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Norwegian acoustic criteria for accessibility for all

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Norwegian acoustic criteria for universal design are finalized [1]. The work has focused on room acoustics and noise conditions suitable for all in public and work buildings. A socio-acoustic survey was conducted among hearing and visually disabled [2, 3]. Their experiences of acoustics in spaces and rooms were applied as a basis for where to focus. The selected criteria are considered more satisfactory for all. The classification concerns dwellings, hospitals, schools, kindergartens, offices, work premises etc. Updates were made for these buildings, in specific for open plan teaching environments and open plan offices. Buildings that did not have specified acoustic limits, e.g. museums, lobbies, assembly halls, etc., were evaluated for room acoustics and noise levels. Acoustic quality was defined by measures for reverberation time related to room height, acoustic absorption, noise, speech intelligibility etc. Also, sound amplification systems and devices for assisted listening were applied. The standard for acoustic quality classification, NS 8175 [1], is closely connected to building codes. It contains noise and sound insulation criteria for indoor conditions, outdoor noise nearby buildings and in surrounding outdoor areas. In order to follow up the needs for aging population, children, hearing and visually disabled and others, the criteria are adopted in NS 8175.

1 Introduction

Preparation of Norwegian acoustic criteria for universal design started as a consequence of adopting various legal requirements on accessibility for all or universal design [4, 5, 6, 7]. Literature about acoustic conditions suitable for hearing and visually disabled was studied. Empirical data and experience of experts working with hearing or visually disabled were collected and evaluated. In order to find out how acoustic and noise conditions are functioning for hearing and visually disabled in work buildings and buildings open to public, a socio-acoustic survey was conducted among members of their special interest organization [2]. The study was made in order to study which types of buildings should be regulated, and to measure the degree of annoyance in order to find suitable limit values. Table 1 contains a short overview of some of the results for hearing disabled. The general annoyance score was of interest, in addition to the fact that the main focus was on room acoustics, noise from service equipment and speech, and applicability of sound amplification and/or assisted listening systems. The criteria for acoustics were considered specifically for room acoustics, noise levels from service equipment and the sound amplification systems.

2 Acoustic classification of work buildings and buildings open to public

The present Norwegian classification system is based on four sound quality classes (A, B, C and D), originally agreed on in INSTA Nordic committee [8]. The classification is kept in the revised standard. Today classes for acoustic quality concern dwellings, hospitals, schools, kindergartens, offices, hotels, noisy work premises etc. Updates were made for these buildings, in specific for open plan teaching environments and offices. Additional or modified criteria were given for areas that already have requirements for room acoustics or noise level from service equipment. Room acoustics, noise levels and needs of sound amplification systems were evaluated for all buildings, also for those not having specified acoustic limits today, e.g. museums, lobbies, assembly halls, cultural buildings, terminals, station areas etc. Requirements for sound insulation are unchanged, except that new requirements are added for video conference rooms.

Table 1: Percentage of extremely and very much annoyed persons among hearing disabled in some buildings and spaces

Building/Space	Annoyance %
Production hall	61,2
Cafeteria/restaurant/café	49,8
Exposition and congress hall	47,6
Sports hall	46,8
Swimming pool	44,7
Indoor terminal/station for public transport	38,9
School yard	37,1
Culture centre/assembly hall	36,8
Cinema	33,6
Outdoor restaurant	31,5
Auditorium/meeting hall	29,4
Concert halls	28,0
Theatre halls	28,4
Meeting room	27,7
Open plan office/school	27,6
Shopping centre/enterprise	24,6
Outdoor terminal/area for public transport	23,3
Entrance with waiting room	20,6
Court rooms	20,2
Counter/reception/expedition	19,9
Staircase	18,8

Table 2: A simplified example of acoustic classes for receptions, entrance halls and similar spaces. Room acoustics and noise level from service equipment

Quantity	Symbol	Sound class			
		A[a]	B[a]	C[a]	D[a]
Average sound absorption coefficient	$\overline{\alpha}$	0,30	0,25	0,20	0,15
Highest reverberation time related to room height	T_h (s)	$0{,}13 \times h$	$0{,}16 \times h$	$0{,}20 \times h$	$0{,}27 \times h$
Noise level from service equipment in the same building or in another building	$L_{p,\mathrm{A}T}$ (dB)	23	23	28	33
	$L_{p,\mathrm{AF,max}}$ (dB)	25	25	30	35
[a] Sound amplification systems shall secure good speech intelligibility and communication. The system shall be supplemented with induction loops or similar devices.					

For spaces and areas that are similar in various buildings, the limits are kept equal, unless in cases there are specific reasons for not to do so. Some spaces like receptions, entrance halls, dining spaces, corridors and stairways and similar spaces have mostly the same limits in various buildings. The structure of the tables was changed for these common facilities, i.e. room acoustic and noise level criteria were put in the same tables in order to have a better overview. See Table 2.

The new acoustic classes for work buildings and buildings open to public contain mainly limits for room acoustics and noise level from service equipment, see sections 3 and 4.

3 Room acoustics

Various measures for room acoustics have been considered during the revision work. Reverberation time and the average acoustic absorption have already been practised for a long time in the Nordic countries. Other room acoustic criteria given in EN ISO 3382-3 [9] have been considered to be used for open plan spaces, like speech intelligibility index STI, distraction distance (r_D), spatial decay rate of speech or A-weighted SPL of speech at a distance of 4 m. In the following the selected criteria are described.

The main room acoustic criteria are either given as the highest reverberation time, *T*, or as reverberation time related to the room height, T_h, and as average acoustic absorption, $\overline{\alpha}$. Limits for reverberation time are specified as space average in each of the octave bands from 125 Hz up to 4 kHz. For the octave band 125 Hz, reverberation time may exceed the tabled values up to 40 % in some cases. Limits for T_h are in specific applied for work buildings and buildings open to public. Reverberation time related to room height is practised by acoustic consults in spaces with high ceiling in order to avoid too short reverberation and unnecessary costs for acoustic damping. The flexibility at 125 Hz has also been chosen for practical and economic reasons.

The average acoustic absorption $\overline{\alpha}$ is applied for unfurnished rooms, and the average is taken for surfaces of floors, walls and roofs in octave bands from 250 Hz to 4 kHz. In some cases, the requirements for acoustic absorption $\overline{\alpha}$ may differ from those of T_h. The criteria for acoustic absorption are considered as basic requirements, and the reverberation time related to room height shall not exceed T_h. If these measures end up with different results, the most stringent is always to be followed. For gym and sports halls, swimming pools, large premises for industry and open space teaching areas, the reverberation times are applied from the octave band 250 Hz and for staircases from 500 Hz.

The limits for reverberation time are in most cases made more stringent. The understanding of mushy speech, and noise from speech in general, was considered to be most problematic by the hearing and visually disabled in many spaces [2]. Specified limits for speech intelligibility index, STI, were also given for open plan school environments and open plan offices. Table 3 contains limits for room acoustics on schools. Limits of STI are not considered to give satisfactory speech conditions alone, but STI should be balanced with reverberation time and noise level.

Table 3: Acoustic classes for education buildings. Room acoustics

Space	Measure	Acoustic class			
		A	B	C	D
In teaching rooms, carpentry halls, meeting rooms	T (s)	0,4	0,4	0,5	0,6
In staircases	T (s)	0,6	0,7	0,8	1,0
In large teaching rooms, auditoria and other teaching and staff rooms	T_h (s)	$0{,}16 \times h$	$0{,}16 \times h$	$0{,}20 \times h$	$0{,}27 \times h$
In open plan teaching areas	T (s)	0,3	0,3	0,4	0,5
	STI	0,80	0,75	0,70	0,60
In gym halls, swimming pools, other rooms with noisy activities, common areas and corridors	T_h (s)	$0{,}16 \times h$	$0{,}16 \times h$	$0{,}20 \times h$	$0{,}27 \times h$

The room acoustic criteria given in EN ISO 3382-3 [9] are recommended to be used for open plan offices, such as distraction distance (r_D), spatial decay rate of speech or A-weighted SPL of speech at a distance of 4 m, or other quantities. In an informative annex of the standard, tabled values are implemented. The annex was made informative, as a recommendation, due to lack of knowledge of practical application of these criteria.

4 Noise levels

In many spaces, noise from service equipment was considered annoying by the hearing and visually disabled, in addition to noise from speech [2]. Places described as most annoying were evaluated, and the present limits for A-weighted or C-weighted time-averaged and maximum sound pressure levels were reconsidered for suitability for hearing and visually disabled. In addition, application of the existing octave band limits was evaluated. The C-weighted limits were applied in the earlier versions of the standard due to practical reasons. They were easy to measure, and resulted in some limitation for low-frequency noise.

Better descriptors were necessary for improving the noise conditions. There is a lot of evidence in the literature that the C-weighting is not a representative descriptor for annoyance for people. C-weighted limits for dwellings and hospitals and similar were therefore replaced by modified evaluation of RC-values in octave bands. The limits for RC-values are based on limits of the A-weighted time-averaged sound pressure levels as follows:

$$\text{RC - value} = L_{p,\text{A},T} - 7\ \text{dB} \tag{1}$$

Determination of the RC-value was modified in order to take more into consideration the annoyance in low frequencies, in specific at 31,5 Hz and 63 Hz. The maximum deviations in octave bands from the neutral spectrum of RC-curves that are described in the method for determination of RC-values [10], were therefore changed to $\leq$ 3 dB for frequencies at 500 Hz or lower, and $\leq$ 5 dB for frequencies at 1 kHz or higher. So, the noise level limits for service equipment are given as A-weighted time-averaged and maximum sound pressure level and as RC-value in accordance with Equation (1).

For outdoor noise sources, limit values are mainly the same as before, with a few exceptions when the noise level from service equipment is very stringent and the annoyance of outdoor noise level becomes dominant. Limits for outdoor levels are still based on a guideline from the Ministry of the Environment [11] that has been revised. The survey on annoyance outdoors did not give very high scores, except for terminals, outdoor station areas and similar areas [2].

5 Sound amplification systems

Provisions on universal design in the regulations [4, 5, 6] require applicability of buildings without any specific additional adaptation. Sound transmission devices may be necessary for improving acoustic conditions of some spaces or buildings for visually and hearing impaired people, elderly people, children, etc., for example by using induction loops or wireless sound transmission devices in addition to the acoustic measures. The building codes [4] require implementing of sound transmission devices in all work buildings and buildings open to public. The builder has to give documentation whenever he/she thinks it is not necessary to implement sound transmission devices in work buildings and buildings open to public. The sound classification standard includes additional instructions regarding when to apply such devices.

EU has given requirements for speech signals in elevators, and the technical details are given in EN 81-70 [12]. Speech signals in elevators shall be adjusted to a level of 60 dB to 70 dB, i.e. natural speech voice. In order to have audible sound signals for persons with reduced hearing ability, NS 8175 requires a broad band character for other signals.

Additionally, in order to secure a good speech quality, an induction loop or a similar wireless device shall be connected to the sound amplification system. In some cases, specific measures have to be taken. Individually adapted devices for assisted listening may be relevant, e.g. when work places are adapted for hearing or visually disabled. Provisions on warning signals for hearing and visually disabled are given in Norwegian standard, NS 11001-1, for universal design [13].

Rooms or spaces in buildings that were studied by the questionnaire survey [2], showed that public address systems and induction loops often were out of order, worked insufficiently or were not used in a proper way. Better follow-up and in-service training systems should therefore be established. Relevant spaces for such systems are for example reception areas/desks, waiting rooms and spaces, terminals, station areas, restrooms, cafeterias, common corridors, entrances, staircases, etc.

6 Summary

In order to follow up the needs of the aging population, children, hearing and visually disabled and others, new criteria were adopted in NS 8175 [1]. Norwegian acoustic criteria for universal design have focus on room acoustics and noise

conditions suitable for all in work buildings and buildings with public access. Results from the socio-acoustic survey conducted among hearing and visually disabled on their experiences of acoustics in spaces and rooms were applied as the basis for where to focus. The selected criteria are considered to give more satisfactory sound conditions for all users.

The acoustic classification was updated for all types of buildings, specifically for open plan teaching environments and open plan offices. For new types of buildings that were classified, acoustic quality is defined by using measures like reverberation time related to room height, acoustic absorption, noise level and speech intelligibility index. Provisions for sound amplification systems and devices for assisted listening are required whenever relevant.

The Norwegian standard for acoustic quality classification, NS 8175 [1], is closely connected to the Norwegian building codes [4] and the guidelines for environmental noise conditions [11]. The standard provides the technical criteria for noise and sound insulation for indoor conditions, outdoor noise nearby buildings and in surrounding outdoor areas.

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