max} > 55$ dB</td><td>I</td><td>62</td><td>58</td><td>52</td><td>48</td><td>44</td><td>40</td></tr><tr><td>II</td><td>59</td><td>55</td><td>49</td><td>45</td><td>41</td><td>37</td></tr><tr><td>III</td><td>56</td><td>52</td><td>46</td><td>42</td><td>38</td><td>34</td></tr><tr><td rowspan="3">Low Level Noise (DG) $L_{AF,max} \leq 55$ dB</td><td>I</td><td>56</td><td>52</td><td>46</td><td>42</td><td>38</td><td>34</td></tr><tr><td>II</td><td>53</td><td>49</td><td>43</td><td>39</td><td>35</td><td>31</td></tr><tr><td>III</td><td>50</td><td>46</td><td>40</td><td>36</td><td>32</td><td>28</td></tr></table> 1 $D_{nT,A} = D_{nT,w} + C$ 2 In cases specified in Article 10, $D_{nT,50} = D_{nT,w} + C_{50-3150}$ value can also be used. In this case, the limit values will be reduced by 4 dB. 3 For building elements containing doors: the sound insulation value provided with the door is allowed to be 14 dB lower than the limit values specified in the Regulation. 4 Regulation Appendix-3- Table 3.4 will use for partitioning elements within independent units in residential buildings. <i>* If the neighborhood relationship is not defined in the regulation, the lowest airborne sound insulation value will be determined using Appendix 3, Table 3.2 of the regulation. For source room noise and receiver room sensitivity, Regulation Appendix-2 Table 2.1 will be used (Regulation/Article 11-7).</i>	SOURCE ROOM NOISE LEVEL	SENSITIVITY OF THE RECEIVER ROOM	ACOUSTIC PERFORMANCE CLASS ^{3,4}						A	B	C	D	E	F	High Level Noise (YG) $L_{AF,max} > 75$ dB	I	68	64	58	54	50	46	II	65	61	55	51	47	43	III	62	58	52	48	44	40	Moderate Level Noise (OG) $75 \geq L_{AF,max} > 55$ dB	I	62	58	52	48	44	40	II	59	55	49	45	41	37	III	56	52	46	42	38	34	Low Level Noise (DG) $L_{AF,max} \leq 55$ dB	I	56	52	46	42	38	34	II	53	49	43	39	35	31	III	50	46	40	36	32	28
SOURCE ROOM NOISE LEVEL	SENSITIVITY OF THE RECEIVER ROOM			ACOUSTIC PERFORMANCE CLASS ^{3,4}																																																																													
		A	B	C	D	E	F																																																																										
High Level Noise (YG) $L_{AF,max} > 75$ dB	I	68	64	58	54	50	46																																																																										
	II	65	61	55	51	47	43																																																																										
	III	62	58	52	48	44	40																																																																										
Moderate Level Noise (OG) $75 \geq L_{AF,max} > 55$ dB	I	62	58	52	48	44	40																																																																										
	II	59	55	49	45	41	37																																																																										
	III	56	52	46	42	38	34																																																																										
Low Level Noise (DG) $L_{AF,max} \leq 55$ dB	I	56	52	46	42	38	34																																																																										
	II	53	49	43	39	35	31																																																																										
	III	50	46	40	36	32	28																																																																										
Highest impact sound levels to be provided based on source and receiver room characteristics ($L_{nT,w}$,dB)	9. The highest impact sound limit values to be taken as a basis for the floors separating the spaces for which the noise and sensitivity levels are determined are given in Appendix 3, Table 3.3 (Regulation/Article 11-6). (Table 4.9). Table 4.9. Highest impact sound levels to be provided according to source and receiver room characteristics ($L'_{nT,w}^1$, dB) (Regulation, 2017). <table><tr><th rowspan="2">SOURCE ROOM NOISE LEVEL</th><th colspan="6">ACOUSTIC PERFORMANCE CLASS ²</th></tr><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td>High Level Noise (YG)</td><td>40</td><td>44</td><td>48</td><td>52</td><td>56</td><td>60</td></tr><tr><td>Moderate Level Noise (OG)</td><td>46</td><td>50</td><td>54</td><td>58</td><td>62</td><td>66</td></tr><tr><td>Low Level Noise (DG)</td><td>50</td><td>54</td><td>58</td><td>62</td><td>66</td><td>70</td></tr></table> 1 In cases specified in Article 14, the value $L'_{nT,50} = L'_{nT,w} + C_{I, 50-2500}$ can also be used. In this case, the limit values will be increased by 4 dB. 2 Regulation Appendix-3- Table 3.5 will use for partition elements in independent units in residential buildings. <i>* If the neighborhood relationship is not defined in the regulation, the maximum impact sound limit value will be determined using Appendix 3 Table 3.3 of the regulation. For source room noise and receiver room sensitivity, Regulation Appendix-2 Table 2.1 will be used (Regulation/Article 11-7).</i>	SOURCE ROOM NOISE LEVEL	ACOUSTIC PERFORMANCE CLASS ²						A	B	C	D	E	F	High Level Noise (YG)	40	44	48	52	56	60	Moderate Level Noise (OG)	46	50	54	58	62	66	Low Level Noise (DG)	50	54	58	62	66	70																																														
SOURCE ROOM NOISE LEVEL	ACOUSTIC PERFORMANCE CLASS ²																																																																																
	A	B	C	D	E	F																																																																											
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Moderate Level Noise (OG)	46	50	54	58	62	66																																																																											
Low Level Noise (DG)	50	54	58	62	66	70																																																																											

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS	Requirements Regarding Sound Insulation Limit Values		Lowest Airborne Sound Insulation Values to be Provided between Adjacent Volumes in Different Building Types ($D_{nT,A}$, dB)	10. The neighborhood relations of adjacent or adjacent volumes are defined for frequently encountered building types and spaces, and the relevant limit values are given in Appendix 3 Tables 3.4 and 3.5 (Table 4.10). Table 4.10. The lowest airborne sound insulation values to be provided between adjacent volumes in different building types ($D_{nT,A}^{1,2}$, dB) (Regulation, 2017) <table><tr><th rowspan="2">Building Function</th><th colspan="2">ADJACENT RELATION</th><th colspan="6">ACOUSTIC PERFORMANCE CLASS³</th></tr><tr><th>Source Room</th><th>Receiver Room</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td rowspan="5">RESIDENTIAL BUILDING</td><td>Commercial Use Technical Room</td><td>Independent unit</td><td>68</td><td>64</td><td>58</td><td>54</td><td>50</td><td>46</td></tr><tr><td>Independent unit Common Area</td><td>Independent unit Common Area</td><td>62</td><td>58</td><td>52</td><td>48</td><td>44</td><td>40</td></tr><tr><td>Bedroom</td><td>Located in the same independent unit;</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Living Areas</td><td>Bedroom</td><td>54</td><td>50</td><td>44</td><td>40</td><td>36</td><td>32</td></tr><tr><td>Kitchen / Bathroom</td><td>Living Areas</td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table> 1 $D_{nT,A} = D_{nT,w} + C$ 2 In cases specified in Article 10, $D_{nT,50} = D_{nT,w} + C_{50-3150}$ value can also be used. 3 For building elements containing doors: the sound insulation value provided with the door is allowed to be 14 dB lower than the limit values specified in the Regulation	Building Function	ADJACENT RELATION		ACOUSTIC PERFORMANCE CLASS ³						Source Room	Receiver Room	A	B	C	D	E	F	RESIDENTIAL BUILDING	Commercial Use Technical Room	Independent unit	68	64	58	54	50	46	Independent unit Common Area	Independent unit Common Area	62	58	52	48	44	40	Bedroom	Located in the same independent unit;							Living Areas	Bedroom	54	50	44	40	36	32	Kitchen / Bathroom	Living Areas						
	Building Function	ADJACENT RELATION		ACOUSTIC PERFORMANCE CLASS ³																																																										
		Source Room	Receiver Room	A	B	C	D	E	F																																																					
	RESIDENTIAL BUILDING	Commercial Use Technical Room	Independent unit	68	64	58	54	50	46																																																					
Independent unit Common Area		Independent unit Common Area	62	58	52	48	44	40																																																						
Bedroom		Located in the same independent unit;																																																												
Living Areas		Bedroom	54	50	44	40	36	32																																																						
Kitchen / Bathroom		Living Areas																																																												
		Highest Impact Sound Levels for Source Room Floors in Different Building Types ($L_{nT,w}$, dB)	11. The neighborhood relations of adjacent or adjacent volumes are defined for frequently encountered building types and spaces, and the relevant limit values are given in Appendix -3 Tables 3.4 and 3.5 (Table 4.11). Table 4.11. Highest impact sound levels in residential buildings source room floors ($L'_{nT,w}^1$, dB) (Regulation, 2018). <table><tr><th rowspan="2">Building Function</th><th colspan="2">ADJACENT RELATION</th><th colspan="6">ACOUSTIC PERFORMANCE CLASS</th></tr><tr><th colspan="2">Source Room (Upper Floor)</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td rowspan="4">RESIDENTIAL BUILDINGS</td><td colspan="2">Independent unit Common Area</td><td>46</td><td>50</td><td>54</td><td>58</td><td>62</td><td>66</td></tr><tr><td colspan="2">Commercial Use Technical Room, Rooftop equipment</td><td>40</td><td>44</td><td>48</td><td>52</td><td>56</td><td>60</td></tr><tr><td colspan="2">Floors inside the same dwelling</td><td>54</td><td>58</td><td>62</td><td>66</td><td>70</td><td>74</td></tr></table> 1 In cases specified in Article 14, the value $L_{nT,50} = L_{nT,w} + C_1$, 50-2500 can also be used.	Building Function	ADJACENT RELATION		ACOUSTIC PERFORMANCE CLASS						Source Room (Upper Floor)		A	B	C	D	E	F	RESIDENTIAL BUILDINGS	Independent unit Common Area		46	50	54	58	62	66	Commercial Use Technical Room, Rooftop equipment		40	44	48	52	56	60	Floors inside the same dwelling		54	58	62	66	70	74																	
Building Function	ADJACENT RELATION		ACOUSTIC PERFORMANCE CLASS																																																											
	Source Room (Upper Floor)		A	B	C	D	E	F																																																						
RESIDENTIAL BUILDINGS	Independent unit Common Area		46	50	54	58	62	66																																																						
	Commercial Use Technical Room, Rooftop equipment		40	44	48	52	56	60																																																						
	Floors inside the same dwelling		54	58	62	66	70	74																																																						
	Permissible Indoor Noise Levels in Spaces		Maximum Permissible Indoor Noise Levels Based on Acoustic Performance Class, dB	12. Permissible indoor noise levels in residential buildings, depending on the acoustic performance class, are given in Table 4.1 of Appendix 4 (Regulation/Article 12-1). (Table 4.12). Table 4.12. Maximum permissible indoor noise levels depending on the acoustic performance class, dB (Regulation, 2018). <table><tr><th rowspan="3">BUILDING FUNCTION</th><th rowspan="3">AREA</th><th rowspan="3">TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00</th><th colspan="6">Indoor Noise Level, L_{Aeq}^1</th></tr><tr><th colspan="6">ACOUSTIC PERFORMANCE CLASS</th></tr><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td rowspan="3">Residential Buildings</td><td>Bedroom</td><td>Night</td><td>26</td><td>30</td><td>34</td><td>38</td><td>42</td><td>46</td></tr><tr><td>Living Areas</td><td>24 hours</td><td>31</td><td>35</td><td>39</td><td>43</td><td>47</td><td>51</td></tr><tr><td>Kitchen</td><td>24 hours</td><td>31</td><td>35</td><td>39</td><td>43</td><td>47</td><td>51</td></tr></table> 1 If there are sudden sounds, sounds with low-frequency components, singular noise events, and tonal components in the internal noise characteristic, evaluations will be made by applying corrections according to TS 9315 ISO 1996-1.	BUILDING FUNCTION	AREA	TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00	Indoor Noise Level, L_{Aeq}^1						ACOUSTIC PERFORMANCE CLASS						A	B	C	D	E	F	Residential Buildings	Bedroom	Night	26	30	34	38	42	46	Living Areas	24 hours	31	35	39	43	47	51	Kitchen	24 hours	31	35	39	43	47	51												
BUILDING FUNCTION	AREA	TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00	Indoor Noise Level, L_{Aeq}^1																																																											
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Residential Buildings	Bedroom	Night	26	30	34	38	42	46																																																						
	Living Areas	24 hours	31	35	39	43	47	51																																																						
	Kitchen	24 hours	31	35	39	43	47	51																																																						
Limit Values for Internal Noise Originating from Installation and Service Equipment		Highest Permissible Internal Noise Levels Due to Continuous Noise Service Equipment	13. At least the C class is provided for new buildings. Furthermore, in existing buildings, in the case of a change in the purpose of the use or a substantial renovation, at least the D class is provided (Regulation/Article 12-3). 14. Noise levels arising from service equipment producing continuous noise cannot exceed the values in Appendix 5, Table 5.1 (Regulation/Article 13-1). (Table 4.13). Table 4.13. Highest permissible indoor noise levels due to continuous noise service equipment (Regulation, 2017) <table><tr><th rowspan="3">BUILDING FUNCTION</th><th rowspan="3">AREA</th><th rowspan="3">TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00</th><th colspan="6">Service equipment noise level, $L_{Aeq,aT}^1$</th></tr><tr><th colspan="6">ACOUSTIC PERFORMANCE CLASS</th></tr><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td rowspan="3">Residential Buildings</td><td>Bedroom</td><td>Night</td><td>22</td><td>26</td><td>30</td><td>34</td><td>38</td><td>42</td></tr><tr><td>Living Areas</td><td>24 hours</td><td>27</td><td>31</td><td>35</td><td>39</td><td>43</td><td>47</td></tr><tr><td>Kitchen</td><td>24 hours</td><td>27</td><td>31</td><td>35</td><td>39</td><td>43</td><td>47</td></tr></table> 1 It is calculated by subtracting 4 dBA from the internal noise levels given in Regulation Appendix-4- Table 4.1. 15. At least the C class is provided for new buildings. Furthermore, in existing buildings, in the case of a change in the purpose of the use or a substantial renovation, at least the D class is provided (Regulation/Article 12-3).	BUILDING FUNCTION	AREA	TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00	Service equipment noise level, $L_{Aeq,aT}^1$						ACOUSTIC PERFORMANCE CLASS						A	B	C	D	E	F	Residential Buildings	Bedroom	Night	22	26	30	34	38	42	Living Areas	24 hours	27	31	35	39	43	47	Kitchen	24 hours	27	31	35	39	43	47													
BUILDING FUNCTION	AREA	TIME PERIOD Night : 23.00 – 07.00 Evening: 19.00 – 23.00 Day: 07.00-19.00	Service equipment noise level, $L_{Aeq,aT}^1$																																																											
			ACOUSTIC PERFORMANCE CLASS																																																											
			A	B	C	D	E	F																																																						
Residential Buildings	Bedroom	Night	22	26	30	34	38	42																																																						
	Living Areas	24 hours	27	31	35	39	43	47																																																						
	Kitchen	24 hours	27	31	35	39	43	47																																																						

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

4. LIMIT VALUES FOR ACOUSTIC PERFORMANCE CLASSES IN BUILDINGS	Limit Values for Internal Noise Originating from Installation and Service Equipment	Highest Permissible Internal Noise Levels Due to Intermittent Noise Service Equipment	16. Noise levels arising from service equipment producing intermittent noise cannot exceed the values in Table 5.2 of Appendix 5 (Regulation/AArticle 13-2). (Table 4.14). Table 4.14. Highest permissible indoor noise levels due to other plumbing and service equipment (Regulation, 2017) <table><tr><th rowspan="3">RECEIVER AND NOISE SOURCE</th><th colspan="6">Service equipment noise level, $L_{AF,max,nT}$</th></tr><tr><th colspan="6">ACOUSTIC PERFORMANCE CLASS</th></tr><tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr><tr><td>Service equipment with intermittent noise</td><td>26</td><td>30</td><td>34</td><td>38</td><td>42</td><td>46</td></tr></table>	RECEIVER AND NOISE SOURCE	Service equipment noise level, $L_{AF,max,nT}$						ACOUSTIC PERFORMANCE CLASS						A	B	C	D	E	F	Service equipment with intermittent noise	26	30	34	38	42	46
		RECEIVER AND NOISE SOURCE	Service equipment noise level, $L_{AF,max,nT}$																										
			ACOUSTIC PERFORMANCE CLASS																										
A	B		C	D	E	F																							
Service equipment with intermittent noise	26	30	34	38	42	46																							
Noise Levels from Elevators	17. In addition to regulation data, British standards can be consulted for noise levels from elevators (İnce and Demirel, 2022). The values given in Table 4.15 for maximum noise levels from elevators in the residential unit should be considered as upper guide values. Noise and vibration must be minimized at the source for lower levels to occur in practice (BS 8233, 2014). Table 4.15. Noise levels from elevators in places (BS 8233, 2014). <table><tr><th>Room</th><th>Maximum noise level (dB $L_{Amax,F}$)</th></tr><tr><td>Bedroom</td><td>25</td></tr><tr><td>Living Room</td><td>30</td></tr><tr><td>Other Areas</td><td>35</td></tr><tr><td colspan="2">Note: These values only include both airborne and structural noise from elevators regardless of the transmission mechanism and do not take into account other noise sources.</td></tr></table> 18. In order not to exceed the maximum noise levels specified in the legislation, the elevator motor and related equipment should be installed in a suitable place. Anti-vibration mounts should be used to prevent vibration from being transmitted to any part of the living space. Elevators should be located in such a way as to minimize disturbances caused by noise. Elevator doors should work silently and acoustically. Signals announcing the arrival of the elevator should not be heard in the residences (BS 8233, 2014). 19. Elevator lobbies: Elevator operating noise and any occupancy level in any part of the elevator loop, including announcements, must not exceed 55 dB $L_{Amax, F}$ (BS 8233, 2014).	Room	Maximum noise level (dB $L_{Amax,F}$)	Bedroom	25	Living Room	30	Other Areas	35	Note: These values only include both airborne and structural noise from elevators regardless of the transmission mechanism and do not take into account other noise sources.																			
Room	Maximum noise level (dB $L_{Amax,F}$)																												
Bedroom	25																												
Living Room	30																												
Other Areas	35																												
Note: These values only include both airborne and structural noise from elevators regardless of the transmission mechanism and do not take into account other noise sources.																													
Limit Values for Reverberation Time	20. The highest limit values of the allowed reverberation time in residential buildings are given in Table 6.1 of Appendix 6. These values are used in the calculation of the lowest airborne sound insulation values required from the building elements (Regulation/Article 14-1). (Table 4.16). Table 4.16. Highest reverberation times to be provided depending on the acoustic performance class ¹ (Regulation, 2017). <table><tr><th rowspan="2">BUILDING FUNCTION</th><th rowspan="2">Area</th><th>ACOUSTIC PERFORMANCE CLASS</th></tr><tr><th>C - D²</th></tr><tr><td rowspan="3">Residential Buildings</td><td>Circulation areas ³</td><td>1.2</td></tr><tr><td>Bedroom</td><td>0.5</td></tr><tr><td>Living areas, kitchen</td><td>0.8</td></tr></table> ¹ The limit value given is the arithmetic mean of the values at frequencies of 250, 500, 1000, and 2000 Hz. ² For other performance classes, the international limit values will be examined and the acoustic expert will decide on the limitvalues. ³ "Circulation area" refers to common areas such as corridors, stair halls, and entrance halls.	BUILDING FUNCTION	Area	ACOUSTIC PERFORMANCE CLASS	C - D ²	Residential Buildings	Circulation areas ³	1.2	Bedroom	0.5	Living areas, kitchen	0.8																	
BUILDING FUNCTION	Area			ACOUSTIC PERFORMANCE CLASS																									
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Residential Buildings	Circulation areas ³	1.2																											
	Bedroom	0.5																											
	Living areas, kitchen	0.8																											

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

5. INSTALLATION AND SERVICE EQUIPMENT NOISE CONTROL MEASURES

Noise Control in Installation and Service Equipment

Ventilation Ducts

21. Ventilation duct sections are designed to provide air velocities suitable for the characteristics of the building and the minimum noise levels given in Appendix 5.1. During these designs, the noise level in the duct is also calculated (Regulation/Appendix 8.1-1).

22. In the ventilation ducts, in case the minimum noise levels given in Appendix 5.1 are exceeded due to the characteristics of the building, in-duct sound insulation is applied to ensure the minimum noise level. Relevant calculations and project details are prepared (Regulation /Appendices 8.1–2).

23. In high-speed ducts, measures are taken with flexible material to prevent air leaks that may occur in duct connections. Care is taken to ensure that the air flow through the duct is smooth, that no sudden cross-section and direction changes are made, and that the duct cross-section is not chosen too small (Regulation/Appendix 8.1-3).

24. The length of the canal to which the material to be used in the lining of the canal will be applied is determined by calculation. sound-absorbing material to be used for this purpose; especially at low frequencies, the absorption coefficient is selected to be high. If fibrous material is to be used, precautions must be taken to prevent the fibers from breaking and moving with the air. Materials for channel lining or double wall applications are chosen based on calculations and the material's sound reduction improvement performance (Regulation / Appendix 8.1- 4).

25. Flexible special hangers without a sound bridge are used for hanging the ducts to the steel structure carrier system and the metal grid constructions carrying the ducts to the upper reinforced concrete carrier system. In places where the duct hangers pierce the acoustically suspended ceiling, sound leakage is prevented with rubber gaskets (Regulation/Appendix 8.1–5).

26. In addition to the regulation, data on HVAC noise in American standards can be consulted (İnce ve Demirel, 2022). Table 4.17 (ASHRAE, 2015) and Table 4.18 (AHRI, 2008) include the design guidelines for HVAC systems in American legislation.

Table 4.17. Design guidelines for HVAC background sound in rooms (ASHRAE, 2015).

Design Guidelines for HVAC Related Background Sound In Rooms				
		Octave Band Analysis	Approximate Overall	Sound Pressure Level
Room Types		NC/RC	dBA	dBC
Residences, Apartments, Condominiums	Living Areas	30	35	60
	Bathrooms, Kitchens, Utility Rooms	35	40	60

Table 4.18. Design guidelines for HVAC system noise in unoccupied spaces (AHRI,2008).

Design Guidelines for HVAC System Noise in Unoccupied Spaces	
Space	RC (N)
Residences, Apartments, Condominiums	25 to 35

Control of Equipment Noise

27. It is essential that all devices and equipment that may be a source of noise in the mechanical or electrical installation inside or outside the building be selected in a way that can provide the minimum noise levels given in this appendix (Regulation/Appendix 8.2-1).

28. Vibration isolators are used in the connection of service equipment to the ground and in pipe and duct connections (Regulation/Appendix 8.2-2).

29. Service equipment is placed on inertia blocks, the dimensions of which will be determined according to the calculations to be made depending on their weight on the ground (Regulation/Appendix 8.2-3).

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

5. INSTALLATION AND SERVICE EQUIPMENT NOISE CONTROL MEASURES	Control of Equipment Noise	Fans- Fancoils	30. Measures are taken to ensure the values given in Annex 5 for fans and fan coils (Regulation/Annex 8.2.1-1). 31. Fans cannot be placed on the ceiling of places that are very sensitive to noise without taking precautions (Regulation/Appendix 8.2.1-2). 32. A quiet fan type with reduced noise emission should be selected. Airflow, fan speed, and static pressure should be adjusted to reduce noise, and the fan should be directed to reduce air turbulence (Regulation/Annex 8.2.1-3). 33. For noisy fans, lined fan boxes are made, the metal wall thickness is increased, or inner-lined soundproof boxes are used (Regulation/Appendix 8.2.1-4). 34. Care should be taken that the fan and fan coil boxes do not come into direct contact with the ceiling boards and other carriers that will create a sound bridge and that flexible cushions are used in between (Regulation/Appendix 8.2.1-5).
		Combi Devices	35. Combi boilers to be found in kitchens and bathrooms in the residences are selected to provide the minimum noise levels given in this Appendix 5.1 (Regulation /Appendix 8.2.2-1).
		Acoustic Louvers	36. Special details based on calculations are required for acoustic blinds (Regulation /Appendix 8.2.3-1). 37. For ready-made shutter units, an experiment report determined by measurements according to the standards specified in Appendix -1 is required (Regulation /Appendix 8.2.3-2).
		Chillers	38. In addition to our national regulation, noise control measures related to chillers are included in England legislation. (İnce ve Demirel,2022). If chillers are located near sensitive areas due to high noise and vibration generation, they should be located in a sheltered area. Air gaps that will cause sound transmission should be avoided. Flexible assemblies are often required in the installation (BS 8233, 2014).
		Noise Control Principles for Roofing Equipment	39. Adequate sound insulation will be provided in the cabins of the roof equipment (Regulation/Appendix 8.2.4-1). 40. If the insulation of the ready-made cabins is insufficient, they will be placed in rooms with high sound insulation. In these rooms, the walls, ceiling, floor, and doors will be soundproofed (Regulation/Appendix 8.2.4-2). 41. Special impact sound and vibration control for the equipment to be found on the roof will be made based on calculations, and the measures to be taken will be shown in the architectural and acoustic project (Regulation/Appendix 8.2.4-3). 42. Horizontal and vertical noise maps will be prepared using the noise emission values given at the spectral level for the equipment placed on the roof. Sound levels from surrounding buildings will be displayed at all floor levels. It will also be stated whether it exceeds the limit value (Regulation/Annex 8.2.4-4). 43. The effect of the airborne and impact sounds transmitted by the roof equipment to the lower floors on the neighboring spaces will be estimated by calculation, and measures will be taken (Regulation/Appendix 8.2.4-5). 44. According to the calculation results, if necessary, an acoustic project will be prepared for noise shielding on the roof, and the adequacy of the noise reduction effect of the curtain will be demonstrated. Reflections will be prevented by covering the inner surfaces of the noise curtain with sound-absorbing material (Regulation/Appendix 8.2.4-6). 45. In addition to national regulations, R_w values can be consulted for roofs covered by England legislation (İnce and Demirel, 2022). Roofs and mansards generally have lower sound insulation than masonry facades. The performance of various roof types is indicated in Table 4.19. According to this legislation, skylights should be avoided as precipitation noise can be a problem on light roofs. (BS 8233, 2014).

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

5. INSTALLATION AND SERVICE EQUIPMENT NOISE CONTROL MEASURES	Control of Equipment Noise	Noise Control Principles for Roofing Equipment	Table 4.19. Sound insulation of roofs (BS 8233, 2014). <table><tr><th>Roof Type</th><th>Weighted sound reduction index R_w dB</th></tr><tr><td>Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling</td><td>43</td></tr><tr><td>100 mm flat concrete roof (230 kg/m²)</td><td>52</td></tr><tr><td>Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation</td><td>45</td></tr></table>	Roof Type	Weighted sound reduction index R_w dB	Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling	43	100 mm flat concrete roof (230 kg/m ²)	52	Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation	45
		Roof Type	Weighted sound reduction index R_w dB								
		Tiles on felt, pitched roof with 100 mm mineral wool on plasterboard ceiling	43								
		100 mm flat concrete roof (230 kg/m ²)	52								
Flat timber joist roof, asphalt on boarding, 12 mm plasterboard ceiling, thermal insulation	45										
Noise Control Principles for Plumbing and Other Mechanical , Electrical Service Equipment	46. Precautions will be taken in such a way that all kinds of water pipes adjacent to places that are very and moderately sensitive to noise in buildings do not come into direct contact with either the carrier system or other building elements. Flexible hangers, supports, and fasteners are used in mandatory fixations (Regulation/Appendix 8.2.5-1). 47. All kinds of water supply and discharge system noise levels in buildings that are very and moderately sensitive to noise are selected and implemented in such a way that they meet the values in Appendix 5.2 (Regulation/Appendix 8.2.5-2). 48. Inertia block and vibration isolators based on calculations are selected for the control of impact noise and vibrations caused by pumps, heat exchangers, and similar equipment (Regulation / Appendix 8.2.5-3). 49. In elevator machine rooms and elevator shafts, noise control is made to ensure the airborne sound levels described in Appendix 5.2. At the same places, noise and vibration control measures are taken regarding impact sounds and mechanical vibrations (Regulation/Appendix 8.2.5-4). 50. Garbage chimneys cannot be built adjacent to places that are very sensitive to noise (Regulation/Appendix 8.2.5-5).										
Noise and Vibration Control in Mechanical	51. Mechanical centers on or adjacent to places that are very sensitive to noise and sensitive to noise are designed according to the double-wall application based on acoustic calculations (Regulation/Appendix 8.3-1). 52. The suspended ceiling in the installation center is designed as soundproof, and its details are included in the acoustic project (Regulation/Appendix 8.3-2). 53. The desired insulation values for the doors are calculated. The wall where the door is located will provide the relevant insulation values given in this Regulation (Regulation/Appendix 8.3-3). 54. In order to prevent noise transmission through mechanical installation shafts, calculations are made and noise control is applied to the shaft walls (Regulation/Appendix 8.3-4).										
6. DESIGN CRITERIA AND NOISE CONTROL MEASURES FOR INDOOR NOISE	Noise Control Measures	<u>To minimize the disturbance caused by the noise produced in the indoor environment:</u> While the relevant articles are mentioned in the appendix of the regulations (2017) and the Guidance on the Acoustic Design, Application, and Inspection of Buildings, similar articles are also mentioned in the England and America legislation. <i>According to England's legislation,</i> 55. Residential building services should be kept away from bedrooms. When placing bedrooms next to elevators and stairs, circulation areas should be created where less sensitive rooms are used as buffers. Accommodation buildings should be designed and constructed to provide reasonable resistance to sound from other parts of the same building and from adjacent buildings. Rooms in adjoining residences can be made more cohesive by creating identical housing plans. Sound-absorbing materials should be applied to the ceiling surfaces of common corridors and stairwells to reduce noise propagation throughout the building. Flexible floor coverings such as carpets can be used to minimize noise transmission from footsteps on stair steps, corridors, and landings (BS 8233, 2014; Approved Document E, 2010).									

Table 4.1. (continue) Establishment of acoustic performance criteria for residential buildings

6. DESIGN CRITERIA	Noise Control Measures	Noise Control Measures	According to American legislation; 56. The placement of living units adjacent to mechanical equipment rooms and work areas, either vertically or horizontally, should be avoided as far as possible. Where living units are located above noisy areas, double wall construction is often necessary to provide adequate acoustic privacy, as airborne sound insulation is important. (FHA,1967).
7. ACOUSTIC PERFORMANCE CLASS AND CERTIFICATION		Acoustic Performance Class And Certification	57. The validity of the Acoustic Performance Certificate is 10 years (Regulation/Appendix 10.1-1). 58. The acoustic assessment is valid until a change is made in the building's acoustic design or outside noise levels. (Regulation/Appendix 10.1- 2). 59. When there is a change in the project or function of the building during the design or usage phase, the new performance class is determined by calculations (Regulation/Appendix 10.1-3) 60. Measurements are made in the completed building in accordance with the standards specified in Appendix 9. Measurements are made by certified personnel and acoustic experts (Regulation/Appendix 10.1-4). 61. The acoustic properties to be determined are: a) Acoustic performance class for airborne sound insulation of external building elements b) Acoustic performance class for airborne sound insulation of partition elements c) Acoustic performance class for impact sound insulation of floors d) Acoustic performance class according to internal noise levels from service equipment e) Acoustic performance class according to internal noise levels in various places to be selected by the expert f) Reverberation time (Regulation/Appendix 10.1- 5). 62. A sufficient number of measurements should be made for the respective acoustic property. In particular, noise-sensitive spaces and existing lateral transmissions need to be carefully examined. Volumes with low frequency and duration of use, such as kitchens, bathrooms, and warehouses, are not chosen as receiver rooms for measurements unless necessary (Regulation/Appendix 10.1-6). 63. For this purpose, preliminary calculations should also be made. A sufficient number of sample elements for each situation is determined by the acoustic expert. When measuring in unfurnished rooms, a calculation is used to correct the results so that they represent the furnished state (Regulation/Appendix 10.1- 7). 64. In order to assign an acoustic performance class for the entire building or for an individual unit, all measurement results must meet the desired values. No result should differ adversely by more than 2 dB from the desired limit value for that class. If $D_{nT,50}$ and $L_{nT,50}$ values are measured in rooms with a volume of less than 25 m³, an extra 2 dB of flexibility is provided (Regulation/Appendix 10.1- 8). 65. If different stand-alone units, rooms, or acoustic features show different performance classes, the lowest performance class value obtained is assigned. (Regulation/Appendix 10.1- 9). 66. Determining the acoustic class for the whole building: It is prepared if the acoustic project prepared by the acoustic expert is found and the necessary inspections are made. The number of samples should be at least 5% of all spaces and structural elements in the building for the measurements to be made for airborne and solid-media-borne sound insulation, reverberation time, installation, and indoor noise levels. In buildings without acoustic projects, the number of samples should be 10% of all spaces and building elements (Regulation/Appendix 10.1-10). 67. The minimum number of measurements for each structural element type and acoustic performance evaluation criterion is three. If a single independent unit is to be evaluated, the minimum number of measurements is two (Regulation/Appendix 10.1-11). 68. Determination of acoustic performance class for independent units: In order to assign an acoustic performance class to a single independent unit in a building, the ninth paragraph above is applied. At least two samples are taken for each type of building element, space, or acoustic characteristic (Regulation/Appendix 10.1-12).

5. CASE STUDY: AN EXISTING RESIDENTIAL BUILDING IN ANKARA PROVINCE EMEK NEIGHBORHOOD

In this study, within the scope of the Regulation, which forms the basis of the thesis subject, an independent unit belonging to the existing residential building was analyzed with the simulation program Insul (v9.0.24).

5.1. General Information About the Residential Building

The selected residential building was designed in 2003 by Fazlıoğlu Architecture and Engineering Ltd. Sti., and it is in the current building category. This structure is located on 5294 blocks and 23 parcels in Ankara province, Çankaya district, Emek neighborhood (see picture 5.1).



Picture 5.1. The location of the residential building in Çankaya (Yandex Map)

The selected residential building consists of 2 basement floors, a ground floor, 3 floor plans, and an attic floor plan (<7 floors: Acoustic reports can be prepared for residences with less than seven floors, excluding a basement and an attic (Regulation, 2018)). The total construction area used is 1603.44 m² for one block, excluding one basement and attic (<2000 m²). Within the framework of the Regulation on Protection of Buildings Against Noise, an acoustic report is required according to the construction area and the number of floors. In this context, an acoustic report has been prepared for this independent unit (Figure 5.1).

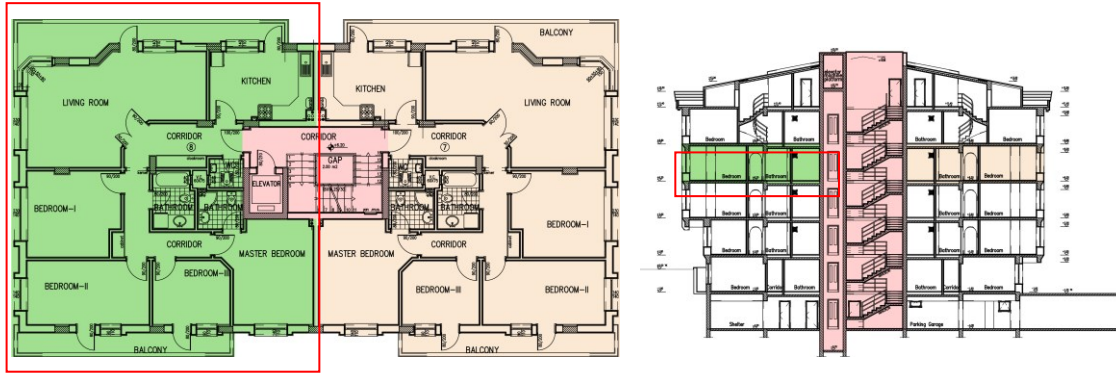


Figure 5.1. The plan and section of the residential building selected as the sample

The selected residential building is of the 4+1 plan type, and only the bedroom and kitchen units are adjacent to the adjacent flat. Wet areas and circulation units are located in the middle of the floor plan. While the wet areas act as a buffer zone for the residential building, the elevator and staircase use the same building element as the bedroom. However, it is seen that there is no sound insulation in the sections.

The project for the residential building has been obtained, and there are warehouses, a shelter, and a parking lot for the apartments on the second basement floor of the building. Due to the slope of the land, there are 1 3+1 and 1 4+1 flats on the first basement floor. There are twin 4+1 flats on the ground floor, first-floor, and second-floor plans (*the residential building chosen as the sample is located on the second floor*). In the third floor plan of the residential building, there are twin 4+1 flats as in the other floor plans; additionally, in this floor plan, there are stairs in the apartments in order to access the attic. In 2 flats on this floor, there are 2 rooms, a wooden attic, and a terrace. A bathroom is also added to the rooms on the front facade. Residential building users stated that they were disturbed by the sound of the air conditioners, which are frequently operated due to the overheating of the attic, especially at night when the background noise decreases.

Views of the residential building selected as a sample are given below. The sample is highlighted in red (Figures 5.2, 5.3, 5.4, and 5.5).



Figure 5.2. Front View of the Building



Figure 5.3. Right View of the Building

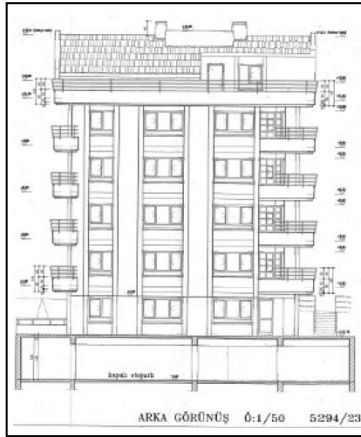


Figure 5.4. Rear View of the Building

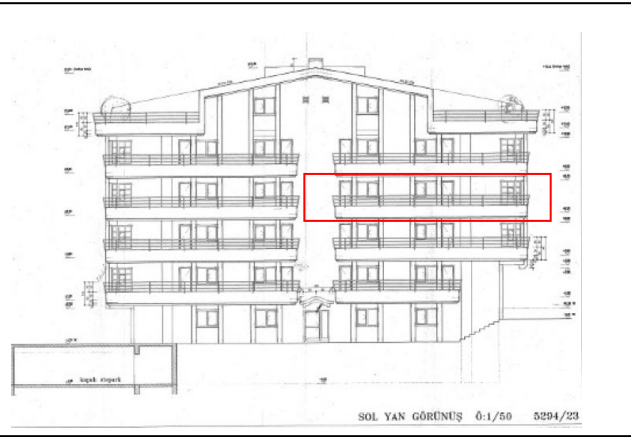


Figure 5.5. Left View of the Building

5.2. Environmental Noise Analysis

The noise level for this residential building has been provided by strategic noise maps obtained from Ankara Metropolitan Municipality. Information about the noise level is given in Table 5.1.

Table 5.1. Determination of noise level with strategic noise map

Level	Situation plan	Lejant	Reference															
L_{den}, dB(A) (Day-evening-night sound level)	 Location of the Building <table><thead><tr><th colspan="2">Exterior Noise Facade Values</th><th>L_{den} dB(A)</th></tr></thead><tbody><tr><td>1</td><td>The loudest facade</td><td>55-59 dB(A)</td></tr><tr><td>2</td><td></td><td>55-59 dB(A)</td></tr><tr><td>3</td><td>Silent facade</td><td>55-59 dB(A)</td></tr><tr><td>4</td><td></td><td>55-59 dB(A)</td></tr></tbody></table>	Exterior Noise Facade Values		L _{den} dB(A)	1	The loudest facade	55-59 dB(A)	2		55-59 dB(A)	3	Silent facade	55-59 dB(A)	4		55-59 dB(A)	Gürültü Seviyesi L_{gag} (dBA) L_{den} (dBA) Gürültü Düzeyi Bandı Noise Level Band 55-59 60-64 65-69 70-74 ≥75 Semboller ve İşaretler Key For Other Map Layers Konutlar Residential Okullar Schools Hastaneler Hospitals Diğer Binalar Other Buildings Karayolları Roads Hesaplama Alanı Calculation Area Aglomerasyon Sınırı Agglomeration Boundary Mahalle Sınırları Mahalle Borders N 1/25000 NMPB '96 Eylül 2015 September 2015	Appendix-1a: Ankara Province Çankaya District (All Highways) Noise Level Map (2015 data)
Exterior Noise Facade Values		L _{den} dB(A)																
1	The loudest facade	55-59 dB(A)																
2		55-59 dB(A)																
3	Silent facade	55-59 dB(A)																
4		55-59 dB(A)																
L_{night}, dB(A) (Night sound level)	 Location of the Building <table><thead><tr><th colspan="2">Exterior Noise Facade Values</th><th>L_{night} dB(A)</th></tr></thead><tbody><tr><td>1</td><td>The loudest facade</td><td>50-54 dB(A)</td></tr><tr><td>2</td><td></td><td>50-54 dB(A)</td></tr><tr><td>3</td><td>Silent facade</td><td>50-54 dB(A)</td></tr><tr><td>4</td><td></td><td>50-54 dB(A)</td></tr></tbody></table>	Exterior Noise Facade Values		L _{night} dB(A)	1	The loudest facade	50-54 dB(A)	2		50-54 dB(A)	3	Silent facade	50-54 dB(A)	4		50-54 dB(A)	Gürültü Seviyesi L_{gece} (dBA) L_{night} (dBA) Gürültü Düzeyi Bandı Noise Level Band 50-54 55-59 60-64 65-69 ≥70 Semboller ve İşaretler Key For Other Map Layers Konutlar Residential Okullar Schools Hastaneler Hospitals Diğer Binalar Other Buildings Karayolları Roads Hesaplama Alanı Calculation Area Aglomerasyon Sınırı Agglomeration Boundary Mahalle Sınırları Mahalle Borders N 1/25000 NMPB '96 Eylül 2015 September 2015	Appendix -1b: Ankara Province Çankaya District (All Highways) Noise Level Map (2015 data)
Exterior Noise Facade Values		L _{night} dB(A)																
1	The loudest facade	50-54 dB(A)																
2		50-54 dB(A)																
3	Silent facade	50-54 dB(A)																
4		50-54 dB(A)																

The distance of the examined housing sample to Mevlana Boulevard, which creates a high noise level, is approximately 350 meters. There are mostly residential buildings around the residential building, and there are two schools a few streets away. *Due to the existing environmental noise sources causing a disturbance in the residential building, 59, which is the upper value of the limit value, was evaluated.*

In addition to traffic noise, the main source of noise is the sounds of the surrounding construction site, the air conditioning units located on the roof of the residential building,

and the announcements of schools that are rarely heard. Environmental noise sources affecting the building are given in Table 5.2.

Table 5.2. Environmental noise sources affecting the building

External Noise Sources	Distance to Building, m	Activity Duration	Activity Hours
Highway Noise	350 m	24 hour	All day
Construction Site Sounds	~ 100-150 m	11 hour	08.00 - 19.00
Air Conditioning Units on Rooftop	On the Rooftop	24 hour	All day (in summer)
Announcement Voice of Schools	~ 200 m	10 hours (at regular intervals)	08.00- 18.00

5.3. Preparation of Key Layouts

Project-specific information, such as the code numbers of the building components for the exterior walls, interior partition walls, floors, and the lists of the building elements, which are marked on the floor plans, are given on the key sheets. The limit values and the sound insulation values and codes foreseen to be provided are shown together in Table 5.3.

Table 5.3. Determination of the project codes of the residential building

Structural Element	Structural Element Code	Source	Receiver Room
Exterior structural elements	dd		
	dd-1a	Environmental Noise	Bedroom 1 (I)
	dd-1b, dd-2a	Environmental Noise	Bedroom 2 (I)
	dd-2b	Environmental Noise	Bedroom 3 (I)
	dd-2c	Environmental Noise	Master Bedroom (I)
	dd-1, dd-2	Environmental Noise	Living Room (II)
I: High-sensitive volumes to noise II: Medium-sensitive volumes to noise III: Less sensitive volumes to noise The coding on the outer walls is done according to the most sensitive area. For this reason, the facades of the spaces (living room and bedrooms) with medium and high sensitivity to noise are considered the receiving spaces.			
Interior structural elements	di	Source Room	Receiver Room
	di-1	Neighboring Independent Unit (Kitchen) (OG)	Independent Unit (Kitchen) (III)
	di-1a	Neighboring Independent Unit (Master Bedroom) (OG)	Independent Unit (Master Bedroom) (I)
	di-2	Independent Unit (Kitchen) (OG)	Same Independent Unit (Living Room) (II)
	di-2a	Independent Unit Corridor (OG)	Same Independent Unit (Living Room) (II)
	di-2b	Independent Unit (Living Room) (OG)	Same Independent Unit (Bedroom -1) (I)
	di-2c	Independent Unit Corridor (OG) / Bedroom-2 (OG)	Same Independent Unit (Bedroom -1) (I)
	di-2d	Independent Unit Corridor (OG)	Same Independent Unit (Bedroom -2) (I)

Table 5.3. (continue) Determination of the project codes of the residential building

Interior structural elements	di-2e	Independent Unit (Bedroom -2) (OG) / Master Bedroom (OG)/ Corridor (OG)	Same Independent Unit (Bedroom -3) (I)
	di-2f	Independent Unit Corridor (OG) / Master Bedroom Bathroom (OG)	Same Independent Unit (Master Bedroom) (I)
	di-3	Elevator (YG)	Independent Unit (Master Bedroom) (I)
	di-3a	Elevator (YG)	Independent Unit (Bathroom) (III)
	di-4	Circulation Area (Stairs) (OG)	Independent Unit (Master Bedroom) (I)
	di-4a	Circulation Area (Apartment Corridor) (OG)	Independent Unit (Corridor) (III)
	di-4b	Circulation Area (Apartment Corridor) (OG)	Independent Unit (Kitchen) (III)
I: High-sensitive volumes to noise II: Medium-sensitive volumes to noise III: Less sensitive volumes to noise YG(in Turkish): High Level Noise OG(in Turkish): Medium Level Noise DG(in Turkish): Low-level noise * The place with higher sensitivity should be selected as the "receiver," and the limit value should be read from the table. If the sensitivity levels of the two volumes are the same, the smaller room in m ² should be chosen as the receiver room (Regulation, 2017).			
Floors	do	Source Room	Receiver Room
	do-1	Independent Unit (Bedroom) (OG)	Independent Unit (Bedroom) (I)
	do-2	Independent Unit (Living Room) (OG)	Independent Unit (Living Room) (II)
I: High-sensitive volumes to noise II: Medium-sensitive volumes to noise III: Less sensitive volumes to noise YG(in Turkish): High Level Noise OG(in Turkish): Medium Level Noise DG(in Turkish): Low-level noise The limit values in the regulation are only defined for the source room. According to the regulation, spaces such as kitchens and bathrooms are not selected for the receiver. Therefore, the flooring in these spaces was not taken into account.			

The codes of the external structural elements of the independent unit discussed are given in Figure 5.6; the codes of the interior partition wall elements are given in Figure 5.7; and the codes of the flooring are given in Figure 5.8.

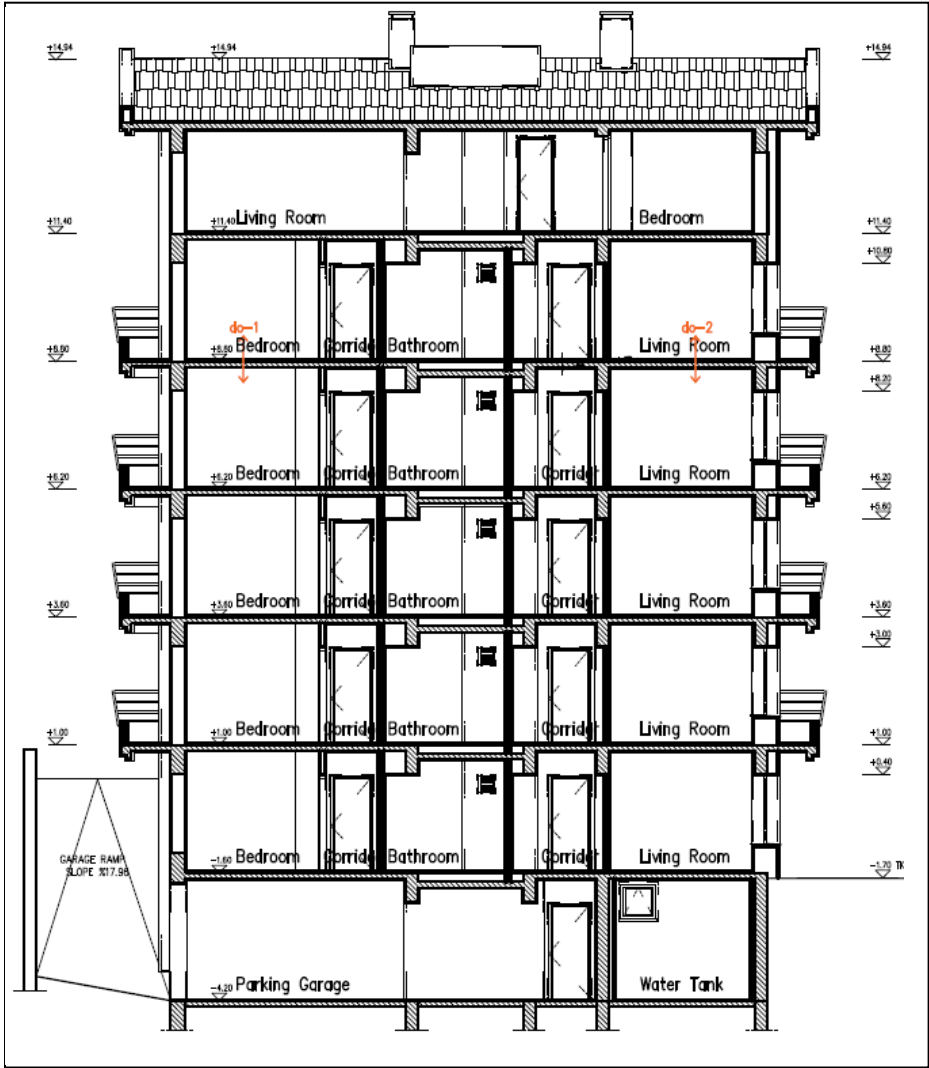


Figure 5.8. Flooring Codes for the Second Floor Plan

5.4. Comparison of Target Limit Values and Values of Existing Structural Elements

Since the selected residential building is a 19-year-old building, it will be evaluated in the existing building category. For this reason, the D-class acoustic performance class is targeted in the acoustic report. The codes specified in Table 5.3 are discussed in detail in this section, and the comparison of the limit values specified in the project according to the regulation and the sound insulation values that are expected to be provided with the existing building elements is given in Table 5.4.

Table 5.4. Limit values and predicted values to be provided by the selected residential building according to the regulation (the upper value of 59 for the L_{den} limit value specified in Section 5.2).

Targeted Acoustic Performance Class: D								
Structural Element	Code	Source	Receiver	Lowest airborne sound insulation values $D_{nT,A}$,dB		Highest impact sound levels L_{nTw} ,dB		Description of the structural element
				Limit value (*)	Provided value	Limit value (**)	Provided value	
Exterior structural elements	dd			$D_{nT,A,tr}$	$D_{nT,A,tr}$			
	dd-1	Environmental Noise	Living Room (Degree of sensitivity: II)	$L_{g-a}-29$ (59-29)=30dB	33,81	-	-	Table 5.6
	dd-1a	Environmental Noise	Bedrom 1 (Degree of sensitivity: I)	$L_{den}-26$ (59-26)=33dB	30	-	-	Table 5.6
	dd-1b	Environmental Noise	Bedrom 2 (Degree of sensitivity: I)	$L_{den}-26$ (59-26)=33dB	32	-	-	Table 5.6
	dd-2	Environmental Noise	Living Room (Degree of sensitivity: II)	$L_{den}-29$ (59-29)=30dB	36,55	-	-	Table 5.6
	dd-2a	Environmental Noise	Bedrom 2 (Degree of sensitivity: I)	$L_{den}-26$ (59-26)=33dB	33	-	-	Table 5.6
	dd-2b	Environmental Noise	Bedrom 3 (Degree of sensitivity: I)	$L_{den}-26$ (59-26)=33dB	31	-	-	Table 5.6
	dd-2c	Environmental Noise	Master Bedrom (Degree of sensitivity: I)	$L_{den}-26$ (59-26)=33dB	33	-	-	Table 5.6
	-For the L_{den} value, noise level maps were used (see Appendices-1a and -1b). - The coding on the outer walls is done according to the most sensitive area. The kitchen was not calculated because the regulation states that measurements should not be taken in low-sensitivity bathrooms, kitchens, and so on unless absolutely necessary. -Conversions were performed using the confidence interval (güven aralı) and simple method specified in the regulation and Appendix 2.							
	di-1	Neighbouring Independent Unit (Kitchen) (OG)	Independent Unit (Kitchen) (III)	48	51	-	-	Table 5.7

Table 5.4. (continue) Limit values and predicted values to be provided by the selected residential building according to the regulation

<i>Interior structural elements</i>	di-1a	Neighboring Independent Unit (Master Bedroom) (OG)	Independent Unit (Master Bedroom) (I)	48	51	-	-	Table 5.7
	di-2	Independent Unit (Kitchen) (OG)	Same Independent Unit (Living Room) (II)	40	52,98	-	-	Table 5.7
	di-2a	Independent Unit Corridor (OG)	Same Independent Unit (Living Room) (II)	40	51,28	-	-	Table 5.7
	di-2b	Independent Unit (Living Room) (OG)	Same Independent Unit (Bedroom -1) (I)	40	51,65	-	-	Table 5.7
	di-2c	Independent Unit Corridor (OG) / Bedroom-2 (OG)	Same Independent Unit (Bedroom -1) (I)	40	45	-	-	Table 5.7
	di-2d	Independent Unit Corridor (OG)	Same Independent Unit (Bedroom -2) (I)	40	45	-	-	Table 5.7
	di-2e	Independent Unit (Bedroom -2) (OG) / Master Bedroom (OG) / Corridor (OG)	Same Independent Unit (Bedroom -3) (I)	40	45	-	-	Table 5.7

Representation in plan with legends: analysis of neighborhood relations

The spaces defined in the regulation are clearly indicated on the floor plans and on the same sheet by using a legend. By preparing space lists, location codes, building element codes, and limit values are shown. In Figure 5.9, the defined limit values for exterior and interior structural elements are as follows: while they are shown on the same plans in the key sections, airborne and impact sound insulations for floors are shown in a separate visual in Figure 5.10.

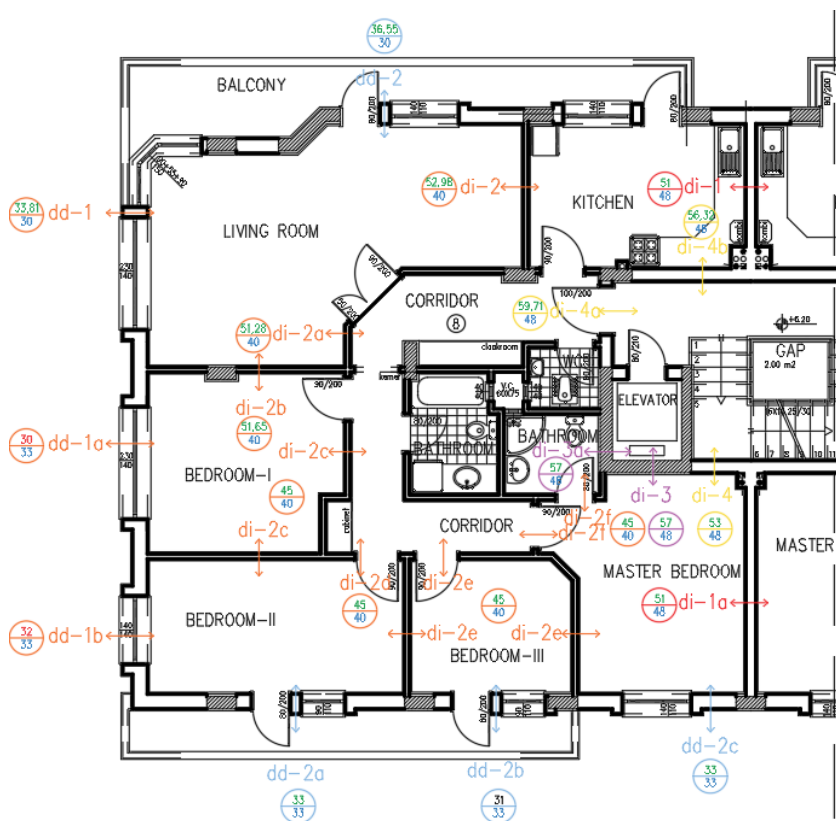


Figure 5.9. Desired and provided airborne sound pressure levels on exterior walls and interior partition walls

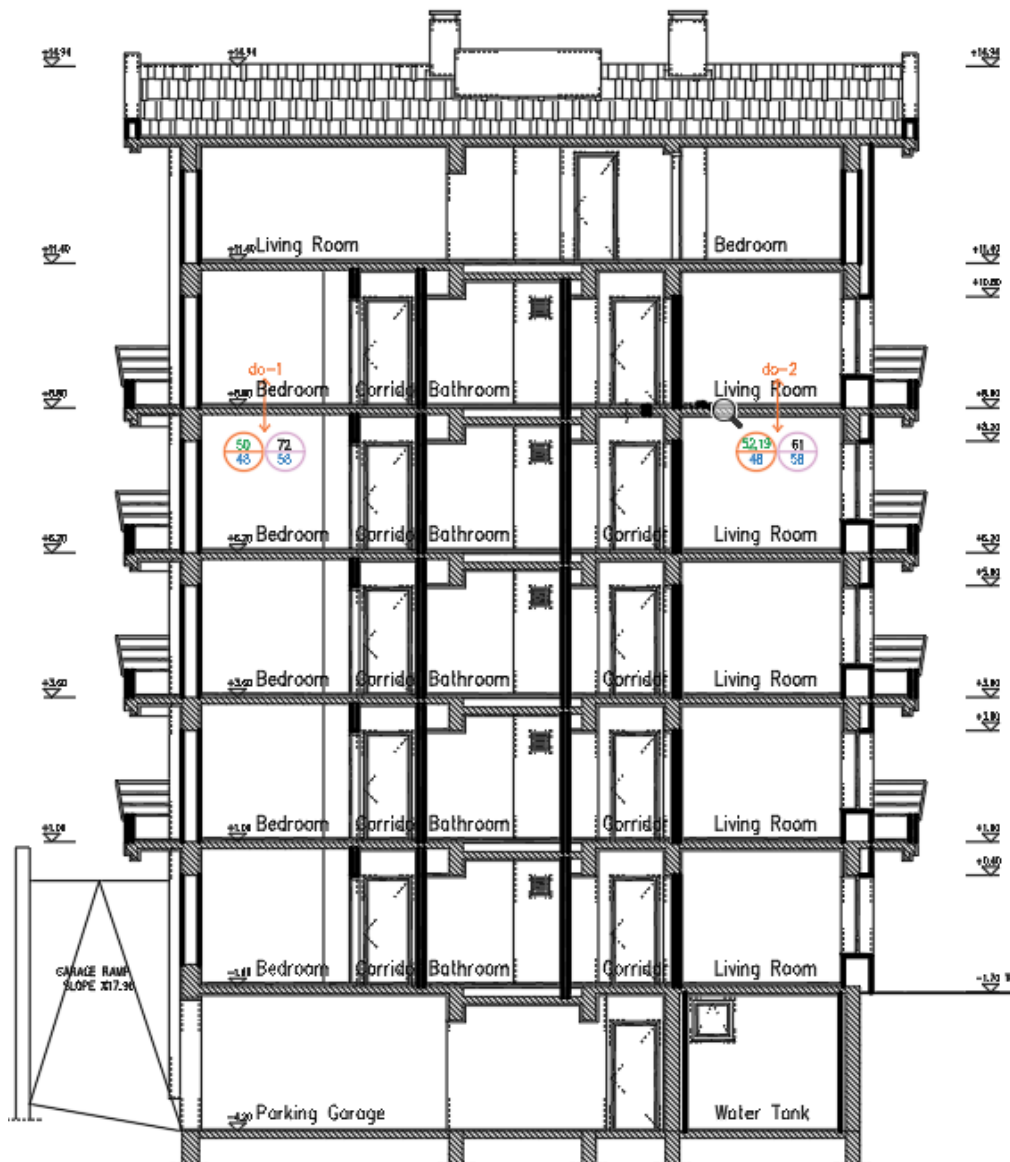
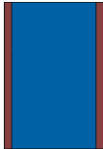
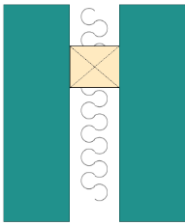
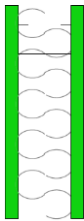


Figure 5.10. Desired and provided airborne and impact sound pressure levels in floors

5.5. Determination of Structural Element Types

The R_w (C,Ctr), dB and $L_{n,w}$, dB values of the current project's materials and construction were calculated using the Insul program. Appendix-2 contains the desired D_{nT} , A, tr, dB values; D_{nT} , A, dB values; and the calculation methods used in the conversion to L'_{nTw} , dB values. The data on the reliability of the Insul program used in the thesis are given in Table 5.5. The program may differ by ± 3 dB from the laboratory results.

Table 5.5. The reliability of the Insul program

Reference	Material Information of Building Components	Detail of Building Component [Insul simulation program]	Measurement Results in Laboratory Conditions: $R_w - STC$	Expected Transmission Loss in Field Conditions: R'_w	Insul Simulation Program: $R_w - STC$
W.Cavanaugh, J.Wilkes, G. Tocci (2010)	6-in. solid concrete, ½ -in. plaster both sides, p.62		53		53
J.H. Rindel (2018)	two layer windows 4 – 12 – 4(mm) , p.272		34		33
	Wall thickness 100 mm, 1+1 plate layers, Cavity depth 75 mm, Mineral wool thickness 45 mm, , p.270		42–44	~ 40	44
M. Mehta, J. Johnson, J. Rocafort (1999)	Two layers of 16 mm gypsum board, 63 mm steel studs, and two layers of 16 mm gypsum board, 53 kg/m2 p.124		46		47
	16 mm gypsum board, 63 mm steel studs, and 16 mm gypsum board, 27 kg/m2 p.124		37		35
	150 mm reinforced concrete wall		56		54

The material layers of the exterior and interior walls, the codes of which are specified in the project, and the airborne sound insulation information are given in Tables 5.6 and 5.7, respectively. The material layers of the floors and the airborne and impact sound insulation information are given in Table 5.8.

Table 5.6. Exterior wall elements

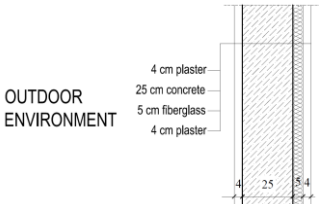
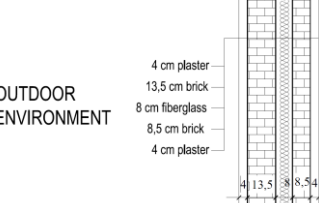
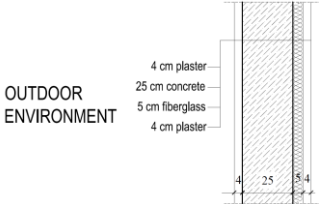
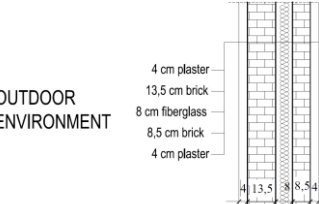
Structural Element	Wall Code and Components	Structural Element Type	$R_w(C;Ctr)$, dB	$D_{nT,A,tr}$, dB	Reference
Exterior structural elements	<i>dd-1</i> <u>Top of the window:</u> reinforced concrete wall (4cm plaster-25cm reinforced concrete-5cm thermal insulation-4cm plaster) - R_w: 61(-1,-4) <u>Window:</u> 4cm glass- 12cm gap- 6cm glass - R_w: 36 (-3,-6) <u>Under the window:</u> double layer brick wall (4 cm plaster-13,5 cm brick-8 cm thermal insulation- 8,5 cm brick- 4 cm plaster) - R_w: 60 (-2,-5)	<i>Top of the window:</i>  <i>Under the Window:</i> 	39(-2,-6)	33,81	Appendix - 3a
	<i>dd-1a</i> <u>Top of the window:</u> reinforced concrete wall (4cm plaster-25cm reinforced concrete-5cm thermal insulation-4cm plaster) - R_w: 61(-1,-4) <u>Window:</u> 4cm glass- 12cm gap- 6cm glass - R_w: 36(-3,-6) <u>Under the window:</u> double layer brick wall (4 cm plaster-13,5 cm brick-8 cm thermal insulation- 8,5 cm brick- 4 cm plaster) - R_w: 60 (-2,-5)	<i>Top of the window:</i>  <i>Under the Window:</i> 	40(-2,-6)	30	Appendix - 3b

Table 5.6. (continue) Exterior wall elements

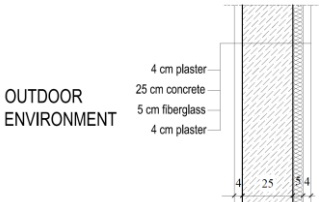
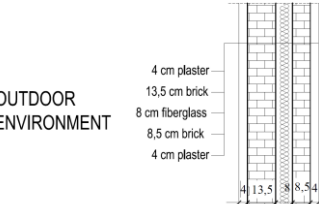
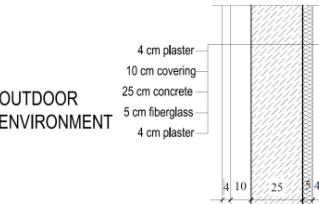
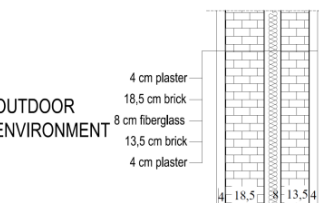
Exterior structural elements	<i>dd-1b</i> <u>Top of the window:</u> reinforced concrete wall (4cm plaster-25cm reinforced concrete-5cm thermal insulation-4cm plaster) - $R_w: 61(-1,-4)$ <u>Window:</u> 4cm glass- 12cm gap- 6cm glass - $R_w: 36(-3,-6)$ <u>Under the window:</u> double layer brick wall (4 cm plaster-13,5 cm brick-8 cm thermal insulation- 8,5 cm brick- 4 cm plaster) - $R_w: 60 (-2,-5)$	<i>Top of the window:</i>  <i>Under the Window:</i> 	42(-3,-6)	32	Appendix - 3c
	<i>dd-2</i> <u>Top of the window:</u> reinforced concrete wall (4cm plaster-25cm reinforced concrete-5cm thermal insulation-4cm plaster) – $R_w: 61(-1,-4)$ <u>Window:</u> 4cm glass- 12cm gap- 6cm glass - $R_w: 36(-3,-6)$ <u>Under the window:</u> double layer brick wall (4cm plaster-18,5cm brick- 8cm thermal insulation-13,5cm brick-4cm plaster) - $R_w: 64(-2,-7)$	<i>Top of the window:</i>  <i>Under the Window:</i> 	43(-2,-6)	36,55	Appendix - 3d

Table 5.6. (continue) Exterior wall elements

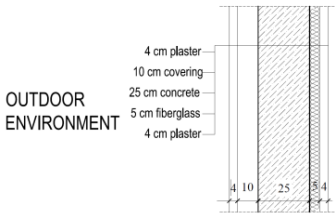
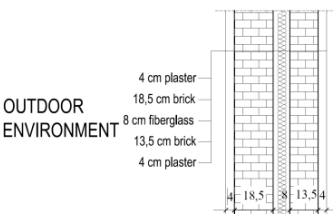
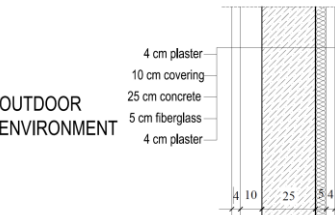
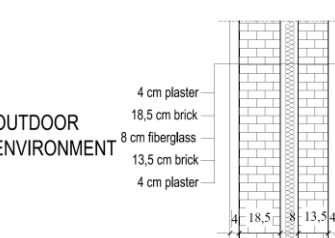
Exterior structural elements	<i>dd-2a</i> <u>Top of the window:</u> reinforced concrete wall (4cm plaster-25cm reinforced concrete-5cm thermal insulation-4cm plaster) - Rw: 61(-1,-4) <u>Window:</u> 4cm glass- 12cm gap- 6cm glass - Rw: 36(-3,-6) <u>Under the window:</u> double layer brick wall (4cm plaster-18,5cm brick- 8cm thermal insulation-13,5cm brick-4cm plaster) - Rw: 64(-2,-7)	<i>Top of the window</i> :  <i>Under the Window:</i> 	43(-2,-6)	33	Appendix - 3e
	<i>dd-2b</i> <u>Top of the window:</u> reinforced concrete wall (4cm plaster-25cm reinforced concrete-5cm thermal insulation-4cm plaster) - Rw: 61(-1,-4) <u>Window:</u> 4cm glass- 12cm gap- 6cm glass - Rw: 36(-3,-6) <u>Under the window:</u> double layer brick wall (4cm plaster-18,5cm brick- 8cm thermal insulation-13,5cm brick-4cm plaster) - Rw: 64(-2,-7)	<i>Top of the window:</i>  <i>Under the Window:</i> 	41(-2,-6)	31	Appendix - 3f

Table 5.6. (continue) Exterior wall elements

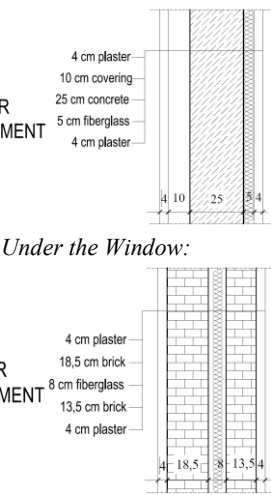
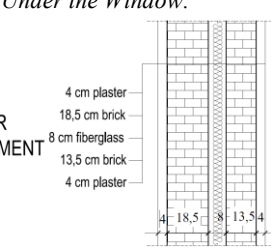
<i>Exterior structural elements</i>	<i>dd-2c</i> <u>Top of the window:</u> reinforced concrete wall (4cm plaster-25cm reinforced concrete-5cm thermal insulation-4cm plaster) - Rw: 61(-1,-4) <u>Window:</u> 4cm glass- 12cm gap- 6cm glass - Rw: 36(-3,-6) <u>Under the window:</u> double layer brick wall (4cm plaster-18,5cm brick- 8cm thermal insulation-13,5cm brick-4cm plaster) - Rw: 64(-2,-7)	<i>Top of the window:</i>  <i>Under the Window:</i> 	43(-2,-6)	33	Appendix - 3g
For bedrooms, the confidence interval (güven aralığı) method was used to convert to the $D_{nT,A,tr}$ value. However, since the hall does not comply with the condition defined in the regulation (a: width, b:length<5m), the conversion of the R_w value will be done with a simple method. Detailed information is given in Appendix 2. - Since it is aimed to stay within the confidence interval, the 10 cm covering was not taken into account, as the material on the dd-2 walls was not defined in the project.					

Table 5.7. Interior partition wall elements

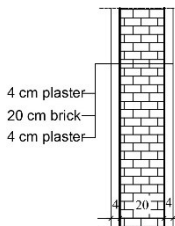
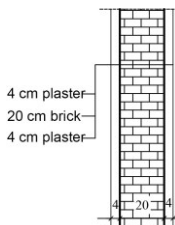
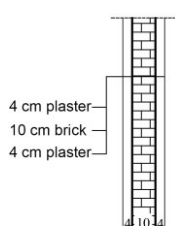
Structural Element	Wall Code and Components	Structural Element Type	$R_w(C;Ctr),dB$	$D_{nT,A,tr},dB$	Reference
<i>Interior Partition Wall Elements</i>	<i>di-1</i> 20 cm brick wall between flats * 4cm plaster * 20 cm brick * 4cm plaster		55(-1,-4)	51	Appendix - 4a
	<i>di-1a</i> 20 cm brick wall between flats * 4cm plaster * 20 cm brick * 4cm plaster		55(-1,-4)	51	Appendix - 4a
	<i>di-2</i> 10 cm brick wall between same flat * 4cm plaster * 10 cm brick * 4cm plaster		49 (-1,-3)	52,98	Appendix - 4b

Table 5.7. (continue) Interior partition wall elements

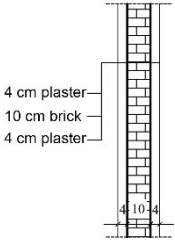
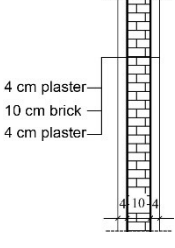
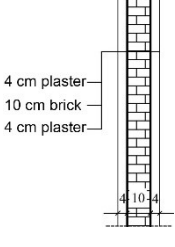
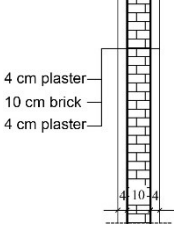
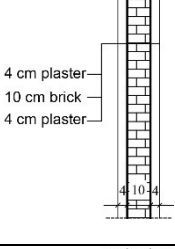
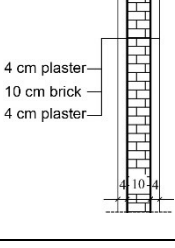
Interior Partition Wall Elements	<i>di-2a</i> 10 cm brick wall between same flat * 4cm plaster * 10 cm brick * 4cm plaster		49 (-1,-3)	51,28	Appendix -4c
	<i>di-2b</i> 10 cm brick wall between same flat * 4cm plaster * 10 cm brick * 4cm plaster		49 (-1,-3)	51,65	Appendix -4d
	<i>di-2c</i> 10 cm brick wall between same flat * 4cm plaster * 10 cm brick * 4cm plaster		49 (-1,-3)	45	Appendix -4e
	<i>di-2d</i> 10 cm brick wall between same flat * 4cm plaster * 10 cm brick * 4cm plaster		49 (-1,-3)	45	Appendix -4e
	<i>di-2e</i> 10 cm brick wall between same flat * 4cm plaster * 10 cm brick * 4cm plaster		49 (-1,-3)	45	Appendix -4e
	<i>di-2f</i> 10 cm brick wall between same flat * 4cm plaster * 10 cm brick * 4cm plaster		49 (-1,-3)	45	Appendix -4e

Table 5.7. (continue) Interior partition wall elements

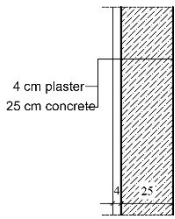
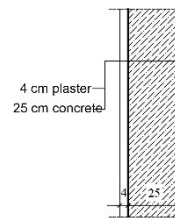
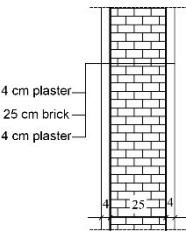
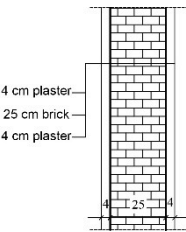
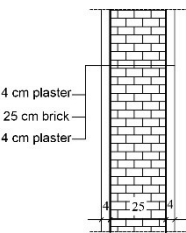
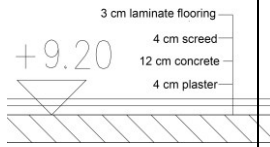
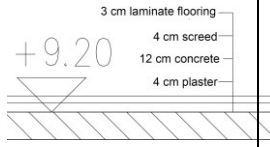
Interior Partition Wall Elements	<i>di-3</i> Around the elevator * 4cm plaster * 25 cm reinforced concrete wall		61(-1,-5)	57	Appendix -4f
	<i>di-3a</i> Around the elevator * 4cm plaster * 25 cm reinforced concrete wall		61(-1,-5)	57	Appendix -4f
	<i>di-4</i> Around the apartment corridor * 4cm plaster * 25 cm brick * 4cm plaster		58(-2,-5)	53	Appendix -4g
	<i>di-4a ***</i> Around the apartment corridor * 4cm plaster * 25 cm brick * 4cm plaster		49(-1,-6)	51,71	Appendix -4h
	<i>di-4b</i> Around the apartment corridor * 4cm plaster * 25 cm brick * 4cm plaster		58(-2,-5)	56,32	Appendix -4i

Table 5.8. Floor elements

Structural Element	Wall Code and Components	Structural Element Type	Airborne Sound		Impact Sound		Reference
			R_w (C;Ctr), dB	$D_{nT,A}$, dB	$L_{n,w}$, dB	$L'_{nT,w}$, dB	
Floors	<i>do-1</i> *3cm laminate flooring *4cm screed *12cm reinforced concrete *4cm plaster		54(-1,-3)	50	69(-6)	72	Appendix -5a
	<i>do-2</i> *3cm laminate flooring *4cm screed *12cm reinforced concrete *4cm plaster		54(-1,-3)	52,19	69(-6)	61	Appendix -5b

5.6. Displaying Point Details

Since the building elements' ability to provide the values specified in the regulation in the discussed residential building largely depends on the application conditions and sound bridges, point details are included in this section. It is important to apply the connection detail principles shown in these drawings in order to achieve better sound insulation (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

Figure 5.11 can be determined as the connection detail of the double-layer brick wall used in the exterior building elements and the brick walls used as the interior divider in the selected residential building. However, no sealed mattress was used in the project of the residential building, and the inner wall layer was not interrupted by the partition wall.

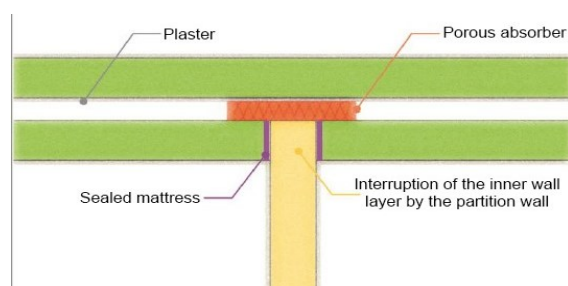


Figure 5.11. Exterior wall - interior wall connection detail (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

Figure 5.12 shows the precautions to be taken against impact noise on floors. In the residential building under consideration, no sound insulation measures have been taken on the floors, and there are no impact sound insulation membranes, flexible filling, or sealed mattress materials.

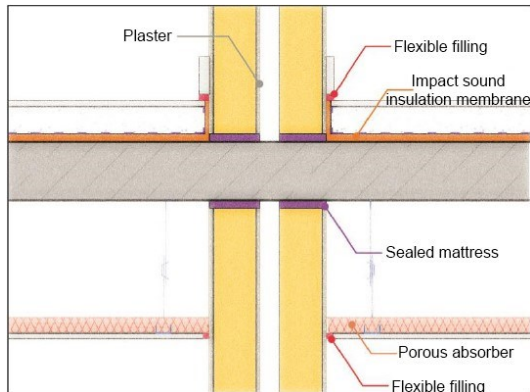


Figure 5.12. Wall-floor joint detail (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

Figure 5.13 shows the precautions to be taken against primarily impact sound and secondarily airborne sound on floors. However, there is no sound insulation measure for the installation system in the residential building. To prevent installation noise, it is necessary to use a porous absorber and flexible filling layers.

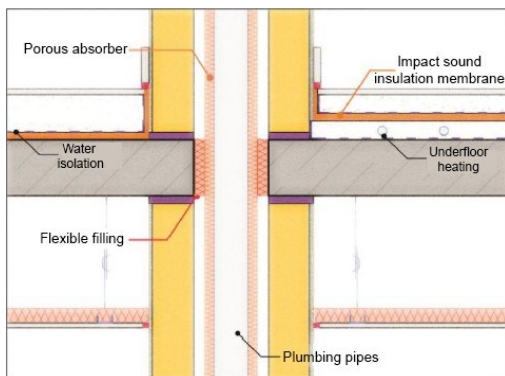


Figure 5.13. Floor - installation system connection detail (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

5.7. Internal Noise Levels from Plumbing and Service Equipment

The location and technical data of the equipment could not be reached within the scope of the acoustic report. Since the simulation/calculation method was used in the thesis, the

sound of water from the main bathroom could not be measured in the rooms. For this reason, this section falls within the limitations of the thesis and was excluded from the evaluation.

5.8. Determination of Indoor Noise Levels

In determining the indoor noise level, it is necessary to show that the permissible value is achieved by comparing the measured levels in the buildings with the limit values. However, measurements cannot be made due to the use of simulation/calculation methods in the thesis. For this reason, this section falls within the limitations of the thesis and was excluded from the evaluation.

5.9. Reverberation Time Control

In this study, the reverberation time will be determined by calculation, and the reverberation time will be calculated in the volumes of the kitchen, living room, master bedroom (chosen because it is a larger volume), and apartment halls defined in the regulation. The value it is expected to provide will be compared with the limit value.

To stay in the safe zone in the bedrooms, the parent bedroom, which is thought to be unable to meet the limit value due to its larger square meters, was chosen as the sample. The room volumes in the other bedrooms were expected to be smaller, and the items were expected to meet the limit value due to their absorbing feature. Therefore, they were not considered samples.

Reverberation time calculation

$$T = \frac{0.16V}{A_{\text{total}}}$$

$$A_{\text{total}} = S_1 \cdot \alpha_1 + S_2 \cdot \alpha_2 + S_3 \cdot \alpha_3 \dots$$

T : Reverberation time, sec (calculated based on frequencies)

V : Volume, m³

A total: Equivalent total absorption area

S1 : Area covered with type 1 material, m²

α1 : Absorption coefficient of type 1 material

S2 : Area covered with type 2 material, m²

α2 : Absorption coefficient of type 2 material (Kılavuz, 2018).

(3.3)

Table 5.9. Calculation of the reverberation time in the kitchen volume

Calculating Reverberation Time – Kitchen															
Surface	Material	Area (S) m ²	Volume (V) m ³	Frequency (Hz)						Frequency (Hz)					
				125	250	500	1000	2000	4000	125	250	500	1000	2000	4000
				a	a	a	a	a	a	Sxa	Sxa	Sxa	Sxa	Sxa	Sxa
Floor *															
Kitchen Floor - 13 m ²	Marble or glazed tile	10		0.01	0.01	0.01	0.01	0.02	0.02	0.10	0.10	0.10	0.10	0.20	0.20
	Wool Carpet 10 mm	3		0.09	0.08	0.21	0.26	0.27	0.37	0.27	0.24	0.63	0.78	0.81	1.11
Ceiling															
Ceiling	concrete, plastered surface	13		0.01	0.01	0.01	0.01	0.02	0.02	0.13	0.13	0.13	0.13	0.26	0.26
Wall															
Door	Solid timber door	3.4		0.14	0.10	0.06	0.08	0.10	0.10	0.47	0.34	0.20	0.27	0.34	0.34
Window	Glass,ordinary window	1.54		0.35	0.25	0.18	0.12	0.07	0.04	0.53	0.38	0.27	0.18	0.10	0.06
Walls	plaster on brick	27.02		0.01	0.02	0.02	0.03	0.04	0.05	0.27	0.54	0.54	0.81	1.08	1.35
	Plaster on concrete block	13.52		0.12	0.09	0.07	0.05	0.05	0.04	1.62	1.21	0.94	0.67	0.67	0.54
	Chair, metal or wood seat, unoccupied	1.5		0.15	0.19	0.22	0.39	0.38	0.30	0.22	0.28	0.33	0.58	0.57	0.45
	Curtains hung in folds	5.28		0.05	0.15	0.35	0.40	0.50	0.50	0.26	0.79	1.84	2.11	2.64	2.64
Volume	h=2.6 m														
Kitchen	Air= Air, 50%RH C°, m ³		33.8				0.01	0.01	0.03				0.33	0.33	1.01
Total			33.8							3.87	4.01	4.98	5.96	7.00	7.96

$$T_{\text{kitchen}} = 0,161V/\Sigma A$$

$$T_{\text{required}}$$

125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1.40	1.35	1.09	0.91	0.77	0.68
0.8	0.8	0.8	0.8	0.8	0.8

Table 5.10. Calculation of the reverberation time in the living room volume

Calculating Reverberation Time – Living Room															
Surface	Material	Area (S) m ²	Volume (V) m ³	Frequency (Hz)						Frequency (Hz)					
				125	250	500	1000	2000	4000	125	250	500	1000	2000	4000
				a	a	a	a	a	a	Sxa	Sxa	Sxa	Sxa	Sxa	Sxa
Floor*															
Living room floor	Wood parquet on concrete	18		0.04	0.04	0.07	0.06	0.06	0.07	0.72	0.72	1.26	1.08	1.08	1.26
	Wool Carpet 10 mm	12		0.09	0.08	0.21	0.26	0.27	0.37	1.08	0.96	2.52	3.12	3.24	4.44
Ceiling															
Ceiling	concrete, plastered surface	30		0.01	0.01	0.01	0.02	0.02	0.02	0.30	0.30	0.30	0.6	0.6	0.6
Wall															
Door	Solid timber door	4.4		0.14	0.10	0.06	0.08	0.10	0.10	0.61	0.44	0.26	0.35	0.44	0.44

Table 5.10. (continue) Calculation of the reverberation time in the living room volume

Window	Glass	8.3		0.35	0.25	0.18	0.12	0.07	0.04	2.90	2.07	1.49	0.99	0.58	0.33
Walls	plaster on brick	42.72		0.01	0.02	0.02	0.03	0.04	0.05	0.42	0.85	0.85	1.26	1.68	2.10
	Plaster on concrete block	29.5		0.12	0.09	0.07	0.05	0.05	0.04	3.54	2.65	2.06	1.47	1.47	1.18
	Chair, metal or wood seat, unoccupied	1.5		0.15	0.19	0.22	0.39	0.38	0.30	0.22	0.28	0.33	0.58	0.57	0.45
	Curtains hung in folds	7.00		0.05	0.15	0.35	0.40	0.50	0.50	0.35	1.05	2.45	2.80	3.50	3.50
Volume	h=2.6 m														
Living room	Air= Air, 50%RH C°, m³		78				0.01	0.01	0.03				0.78	0.78	2.34
Total			78							10.14	9.32	11.52	13.03	13.94	16.64

$$T_{\text{livingroom}} = 0,161V/\Sigma A$$

 T_{required}

125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1.23	1.34	1.09	0.96	0.90	0.75
0.8	0.8	0.8	0.8	0.8	0.8

Table 5.11. Calculation of the reverberation time in the master bedroom volume

Calculating Reverberation Time – Master Bedroom															
Surface	Material	Area (S) m²	Volume (V) m³	Frequency (Hz)						Frequency (Hz)					
				125 a	250 a	500 a	1000 a	2000 a	4000 a	125 Sxa	250 Sxa	500 Sxa	1000 Sxa	2000 Sxa	4000 Sxa
Floor*															
Master bedroom floor	Wood parquet on concrete	13		0.04	0.04	0.07	0.06	0.06	0.07	0.52	0.52	0.91	0.78	0.78	0.91
	Wool Carpet 10 mm	3		0.09	0.08	0.21	0.26	0.27	0.37	0.27	0.24	0.63	0.78	0.81	1.11
Ceiling															
Ceiling	concrete, plastered surface	16		0.01	0.01	0.01	0.02	0.02	0.02	0.16	0.16	0.16	0.32	0.32	0.32
Wall															
Door	Solid timber door	3.4		0.14	0.10	0.06	0.08	0.10	0.10	0.47	0.34	0.20	0.27	0.34	0.34
Window	Glass	1.54		0.35	0.25	0.18	0.12	0.07	0.04	0.53	0.38	0.27	0.18	0.10	0.06
Walls	plaster on brick	32.53		0.01	0.02	0.02	0.03	0.04	0.05	0.32	0.65	0.65	0.97	1.30	1.62
	Plaster on concrete block	7.25		0.12	0.09	0.07	0.05	0.05	0.04	0.87	0.65	0.50	0.36	0.36	0.29
	Chair, metal or wood seat, unoccupied	0.5		0.15	0.19	0.22	0.39	0.38	0.30	0.07	0.09	0.11	0.19	0.19	0.03
	Curtains hung in folds	3.3 1.5* 2.2		0.05	0.15	0.35	0.40	0.50	0.50	0.16	0.49	1.15	1.32	1.65	1.65
Volume	h=2.6 m														
Master bedroom	Air= Air, 50%RH C°, m³		41.60				0.01	0.01	0.03	...	...	...	0.41	0.41	1.24
Toplam			41.60							3.37	3.52	4.58	5.58	6.26	7.57

$$T_{\text{master bedroom}} = 0,161V/\Sigma A$$

 T_{required}

125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1.98	1.90	1.46	1.20	1.06	0.88
0.5	0.5	0.5	0.5	0.5	0.5

Table 5.12. Calculation of the reverberation time in the apartment corridor volume

Calculating Reverberation Time – Corridor															
Surface	Material	Area (S) m ²	Volume (V) m ³	Frequency (Hz)						Frequency (Hz)					
				125	250	500	1000	2000	4000	125	250	500	1000	2000	4000
				a	a	a	a	a	a	Sxa	Sxa	Sxa	Sxa	Sxa	Sxa
Floor*															
Floor	Marble or glazed tile	20.60		0.01	0.01	0.01	0.01	0.02	0.02	0.20	0.20	0.20	0.20	0.40	0.40
Ceiling															
Ceiling	concrete, plastered surface	17.4		0.01	0.01	0.01	0.02	0.02	0.02	0.17	0.17	0.17	0.34	0.34	0.34
Wall															
Door	Solid timber door	3.4		0.14	0.10	0.06	0.08	0.10	0.10	0.47	0.34	0.20	0.27	0.34	0.34
Walls	plaster on brick	29.94		0.01	0.02	0.02	0.03	0.04	0.05	0.29	0.59	0.59	0.89	1.19	1.49
	Plaster on concrete block	11.96		0.12	0.09	0.07	0.05	0.05	0.04	1.43	1.07	0.83	0.59	0.59	0.47
Volume	h=2.6 m														
Apartment Corridor	Air= Air, 50%RH C°, m ³		45.24				0.01	0.01	0.03	...	...	...	0.45	0.45	1.35
Total			45.24							2.56	2.37	1.99	2.74	3.31	4.39

$$T_{\text{apartment corridor}} = 0,161V/\Sigma A$$

$$T_{\text{required}}$$

125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
2.84	3.07	3.66	2.65	2.20	1.65
1.2	1.2	1.2	1.2	1.2	1.2

(The desired reverberation time is the arithmetic mean of values at 250–500–1000 and 2000 Hz.)

- While calculating the reverberation time, the average values in the area of the materials used are taken as a basis.
- For the absorption coefficients of the materials in the room (Egan, 2007, p. 52), - Sound Absorption Data for Common Building Materials and Furnishings (Buxton, 2007 p.10-2 sound) Absorption coefficients (Ermann, 2015, p. 38–43) Absorption coefficients were used.

Since the calculation method was used in the thesis study, the reverberation time could not be measured. Therefore, the reverberation time obtained by measurement was reached by calculation; however, the absorption coefficients of each material in the rooms where the reverberation time was calculated could not be reached. Absorption coefficients of materials such as curtains, chairs, and armchairs from the literature data are taken into account based on the average values for each volume.

Looking at the calculation results, while the reverberation time in the kitchen volume remained below the limit value at high frequencies, it remained well above the limit value at low frequencies. While the reverberation time in the hall volume remained below the limit value only at 4000 Hz, it remained above the limit value at other frequencies. The reverberation time in the bedroom volume remained above the limit value at all frequencies. In the apartment hall, the reverberation time is well above the limit value at all frequencies. The reason for this situation in the apartment hall is that there are almost no absorber materials in this volume, and reflective materials such as marble are concentrated. Since the absorption coefficient of all the materials could not be reached in these places, the reverberation time could be calculated for the empty room except for these materials. *For this reason, it is predicted that if the reverberation time is measured, it will vary according to the absorbance and reflectivity values of the materials and reach lower values than the calculation results.*

5.10. Control of Noise from Plumbing and Service Equipment

In this section prepared within the scope of the acoustic report, no calculations will be made, and the measures that can be taken for this study in accordance with the principal data specified in Appendix 8 of the regulation will be explained and listed. Since the simulation method was used in the case study, the calculation data included in the control of the noise caused by the installation and service equipment were not included due to the limitations of the thesis.

Noise control in ventilation ducts

- In high-speed ducts, measures are taken with flexible material for air leaks that may occur in duct connections.
- Sound absorbing material to be used in canal lining; If fibrous material is to be used by choosing a high absorption coefficient, especially at low frequencies, precautions are taken to prevent the fibers from breaking off and moving with the air.
- Flexible special hangers without sound bridges are used for hanging the ducts to the steel structure carrier system and the metal grid constructions carrying the channels to the upper reinforced concrete carrier system. Preventing ventilation ducts from contacting interior walls, a false ceiling, or upper floor flooring; At the points where

the ventilation ducts pierce the walls, care should be taken that the hole size is not too large than the duct size; the ducts should be wrapped in these areas, and the surrounding space should be filled with a special non-hardening acoustic material (Figure 5.14). (Regulation Appendix-8,2017; The Guideline on Acoustical Design, Installation, and Inspection of Buildings).

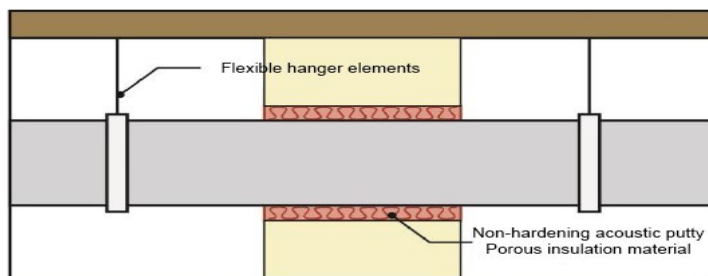


Figure 5.14. Internal partition wall drilling of ducts (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

Control of equipment noise

- It is essential that all devices and equipment that may be a source of noise in the mechanical or electrical installations inside or outside the building be selected in such a way as to provide the specified minimum noise levels.
- Vibration isolators are used in the connection of service equipment to the ground and in pipe and duct connections.
- Service equipment is placed on inertia blocks, the dimensions of which will be determined according to the calculations to be made depending on their weight on the ground (Regulation Appendix -8, 2017).

Combi devices

Combi boilers to be found in kitchens and bathrooms in residences are selected to provide the minimum noise levels given in Appendix 5.1 of the regulation (Regulation Appendix - 8, 2017).

Noise control principles for roofing equipment

- Adequate sound insulation shall be provided in the cabins of the roof equipment.

- If the insulation of the ready-made cabins is insufficient, they will be placed in rooms with high sound insulation. In these rooms, the walls, ceiling, floor, and doors will be soundproofed (Regulation Appendix -8, 2017).

Noise control principles for plumbing and other mechanical, electrical service equipment

- Precautions will be taken in such a way that the water pipes adjacent to the places that are very and moderately sensitive to noise in the buildings do not come into direct contact with the load-bearing system and the building elements. Flexible hangers, supports, and fasteners should be used in obligatory situations (Regulation Appendix -8, 2017).

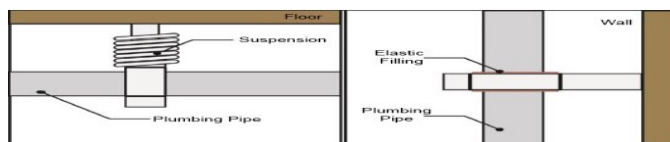


Figure 5.15. Fixing of installation elements to (a) horizontal bearing elements and (b) vertical bearing elements with flexible connections (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

- All kinds of installation sound noise levels in buildings that are very and moderately sensitive to noise are selected and applied in such a way as to provide the values in Appendix 5.2 of the regulation (Regulation Appendix-8, 2017).
- In elevator machine rooms and elevator shafts, noise control is carried out to ensure the airborne sound levels in Appendix 5.2 of the regulation. In the same places, noise and vibration control measures are taken for impact sounds and mechanical vibrations (Regulation Appendix -8, 2017).

5.11. Evaluation of the Case Study

The Insul (v9.0.24) simulation program was used for an independent unit of the evaluated residential building. The evaluation of the current situation is given in Table 5.13.

Table 5.13. Situation analysis of the residential building selected as a sample

Structural Element Codes	Material Information of Structural Element	Detail of the Structure Element	According to national legislation necessary limit values (Class D) $D_{nT,A,dB}$; $L'_{nTw,dB}$		Insul simulation program sound transmission loss value Converted R_w and L_{nw} data: $D_{nT,A,dB}$; $L'_{nTw,dB}$		Evaluation	Recommendations
dd-1	reinforced concrete wall -30cm double layer brick wall -window	Top of the window:  Under the Window: 	Living Room (Sensitivity Degree:II): 30 (L_{den} -29)	-	33,81	-	APPROPRIATE	-
dd-1a	reinforced concrete wall -30cm double layer brick wall -window	Top of the window:  Under the Window: 	Bedroom-1 (Sensitivity Degree:I):3 3 (L_{den} -26)	-	30	-	NOT APPROPRIATE	Appendix -6a: 33/35 Increasing the thickness of the glass and the width between the glasses in the windows / use of laminated glass
dd-1b	reinforced concrete wall -30cm double layer brick wall -window	Top of the window:  Under the Window: 	Bedroom -2 (Sensitivity Degree: I):33 (L_{den} -26)	-	32	-	NOT APPROPRIATE	Appendix -6b: 33/35 Increasing the thickness of the glass and the width between the glasses in the windows / use of laminated glass
dd-2	reinforced concrete wall -40cm double layer brick wall -window	Top of the window:  Under the Window: 	Living Room (Sensitivity Degree:II): 30 (L_{den} - 29)	-	36,55	-	APPROPRIATE	-

Table 5.13. (continue) Situation analysis of the residential building selected as a sample

dd-2a	- reinforced concrete wall -40cm double layer brick wall - window	Top of the window:  Under the Window: 	Bedroom -2 (Sensitivity Degree: I):33 (L _{den} -26)	-	33	-	APPROPRIATE	-
dd-2b	- reinforced concrete wall -40cm double layer brick wall - window	Top of the window:  Under the Window: 	Bedroom -3 (Sensitivity Degree: I):33 (L _{den} -26)	-	31	-	NOT APPROPRIATE	Appendix -6c: 34/36 Increasing the thickness of the glass and the width between the glasses in the windows / use of laminated glass
dd-2c	- reinforced concrete wall -40cm double layer brick wall - window	Top of the window:  Under the Window: 	Master Bedroom (Sensitivity Degree: I):33 (L _{den} -26)	-	33	-	APPROPRIATE	-
di-1	-4cm plaster -10cm brick -4cm plaster		(For common area and independent units) 48	-	51	-	APPROPRIATE	-
di-1a	-4cm plaster -10cm brick -4cm plaster		(For common area and independent units) 48	-	51	-	APPROPRIATE	-
di-2	-4cm plaster -10cm brick -4cm plaster		40	-	52,98	-	APPROPRIATE	-

Table 5.13. (continue) Situation analysis of the residential building selected as a sample

<i>di-2a</i>	-4cm plaster -10cm brick -4cm plaster		40	-	51,28	-	APPROPRIATE	-
<i>di-2b</i>	-4cm plaster -10cm brick -4cm plaster		40	-	51,65	-	APPROPRIATE	-
<i>di-2c</i>	-4cm plaster -10cm brick -4cm plaster		40	-	45	-	APPROPRIATE	-
<i>di-2d</i>	-4cm plaster -10cm brick -4cm plaster		40	-	45	-	APPROPRIATE	-
<i>di-2e</i>	-4cm plaster -10cm brick -4cm plaster		40	-	45	-	APPROPRIATE	-
<i>di-2f</i>	-4cm plaster -10cm brick -4cm plaster		40	-	45	-	APPROPRIATE	-
<i>di-3</i>	-4cm plaster -25cm reinforced concrete		(For common area and independent units) 48	-	57	-	APPROPRIATE	-

Table 5.13. (continue) Situation analysis of the residential building selected as a sample

<i>di-3a</i>	-4cm plaster -25cm reinforced concrete		(For common area and independent units) 48	-	57	-	APPROPRIATE	-
<i>di-4</i>	-4cm plaster -25cm brick -4cm plaster		(For common area and independent units) 48	-	53	-	APPROPRIATE	-
<i>di-4a</i> ***	-4cm plaster -25cm brick -4cm plaster -Ahşap Kapı		(For common area and independent units) 48-14= 34 dB	-	51,71	-	APPROPRIATE	-
<i>di-4b</i>	4cm plaster- 25cm brick- 4cm plaster		(For common area and independent units) 48	-	56,32	-	APPROPRIATE	-
<i>do-1</i>	-3cm laminate flooring -4cm screed -12cm reinforced concrete -4cm plaster		48	58	50	72	NOT APPROPRIATE	Appendix -6d: use of impact absorber under the screed or use of suspended ceiling/absorbent material
<i>do-2</i>	-3cm laminate flooring -4cm screed -12cm reinforced concrete -4cm plaster		48	58	52,19	61	NOT APPROPRIATE	Appendix -6d: use of impact absorber under the screed or use of suspended ceiling/absorbent material

As a result of the analysis of the existing building elements that make up the residential building using the Insul (v9.0.24) simulation program, it has been determined that the insulation performance of the interior walls of the residential building that separate the same independent unit against airborne sound meets the limit values defined in our current regulation. However, due to the composite structure of the external walls (double-layer brick wall + reinforced concrete wall + window), the sound insulation obtained on some walls remained below the limit value. Additionally, according to the results of the Insul (v9.0.24) simulation program, the floors do not comply with the values defined in the regulation for the impact sound. When the project of the selected residential building is examined, it is seen that no sound insulation measures have been taken. Recommendations were made for the building elements in this project to reduce the noise disturbance due to the lack of sound insulation.

Recommendations for lowering environmental noise levels

Balconies in a residential building can be designed as acoustic barriers to reduce the disturbance caused by environmental noise. The sound level reaching the façade can be reduced by covering the lower surfaces of the balconies with sound-absorbing material, as indicated in Figure 5.16, and the use of gapless, rigid material in the balcony barrier increases the acoustic shading effect of the balcony (Üstüner & Demirel, 2021).

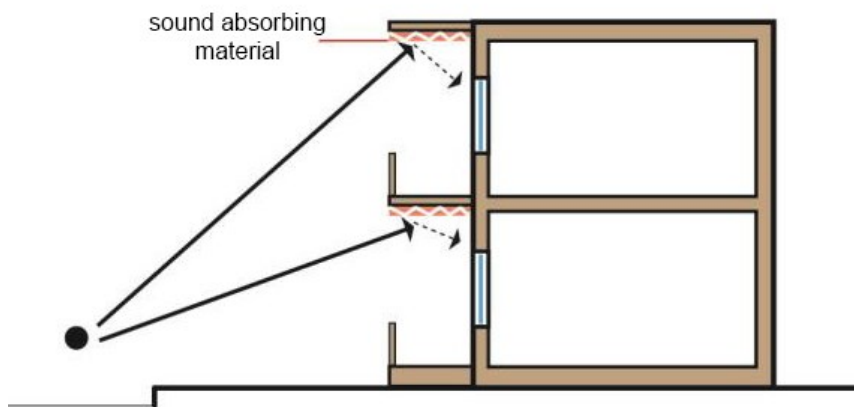


Figure 5.16. Balcony design for noise control (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

Recommendations for sound isolation on interior and exterior walls

While the brick walls used as interior dividers in the residential building are above the D-class limit values defined in the regulation, the sound insulation of some walls in the composite building element used as the exterior walls remained below the limit value. Although the sound insulation of the reinforced concrete wall and double-layered brick walls in the outer wall component is quite high, the R_w value of the composite component remains below the limit value due to the low R_w value of the windows. For this reason, it is necessary to improve the glass thickness (although it is not very effective) and the gap between the glasses in the windows to ensure noise control. Because of the cost, although it is not mostly preferred, an improvement can be made by using laminated glass. The values obtained after window improvement are given in Appendices 6a and 6b. These values are indicated in Table 5.14.

Table 5.14. Sound insulation recommendations for exterior walls

Recommendations for Sound Insulation on Exterior Walls					
Structural Element Code	DnTAtr value defined in the regulation *	Current situation	Recommendations	Provided DnT,A,tr value	Analysis of current situation
dd-1a (Bedroom-1)	33	30	Expansion of glass thicknesses in windows and the space between the glasses (8-16-8)	33	APPROPRIATE
	33	30	Using laminated glass (6cm laminated glass-12cm gap-6cm laminated glass)	35	APPROPRIATE
dd-1b (Bedroom -2)	33	32	Expansion of glass thicknesses in windows and the space between the glasses (8-16-8)	34	APPROPRIATE
	33	32	Using laminated glass (6cm laminated glass-12cm gap-6cm laminated glass)	36	APPROPRIATE
dd-2b (Bedroom -3)	33	31	Expansion of glass thicknesses in windows and the space between the glasses (8-16-8)	34	APPROPRIATE
	33	31	Using laminated glass (6cm laminated glass-12cm gap-6cm laminated glass)	36	APPROPRIATE

* If L_{den} (55- 59) is accepted as the maximum value (59), the limit value will be 33 maximum. Since it is assumed that the limit value will mostly remain below 33 (according to the noise map and the location of the residential building), it is considered appropriate to be equal to the limit value.

In addition, it was determined that the sealed mattress was not used and the inner wall layer was not interrupted by the partition wall. This situation may cause sound

transmission. The formation of a sound bridge can be prevented by using an impermeable mattress at the wall joints.

Recommendations for providing sound insulation on floors

Considering the analyses made with the Insul (v9.0.24) program for the flooring in the residential building under consideration, it is seen that the impact sound insulation values obtained in the floors are well above the limit values defined in the regulation. When the project of the residential building is examined, it is seen that no sound insulation measures were taken in the project.

In order to improve the sound insulation of floors; separating the building elements from each other and using flexible filling and impermeable mattress materials will prevent the lateral transmission of sound and reduce noise-induced disturbance. For the improvement of the floor covering in the residential building, three proposals were presented in Appendix 6d with the Insul (v9.0.24) program. Recommendations are listed in Table 5.15.

Table 5.15. Sound insulation recommendations for floors

Recommendations	Location within the Building	Provided DnT _A , _T r value	DnT _A Tr value defined in the regulation	Provided LnTw value	LnTw value defined in the regulation	Analysis of current situation
<i>Appendix-6d:</i> Recommendation-1 Use of impact absorbing material under the screed <i>DAMTEC System 2 layer (granules together) under cement screen (55mm)</i>	do-1 Bedroom	49	p48	57	58	APPROPRIATE
	do-2 Living Room	51,19	48	52	58	APPROPRIATE
<i>Appendix-6d:</i> Recommendation -2 Use of suspended ceiling and floor covering <i>20 cm suspended ceiling and Ecoroll (5mm&720kg/m³) under concrete screed</i>	do-1 Bedroom	56	48	54	58	APPROPRIATE
	do-2 Living Room	58,19	48	49	58	APPROPRIATE
<i>Appendix-6d:</i> Recommendation -3 Use of suspended ceiling and sound absorbing material <i>20 cm suspended ceiling and 5 cm sound absorbing material</i>	do-1 Bedroom	64	48	53	58	APPROPRIATE
	do-2 Living Room	66,19	48	48	58	APPROPRIATE

As stated in Table 5.15, the use of impact-absorbing material under the screed for the floors in the existing building will provide sufficient sound insulation by providing limit values for class D. In order to achieve better sound insulation, the use of suspended ceilings is recommended. In the third proposal, in the use of suspended ceilings and sound-absorbing materials, values were obtained well above the desired limit value for air-borne sounds and well below the desired limit value for impact sounds. This situation is particularly recommended for noise-sensitive rooms located below the noise source. A proposal for floating flooring is not presented because floating flooring is not preferred in residential buildings except for wet areas.

Recommendations for providing sound insulation in plumbing and service equipment

There is no sound insulation for the plumbing system in the residential building. In order to prevent installation noise, it is necessary to use porous absorbers and flexible filling layers.

Recommendations for air conditioning noise in the roof

If the discomfort caused by the sound of the air conditioner in the attic reaches a very high sound pressure level;

- With the silencer element, the sound level in the channel can be reduced.
- The noise level can be reduced by partially or completely enclosing the source in the cell. In partial ceiling, the surfaces facing the noise source should be covered with absorbent material.
- Increasing the separation area density or using double-layer structures can improve the sound insulation efficiency of the duct wall (Özer, 1979).

Recommendations for providing sound insulation on stairs

Since the staircase (noise source) is adjacent to the bedroom, which is a very sensitive place to noise, sound insulation measures must be taken. Figure 5.17 shows the measures that can be taken to prevent impact noise on stairs.

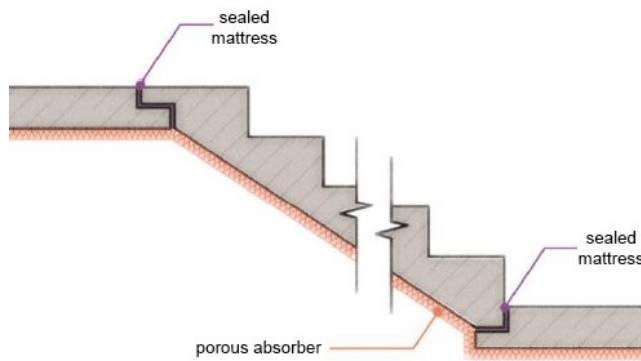


Figure 5.17. Floor - stair joint detail (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

According to this figure, a sealed mattress and porous absorber should be used at the stairs and floor joints to prevent lateral transmission caused by impact sound; however, there is no sound insulation measure in the project.

As another recommendation that can be used on stairs in this project, soft flooring can be preferred on stair steps and landings. There are also different recommendations depending on the fact that the stairs and landings are uncoated:

- If the stairs and landings are coated, there is no need for separating joints; however, if the stairs and landings are uncoated, there should be separating joints on the sides of the rooms.
- If only the landings are coated, it is necessary to have a separating joint on the sides of the stairs (Özer, 1979).

Recommendations for providing sound insulation in elevator

Since the elevator (noise source) is adjacent to the bedroom, which is a very sensitive place, sound insulation measures must be taken. Absorbent ceilings and flex-resistant pre-coating materials can be used in common building elements to prevent the discomfort caused by elevator noise (Özer, 1979).

6. CONCLUSION AND RECOMMENDATIONS

Within the scope of the thesis, first of all, literature data on noise and noise control methods in residential buildings are presented. Afterward, within the scope of our national regulation, Regulation on Protection of Buildings Against Noise, international legislation was also examined, and acoustic performance criteria were established for residential buildings according to the comparative analysis. In line with these criteria, an independent section of the existing residential building, which is considered a sample, has been evaluated in terms of acoustic comfort conditions according to our national regulation.

Since the sample was suitable for the acoustic report, the current situation analysis was made by following the sequence defined for the acoustic report in the regulation. In this analysis, calculations were made using the Insul (v9.0.24) simulation program, and the results were compared with the limit values of class D defined in the regulation (Table 5.13). As a result of this comparison, the current situation is evaluated, and the improvement recommendations for optimizing the noise control in the residential building are given in Tables 5.14 and 5.15.

As a result of this thesis study, it has been tested on an existing residential building to determine whether the building materials commonly used in residential buildings meet the limit values defined in the regulation. In this study, the sound transmission loss is quite high due to the high wall thickness of the composite exterior walls and the use of double-layered structural elements. However, the low sound transmission loss of the windows reduces the insulation value of the composite system. For this reason, it is necessary to improve the windows (by increasing the glass thickness (although it is not very effective) and air gap depth) in order to prevent possible sound leaks. Adequate sound insulation is provided due to the high plaster thicknesses on the interior walls and the wall thicknesses on the walls separating the common area from the flat. However, as in many residential buildings, it has been determined that there are user complaints due to the lack of adequate sound insulation measures in floors, ventilation ducts, and installation equipment. For this reason, in these places, it is necessary to apply the substances defined in the regulation, choose the appropriate thickness and quality building materials, and avoid faulty

workmanship in order not to cause the formation of sound bridges during the manufacturing phase.

According to the results of the analysis made in the residential building, which is considered a sample, improvement recommendations are presented to provide noise control in the buildings to be built in the coming years:

While creating the volume layout

- While designing the plan, noise-sensitive spaces should be placed on the quiet façade opposite the noise source as much as possible in order to avoid external noise.
- Elevators, stairs, circulation areas, and service units that may create indoor noise sources should be designed to be kept away from noise-sensitive units.
- Contact between the stairs and the walls separating the noise-sensitive volumes should be avoided as much as possible.
- The elevator shaft should not be adjacent to noise-sensitive volumes. If there is a neighborhood relationship, additional acoustic measures should be taken.
- By grouping volumes with similar functions together, buffer volumes such as cabinets, warehouses, and the like should be positioned between noisy volumes and noise-sensitive volumes, and these volumes should not be brought side by side or under each other (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

In construction element and other construction element combinations

- If the exterior wall that causes lateral transmission between adjacent independent units is double-hulled, ensure that the interior body of the exterior wall is not continuous and interrupted by the partition element; It is necessary to use a sound barrier that prevents the passage of sound at the level of the interior partition element in the air gap in the section of the exterior wall.
- The use of flexible tape is required in areas where the walls are in contact with the floor, ceiling, side surfaces, and beams (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

On floors

- If an impact insulation material is used under the floating screed and pipes are passing under it, a flexible layer is used to equalize the pipe height and surface level before the impact insulation is applied.
- Impact insulation is installed on all of the floating screed's floor and lateral contact surfaces.
- Application of floating screed to be cut by a partition wall between two adjacent volumes.
- Preventing the contact of the floor covering with the side walls, It is necessary to use flexible filling material between the wall or floor covering and the skirting so that the skirting does not create a sound bridge between the wall and the floor (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

In the combination of construction elements and service systems

The use of rigid connectors between service systems and building elements should be avoided.

- The electrical outlets (cables, sockets, telephones, TVs, etc.) and switches that coincide back-to-back on the partition walls must be placed in a staggered manner and closed in a soundproof manner by taking them into the box.
- Sound insulation material should be wrapped around pipes that pierce the floor.
- Care should be taken that the pipes are not advanced along the wall, continually breaking the solid walls and thinning the wall section thickness; if pipes are led through the wall cavity, they must be advanced through the appropriately sized wall cavity so as not to cause the wall to break continuously. (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

In windows

- Improvement in the sound insulation of windows in environments with high environmental noise can be achieved by increasing the depth of the air gap and the glass

thickness. In addition, applying a soft sealant around the glass surface of the windows against sound leaks will reduce noise disturbance (Mehta et al., 1999; Rindel, 2018).

At the doors

- Heavy doors should be preferred in areas where environmental noise values are high or in residential buildings that will separate noisy volumes from sensitive volumes. Additionally, to be airtight, it must be sealed on all sides (Egan, 2007).

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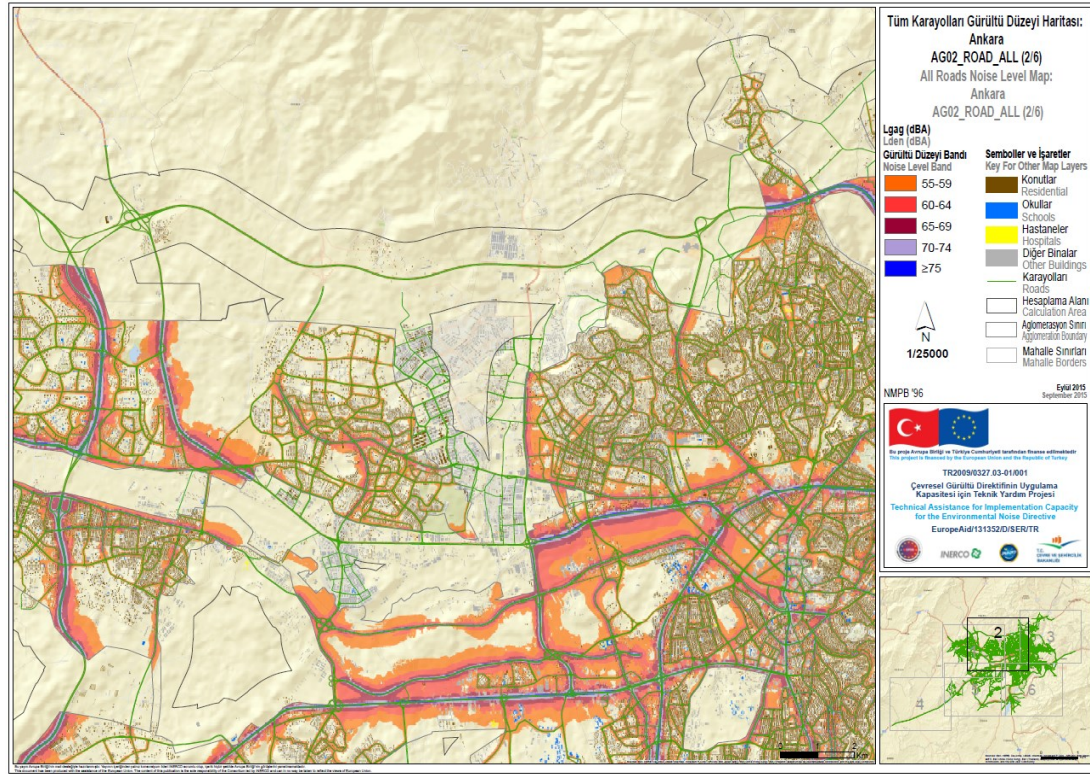
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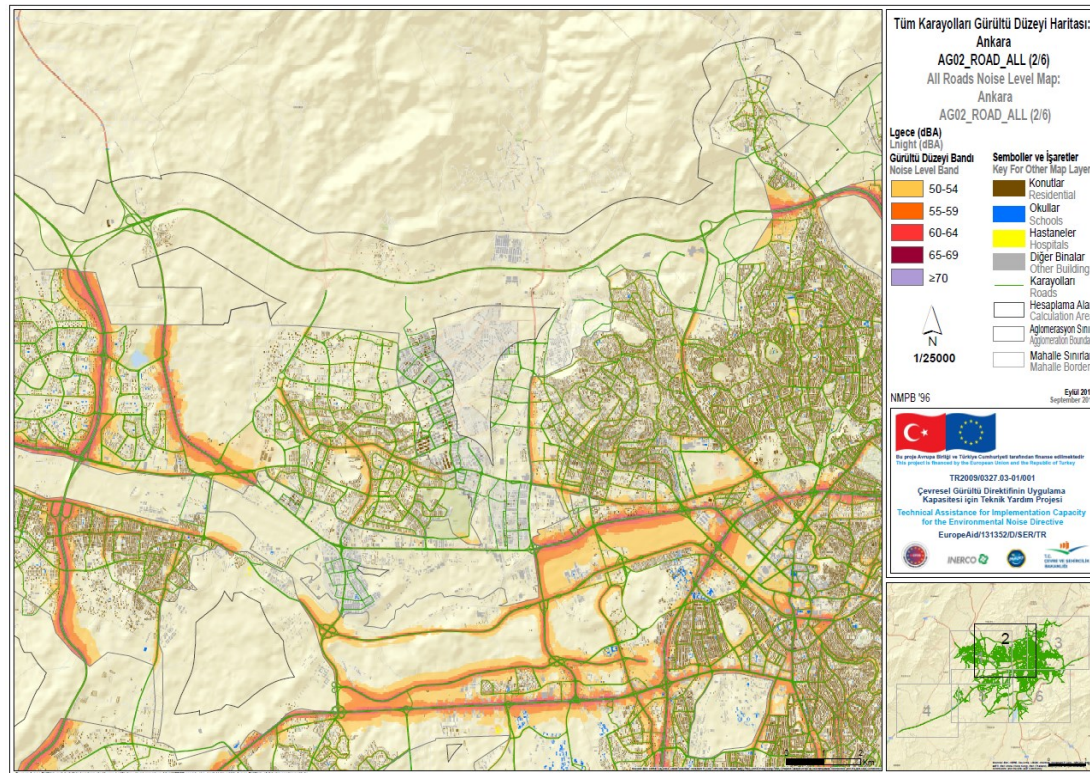
APPENDICES

APPENDIX-1. Ankara province noise level maps (2015)

Appendix -1a. Ankara province L_{den} noise level map (All highways noise level map)



Appendix -1b. Ankara province L_{night} noise level map (All highways noise level map)



APPENDIX-2. Conversion of indicators

The Insul program gives the R_w value, which is the laboratory value of the building elements. This value ($R_w (C;Ctr)$, dB) first changes to the area value ($R'_w (C;Ctr)$, dB) and then the value defined in the regulation ($D_{nT,A,(tr)}$, dB; $L'_{nT,w}$, dB) must be converted. Three different ways can be followed in these transformations:

1) Calculation with Confidence Interval (Güven Aralığı) Method:

For small volume receiver and source places; If the spaces meet the conditions $V1$ and $V2 < 75 \text{ m}^3$, $h < 3 \text{ m}$, $a, b < 5 \text{ m}$, the transformations can be calculated as follows:

$$* D_{nT,A} = R_w (C;Ctr) - 3 \quad * D_{nT,A,tr} = R_w (C;Ctr) - 4 \quad * L'_{nT,w} = L_{n,w} + 3$$

$V1, V2$: The volume of receiver and source places, m^3 h : Room Height, m

a, b : room dimensions (length, width), m (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

2) Calculation with the Simple Method:

-For airborne sound insulation;

In this thesis, the R_w value obtained from Insul should be converted to the D_{nTw} value defined in the regulation. The following sequence should be followed in this conversion:

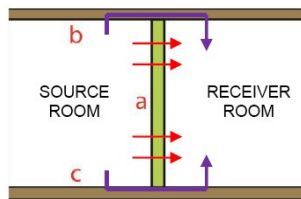
R_w	R'_w	$D_{nT,w}$
<i>sound reduction index</i>	<i>Weighted apparent sound reduction index</i>	<i>Weighted standardized level difference</i>
(Laboratory value)	(Area value: with lateral transmissions)	(Area value: With lateral transmissions and room effect)

(Türk Akustik Derneği Sertifika Notları, 2021).

Conversion of laboratory value to area value ($R_w \rightarrow R'_w$)

The ratio of the unit weight of the partition element to the average unit weight of all elements forming the sound bridge where lateral transmissions take place is calculated (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

APPENDIX-2. (continue) Conversion of indicators



$$\frac{\text{separating element unit weight (kg/m}^2\text{)}}{\text{average unit weight of sound bridge elements (kg/m}^2\text{)}} = \frac{a}{b+c+\dots}$$

	$\frac{a}{b+c+\dots} \left(\frac{kg}{m^2} \right)$			
	≤ 1	$1 < ve \leq 2$	$2 < ve \leq 3$	$3 <$
C_F	0	2	4	6

$$(R'_w)_{\text{provided}} = (R_w)_{\text{sample}} - C_F$$

Evaluation of the room effect ($R'_w \rightarrow D_{nT,w}$)

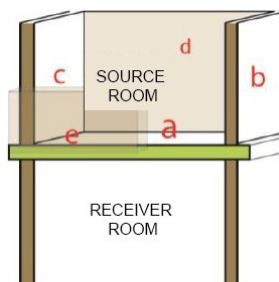
$$D_{nT} = R' + 10 \log \frac{0.16V}{\tau_0 S_s} = R' + 10 \log \frac{0.32V}{S_s} \text{ dB}$$

V: Receiver room volume; S_s: Divider surface area (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

- For impact sound insulation;

Both airborne sound (D_{nTA}) and impact sound (L_{nTw}) are taken into account.

In this thesis, the L_{nw} (CI) value obtained from Insul should be converted to the L_{nTw} value defined in the regulation. The following sequence should be followed in this conversion: For transformations, the ratio of the unit weight of the partition element to the average unit weight of the sound bridge elements where lateral transmissions take place is calculated as follows:



$$\frac{\text{separating element unit weight (kg/m}^2\text{)}}{\text{average unit weight of sound bridge elements (kg/m}^2\text{)}} = \frac{a}{b+c+d+e}$$

(The Guideline on Acoustical Design, Installation, and Inspection of Buildings) Based on this ratio, the correction value for K is found in the table below.

APPENDIX-2. (continue) Conversion of indicators

	$\frac{a}{b+c+\dots} \left(\frac{kg}{m^2} \right)$					
	$\dots < 1$	$1 \leq \dots \leq 2$	$2 < \dots \leq 3$	$3 < \dots \leq 5$	$5 < \dots \leq 7$	$7 < \dots$
K	0	2	3	4	5	6

(The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

	Receiver room volume, m ³						
	$\dots < 10$	$10 \leq \dots < 15$	$15 \leq \dots < 30$	$30 \leq \dots < 50$	$50 \leq \dots < 100$	$100 \leq \dots < 200$	$200 \leq \dots$
Hd	7	5	3	0	-2	-5	-8

Depending on the volume of the receiver room, the Hd correction value is determined (The Guideline on Acoustical Design, Installation, and Inspection of Buildings)

After these correction values, the following transformation is applied.

$$(L'_{nT,50})_{sağlanan} = (L_{n,w} + C_i)_{örnek} + K + Hd$$

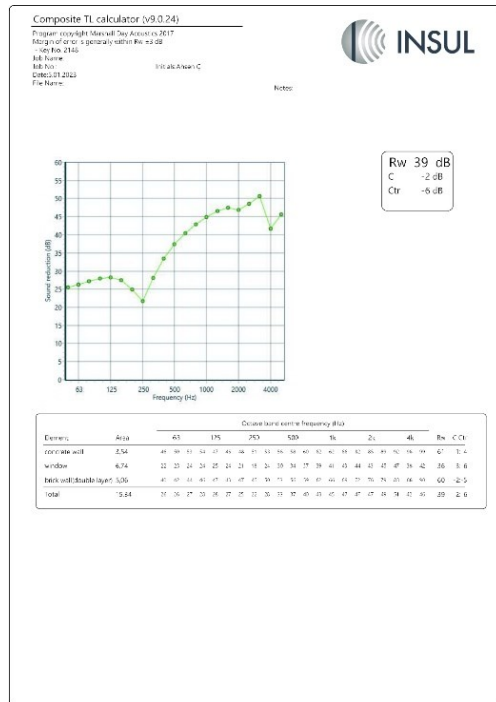
3) Calculation with the expert method

It is calculated by the acoustic expert using the methods of EN 12354-1-2-3.

However, due to the use of the Insul simulation program in this study, in case the receiver and source room are suitable for the transformations, the simple method will be used if the confidence interval method does not.

APPENDIX-3. Insul (V9.0.24) Program Calculation Results For Exterior Walls

Appendix -3a. dd-1: 25 cm reinforced concrete wall + 30 cm double layer brick wall + window: Rw: 39 (-2,-6). The dd-1 wall on the facade of the living room is a composite structure, and the Rw value is given in the table.



- Since the *living room's* volume does not meet the reliance interval (güven aralığı) requirement ($a, b < 5$ m), the conversion will be done with the simple method.

*Acoustic Values of the Partition Element:

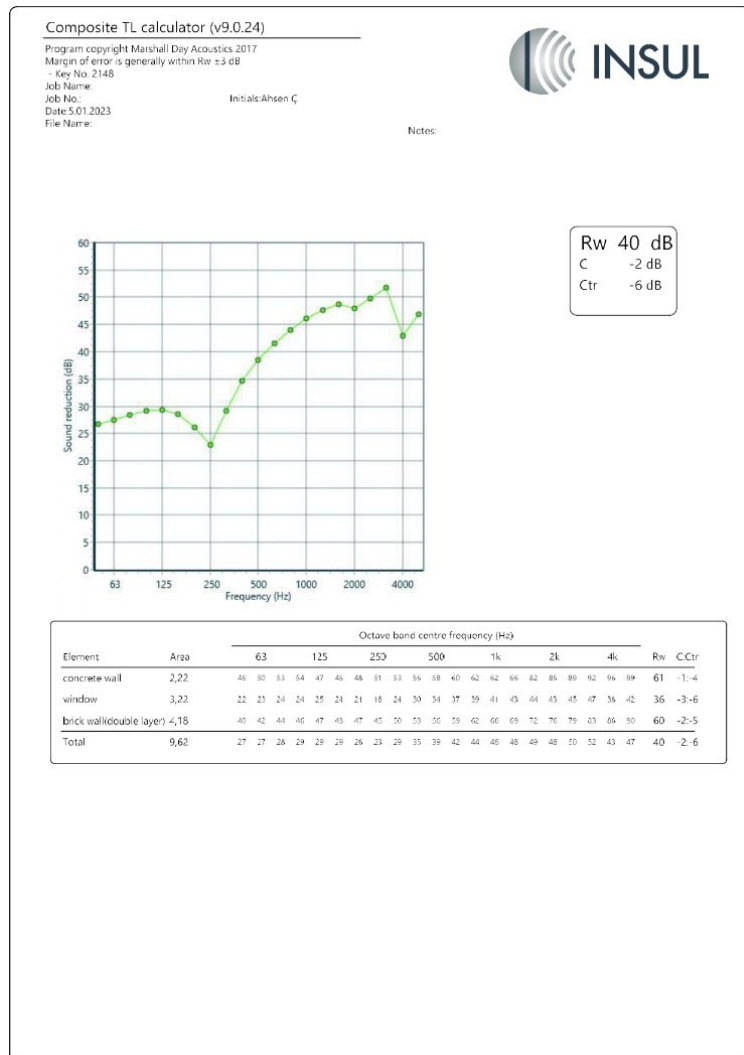
Rw (dB)	Ctr 100-3150 (dB)	Cf	R'w (dB)	DntAtr (dB)
39,00 dB	-6,00 dB	2,00	31,00 dB	33,81 dB
Ss: Partition Element Surface Area (m2): 12,61 m2		V: Receiver Room Volume (m3): 75,55 m3		

*Structural Elements Causing Sound Bridge:

Structural Element	Structural Element Description	Surface Mass (kg/m2)
Partition Element	25 cm concrete wall	714,00
1st Element Forming Flanking Transmission	25 cm concrete wall	714,00
2nd Element Forming Flanking Transmission	12 cm concrete floor	418,00
3rd Element Forming Flanking Transmission	12 cm concrete floor	418,00
4th Element Forming Flanking Transmission	10 cm brick wall	288,00
The surface mass is taken from the Insul program (Demirel, 2022)		

APPENDIX-3. (continue) Insul (V9.0.24) program calculation results for exterior walls

Appendix -3b. dd-1a: 25 cm reinforced concrete wall + 30 cm double layer brick wall + window: R_w : 40 (-2,-6). The dd-1a wall on the facade of Bedroom-1 is a composite structure, and the R_w value is shown in the table.



- Since *bedroom 1*'s width, height, and height definitions provide the reliance interval (güven aralığı) ($V1$ and $V2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

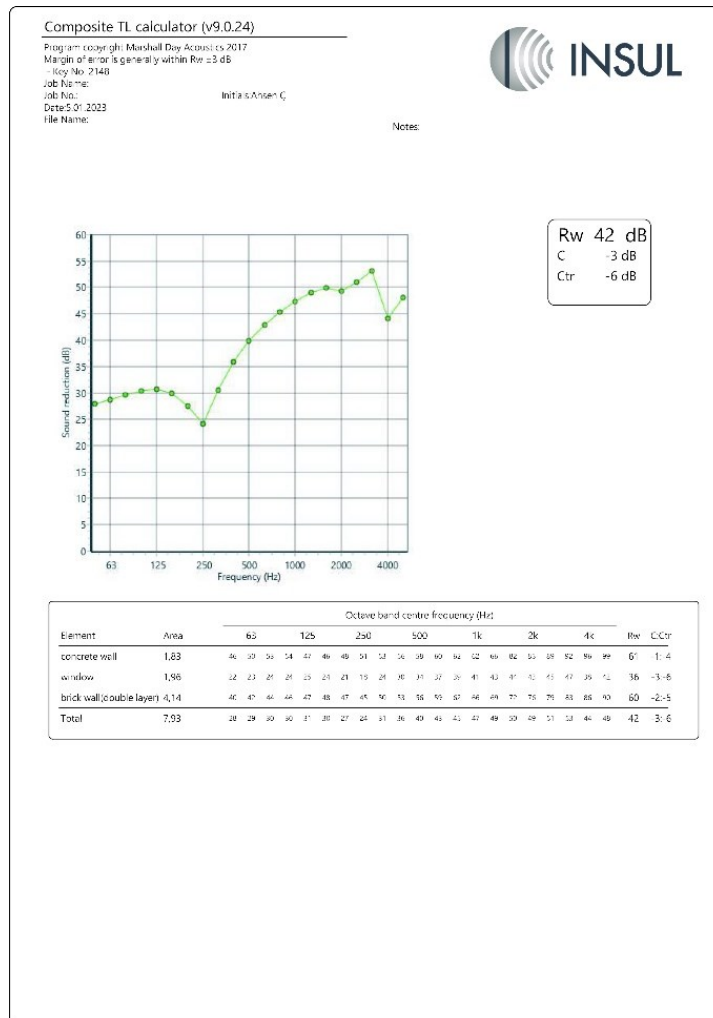
$D_{nT,A,tr} = R_w (C; Ctr) - 4$ (Since it is an external construction element, the Ctr value representing the external noise will be used.)

$$D_{nT,A,tr} = 40 - 6 - 4 = 30 \text{ dB}$$

According to the result, it cannot provide sufficient insulation for air-borne sound on the exterior walls by remaining below the value defined for class D in the regulation ($L_{den} -26$). Therefore, it is necessary to take precautions.

APPENDIX-3. (continue) Insul (V9.0.24) program calculation results for exterior walls

Appendix -3c. dd-1b: 25 cm reinforced concrete wall + 30 cm double layer brick wall + window: R_w : 42 (-3,-6). The dd-1b wall on Bedroom-2's facade is a composite structure, and its R_w value is shown in the table.



- Since *bedroom 2's* width, height, and height definitions provide the reliance interval (güven aralığı) (V_1 and $V_2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

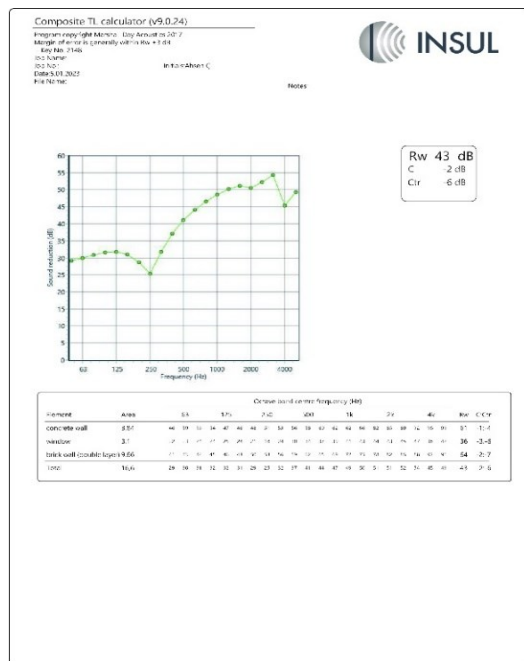
$D_{nT,A,tr} = R_w (C; Ctr) - 4$ (Since it is an external construction element, the Ctr value representing the external noise will be used.)

$$D_{nT,A,tr} = 42 - 6 - 4 = \mathbf{32 \text{ dB}}$$

According to the result, it cannot provide sufficient insulation for air-borne sound on the exterior walls by remaining below the value defined for class D in the regulation ($L_{den} -26$). Therefore, it is necessary to take precautions.

APPENDIX-3. (continue) Insul (V9.0.24) program calculation results for exterior walls

Appendix -3d. dd-2: 25 cm reinforced concrete wall + 40 cm double layer brick wall + window: Rw: 43 (-2,-6). The dd-2 wall on the facade of the living room is a composite structure, and the Rw value is shown in the table.



- Since the *living room's* volume does not meet the reliance interval (güven aralığı) requirement ($a, b < 5$ m), the conversion will be done with the simple method.

*Acoustic Values of the Partition Element:

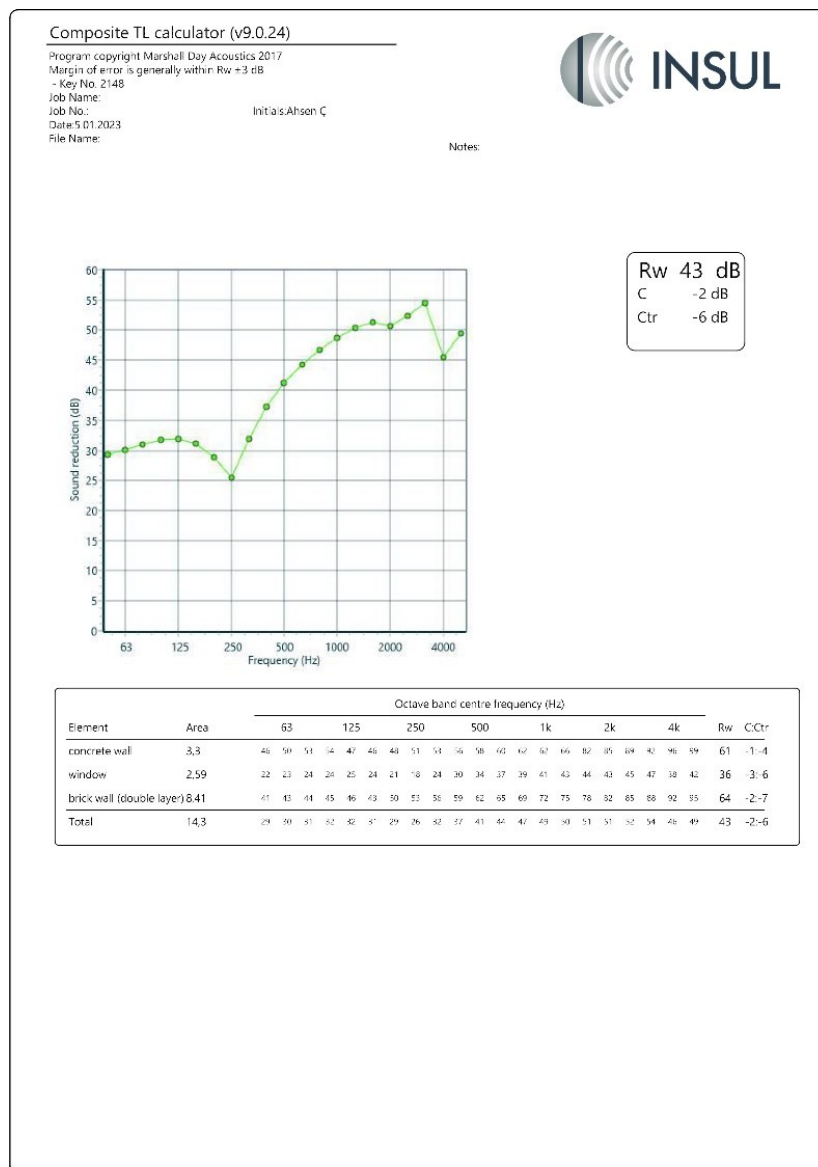
Rw (dB)	Ctr 100-3150 (dB)	Cf	R'w (dB)	DntAtr (dB)
43,00 dB	-6,00 dB	2,00	35,00 dB	36,55 dB
Ss: Partition Element Surface Area (m2): 12,61 m2		V: Receiver Room Volume (m3): 75,55 m3		

* Structural Elements Causing Sound Bridge:

Structural Element	Structural Element Description	Surface Mass (kg/m2)
Partition Element	25 cm concrete wall	714,00
1st Element Forming Flanking Transmission	25 cm concrete wall	714,00
2nd Element Forming Flanking Transmission	12 cm concrete floor	418,00
3rd Element Forming Flanking Transmission	12 cm concrete floor	418,00
4th Element Forming Flanking Transmission	10 cm brick wall	288,00
The surface mass is taken from the Insul program (Demirel, 2022)		

APPENDIX-3. (continue) Insul (V9.0.24) program calculation results for exterior walls

Appendix -3e. dd-2a: 25 cm reinforced concrete wall + 40 cm double layer brick wall + window: R_w : 43 (-2,-6). The dd-2a wall on Bedroom-2's facade is a composite structure, and its R_w value is shown in the table.



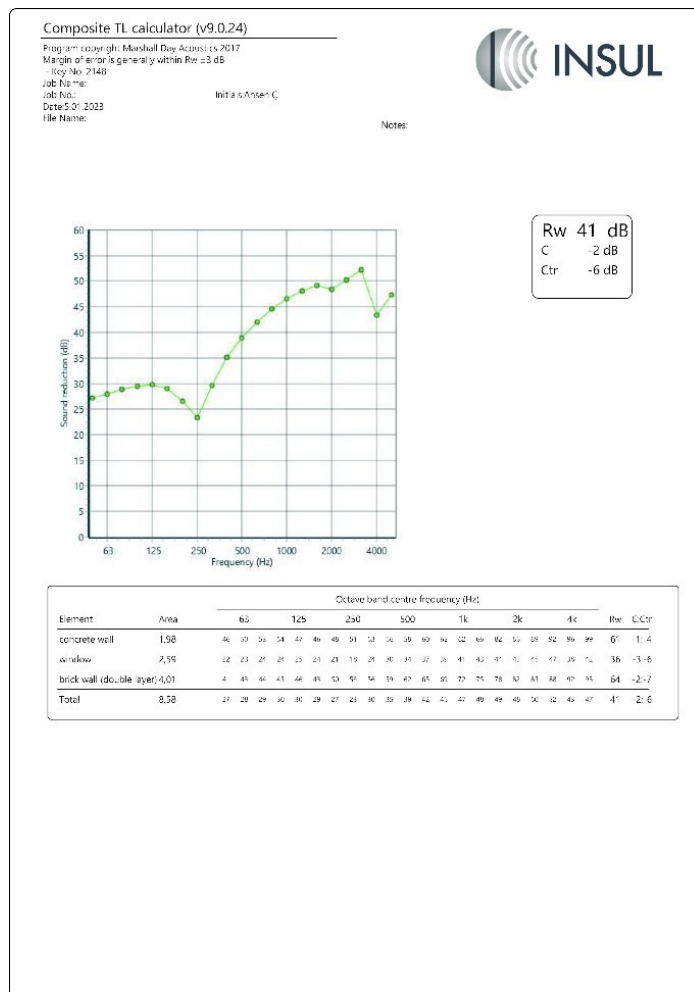
-Since *bedroom 2's* width, height, and height definitions provide the reliance interval (güven aralığı) ($V1$ and $V2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

$D_{nT,A,tr} = R_w (C; Ctr) - 4$ (Since it is an external construction element, the Ctr value representing the external noise will be used.)

$$D_{nT,A,tr} = 43 - 6 - 4 = 33 \text{ dB}$$

APPENDIX-3. (continue) Insul (V9.0.24) program calculation results for exterior walls

Appendix-3f. dd-2b: 25 cm reinforced concrete wall + 40 cm double layer brick wall + window: Rw: 41 (-2,-6). The dd-2b wall on Bedroom-3's facade is a composite structure, and its Rw value is shown in the table.



- Since *bedroom 3's* width, height, and height definitions provide the reliance interval (güven aralığı) ($V1$ and $V2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

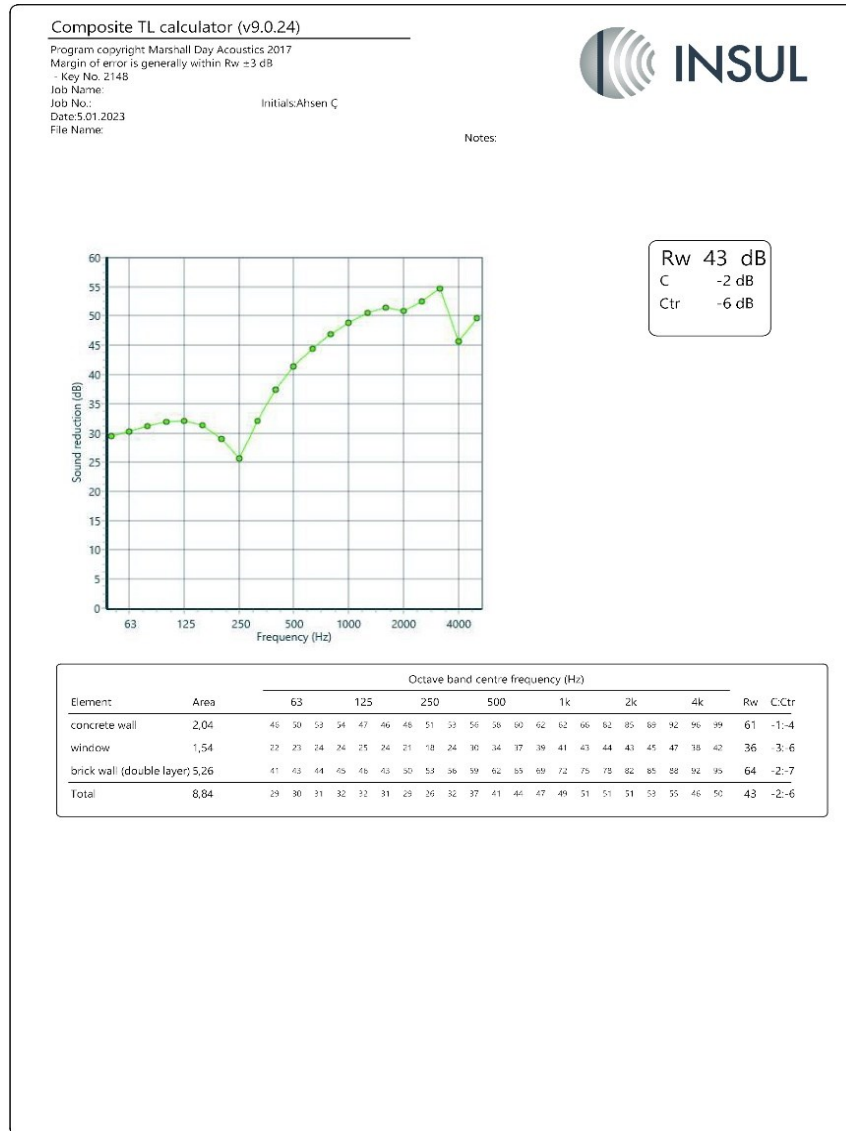
$D_{nT,A,tr} = R_w (C; Ctr) - 4$ (Since it is an external construction element, the Ctr value representing the external noise will be used.)

$$D_{nT,A,tr} = 41 - 6 - 4 = 31 \text{ dB}$$

According to the result, it cannot provide sufficient insulation for air-borne sound on the exterior walls by remaining below the value defined for class D in the regulation ($L_{den} - 26$). Therefore, it is necessary to take precautions.

APPENDIX-3. (continue) Insul (V9.0.24) program calculation results for exterior walls

Appendix -3g. dd-2c: 25 cm reinforced concrete wall + 40 cm double layer brick wall + window: Rw: 43 (-2,-6). The dd-2c wall on Master bedroom's facade is a composite structure, and its Rw value is shown in the table.



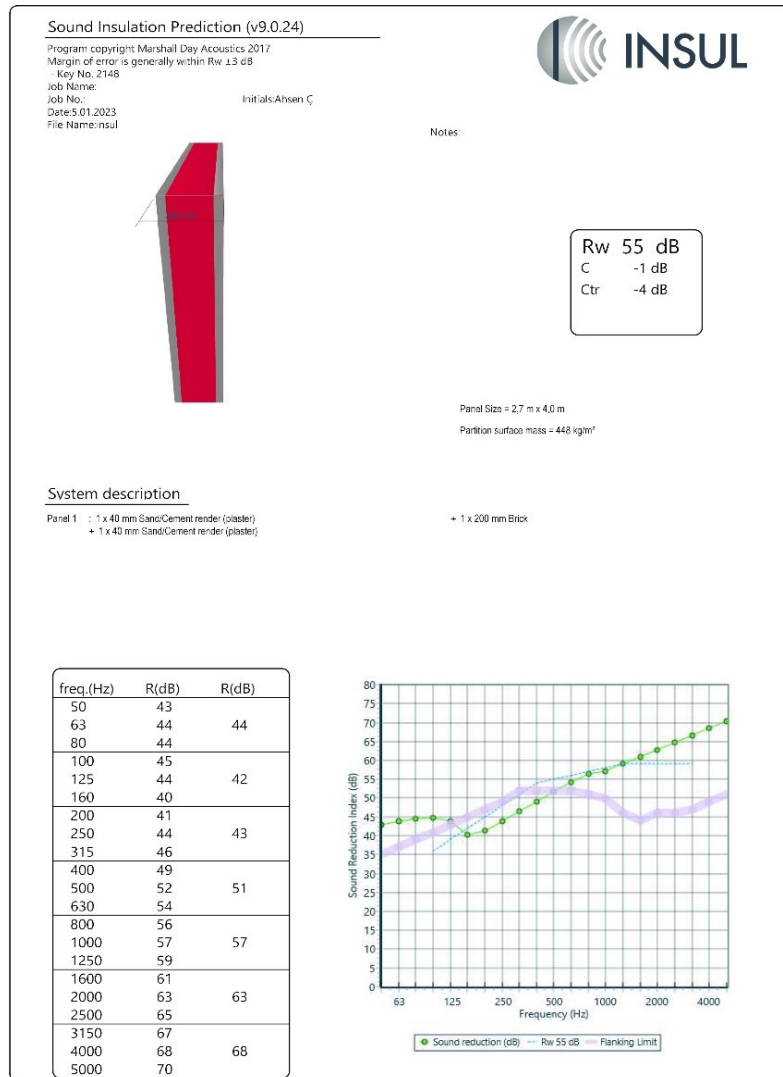
- Since *master bedroom's* width, height, and height definitions provide the reliance interval (güven aralığı) ($V1$ and $V2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

$D_{nT,A,tr} = R_w (C; Ctr) - 4$ (Since it is an external construction element, the Ctr value representing the external noise will be used.)

$$D_{nT,A,tr} = 43 - 6 - 4 = 33 \text{ dB}$$

APPENDIX-4. Insul (V9.0.24) program calculation results for interior walls

Appendix -4a. di-1 and di-1a: 20 cm brick wall - R_w : 55 (-1,-4). The R_w value of the di-1 and di-1a walls (between 2 independent units: the kitchen and the master bedroom) is given in the table.



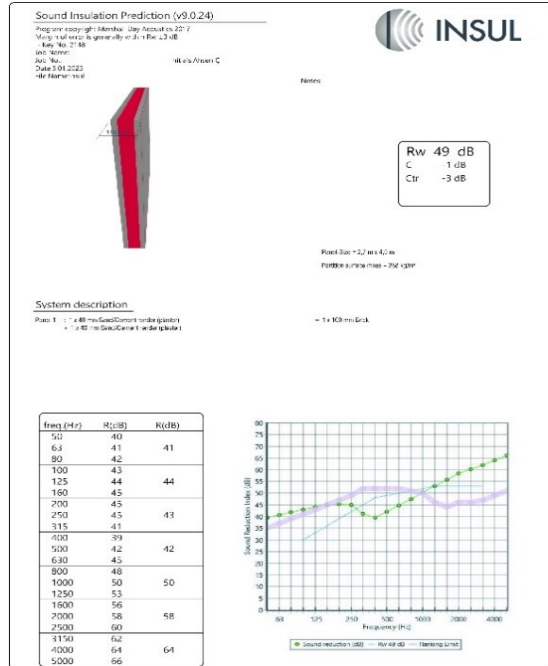
- Since the kitchen and master bedroom's width, height, and height definitions provide the reliance interval (güven aralığı) (V_1 and $V_2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

$D_{nT,A} = R_w (C; C_{tr}) - 3$ (C value representing internal noise will be used since it is an internal structural element)

$$D_{nT,A} = 55 - 1 - 3 = 51 \text{ dB}$$

APPENDIX-4. (continue) Insul (V9.0.24) program calculation results for interior walls

Appendix -4b. di-2: 10 cm brick wall - R_w : 49 (-1,-3). The R_w value of the di-2 wall between the living room and the kitchen is given in the table.



- Since *living room's* width, height, and height definitions provide the reliance interval (güven aralığı) (V_1 and $V_2 < 75 \text{ m}^3$, $h < 3 \text{ m}$, $a, b < 5 \text{ m}$); the following formula is used:

*Acoustic Values of the Partition Element:

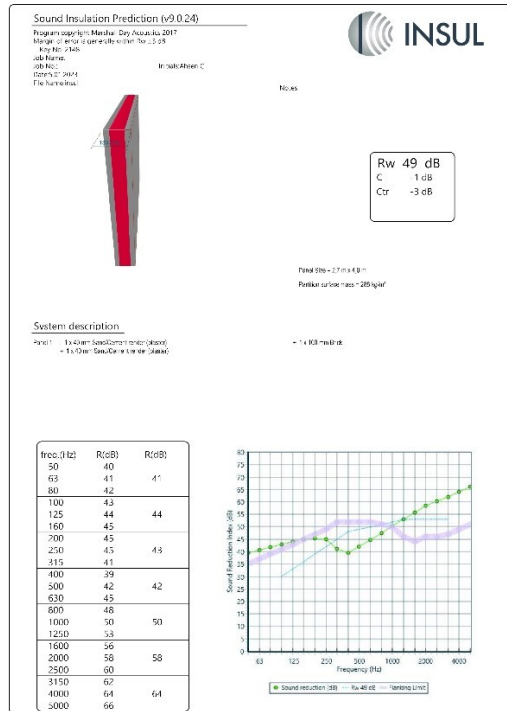
R_w (dB)	C 100-3150 (dB)	C_f	R'_w (dB)	DntA (dB)
49,00 dB	-1,00 dB	0,00	48,00 dB	52,98 dB
Ss: Partition Element Surface Area (m2): 7,67 m2		V: Receiver Room Volume (m3): 75,55 m3		

*Structural Elements Causing Sound Bridge:

Structural Element	Structural Element Description	Surface Mass (kg/m2)
Partition Element	10 cm brick wall	288,00
1st Element Forming Flanking Transmission	25 cm concrete wall	714,00
2 nd Element Forming Flanking Transmission	12 cm concrete floor	418,00
3 rd Element Forming Flanking Transmission	12 cm concrete floor	418,00
4 th Element Forming Flanking Transmission	10 cm brick wall	288,00
The surface mass is taken from the Insul program (Demirel, 2022)		

APPENDIX-4. (continue) Insul (V9.0.24) program calculation results for interior walls

Appendix -4c. di-2a: 10 cm brick wall - R_w : 49 (-1,-3). The R_w value of the di-2a wall between the living room and the corridor is given in the table.



- Since *living room's* width, height, and height definitions provide the reliance interval (güven aralığı) (V_1 and $V_2 < 75 \text{ m}^3$, $h < 3 \text{ m}$, $a, b < 5 \text{ m}$); the following formula is used:

*Acoustic Values of the Partition Element:

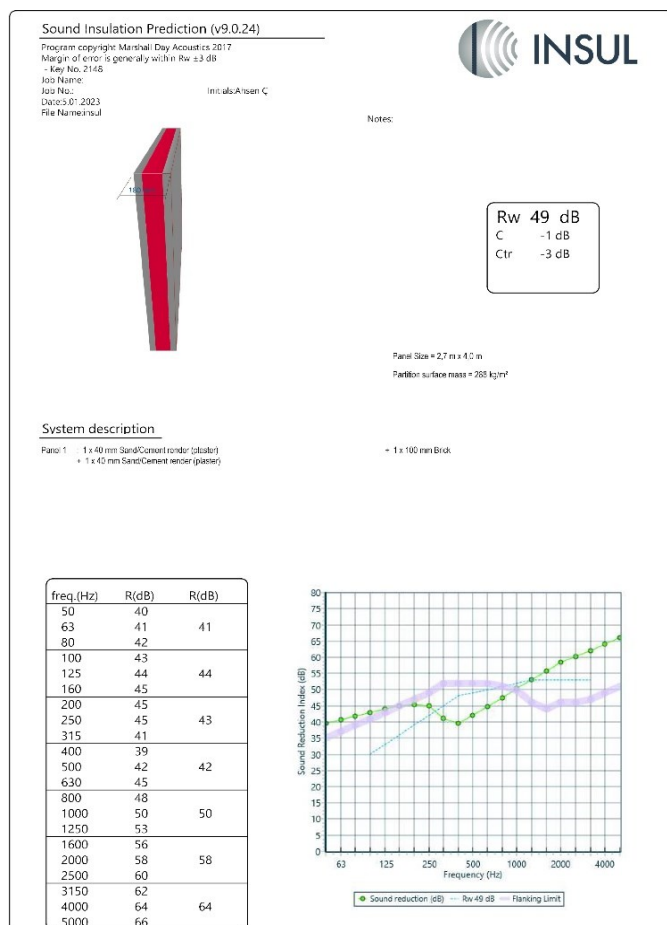
R_w (dB)	C 100-3150 (dB)	C_f	R'_w (dB)	DntA (dB)
49,00 dB	-1,00 dB	0,00	48,00 dB	51,28 dB
Ss: Partition Element Surface Area (m2): 11,33 m2		V: Receiver Room Volume (m3): 75,55 m3		

*Structural Elements Causing Sound Bridge:

Structural Element	Structural Element Description	Surface Mass (kg/m2)
Partition Element	10 cm brick wall	288,00
1st Element Forming Flanking Transmission	25 cm concrete wall	714,00
2nd Element Forming Flanking Transmission	12 cm concrete floor	418,00
3rd Element Forming Flanking Transmission	12 cm concrete floor	418,00
4th Element Forming Flanking Transmission	10 cm brick wall	288,00
The surface mass is taken from the Insul program (Demirel, 2022)		

APPENDIX-4. (continue) Insul (V9.0.24) program calculation results for interior walls

Appendix-4e. di-2c, di-2d, di-2e, and di-2f: 10 cm brick wall - R_w : 49 (-1,-3). *di-2c wall*; it is located between the corridor and bedroom 1, and bedroom 1 and bedroom 2. *di-2d wall*; it is located between the corridor and bedroom-2. *di-2e wall*; corridor, and bedroom-3. It is located between bedroom 2 and bedroom 3, and bedroom 3 and the master bedroom. The *di-2f wall*; is located between the hallway and the master bedroom, and between the master bedroom and the master bedroom bathroom. The R_w value of these walls is given in the table.



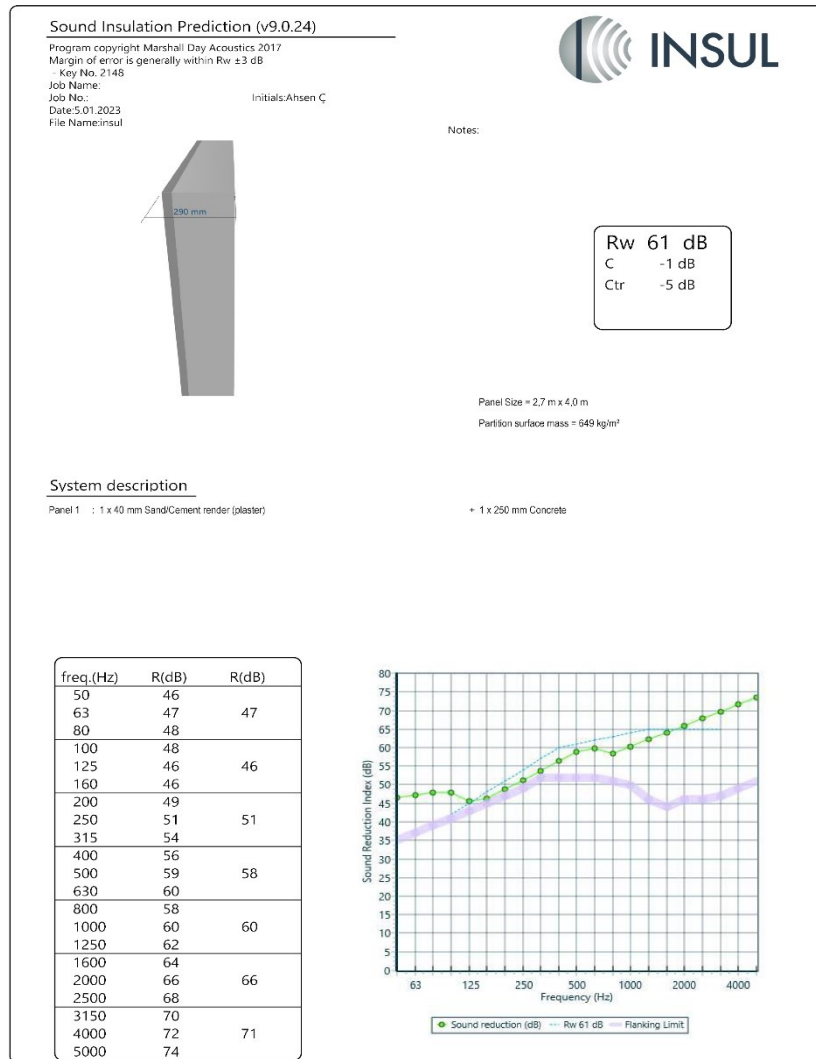
- Since *corridor and bedroom's* width, height, and height definitions provide the reliance interval (güven aralığı) (V_1 and $V_2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

$D_{nT,A} = R_w (C; C_{tr}) - 3$ (C value representing internal noise will be used since it is an internal structural element)

$$D_{nT,A} = 49 - 1 - 3 = 45 \text{ dB}$$

APPENDIX-4. (continue) Insul (V9.0.24) program calculation results for interior walls

Appendix-4f. di-3 and di-3a: 25 cm concrete wall - R_w : 61 (-1,-5). The R_w value of the di-3 wall between the master bedroom and the master bedroom bathroom and between the master bedroom and the elevator is given in the table.



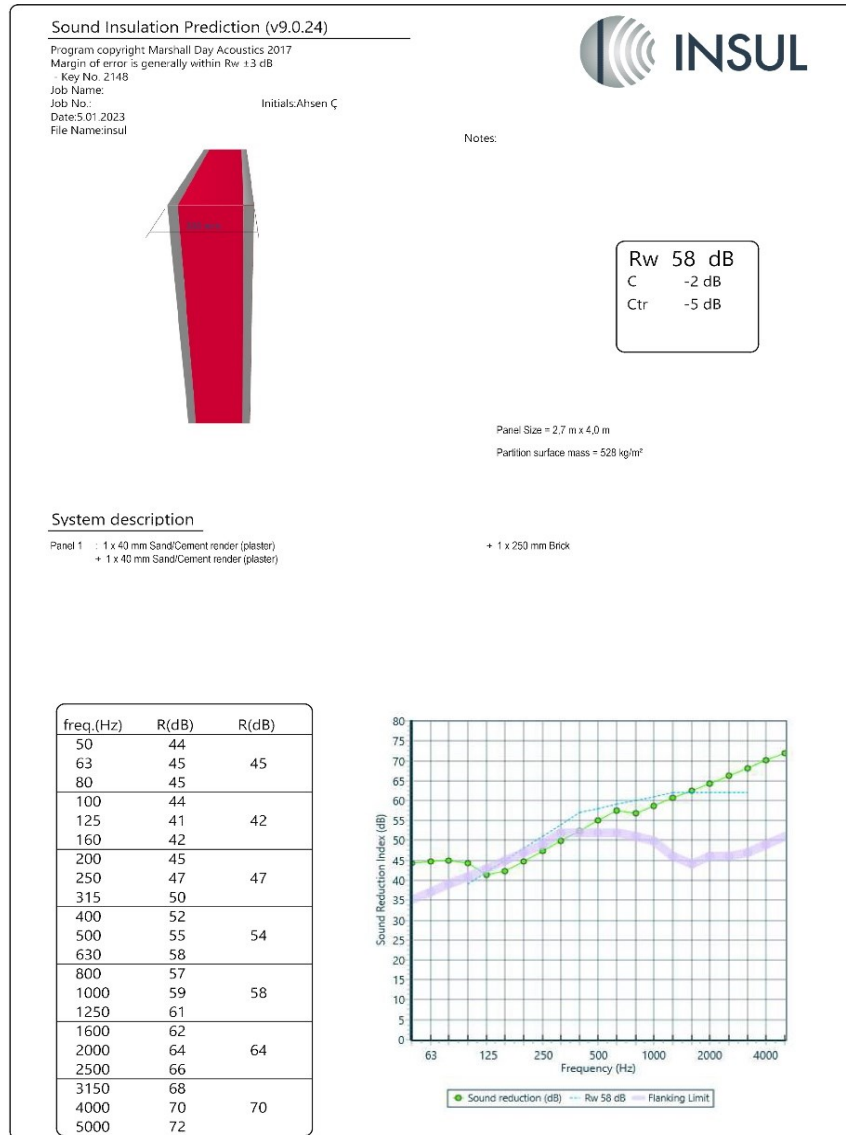
- Since the master bedroom, master bedroom's bathroom, and elevator's width, height, and height definitions provide the reliance interval (güven aralığı) ($V1$ and $V2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

$D_{nT,A} = R_w (C; C_{tr}) - 3$ (C value representing internal noise will be used since it is an internal structural element)

$$D_{nT,A} = 61 - 1 - 3 = 57 \text{ dB}$$

APPENDIX-4. (continue) Insul (V9.0.24) program calculation results for interior walls

Appendix-4g. di-4: 25 cm brick wall - R_w : 58 (-2,-5). The R_w value of the di-4 wall between the stair and the master bedroom is given in the table.



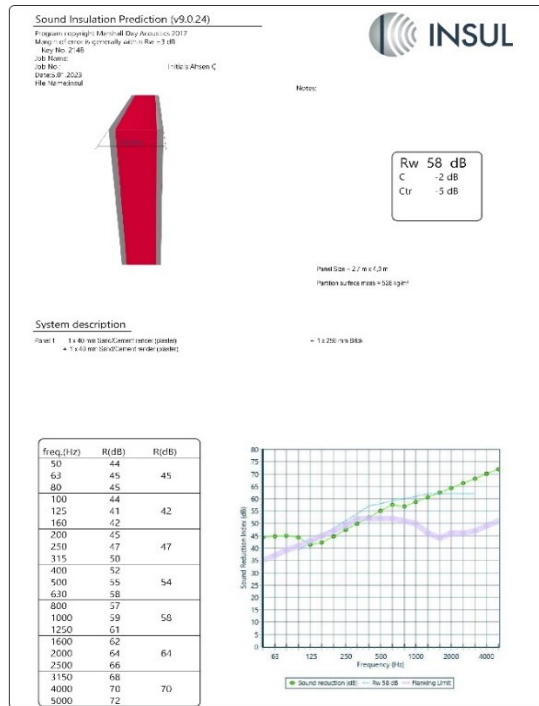
- Since the *stair and master bedroom* 's width, height, and height definitions provide the reliance interval (güven aralığı) (V_1 and $V_2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:

$D_{nT,A} = R_w (C; C_{tr}) - 3$ (C value representing internal noise will be used since it is an internal structural element)

$$D_{nT,A} = 58 - 2 - 3 = 53 \text{ dB}$$

APPENDIX-4. (continue) Insul (V9.0.24) program calculation results for interior walls

Appendix-4i. di-4b: 25 cm brick wall - R_w : 58 (-2,-5). The R_w value of the di-4b wall between the stair hall and the kitchen is given in the table.



- Since the *stair hall's* width, height, and height definitions provide the reliance interval (güven aralığı) ($a, b < 5$ m); the following formula is used:

*Acoustic Values of the Partition Element:

R_w (dB)	C 100-3150 (dB)	C_f	R'_w (dB)	D_{ntA} (dB)
58,00 dB	-2,00 dB	2,00	54,00 dB	56,32 dB
Ss: Partition Element Surface Area (m2): 6,24 m2		V: Receiver Room Volume (m3): 33,38 m3		

*Structural Elements Causing Sound Bridge:

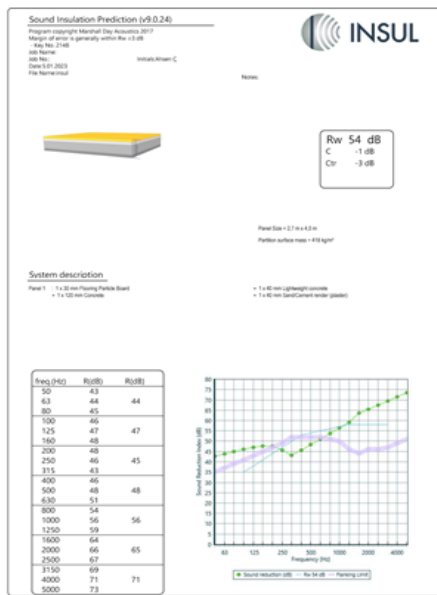
Structural Element	Structural Element Description	Surface Mass (kg/m2)
Partition Element	25 cm brick wall	528,00
1st Element Forming Flanking Transmission	25 cm brick wall	528,00
2nd Element Forming Flanking Transmission	12 cm concrete floor	418,00
3rd Element Forming Flanking Transmission	12 cm concrete floor	418,00
4th Element Forming Flanking Transmission	10 cm brick wall	288,00
The surface mass is taken from the Insul program (Demirel, 2022)		

APPENDIX-5. (continue) Insul (V9.0.24) program calculation results for floors

Appendix-5b. do-2: 12 cm concrete floor - $R_w:54$ (-1,-3) ; $L_{n,w}: 69$ (-6)

Airborne and impact sound calculation analyses of the do-1 flooring (structural elements in the existing residential building) located between 2 independent units are given below.

do-2 Airborne sound insulation calculation $R_w:54$ (-1,-3)



-Since the *living room's* width, height, and height definitions provide the reliance interval (güven aralığı) ($a, b < 5$ m); the following formula is used:

*Acoustic Values of the Partition Element:

R_w (dB)	C 100-3150 (dB)	C_f	R'_w (dB)	DntA (dB)
54,00 dB	-1,00 dB	0,00	53,00 dB	52,19 dB

Ss: Partition Element Surface Area (m2): 29,06 m2

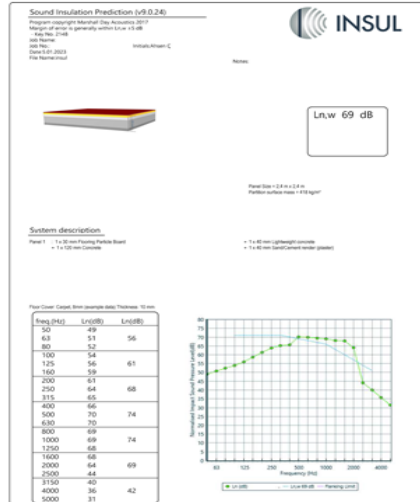
V: Receiver Room Volume (m3): 75,55 m3

*Structural Elements Causing Sound Bridge:

Structural Element	Structural Element Description	Surface Mass (kg/m2)
Partition Element	12 cm concrete floor	418,00
1st Element Forming Flanking Transmission	10 cm brick wall	288,00
2nd Element Forming Flanking Transmission	10 cm brick wall	288,00
3rd Element Forming Flanking Transmission	30 cm brick wall (double layer)	529,00
4th Element Forming Flanking Transmission	40 cm brick wall (double layer)	689,00
The surface mass is taken from the Insul program (Demirel, 2022)		

APPENDIX-5. (continue) Insul (V9.0.24) program calculation results for floors

do-2 Impact sound insulation calculation L_{nw} : 69 (-6)



-Since the *living room's* width, height, and height definitions provide the reliance interval (güven aralığı) ($a, b < 5$ m); the following formula is used:

*Acoustic Values of the Partition Element:

L_{nw} (dB)	CI (dB)	K	Hd	L'_{nTw} (dB)
69,00 dB	-6,00 dB	0,00	-2,00 dB	61,00 dB
Ss: Partition Element Surface Area (m2): 29,06 m2		V: Receiver Room Volume (m3): 75,55 m3		

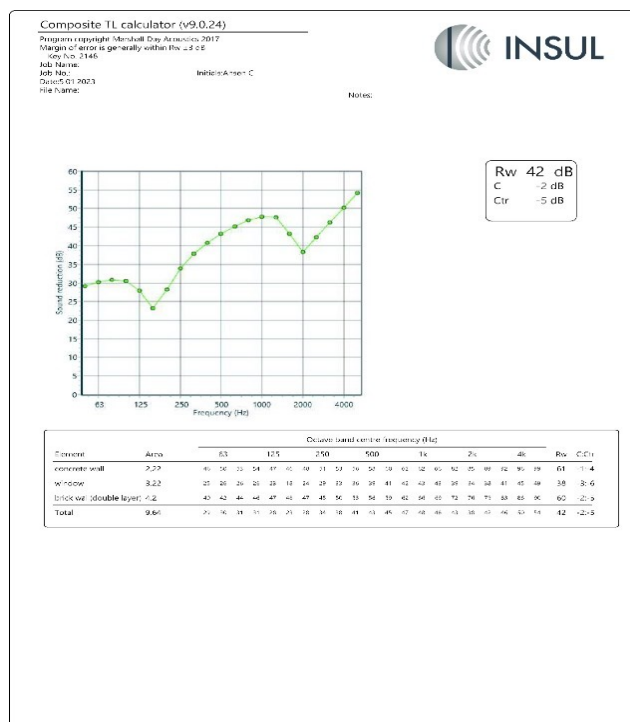
*Structural Elements Causing Sound Bridge:

Structural Element	Structural Element Description	Surface Mass (kg/m2)
Partition Element	12 cm concrete floor	418,00
1st Element Forming Flanking Transmission	10 cm brick wall	288,00
2nd Element Forming Flanking Transmission	10 cm brick wall	288,00
3rd Element Forming Flanking Transmission	30 cm brick wall (double layer)	529,00
4th Element Forming Flanking Transmission	40 cm brick wall (double layer)	689,00
The surface mass is taken from the Insul program (Demirel, 2022)		

According to the findings, it cannot provide adequate insulation for impact sound in floors by remaining well above the values defined in the regulation for class D. Therefore, it is necessary to take precautions.

APPENDIX-6. Recommendations for structural elements not providing limit values

Appendix-6a. dd-1a: 25 cm reinforced concrete wall + 30 cm double layer brick wall + window: R_w : 42 (-2,-5). The sound insulation of the composite facade element can be improved by increasing the glass thickness in the windows and the gap width (8–16–8) between the windows in the existing structure.



Since *bedroom-1*'s width, height, and height definitions provide the reliance interval (güven aralığı) ($V1$ and $V2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:
 $D_{nT,A,tr} = R_w (C; C_{tr}) - 4$ (Since it is an external construction element, the C_{tr} value representing the external noise will be used.) $D_{nT,A,tr} = 42 - 5 - 4 = 33$ dB

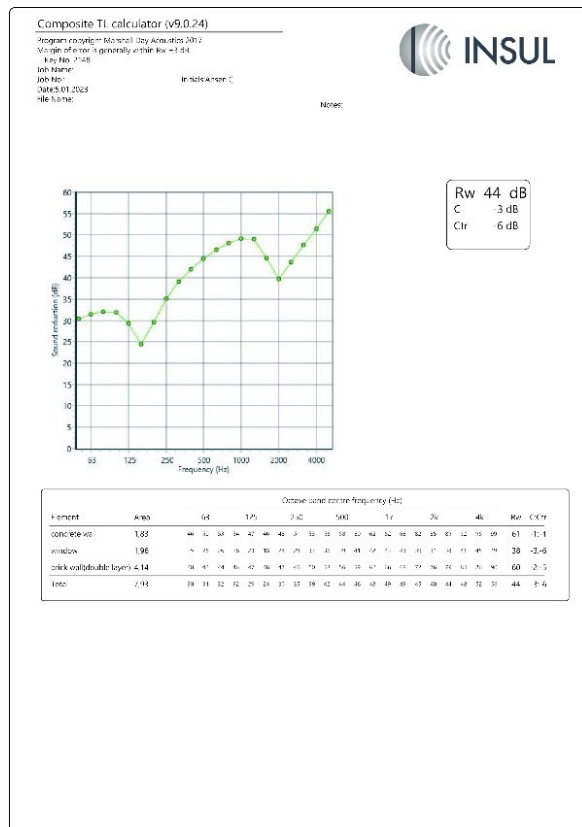
As a second recommendation, laminated glass R_w : 40 (-2, -6) can be used in the existing structure, although the cost is high (6 cm laminated glass, 12 cm gap, 6 cm laminated glass). The composite system's R_w value is calculated as 45 (-2, -6) when laminated glass is used. $D_{nT,A,tr} = 45 - 6 - 4 = 35$ dB

The second method provides better noise control.

(The values were obtained with the Insul (v9.0.24) simulation program.)

APPENDIX-6. (continue) Recommendations for structural elements not providing limit values

Appendix-6b. dd-1b: 25 cm reinforced concrete wall + 30 cm double layer brick wall + window:Rw: 44 (-3,-6). The sound insulation of the composite facade element can be improved by increasing the glass thickness in the windows and the gap width (8–16–8) between the windows in the existing structure.



Since *bedroom-2's* width, height, and height definitions provide the reliance interval (güven aralığı) (V_1 and $V_2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:
 $D_{nT,A,tr} = R_w (C; C_{tr}) - 4$ (Since it is an external construction element, the C_{tr} value representing the external noise will be used.) $D_{nT,A,tr} = 44 - 6 - 4 = 34$ dB

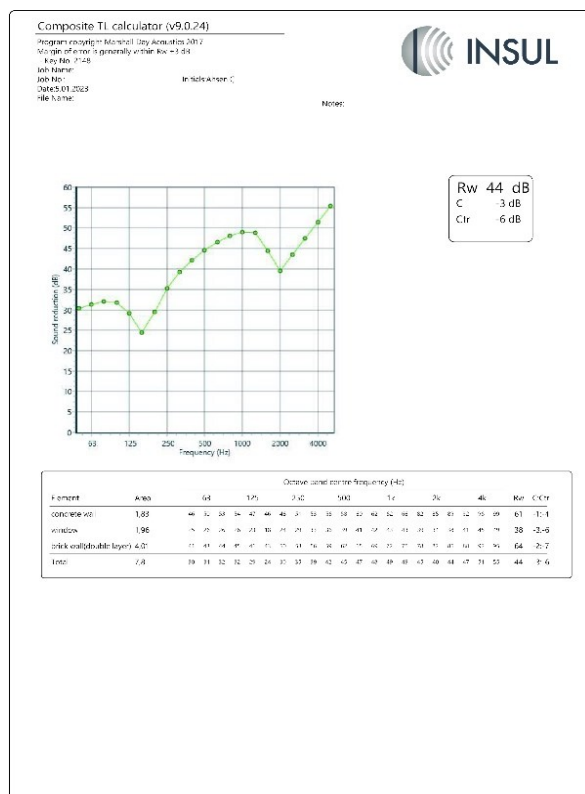
As a second recommendation, laminated glass R_w : 40 (-2, -6) can be used in the existing structure, although the cost is high (6 cm laminated glass - 12 cm gap - 6 cm laminated glass) The composite system's R_w value is calculated as 46 (-2,6) when laminated glass is used. $D_{nT,A,tr} = 46 - 6 - 4 = 36$ dB

The second method provides better noise control.

(The values were obtained with the Insul (v9.0.24) simulation program.)

APPENDIX-6. (continue) Recommendations for structural elements not providing limit values

Appendix-6c. dd-2b: 25 cm reinforced concrete wall + 40 cm double layer brick wall + window: R_w : 44 (-3,-6). The sound insulation of the composite facade element can be improved by increasing the glass thickness in the windows and the gap width (8–16–8) between the windows in the existing structure.



Since *bedroom-3's* width, height, and height definitions provide the reliance interval (güven aralığı) ($V1$ and $V2 < 75$ m³, $h < 3$ m, $a, b < 5$ m); the following formula is used:
 $D_{nT,A,tr} = R_w (C; Ctr) - 4$ (Since it is an external construction element, the Ctr value representing the external noise will be used.) $D_{nT,A,tr} = 44 - 6 - 4 = 34$ dB

As a second recommendation, laminated glass R_w : 40 (-2, -6) can be used in the existing structure, although the cost is high (6 cm laminated glass, 12 cm gap, 6 cm laminated glass) The composite system's R_w value is calculated as 46 (-2,6) when laminated glass is used. $D_{nT,A,tr} = 46 - 6 - 4 = 36$ dB

The second method provides better noise control.

(The values were obtained with the Insul (v9.0.24) simulation program)

APPENDIX-6. (continue) Recommendations for structural elements not providing limit values

Appendix-6d Recommendation -1: do-1 and do-2: 12 cm concrete floor $R_w:52$ (0,-3) ; $L_{n,w}$: 54 (0). To improve floor sound insulation: The first recommendation was to use an impact absorber beneath the screed. This method provides airborne and impact-borne sound insulation for class D limit values.

Recommendation for Sound Insulation for the Flooring Element (Impact Absorbing Material Under Screed)	
Airborne Sound Insulation: $R_w: 52$ (0,-3)	Impact Sound Insulation: $L_{n,w}: 54$ (0)
	
* Panel 1: 1x120 mm concrete 1x40 mm SandCement render (plaster)	* Panel 1: 1x120 mm concrete 1x40 mm SandCement render (plaster) *Floor cover: DAMTEC System 2 layer (granules together) under cement screen (55mm)
The values and images are taken from the Insul (v9.0.24) simulation program.	

- Since *bedroom* volumes provide the confidence interval, the following formulas are used:

Airborne sound insulation calculation: $D_{nT,A} = R_w(C;Ctr) - 3$

$D_{nT,A} = 52-0-3= 49$ dB (It is a value above the limit value (48)) **APPROPRIATE**

Impact sound insulation calculation: $L'_{nT,w} = L_{n,w} + 3$

$L'_{nT,w} = 54+0+3= 57$ dB (It is below the limit value (58)) **APPROPRIATE**

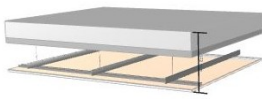
-The following formulas are used as the *living room* volumes do not fit the confidence interval:

R_w (dB)	C 100-3150 (dB)	C_f	R'_w (dB)	$D_{nT,Atr}$ (dB)
52,00 dB	0,00 dB	0,00	52,00 dB	51,19 dB
$D_{nT} = 52 + 10 \log (0,32 \cdot 75,55 / 29,06) = 51,19$ dB (It is a value above the limit value (48)) APPROPRIATE				

$L_{n,w}$ (dB)	CI (dB)	K	Hd	$L'_{nT,w}$ (dB)
54,00 dB	0,00 dB	0,00	-2,00 dB	52,00 dB
$L'_{nT,w} = 54+0+0-2= 52$ dB (It is below the limit value (58)) APPROPRIATE				

APPENDIX-6. (continue) Recommendations for structural elements not providing limit values

Appendix -6d Recommendation -2: do-1 and do-2: 12 cm concrete floor - R_w :61 (-2,-6) ; $L_{n,w}$: 50 (1) To improve floor sound insulation: It is suggested to use a suspended ceiling as the second recommendation. Suspended ceiling is calculated at 20 cm. However, while only a suspended ceiling provides airborne sound insulation, the floor could not provide the impact sound limit value defined for class D ($L_{n,w}$: 62 (-3)). For this reason, it is recommended to use a floor covering. Compared to the first method, this one is more effective, especially in airborne sound insulation.

Recommendation for Sound Insulation for the Flooring Element (Suspended Ceiling and Floor Cover)	
Airborne Sound Insulation: R_w : 61 (-2,-6)	Impact Sound Insulation: $L_{n,w}$: 50 (1)
	
* Panel 1:1x 120 mm concrete 1x40 mm SandCement render (plaster) *Suspended Light Steel Grid (200mmx45mm), Stud spacing 600mm; Cavity Width 200mm (Empty Cavity) * Panel 2: 1x12,5 mm plasterboard	* Panel 1:1x 120 mm concrete 1x40 mm SandCement render (plaster) *Suspended Light Steel Grid (200mmx45mm), Stud spacing 600mm; Cavity Width 200mm (Empty Cavity) * Panel 2: 1x12,5 mm plasterboard * Floor cover: Ecoroll (5mm&720kg/m ³) under concrete screed
The values and images are taken from the Insul (v9.0.24) simulation program.	

- Since *bedroom* volumes provide the confidence interval, the following formulas are used:

Airborne sound insulation calculation: $D_{nT,A} = R_w(C;Ctr) - 3$ $D_{nT,A} = 61-2-3= 56 \text{ dB}$ (It is a value above the limit value (48)) **APPROPRIATE**

Impact sound insulation calculation: $L'_{nT,w} = L_{n,w} + 3$: $L'_{nT,w} = 50+1+3= 54 \text{ dB}$ (It is below the limit value (58)) **APPROPRIATE**. The following formulas are used as the *living room* volumes do not fit the confidence interval:

R_w (dB)	C 100-3150 (dB)	Cf	R'_w (dB)	DntAtr (dB)
61,00 dB	-2,00 dB	0,00	59,00 dB	58,19 dB

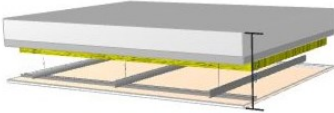
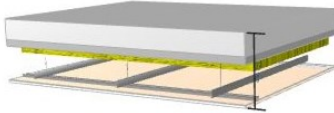
$DnT = 59 + 10 \log (0,32 \cdot 75,55 / 29,06) = 58,19 \text{ dB}$ (It is a value above the limit value (48)) **APPROPRIATE**

$L_{n,w}$ (dB)	CI (dB)	K	Hd	L'_{nTw} (dB)
50,00 dB	1,00 dB	0,00	-2,00 dB	49,00 dB

$L'_{nTw} = 50+1+0-2= 49 \text{ dB}$ (It is below the limit value (58)) **APPROPRIATE**

APPENDIX-6. (continue) Recommendations for structural elements not providing limit values

Appendix-6d Recommendation-3: do-1 and do-2: 12 cm concrete floor - R_w :69 (-2,-4) ; $L_{n,w}$: 60 (-10) : To improve floor sound insulation: As the third recommendation, it is suggested to use sound-absorbing material in the suspended ceiling and suspended ceiling space. This method gives the most effective result in sound insulation. Calculations are made without floor covering. Despite this, the values are suitable for class D. It is possible to achieve better sound insulation by using floor coverings.

Recommendation for Sound Insulation for the Flooring Element (Suspended Ceiling and Absorbent Material)	
Airborne Sound Insulation: R_w : 69(-2,-4)	Impact Sound Insulation: $L_{n,w}$: 60(-10)
	
* Panel 1:1x 120 mm concrete 1x40 mm SandCement render (plaster) *Suspended Light Steel Grid (200mmx45mm), Cavity Width 200mm + 50 mm Fibreglass(10kg/m ³) * Panel 2: 1x12,5 mm plasterboard	* Panel 1:1x 120 mm concrete 1x40 mm SandCement render (plaster) *Suspended Light Steel Grid (200mmx45mm), Cavity Width 200mm + 50 mm Fibreglass(10kg/m ³) *Panel 2: 1x12,5 mm plasterboard * Floor cover: None
The values and images are taken from the Insul (v9.0.24) simulation program.	

- Since *bedroom* volumes provide the confidence interval, the following formulas are used:

Airborne sound insulation calculation: $D_{nT,A} = R_w (C; C_{tr}) - 3$

$D_{nT,A} = 69-2-3 = 64 \text{ dB}$ (It is a value above the limit value (48)) **APPROPRIATE**

- Impact sound insulation calculation: $L'_{nT,w} = L_{n,w} + 3$

$L'_{nT,w} = 60-10+3 = 53 \text{ dB}$ (It is below the limit value (58)) **APPROPRIATE**

*The following formulas are used as the *living room* do not fit the confidence interval:

R_w (dB)	C 100-3150 (dB)	C_f	R'_w (dB)	$D_{nT,Atr}$ (dB)
69,00 dB	-2,00 dB	0,00	67,00 dB	66,19 dB

$D_{nT} = 67 + 10 \log (0,32 \cdot 75,55 / 29,06) = 66,19 \text{ dB}$ (It is a value above the limit value (48)) **APPROPRIATE**

$L_{n,w}$ (dB)	CI (dB)	K	Hd	$L'_{nT,w}$ (dB)
60,00 dB	-10,00 dB	0,00	-2,00 dB	48,00 dB

$L'_{nT,w} = 60-10+0-2 = 48 \text{ dB}$ (it is below the limit value (58)) **APPROPRIATE**



Gazili olmak ayrıcalıktır...