Acoustic Design in Health

Why acoustics in healthcare matter

Noise in hospitals and medical facilities has a significant impact on patient health and on staff wellbeing. From increased blood pressure and heart rates, to errors by clinicians and staff burnout, noise pollution affects the quality of healthcare that can be delivered.

Noise in hospitals

The World Health Organisation recommends maximum daytime background noise in hospital patient rooms of 35 decibels in the day and 30 decibels at night. But according to a series of studies from 1993-2005[1], peak noise levels in hospitals can be as high as 85 decibels (as loud as a vacuum cleaner). Other studies have recorded peaks of 120 decibels (as loud as a jet plane taking off).

Noise in hospitals has steadily increased over the past half century. According to a 2005 study[2] published in the *Journal of Acoustical Society of America*, daytime noise in hospitals has gone up 200% since 1960; and night time noise has gone up 400%. The study looked at 35 reports on noise levels in hospitals and found that none of the hospitals surveyed complied with WHO guidelines.

"Peak noise in hospitals can be as loud as a jet plane."

[1] Aaron et al. 1996: Balogh et al. 1993; Blomkvist et al. 2005; Cureton-Lane and Fontaine 1997 Guimararaes et al. 1996; Holmberg and Coon 1999; Kent et al. 2002; Tijunelis, Fitzsullivan and Henderson 2005.

[2] Busch-Vishniac, I., J.West, C. Barnhill, T.Hunter, D. Orellana, and R.Chivulkula. 2005. Noise levels in Johns Hopkins Hospital, *Journal of Acoustical Society of America* 118(6):3629-45

Why does it matter?

Sound is critically important in healthcare settings. According to the Centre for Health Design, ambient noise levels as well as peak levels can have a serious effect on both patients and staff, including on:

- Sleep quality/quantity
- Pain perception
- Elevated blood pressure and heart rates
- Emotional exhaustion
- Staff burnout

Poor acoustics in healthcare environments can also have a serious impact on:

- Patient-clinician confidentiality
- Accurate dispensing of medication[3]

Noise and patients

Loud noises in hospitals have been linked to sleep disturbance and arousals among patients, including in neonatal intensive care units[4], pediatric units and amongst adult patients[5]. The consequences include:

- Decreased oxygen saturation
- Decreased rate of wound healing
- Higher incidence of rehospitalisation

"Sound control is critically important in healthcare settings."

Centre for Health Design

[3] Whitepaper, *Effects of noise pollution on healthcare staff and patients*, www.soundmask.com.au

[4] Strauch, C., S. Brandt, and J. Edwards-Beckett. 1993. Implementation of a quiet hour: Effect on noise levels and infant sleep states. *Neonatal Network* 12(2):31–35.

[5] Schnelle, J. F., J. G. Ouslander, S. F. Simmons, C. A. Alessi, and M. D. Gravel. 1993. The nighttime environment, incontinence care, and sleep disruption in nursing homes. *Journal of the American Geriatrics Society* 41(9):910–14.

Noise and staff

Noise can be a source of stress for hospital and medical staff and may interfere with their ability to work effectively.

A number of studies have found that noise is strongly related to stress and annoyance amongst nursing staff and excessively high noise levels interfered with their work.[6]

According to the Centre for Health Design, noise-induced stress has also been related to:

- Increased perceived work pressure
- Increased fatigue
- Emotional exhaustion and burnout
- Difficulty in communication, possibly leading to errors

STATISTICS

1 Daytime noise levels in hospitals have gone up 200% since 1960.[6]

2 Night time noise levels in hospitals have gone up 400% since 1960.[7]

[6] Bayo, M. V., A. M. Garcia, and A. Garcia. 1995. Noise levels in an urban hospital and workers' subjective responses. *Archives of Environmental Health* 50(3):247–51.

[6] Busch-Vishniac, I., J.West, C. Barnhill, T.Hunter, D. Orellana, and R.Chivulkula. 2005. Noise levels in Johns Hopkins Hospital, *Journal of Acoustical Society of America* 118(6):3629-45

[7] Ibid.

Danish architect Lone Wiggers says good acoustic design in hospitals can support the link between the senses and healing, to improve patient recovery times.

“Since the birth of the welfare state in Denmark after World War II, there has been a strong tradition of solving societal problems through design. As a result, design has become completely integrated into the healthcare sector in my country.

For my architectural firm, C. F. Møller, this means not only designing for functionality and for work-flow, but also designing for the senses, including the role they play in patient recovery.

Mounting evidence suggests that supporting the senses can speed up patient recovery times. This can range from ensuring wards have direct sunlight (one study showed that patients being treated for depression spent 3.67 fewer days in hospital if their room had direct sunlight in the morning), to having a view of a natural landscape, to stimulating the brain with natural, chaotic sounds.

Studies have shown that stimulating the brain with chaotic sounds like birdsong, leaves rustling and running water can have a positive effect on healing times. That's because when a patient hears chaotic noise, they don't try to listen to it or concentrate on understanding it. As a result, the chaos of the noise is calming and recovery times can be shortened.

It is possible to create these sounds artificially or by building hospitals in rural areas. Even city-based hospitals can tap into some of the chaotic noise of a city, like the honking horns of traffic flow.

The other type of sound that is important with regards to patient healing time is the need for quiet. As a result, our designs emphasize having only one patient per room. We also use sound insulation on windows (triple glazing) as well as acoustic treatments on ceilings and walls, to reduce noise.

Through these carefully selected architectural enablers, it is possible to have an impact on how we sense our surroundings and create a basis for happiness, relaxation and renewed energy.

Previously these had been considered to be 'soft' values in design, but more and more they are being seen as 'hard' values that deliver positive economic benefits. ”

"... more and more they are being seen as 'hard' values that deliver positive economic benefits."

Acoustics is the science of sound and how the built environment affects the way we react to and interpret what we hear.

All of us have an emotional connection to sound, based on physical stimuli, psychological factors, subjective preferences and expectations. And a room's acoustics can significantly change our experience of sound.

Sound is a form of energy that travels in waves. The frequency of a sound wave determines how we perceive it. High frequency waves are short and produce high-pitched sounds. Low frequency waves are long and produce deep sounds (bass, rumbles).

Different materials have the ability to absorb or reflect sound energy, which can change the way we hear things. They can also impact the level and type of sound within any given space. In general, heavy objects with smooth surfaces, like glass or concrete, reflect sound energy; lightweight materials with porous surfaces, like textiles and fabrics, absorb sound.

This means that a room with a polished concrete floor will be noisier than a room with carpet because the sound energy is reflected off the hard surface. Carpet on the other hand, absorbs the sound energy.

Although the noise from outside the room space must be blocked by appropriately rated sound insulating walls, windows, doors and floors, sound absorption, reflection and diffusion inside the room strongly affects how people perceive the noise transmitted into the room space from outside or generated in the room space.

Sound absorption

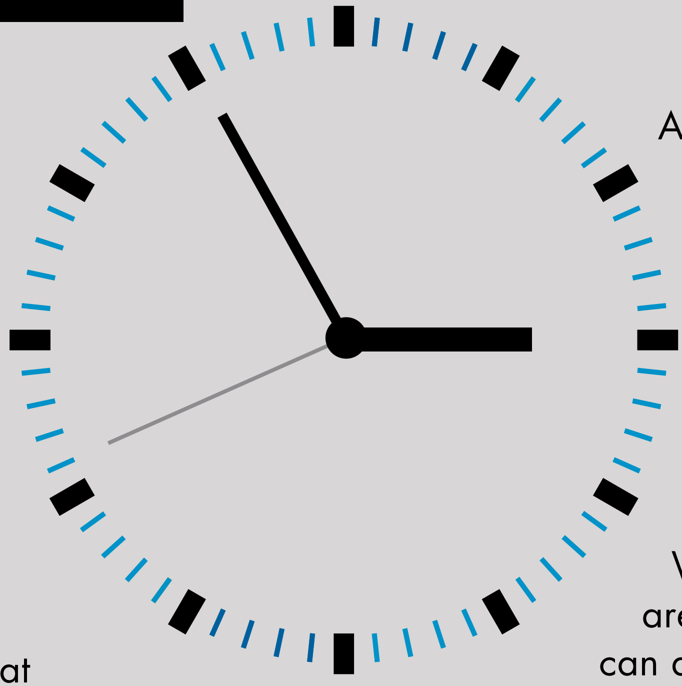
Calculating acoustics involves determining how much a material can absorb sound, known as its sound absorption coefficient, alpha (α). If a material's sound absorption coefficient is 0 then it is totally reflective. If the sound absorption coefficient is 1, then the material is totally absorbing.

This ability of a material to absorb or reflect sound is typically different at different sound frequencies. This balance of sound absorption properties is critical when it comes to acoustic comfort in room spaces.

Imagine if all you could hear were the high pitched sounds — how uncomfortable and unnatural this would be.

Sound diffusion

Materials not only have the ability to absorb and reflect sound — they also have the ability to diffuse or 'spread' sound. This is called sound diffusion and is related to the surface texture of a material.



A rough or uneven surface is a good sound diffuser. Sound waves that are reflected back from a rough surface are spread out in many directions and this helps to dissipate or break down the sound energy.

Acoustic comfort

While sound absorption coefficients are a good indicator of how materials can affect the acoustic environment of the space that they are used in, one of the key indicators of acoustic comfort in an enclosed space is the **reverberation time** (measured in seconds) of that space. This is the most obvious acoustic experience we get when we enter a room.

Imagine a church or a large, completely empty room with smooth, hard surfaces — these spaces have long reverberation times. That is, the sound persists for a long time.

Cinemas and theatres with lots of sound-absorbing materials have very short reverberation times — often the sound is referred to as being 'dead'.

The following reverberation times are stipulated for healthcare spaces:

AS/NZS 2107:2000 ACOUSTICS REQUIREMENTS FOR HEALTHCARE BUILDINGS

ZONE	CHARACTERISED BY	EXAMPLES	RECOMMENDED MAXIMUM DESIGN SOUND LEVEL, L_{Aeq}, dB(A)	RECOMMENDED REVERBERATION TIME (T), s
1	Very quiet space, less communication	Wards	40	0.4 - 0.7
2	Quiet space, one-to-one communication	Casualty areas, Consulting rooms, Dental clinics, Geriatric rehabilition, Intensve care wards	45	0.4 - 0.6
3	Quiet space, multiple interactions	Nurses stations, Office areas, Surgeries	45	0.4 - 0.7
4	Noisy space, multiple interactions	Delivery suites, Pharmacies, Corridors and lobby spaces	50	0.4 - 0.6
5	Relatively large and noisy space, multiple interactions	Laboratories, Waiting rooms, Reception areas	50	0.4 - 0.7
6	Very noisy space, few interactions	Kitchens, Sterilising and service areas	55	0.4 - 0.8

Notes:

Recommended reverberation times are referred to the medium frequencies (e.g. 500 Hz or 1000 Hz)

For large volumes, the recommended reverberation times assume two-thirds occupancy and it is generally considered acceptable to have some increase in reverberation time towards the low frequencies.

For small volumes, it may be more suitable to make reverberation time independent of frequency.

Where the control of reverberation time in spaces is carried out for noise control purposes, the reverberation time should be minimized as far as practicable unless the designers of the space intend to provide a particular acoustic ambience.

The location of sound-absorbing surfaces and sound-reflecting surfaces required to achieve the design reverberation time is important.

Requirements of AS/NZS 1269.4 must be followed for recommended maximum design sound level in audiological test rooms.

Specialist advice should be sought for recommended reverberation time in audiological test rooms and operation theatres.

Any acoustics material and/or construction must meet the latest Australasian Health Facility Guidelines (AustHFG) regarding hygienic environmental control. In general, all surfaces in patient care areas should be smooth and impervious, and easy to clean.

Calculating acoustics: why 'averages' don't tell the whole story

*One common way to calculate acoustics is to take an average of how a material absorbs and reflects different sound waves (under laboratory conditions). This average is known as the **Noise Reduction Coefficient (NRC)**. But, as with any averaged figure, it doesn't tell the whole story.*

In simple terms, an NRC (Noise Reduction Coefficient) is a number that rates how effectively a material absorbs sound. It is calculated by averaging out a materials' absorbing or reflective qualities — its sound absorption coefficients — at four different sound frequencies (250hz, 500hz, 1000hz, and 2000hz).

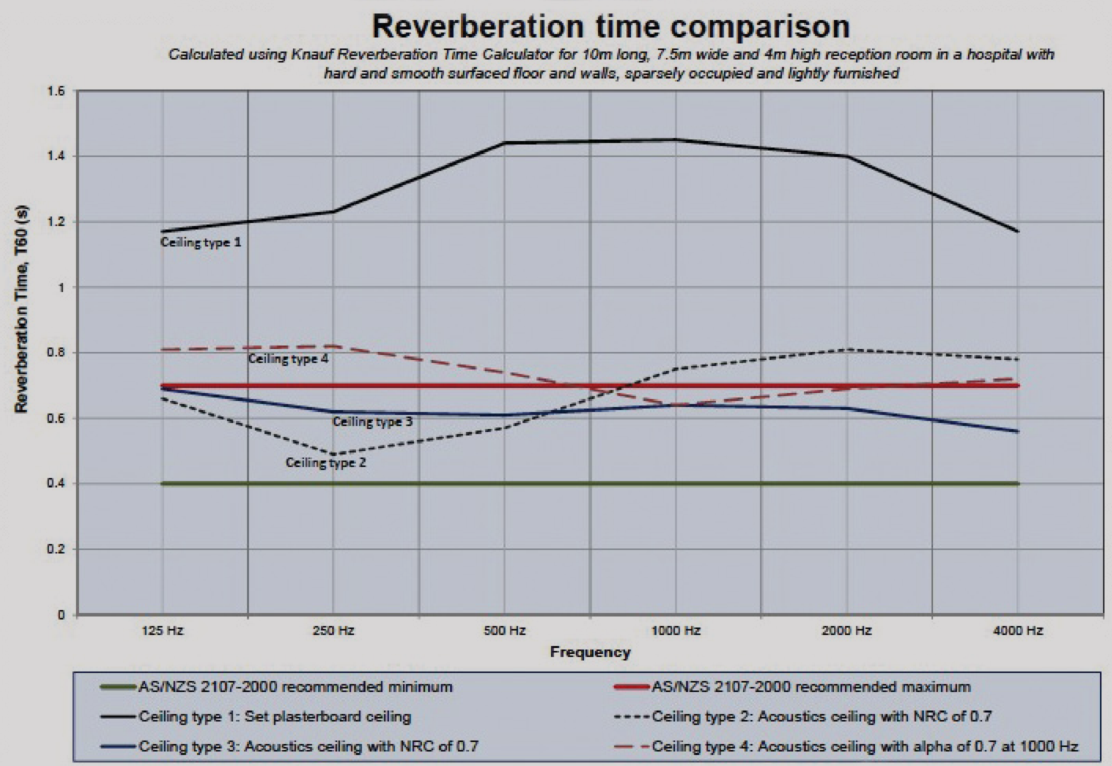
Designing room acoustics based on NRC can however, deliver poor acoustic performance in practice. That's because different materials can perform differently at different frequencies. As a result, two materials with the same NRC may not perform the same way in reality.

A more sophisticated way to measure acoustic performance is to calculate what is called a **weighted sound absorption coefficient** (α_w). Like the NRC, it is also calculated as a single number, but is considered to be more representative of how the human ear interprets sound.

That's because it is calculated by comparing sound absorption coefficients to a standard curve. While it's a more complicated calculation, it gives a better picture of a material's performance across all of the important frequencies.

The higher the α_w figure, the more evenly a material absorbs sound across all of the important frequencies. It has become the preferred European unit for making comparisons of sound absorption performance.

Calculating acoustics: *why 'averages' don't tell the whole story*



The table above illustrates this point: wider frequency analysis approach is important when selecting an acoustic material. Ceilings 2, 3 and 4 all use a material that has a single number sound absorption rating of 0.7, and yet the results couldn't be more different.

For instance, Ceiling 2 meets reverberation time requirements at lower frequencies only and Ceiling 4 meets them at only 1000 Hz and 2000 Hz. Only Ceiling 3 meets reverberation time at all frequencies.

Ceiling type 1 does not meet the reverberation time requirements of AS/NZS 2107-2000.

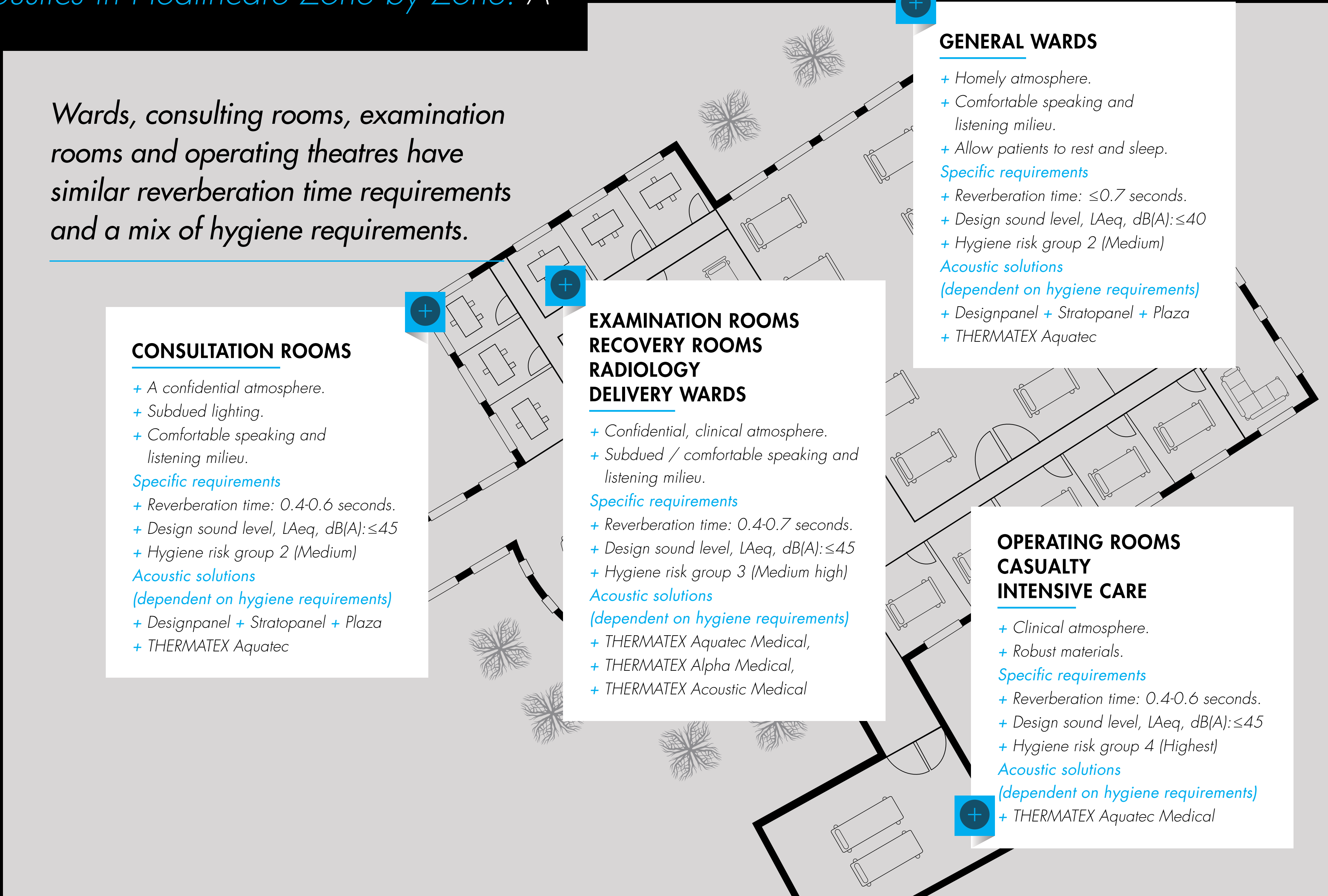
Ceiling type 2 has a NRC rating of 0.7, but as since the sound absorption coefficient is not uniform throughout the frequency range, reverberation time requirements are met at lower frequencies only.

Ceiling type 3 has same NRC rating of 0.7 as ceiling type 2, but as since the sound absorption coefficient is relatively uniform throughout the frequency range, reverberation time requirements are met at all frequencies.

Ceiling type 4 has sound absorption coefficient of 0.7 at 1000 Hz frequency, reverberation time requirements are met at 1000 Hz and 2000 Hz only.

Note: For smaller spaces, AS/NZS 2107-2000 recommends making reverberation time independent of frequency. Even for larger spaces, only some increase in reverberation time towards low frequencies is acceptable.

Wards, consulting rooms, examination rooms and operating theatres have similar reverberation time requirements and a mix of hygiene requirements.



CONSULTATION ROOMS

+ A confidential atmosphere.
+ Subdued lighting.
+ Comfortable speaking and listening milieu.

Specific requirements

+ Reverberation time: 0.4-0.6 seconds.
+ Design sound level, LAeq, dB(A):≤45
+ Hygiene risk group 2 (Medium)

Acoustic solutions
(dependent on hygiene requirements)

+ Designpanel + Stratopanel + Plaza
+ THERMATEX Aquatec

EXAMINATION ROOMS RECOVERY ROOMS RADIOLOGY DELIVERY WARDS

+ Confidential, clinical atmosphere.
+ Subdued / comfortable speaking and listening milieu.

Specific requirements

+ Reverberation time: 0.4-0.7 seconds.
+ Design sound level, LAeq, dB(A):≤45
+ Hygiene risk group 3 (Medium high)

Acoustic solutions
(dependent on hygiene requirements)

+ THERMATEX Aquatec Medical,
+ THERMATEX Alpha Medical,
+ THERMATEX Acoustic Medical

GENERAL WARDS

+ Homely atmosphere.
+ Comfortable speaking and listening milieu.
+ Allow patients to rest and sleep.

Specific requirements

+ Reverberation time: ≤0.7 seconds.
+ Design sound level, LAeq, dB(A):≤40
+ Hygiene risk group 2 (Medium)

Acoustic solutions
(dependent on hygiene requirements)

+ Designpanel + Stratopanel + Plaza
+ THERMATEX Aquatec

OPERATING ROOMS CASUALTY INTENSIVE CARE

+ Clinical atmosphere.
+ Robust materials.

Specific requirements

+ Reverberation time: 0.4-0.6 seconds.
+ Design sound level, LAeq, dB(A):≤45
+ Hygiene risk group 4 (Highest)

Acoustic solutions
(dependent on hygiene requirements)

+ THERMATEX Aquatec Medical

Acoustics in Healthcare Zone by Zone: B

Offices, corridors and public areas like lobbies, receptions and waiting rooms have similar reverberation time requirements and a mix of hygiene requirements.

LOBBIES, RECEPTIONS, FOYERS WAITING ROOMS COMMON ROOMS (STAFF ROOMS, LOUNGES)

+ *Relaxed, lively atmosphere.*
+ *Welcoming, homely atmosphere, nonclinical expression.*
+ *Comfortable speaking and listening milieu.*

Specific requirements

+ *Reverberation time: 0.4-0.7 seconds.*
+ *Design sound level, LAeq, dB(A):≤50*
+ *Hygiene risk group 1 (Low)*

Acoustic solutions
(dependent on hygiene requirements)

+ *Designpanel* + *Stratopanel* + *Plaza* + *THERMATEX Range*

OFFICES

+ *Professional atmosphere.*
+ *Comfortable speaking and listening milieu*

Specific requirements

+ *Reverberation time: 0.4-0.7 seconds.*
+ *Design sound level, LAeq, dB(A):≤45*
+ *Hygiene risk group 1 (Low)*

Acoustic solutions
(dependent on hygiene requirements)

+ *Designpanel*
+ *Stratopanel*
+ *Plaza*
+ *THERMATEX Range*

CORRIDORS

+ *Homely atmosphere.*
+ *Robust materials.*
+ *Easy access to technical installations.*

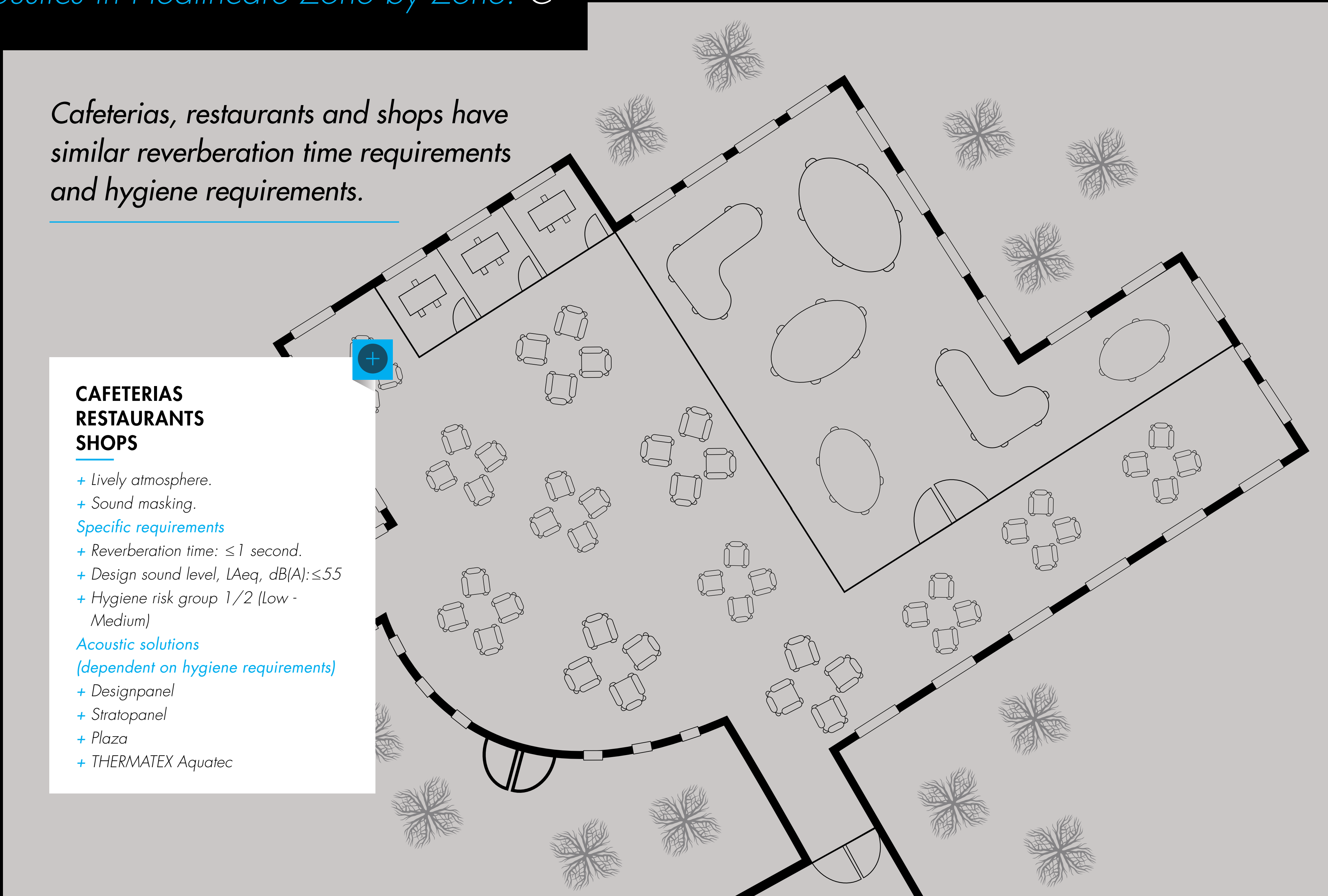
Specific requirements

+ *Reverberation time: 0.4-0.6 seconds.*
+ *Design sound level, LAeq, dB(A):≤50*
+ *Sound reduction in relation to other rooms.*
+ *Hygiene risk group 2 (Medium)*

Acoustic solutions
(dependent on hygiene requirements)

+ *Designpanel*
+ *Stratopanel*
+ *Plaza*
+ *THERMATEX Aquatec*

Cafeterias, restaurants and shops have similar reverberation time requirements and hygiene requirements.



CAFETERIAS
RESTAURANTS
SHOPS

+ Lively atmosphere.
+ Sound masking.

Specific requirements

+ Reverberation time: ≤1 second.
+ Design sound level, LAeq, dB(A):≤55
+ Hygiene risk group 1/2 (Low - Medium)

Acoustic solutions (dependent on hygiene requirements)

+ Designpanel
+ Stratopanel
+ Plaza
+ THERMATEX Aquatec

Denmark's largest private hospital chose Knauf's Danoline ceiling tiles for their hygiene and sound-absorbing qualities.

Hamlet Private Hospital in Søborg – about 15 minutes' drive north of Copenhagen city centre — is the largest private hospital in Denmark. Built in 2008, it operates over 90 beds, with 40 permanent physicians and 20 affiliated consultants. It conducts around 11,000 operations per year, ranging from elective plastic surgery to hip replacements.

The hospital specified that its ceilings needed to be easy to clean and that they were as light in colour as possible. They also had to be sound absorbing, in line with the building code.

"When we defined the objectives for the hospital's interior we took the needs of patients and staff into account."

Kasper Færk Jacobsen, Technical Manager at Hamlet.

"The wellbeing of both groups had to be ensured with the help of a pleasant indoor climate, clean air, the right level of humidity and a relaxed atmosphere."

The hospital also set out to use the lighting and colour scheme to create a "peaceful" expression, said Jacobsen: "The interior had to give the least possible impression of a hospital."

Knauf's Danoline ceiling tiles helped create this expression according to Jacobsen, thanks to their "simple, discreet design".

FACT FILE

Project name:
Hamlet Private Hospital

Location:
Søborg, Denmark

Architect:
Aarhus Arkitekterne, Nils Jakobsen

Knauf products used: Danotile, Markant Globe

If you'd like to go beyond NRC and use a reverberation time calculation on your next project, or learn more about acoustic solutions for walls and ceilings, don't hesitate to ask.

Both the Specification and Commercial Sales Team and the Knauf Tech Team work with architects, acoustic engineers and builders throughout the specification and construction process. In addition to advice on the right product to meet your specific acoustic requirements we also offer:

K-Spec Pro

A custom design specification proposal for your project, developed by Knauf and catered to your project's requirements. Knauf engineers can develop a project-wide proposal that details the most cost-efficient wall and ceiling systems for each and every wall and ceiling in your building, ensuring a first-class system selection and reducing time and effort to design and specify.

BIM Wall Creator (Revit add-on)

The first Australian Revit wall creator that intelligently generates Revit-based wall types with detailed specification information. Creates wall types quickly and easily using performance parameters, including FRL, Rw, wall width and performance requirements and is compliant with all AS/NZ BIM standards.

Cost estimates

Project-specific supply and installation cost estimations, developed to help you decide between similar systems to meet project requirements. Simply contact Knauf and we can develop an estimate from a single wall, right through to an estimated project-wide approximate cost.

To get technical help, go to www.knaufplasterboard.com.au/resources or call us on 1300 724 505.

To find out more about Knauf Products go to www.knaufplasterboard.com.au

BEN WRIGHT

Technical Services Manager

Ben is a qualified Civil Engineer from the University of Western Sydney and he leads Knauf Technical Services team. His employment history includes project engineering roles, marketing roles and also technical engineering support roles for manufacturers of concrete and steel products as well as plasterboard and associated products. He has worked for building material manufacturers for 14 years. As well as his interest in steel structures, he is also experienced in fire and acoustic engineering, the Building Code of Australia and also has a particularly keen interest in training.

SASAN SAIDIAN

Structural Engineer

Sasan is a professional civil/ structural engineer with recognised qualifications by the Institution of Engineers Australia. His employment history includes project engineering and project management roles; structural engineering and technical management roles; commercial, sales and marketing management roles; and he has run his own private business as a prefabricated building manufacturer and a drywall and ceilings contractor. He has over 15 years of experience in diverse areas including civil, residential and commercial construction; construction chemicals; building physics (acoustics, thermal insulation and fire protection); modular building systems; and structural analysis and design. Sasan is particularly interested in cold-formed steel design and structural dynamics (seismic design).

ERIK MONEY

Technical Services Engineer

Erik graduated from Materials Science at UTS in Sydney. He has worked for building materials manufacturers for 19 years specifically fibre cement and plasterboard. His employment history includes roles in research, product development, building system development, customer technical support, technical documentation, process engineering and engineering projects. Erik has hands on experience in a wide variety of materials and systems testing in areas such as mechanical properties, durability, impact, acoustic and fire performance. While providing customer technical support for the building industry, Erik has gained an interest and wide general knowledge in construction techniques, building physics and in particular, fire protection.

SHAILESH KOIRALA

Technical Services Engineer

Shailesh is a qualified Civil Engineer with extensive knowledge of lightweight building construction and building physics like architectural acoustics and thermal insulation. He has worked for different building material manufacturers for more than 14 years, mainly in technical support and management roles including the last 10 years with Knauf. He has a strong command of Chinese Mandarin language and very keen interests in computer programming. He has personally developed several Windows based engineering application tools such as the Knauf Bracing Calculator, Knauf Reverberation Time Calculator, and Knauf Proposal Writer.

REZA KARANI

Technical Services Engineer/Architect

Reza is an architect with 10 years of experience in civil and light weight constructions. He has experience in project management, training and inspection management roles and also building physics including acoustics, thermal insulation and fire protection. Reza had a key role in the compilation of the 400 page drywall manual creating over 500 construction details and has issued more than 20 technical documents for Knauf Australia.

To get technical help, go to www.knaufplasterboard.com.au/resources or call us on 1300 724 505.

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