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THE LEGISLATIVE LEAP FORWARD TOWARDS REGULATING THE ACOUSTICS IN BUILDINGS IN CROATIA

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ABSTRACT

For a long time, acoustics in buildings in Croatia has been poorly regulated in terms of appropriate legislative documents. The future of this field has been brightened by the recent development and completion of a comprehensive technical regulation on the subject matter. This document addresses the aspects of acoustics in buildings that concern room acoustics, building acoustics, and noise, providing a set of requirements for the architects and other involved experts to adhere to, thus facilitating better building design in terms of acoustics in buildings. The aim of this paper is to present the key provisions of this document that will help achieve this goal. Details will be given on the stipulated requirements on sound insulation and permitted noise levels in buildings that are considered acoustically sensitive, such as residential buildings, office buildings, buildings used for accommodation, buildings used for activities on all levels of education, and healthcare buildings. The requirements on the design for optimal room acoustics will be given for rooms used for music, speech, education, and sports, as well as requirements on room acoustics in noise-sensitive spaces focused on reducing excessive reverberance and excessive noise that stems from it.

Keywords: *technical regulation, acoustics in buildings, room acoustics, building acoustics, noise.*

1. INTRODUCTION

Acoustics in buildings is a field that has not been properly addressed during the entire existence of Croatia as a sovereign state, despite several prior attempts that have been made to improve this status quo. The latest efforts to rectify the situation have been encouraged by the European Union, stating that the Croatian regulations in this field are outdated and in need of updating. After 18 months of work, the new Technical Regulation on Acoustics in Buildings has been created. The document has passed scrutinization on all levels and is now ready to be published in the Official Gazette of the Republic of Croatia.

In [1,2] details have been given on the history of the field of acoustics in buildings in Croatia in the past 40 years, explaining the urgent need for creating a comprehensive regulation that has been lacking all these years. A description of the workflow that resulted in the creation of this document has also been given, as well as the description of its scope, and a general overview of its content.

This paper focuses on the technical requirements stipulated by the Regulation in terms of airborne and impact sound insulation, maximum permissible noise levels inside buildings, and the requirements on room acoustics (where applicable). In terms of sound insulation and noise, a detailed overview of these criteria is given for buildings that contain spaces that are deemed as noise-sensitive and must, therefore, be protected from noise. The spaces to be protected are housing units in strictly residential and mixed residential-commercial buildings, office spaces in commercial buildings, commerce spaces in shopping malls, accommodation units in hotels, dormitories, etc., spaces used for activities at all levels of education, spaces in healthcare facilities, and preschool spaces. In terms of room acoustics, the Regulation addresses spaces used for music, speech, education, and sports, for which optimal acoustics

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needs to be achieved. In addition, mandatory acoustic treatment is stipulated for certain spaces that are expected to benefit from reduction of excessive reverberance and consequent noise reduction inside those spaces.

2. KEY PROVISIONS IN THE REGULATION

This Regulation is to be applied in design and construction of new buildings, reconstruction of the existing ones, and construction of simple buildings that do not require a building permit, so that the fundamental requirement that concerns the protection from noise is met in every aspect.
The technical requirements in terms of acoustics in buildings are stipulated as:

- $R'_{w,min}$ or $D_{nT,w,min}$ or $R_{w,min}$ as the minimum required value for airborne sound insulation of a building element (door, window, glass wall) or between two spaces in a building
- $L'_{n,w,max}$ as the maximum permissible value for impact sound insulation between two spaces
- $L_{R,Aeq}$ as the maximum permissible noise rating level in dwelling rooms for living and rest, work rooms, and special-purpose rooms
- $L_{AF,max,nT}$ as the maximum permissible level of service equipment noise
- T_{Soll} as the required reverberation time for spaces that require optimal room acoustic conditions
- A/V as the minimum required ratio of the equivalent absorption area and room volume for spaces that require reduction of reverberance

The airborne sound insulation of the outer shell of a building is to be designed to meet the requirements on the maximum permissible noise rating level $L_{R,Aeq}$ in the protected spaces inside the building, taking into account the most exposed spaces and the least favourable conditions during the day, evening or night. The outdoor noise level is to be obtained from (in the given order of priority) noise measurements, calculation estimates, or taken as maximum permissible outdoor noise level in the particular noise zone.
Rooms inside a building that contain service and other equipment or host activities connected with commercial exploitation are divided into three noisiness groups according to the expected, designed, or measured noise rating level $L_{R,Aeq}$:

- N1 – the noise rating level is below 70 dBA
- N2 – the noise rating level is between 70 and 80 dBA
- N3 – the noise rating level exceeds 80 dBA

These designations shall be used in the remainder of the article. In new buildings, no direct contact between N3-rated spaces and critically protected spaces is allowed, in terms of sharing a common party wall or floor.

To prove that the requirements will be met, this Regulation stipulates the use of the EN 12354 series of standards [3-7] in the design process but also allows the use of calculation methods or models (e.g. ray-tracing methods in room acoustics) that are based on verified technical solutions and/or new advancements and solutions in the fields of noise protection and room acoustics. Laboratory reports on sound insulation and sound absorption of materials and constructions may/should be used as input data for the design process.

The proof of meeting the set requirements in the design and construction process shall be obtained through measurements according to relevant standards [8-18]. The "simple acceptance" rule shall be applied. In exceptional cases, the required proof may be obtained through reports provided by all parties that partake in the building process.

3. SOUND INSULATION REQUIREMENTS

The requirements on airborne and impact sound insulation in critical types of buildings are presented in detail in Tables 1 to 7. In specific cases, $D_{nT,w}$ or R_w are used instead of R'_w.

Table 1. Sound insulation requirements for residential and residential-commercial buildings

Residential and residential-commercial use	$R'_{w,min}$ (dB)	$L'_{n,w,max}$ (dB)
Party wall between any two rooms in two housing units (within a multi storey building or in two adjacent buildings in direct contact)	52	
Party wall between dwelling rooms of a housing unit and a technical/commercial space* – N1; N2; N3***	57 62 67	
Party wall between other rooms in a housing unit and a technical/commercial space* – N1; N2; N3	52 57 62	
Party wall between a housing unit and storage rooms, entrance spaces, stairwells	52	
Party wall between a housing unit and garbage rooms, fitness, wellness, other common spaces for residents only	57	
Entrance door to the housing unit (R_w)** - with buffer space with a second door	30	
Entrance door to the housing unit (R_w)** - without buffer space	37	

Party wall with a door between a housing unit and common hallway or stairway ($D_{nT,w,min}$)	42	
Party wall between dwelling rooms of a housing unit and a single garage	55	
Party wall between dwelling rooms of a housing unit and a common garage, common garage entrance or exit	57	
Party floor between all rooms of two housing units	52	55
Party ceiling of a housing unit towards a terrace or a loggia of another housing unit		53
Party ceiling of a housing unit towards a common terrace		50
Party floor of a housing unit towards technical or commercial spaces* – N1; N2; N3***	57 62 67	58
Party ceiling of a housing unit towards technical or commercial spaces* – N1; N2; N2 fitness and sports; N3***	57 62 62 67	48 48 46 46
Party floor of a housing unit towards storage rooms, entrance spaces, stairwells	52	58
Party floor of a housing unit towards garbage rooms, fitness, wellness, other common spaces for residents only	57	58
Party ceiling of a housing unit towards storage rooms, entrance spaces, stairwells	52	48
Party ceiling of a housing unit towards garbage rooms, fitness, wellness, other common spaces for residents only	57	48
Party floor of a housing unit towards a single garage	55	58
Party floor of a housing unit towards a common garage, common garage entrance or exit	57	58
Party floor or floor on the ground of a housing unit towards another housing unit		55
Stairwells, balconies, common hallways, gallery hallways		58
Party floor or floor on the ground of commercial spaces or N2 and N3*** rooms towards a housing unit		48
Party floor or floor on the ground of an N3 room, towards housing unit (no direct contact is allowed!)		42
Outdoor entrance door to a housing unit (R_w)**	30	
Windows and balcony doors (R_w)**	30	

Notes:

*N3 rooms are not allowed in strictly residential buildings

*N3 rooms are allowed in residential-commercial buildings, but they must not be in direct contact with dwellings in the building

**R_w of a door, window, or a glass wall must be 2 dB higher than stipulated by this Regulation

***Not allowed in new buildings; allowed when reconstructing an existing N3 room in an old building, or when such room has already been designed and partially constructed

Table 2. Sound insulation requirements for office-commercial buildings

Office-commercial use	$R'_{w,min}$ **(dB)**	$L'_{n,w,max}$ **(dB)**
Party wall between two different users	52	
Wall between rooms for intellectual work within offices of a single user	44	
Wall between demanding workrooms or between a conference room and other spaces of the same user	47	
Wall between a room for intellectual work and other rooms – N1; N2 and garages; N3	47 52 57	
Wall between a room for intellectual work and communication spaces of a single user	44	
Door between a room for intellectual work and a hallway or other rooms (R_w)*	30	
Door between a demanding workroom or a conference room and a hallway or other rooms (R_w)*	32	
Glass wall between rooms for intellectual work of the same user (R_w)*	30	
Party floor/ceiling between all rooms for intellectual work and rooms of different users	52	58
Party floor of a room for intellectual work towards other rooms – N1; N2; N3	47 52 57	58
Party ceiling of a room for intellectual work towards other rooms – N1; N2; N3	47 52 57	55
Party floor or floor on the ground of service equipment rooms or N2 and N3 rooms towards dwelling rooms		48

Notes:

*R_w of a door, window, or a glass wall must be 2 dB higher than stipulated by this Regulation

Table 3. Sound insulation requirements for shopping malls

Shopping malls	$R'_{w,min}$ **(dB)**	$L'_{n,w,max}$ **(dB)**
Party wall between commerce rooms of two different users*	44	
Wall between a commerce room of a single user and other rooms – N1; N2 and garages; N3	44 47 52	
Party floor/ceiling	44	

Notes:

*The requirement is not set for commerce rooms that are open towards common areas of the shopping mall

Table 4. Sound insulation requirements for hotels, motels, dormitories and other accommodation buildings

Hotels and other types of accommodation	$R'_{w,min}$ (dB)	$L'_{n,w,max}$ (dB)
Party wall between accommodation units (four-star and five-star category)	52	
Party wall between accommodation units (other categories)	47	
Party wall with a door between connected accommodation units (four-star and five-star category) ($D_{nT,w,min}$)	52	
Party wall with a door between connected accommodation units (other categories) ($D_{nT,w,min}$)	47	
Wall between an accommodation unit and a hallway (four-star and five-star category)	52	
Wall between an accommodation unit and a hallway (other categories)	47	
Wall between an accommodation unit and other rooms – N1; N2 and garages	52 57	
Party floor/ceiling between accommodation units	52	58
Party floor of an accommodation unit towards other rooms – N1; N2 and garages	52 57	58
Party ceiling of an accommodation unit towards other rooms – N1; N2 and garages	52 57	48
Party floor or floor on the ground of service equipment rooms towards dwelling rooms		48
Entrance door to the accommodation unit (four-star and five-star category) (R_w)*	35	
Entrance door to the accommodation unit (other categories) (R_w)*	27	

Notes:

*R_w of a door, window, or a glass wall must be 2 dB higher than stipulated by this Regulation

Table 5. Sound insulation requirements for healthcare facilities

Healthcare use	$R'_{w,min}$ (dB)	$L'_{n,w,max}$ (dB)
Wall between hospital rooms	47	
Wall between hospital suites	52	
Wall between a hospital room and other rooms – N1; N2 and garages	52 57	
Wall between a hospital room and a hallway	47	
Wall between a hospital suite and a hallway	52	
Wall between an operating room and other rooms – N1; N2 and garages	52 57	
Wall between operating rooms	42	
Party floor/ceiling between accommodation units	52	58
Party floor of an accommodation unit towards other rooms – N1; N2 and garages	52 57	58
Party ceiling of an accommodation unit towards other rooms – N1; N2 and garages	52 57	48
Party floor or floor on the ground of service equipment rooms towards dwelling rooms		48
Entrance door to the accommodation unit (four-star and five-star category) (R_w)*	35	
Entrance door to the accommodation unit (other categories) (R_w)*	27	

Notes:

N3 rooms must not be in direct contact with hospital rooms/suites

*R_w of a door, window, or a glass wall must be 2 dB higher than stipulated by this Regulation

Table 6. Sound insulation requirements for educational facilities (elementary, middle and higher education; other education)

Educational use	$R'_{w,min}$ (dB)	$L'_{n,w,max}$ (dB)
Wall between classrooms and/or teachers' cabinets	52	
Wall between classrooms, teachers' cabinets or libraries and (class)rooms for physical, technical, or musical education	60	
Wall between classrooms or teacher's cabinets and communication spaces (hallways, stairwells, galleries, etc.) in schools	52 49	
Wall between classrooms or teacher's cabinets and communication spaces (hallways, stairwells, galleries, etc.) in higher education institutions	52	
Wall between a library and communication spaces (hallways, stairwells, galleries, etc.)	52	
Wall between classrooms, teachers' cabinets or libraries and other rooms – N1; N2 and garages, multipurpose spaces, mess halls, sports or multipurpose halls	52 60	
Party floor of classrooms, teachers' cabinets, libraries and communication spaces above – N1 and classrooms and teachers' cabinets; N2 and garages, sports or multipurpose halls, mess halls, and (class)rooms for physical, technical and musical education	52 60	48 58
Party ceiling of classrooms, teachers' cabinets, libraries and communication spaces above – N1 and classrooms and teachers' cabinets; N2 and garages, sports or multipurpose halls, mess halls, and (class)rooms for physical, technical and musical education	52 60	48 46
Party floor or floor on the ground of service equipment rooms, towards dwelling room		48
Other party floors/ceilings towards dwelling rooms	52	48
Door between a classroom and a teacher's cabinet (R_w)*	32	
Door and/or a transom between classrooms, teachers' cabinets or libraries and hallways or other	37	

rooms (R_w)*	
Door to a sports or multipurpose hall (R_w)*	35
Door to a technical room or a service equipment room (R_w)*	37
Wall with a door of a sports or multipurpose hall ($D_{nT,w,min}$)	45
Wall with a door of a technical room or a service equipment room ($D_{nT,w,min}$)	45

Notes:
N3 rooms must not be in direct contact with dwelling rooms
*R_w of a door, window, or a glass wall must be 2 dB higher than stipulated by this Regulation

Table 7. Sound insulation requirements for preschool facilities

Preschool use	$R'_{w,min}$ **(dB)**	$L'_{n,w,max}$ **(dB)**
Wall between rooms for daily dwelling of children and communication spaces or other units	52	
Wall between rooms for daily dwelling of children and other rooms – N1; N2 and garages; N3***	52 60 65	
Party floor of rooms for daily dwelling of children, offices, dwelling rooms, and communication spaces above – N1, rooms for daily dwelling of children or offices; N2, garages, sports or multipurpose halls, and mess halls; N3***	52 60 65	48
Party ceiling of rooms for daily dwelling of children, offices, dwelling rooms, and communication spaces below – N1, rooms for daily dwelling of children or offices; N2, garages, sports or multipurpose halls, and mess halls; N3***	52 60 65	48 46 46
Party floor or floor on the ground of service equipment rooms, towards dwelling room		48
Other party floors/ceilings towards dwelling rooms	52	48
Door to a sports or multipurpose hall (R_w)*	35	
Door to a technical room or a service equipment room (R_w)*	37	
Wall with a door of a sports or multipurpose hall ($D_{nT,w,min}$)	45	
Wall with a door of a technical room or a service equipment room ($D_{nT,w,min}$)	45	

Notes:
N3 rooms must not be in direct contact with dwelling rooms
*R_w of a door, window, or a glass wall must be 2 dB higher than stipulated by this Regulation
***Not allowed in new buildings; allowed when reconstructing an existing N3 room in an old building, or when such room has already been designed and partially constructed

Specific additional provisions stipulate that no requirement is set on the impact sound insulation for the fire escape stairwell if a non-residential building has an elevator. Furthermore, common garages are classified as N2 spaces. Rooms used by the hospitality industry or craftsmen, as well as rooms used for games and fun (movie theatres, game rooms, etc.) are classified as N3 spaces by default, regardless of the predicted or measured A-weighted noise rating level $L_{R,Aeq}$. Engine rooms, technical rooms, and service equipment rooms are also classified as N3 by default, regardless of the predicted or measured A-weighted noise rating level $L_{R,Aeq}$. Finally, the requirements set for impact sound insulation as $L'_{n,w,max}$ are valid for all possible directions of sound propagation.

4. NOISE REQUIREMENTS

The requirements regarding the maximum permissible noise levels in critically protected spaces are given in detail in Tables 8 to 11.

Table 8. Maximum permissible noise rating levels in dwelling spaces used for rest and living

Room type	$L_{R,Aeq,max}$ **(dBA)**		
	day	***evening***	***night***
Dwelling rooms in a housing unit	35	35	30
Dwelling rooms in accommodation units in community housing buildings	35	35	30
Dwelling rooms in accommodation units in buildings used for accommodation or in other buildings	35	35	30
Hospital rooms in healthcare facilities (not including the noise of medical equipment)	30	30	30

Table 9. Maximum permissible noise rating levels in workplace spaces

Room type	$L_{R,Aeq,max}$ **(dBA)**
Doctor's offices, infirmaries, operation rooms, etc.	35
Classrooms, lecture rooms, teachers' and study cabinets, libraries, reading rooms, offices for focused intellectual work, laboratory facilities, etc.	35
Dwelling rooms for children in kindergartens and nurseries, multipurpose halls and mess halls, sports halls in schools and kindergartens	40
Offices, meeting rooms, conference rooms	40

Table 10. Maximum permissible noise rating levels in special-purpose spaces

Room type	$L_{R,Aeq,max}$ (dBA)
Concert halls, theatres, etc.	25
Movie theatres, reading rooms, exhibition rooms	35

Note: The requirement is valid with the electroacoustic equipment switched on, but not reproducing sound.

Table 11. Maximum permissible levels of service equipment noise or noise originating in other spaces, in dwelling spaces

Room type	$L_{AF,max,nT}$ (dBA)	
	Stationary or intermittent noise	Short-term or fluctuating noise
Dwelling rooms in housing units	30	35
Dwelling rooms in accommodation units in buildings used for accommodation or in other buildings	30	35
Dwelling rooms in accommodation units in community housing buildings	30	35
Hospital rooms in healthcare facilities (not including the noise of medical equipment)	30	35
Doctor's offices, infirmaries, operation rooms, etc.	35	40
Classrooms, lecture rooms, teachers' and study cabinets, libraries, reading rooms, offices for focused intellectual work, laboratory facilities, etc.	35	40
Dwelling rooms for children in kindergartens and nurseries,	35	40
Offices, meeting rooms, conference rooms, multipurpose halls and mess halls, sports halls in schools and kindergartens	40	45

Additional provisions stipulate that sound insulation of building parts must be designed to ensure that the requirements given in Tables 8 to 11 are met. The noise rating levels given in these tables are set for fully furnished rooms. The levels of noise in dwelling rooms, coming from service equipment or from other rooms, must not exceed maximum permissible noise levels set in Table 11. Maximum permissible noise levels $L_{AF,max,nT}$ are normalized taking into account the actual reverberation time in the room.

5. ROOM ACOUSTICS REQUIREMENTS

The room acoustics requirements stipulated in this Regulation are based on the HRN DIN 18041:2024 standard [19]. As opposed to sound insulation and noise requirements which are given directly as fixed values, the room acoustics requirements are given implicitly, and the required values need to be calculated based on the size and the type of the room for which they are to be defined. All spaces for which the room acoustics requirements are set in this Regulation are divided into type A and type B.

Type A is further divided into five categories, named and marked as "Music" (A1) "Speech / lecture" (A2), "Education / communication" and "Speech / lecture (inclusive)" (A3), "Education / communication" (inclusive)" (A4), and "Sports" (A5). The technical requirement set on type A rooms is the required reverberation time T_{Soll}, calculated from the room volume V according to the category of the given room. The Regulation provides a general description of each category, and the actual categorization is to be made using the HRN DIN 18041 standard. Figure 1 shows a graphic display of the required reverberation time T_{Soll} depending on the category and the size of type A rooms.

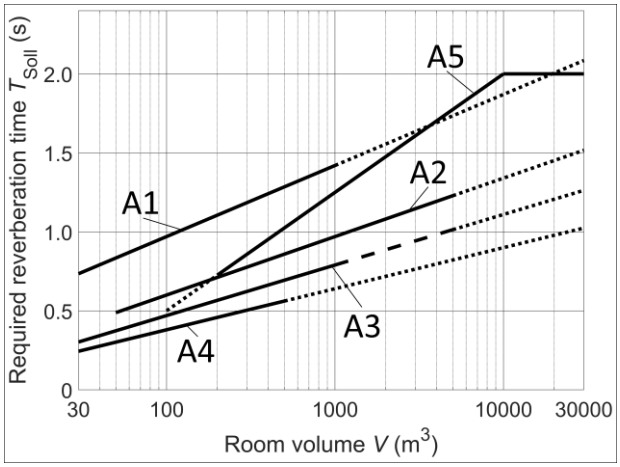

Figure 1. The required reverberation time T_{Soll} for type A rooms, depending on size (room volume) and the category (A1 to A5) of the room.

The obtained value of T_{Soll} is the one the architect/engineer should strive to obtain by designing appropriate acoustic treatment of a room. The tolerances within which the reverberation time T obtained by design should fall are

shown in Figure 2 as values normalized to the required reverberation time T_{Soll}.

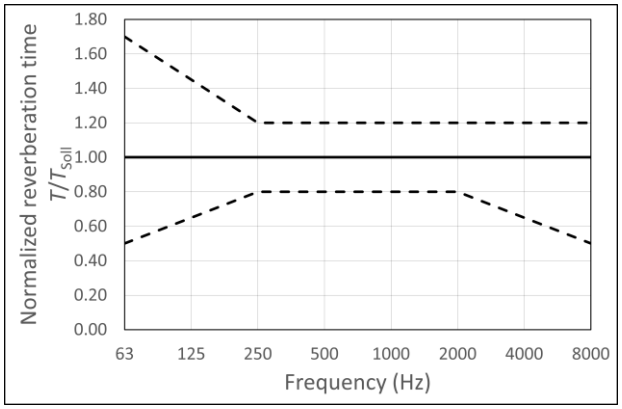

Figure 2. The tolerances of the required reverberation time T_{Soll} in type A rooms.

Type B spaces are defined as the ones that require some sort of acoustic treatment to prevent excessive reverberance. Although the HRN DIN 18041 standard lists the requirements for this type of spaces purely as recommendations, this Regulation stipulates them as mandatory for the following spaces: common rooms in kindergartens and nurseries, teaching cabinets; multipurpose spaces in kindergartens, nurseries, elementary and middle schools; teacher lounges; sports halls in schools; libraries; hallways in front of classrooms and lecture rooms; common hospital rooms; hospital hallways and waiting rooms; open-plan offices and call centres; administrative spaces in which multiple clients are handled simultaneously; entrance halls in public and other buildings (schools, hotels, train stations, airports, etc.). The spaces are categorized into categories B1 to B5 according to the HRN DIN 18041 standard. The technical requirement set on type B rooms is the minimal required ratio *A/V* of the equivalent absorption area *A* and room volume *V*, according to the category of the given room and the ceiling height *h* of the room. No requirement is set for category B1. The illustration of the requirements set for categories B2 to B5 is shown in Figure 3. The minimal required values of the *A/V* ratio are fixed for each category for ceiling heights up to 2.5 metres, and they continuously decrease with the ceiling height increasing above that threshold value.

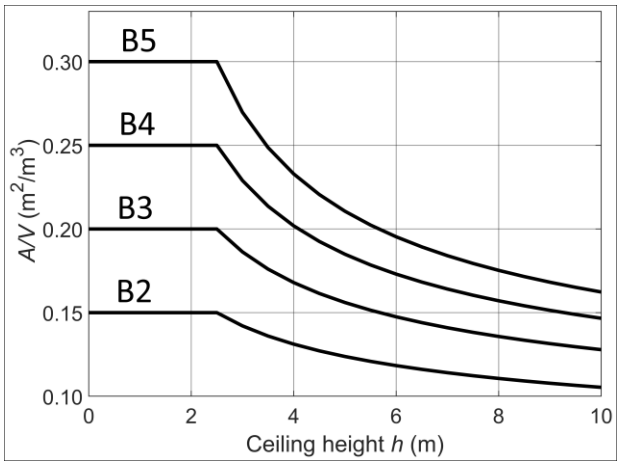

Figure 3. The minimum required value of the ratio *A/V* of the equivalent absorption area *A* and room volume *V* for type B spaces (categories B2 to B5), depending on ceiling height *h* and the category of the room.

6. CONCLUSION

The new Technical Regulation on Acoustics in Buildings that is now awaiting official publication represents a big legislative leap forward towards regulating this particular field in Croatia, after decades of neglect. Prior publications have given an overview of this document, its scope and content, the historical and technical reasons for its creation, and a description of the efforts and the employed workflow that was required to achieve this goal. This technical regulation contains comprehensive information for all who participate in the building process, in terms of the set requirements that need to be met, the methods to be used in the design process for the purpose of meeting the set requirements, and the methods of checking and verifying that the design values have indeed been achieved. For the first time, all the key factors of acoustics in buildings have been addressed in a single document.

This paper has provided key provisions of this Regulation that will facilitate correct building design in terms of acoustic comfort. A detailed overview of the technical requirements stipulated in this document has been given as well, in terms of airborne and impact sound insulation between rooms in critically sensitive buildings, permitted noise levels, and optimal room acoustics conditions depending on the use of a room/space.

The authors hope that the application of this Regulation will improve acoustic design of buildings in Croatia.

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