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Room acoustics of Finnish hospitals - measurements, recommendations and sound samples

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Hospitals are often noisy places. Noise is caused by activities of staff and patients and by equipment. Room surfaces are in many case acoustically hard (because of hygienic requirements) which means long reverberation time. Noisy environment has negative effects on staff and patients. These are increased stress level, lower efficiency and longer healing time. Speech intelligibility is also poor which can cause communication problems and lead to mistakes. During 2010’s several hospital buildings have been built or renovated in Finland. The room acoustics in buildings has been taken into special consideration in some of these premises. A short overview of the buildings and the measured room acoustic values are shown in this presentation. Also the comparison to the recommended values and recent research results in point of personnel’s view are done. Some considerations of developing good practices are presented. Special attention is laid on the use and placement of proper absorption material in the rooms and corridors. Some recommendations of using additional methods to reduce sound level and propagation especially in the corridors and lobby areas are included. Sound samples are recorded to make differences of acoustical parameters more clear for those (e.g. hospital staff) who are not familiar with them.

1 Introduction

Hospital noise is one of the most important reasons of complaints of patients and hospital staff. Main noise sources are equipment and people. World Health Organisation (WHO) recommends that sound level should not exceed 40dB(A) during day and evening [1]. For night the maximum value L_{Aeq} = 30 dB. These values are met very seldom.

High noise levels combined with poor speech intelligibility reduce the performance and wellbeing. It is possible to improve hospital sound environment with good acoustic planning and proper use of acoustical materials. Benefits of good sound environment include [2,3]:

- an overall better quality of care
- lowered blood pressure
- improved quality of sleep and faster recovery
- reduced intake of pain medication
- lowered stress levels
- improved staff wellbeing and increased performance.

Healthcare buildings are often designed with function and safety in mind. This means that surface materials have to be resilient to wear and tear and most of all cleanable. Hard and imperforate surfaces have been used widely on walls and floors to avoid accumulation of dirt and to guarantee that the appropriate cleaning and disinfection procedures may be applied. Hard surfaced materials cause the sound to be reflected which means that the sound level builds up and speech intelligibility is poor. A good sound propagation can also reduce privacy.

Because of these problems sound absorption materials meeting hygienic requirements set for hospital buildings and absorption class A requirements according to EN ISO 11654 standard [4] have been developed. Typically they are used as ceiling tiles and on walls.

Finnish standard SFS 5907 'Acoustic classification of spaces in buildings' [5] gives reverberation time guide values for different room types in health care buildings.

2 Methods

In this study the room acoustical measurements has been done at three new hospital buildings situated in Finland. Evaluation is done how they meet given reverberation time guide values for the recommended level A/B. Given values were determined from impulse responses measured with precision sound level meter. Reverberation time T_{60} was measured according to the standard SFS-EN ISO 3382-2:2008. [6] Speech transmission index is evaluated according to standard IEC 60268-16. [7] Also the sound pressure level decays $D_{2,s}$ according to the standard SFS-EN ISO 3382-3:2012 [8] were measured in selected spaces. Acoustical treatment of ceiling and walls were observed. Sound samples were also recorded at selected rooms.

3 Results

Hospital 1 is an operational hospital and it was taken to use year 2017. All spaces have absorption class A ceiling. On staff room a there is also sound absorbing material on wall. Some comparison measurements were made in the soon-to-be-renovated old building made in the 1980’s. Results of measurements are given on table 1.

Table 1: Reverberation time (s), SFS 5907 level, STI values and $D_{2,s}$ values at hospital 1.

room type	octave band centre frequency f [Hz]						SFS 5907 level	STI	$D_{2,s}$
	125	250	500	1000	2000	4000			
staff room w/ wall absorption	0,45	0,50	0,40	0,47	0,57	0,60	A/B	0,75	
staff room 2	0,62	0,50	0,43	0,44	0,51	0,51	A/B	0,78	
lobby	0,62	0,44	0,34	0,35	0,41	0,38	A/B	0,85	3,7 dB
operation room w/o wall absorption	0,58	0,68	0,69	0,51	0,54	0,63	C	0,72	
inspection room w/ wall absorption	0,48	0,45	0,39	0,36	0,36	0,39	A	0,83	
corridor w/o wall absorption	0,56	0,56	0,52	0,63	0,73	0,65	C	0,82	4,0 dB
old lobby with perforated metal sheet ceiling	0,59	0,53	0,53	0,59	0,61	0,64	C	0,80	3,5 dB
old operation room with perforated metal sheet ceiling	0,83	0,70	0,78	0,94	0,97	0,93	C	0,62	
old corridor with perforated metal sheet ceiling	0,60	0,77	0,65	0,59	0,60	0,59	C	0,75	4,0 dB

Hospital 2 is general hospital department including e.g. laboratories, TT scanning and EEG monitoring. Hospital operations started year 2016. All other spaces have absorption class A mineral wool ceiling. Results of measurements are on table 2.

Table 2: Reverberation time (s), SFS 5907 level, STI values and $D_{2,s}$ values at hospital 2..

room type	octave band centre frequency f [Hz]						SFS 5907 level	STI	$D_{2,s}$
	125	250	500	1000	2000	4000			
Scanning, room for recovery	0,67	0,58	0,54	0,44	0,46	0,49	A/B	0,78	
Inspection room	0,65	0,58	0,44	0,38	0,41	0,48	A/B	0,82	
Recovery room, small	0,81	0,81	0,52	0,44	0,48	0,56	C	0,78	
Office room	0,45	0,40	0,40	0,30	0,34	0,37	A/B	0,81	
Lobby w/ perforated metal sheet ceiling absorption	0,95	1,13	0,99	1,29	1,26	1,00	-	0,66	4,0 dB
Inspection room w/o wall absorption	0,73	0,78	0,52	0,43	0,50	0,53	C	0,78	
Operation room 1	0,68	0,54	0,55	0,42	0,45	0,48	A/B	0,77	
Operation room 2	0,81	0,69	0,55	0,44	0,63	0,62	A/B	0,74	
Office room	0,80	0,58	0,51	0,50	0,57	0,57	A/B	0,80	
Staff room	0,64	0,59	0,49	0,39	0,51	0,57	A/B	0,66	

Hospital 3 is hospital building for supporting operations like a personnel canteen, offices, auditorium etc. The building was completed year 2016. Part of the spaces have absorption class A mineral wool ceiling and certain rooms have a perforated metal sheet ceiling. There was also corridors with (class A ceiling) and without acoustical treatment on the walls.

Table 3: Reverberation time (s), SFS 5907 level, STI values and $D_{2,s}$ values at hospital 3.

room type	frequency Hz						SFS 5907 level	STI	$D_{2,s}$
	125	250	500	1000	2000	4000			
Corridor, w/o wall absorption	0,60	0,76	0,77	0,82	0,80	0,75	C	0,6–0,8	3,7 dB
Corridor, w/ wall absorption	0,62	0,68	0,68	0,70	0,62	0,60	A/B	0,78	5,1 dB
Conference room 1	1,08	0,56	0,42	0,43	0,50	0,44	A/B	0,78	
Conference room 2	0,56	0,53	0,40	0,47	0,50	0,45	A/B	0,78	
Maternity clinic, w/o wall absorption	0,70	0,54	0,45	0,67	0,71	0,66	C	0,68	
Dining hall	0,90	0,78	0,71	0,75	0,78	0,79	A/B	0,70	
Kitchen, cooking, w/ mineral wool ceiling	0,68	0,53	0,50	0,53	0,59	0,59	nc	0,72	5,7 dB
Kitchen, dishwashing, w/ perforated metal sheet ceiling	0,72	0,75	0,74	0,77	0,75	0,69	nc	0,68	3,3 dB
Auditorium w/ microperforated wooden ceiling and walls	0,56	0,53	0,38	0,37	0,42	0,40	A/B	0,80	

4 Remarks and conclusions

Based on measured reverberation time values room acoustic level A/B stated in the Finnish standard SFS 5907 are achievable and are met in many type of hospital rooms with treating ceiling with absorption class A material. However, results show that it is important to plan and implement room acoustics during planning and construction phase of building. When room acoustic is improved afterwards it might be difficult to install absorptive material enough to have the best possible result. When reverberation time is on level A/B also speech intelligibility is usually good.

Bigger spaces not related directly to patient care (as lobby, canteen, auditorium) do also reach the level A/B as well as other rooms.

Hospital 3 kitchen comparison was done in identical spaces except the perforated metal sheet ceiling in the dishwashing line and respectively mineral wool ceiling in the cooking line. Difference on reverberation time is about 0,2 seconds and the sound pressure level decay is about 2,5 dB. Sound recording shows clearly that this difference causes remarkable change on hearing experience.

Generally these measured spaces meet level A/B when sound absorption of ceiling is good. Usually it is important to attenuate also small frequency sounds to avoid booming sound environment especially in spaces with concrete walls.

In the corridor and lobby areas the spatial decay rate of the speech sound pressure level is usually quite low, the background noise level is sufficient and the speech intelligibility due to the sound absorption is good. Therefore at the corridor and lobby areas some extraneous sound may be useful to mask the high frequency sounds of speech.

Good indoor environment is vital for hospital buildings and sound environment is important part of it. To make room acoustic good for to work and heal it is important to plan and implement it properly as early stage as possible during building process. Later improvements might be difficult because there might be lack of space to install sound absorbing material enough and best possible placement could be impossible.

References

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[3] M. Topf, Hospital noise pollution: an environmental stress model to guide research and clinical interventions, *Journal of Advanced Nursing*, Volume 31, Issue 3, 1996

[4] ISO 11654 Acoustics – Sound absorbers for use in buildings -- Rating of sound absorption, ISO, Geneva, 1997.

[5] SFS 5907 Acoustics – Acoustic classification of buildings, SFS, Helsinki, 2004

[6] ISO 3382-2 Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms, ISO, Geneva, 2008

[7] IEC 60268-16 Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index, IEC, Geneva, 2011

[8] ISO 3382-3 Acoustics – Measurement of room acoustic parameters – Part 3: Open plan offices, ISO, Geneva, 2012