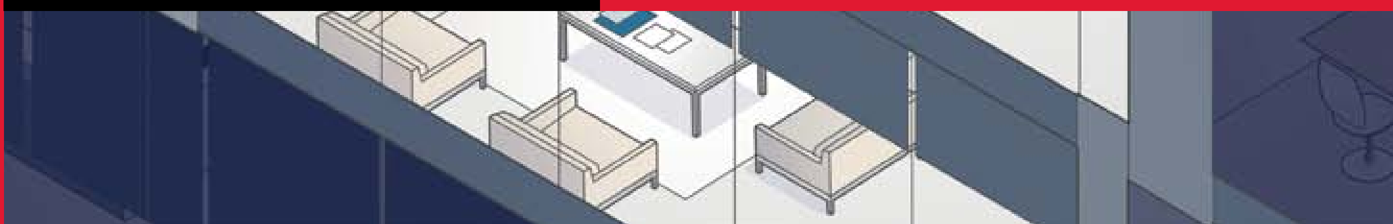
Safe'n'Silent™
Solutions in
Partition Systems

Ambient Noise Control

Technical Manual

ROCKWOOL®
FIRESAFE INSULATION



Contents

1. Introduction **4**

2. The Problem of Noise in the Built Environment **5**

3. Fundamentals of Acoustics **6**
3.1 How is Sound Created 6
3.2 Basic Terminologies Defined (Frequency, Wavelength, Amplitude) 6
3.3 How Do We Hear Sound? 10
3.4 Propagation of Sound 10

4. The Need for Solutions **11**
4.1 The Effects of Noise 11

5. How Much Sound is Acceptable? **12**
5.1 Noise Criteria (NC) 13

6. Sound Paths – Airborne and Structure Borne **14**

7. Airborne Sound Transmission **15**
7.1 Sound Transmission Class (STC) 15
7.2 Consideration on Flanking Paths 16

8. Sound Absorption **17**
8.1 Noise Reduction Coefficient (NRC) 17
8.2 The Need and Properties for Sound Absorbers 18
8.3 Sound Level Reduction Calculation 18
8.4 Reverberation Time 18

9. Noise Control Solutions **19**
9.1 Noise Control Mistakes to Avoid 19
9.2 Case studies – Assumptions and Presets 20

10. Case Study - Residential **21**
10.1 Use of Space and Occupancy 21
10.2 Ambient Noise Level Consideration 21
10.3 Bedrooms and AV room 23
10.4 Recommended Specifications 24

11. Case Study - Office **27**
11.1 Use of Space and Occupancy 27
11.2 Ambient Noise Level Consideration 28
11.3 Meeting Rooms and Workstations 29
11.4 Recommended Specifications 30

12. Case Study - Educational Institution **33**
12.1 Use of Space and Occupancy 33
12.2 Ambient Noise Level Consideration 34
12.3 Lecture Hall and Auditorium 35
12.4 Recommended Specifications 36

13. Case Study - Healthcare Centre **39**
13.1 Use of Space and Occupancy 39
13.2 Ambient Noise Level Consideration 40
13.3 Patient Wards and Common Areas 40
13.4 Recommended Specifications 42

14. ROCKWOOL Safe'n'Silent **44**

1.0 Introduction

Our lives are very much affected by the increasing level of noise in our environment. As population continues to grow in the recent decades, so has the amount of noise in our surrounding, be it coming from noisy machines we employ at work or at home, and the activities that we engage in while occupying a particular space for various purposes.

However, the policies and guidelines regulating the ambient noise level in our occupied spaces are still at its infancy stage. Hence it is important to address the need for having a comfortable environment in relations to the optimal ambient noise level and then subsequently the most effective way to control it.

The development of this technical manual is intended to provide answers and solutions to address these concerns, as stated below.

The key objectives of this technical manual are to:

1. Explain and highlight the growing concerns of urban noise and noise around the environment of living and occupied spaces.
2. Explain the effects of unwanted sound or noise to occupants and users within the space.
3. Illustrate how sound and noise propagates through fundamental knowledge on acoustics.
4. Address the holistic concept of ambient noise level through Noise Criteria (NC).
5. Provide suggestions that assist in the design and selection of specifications in accordance to the desired Noise Criteria (NC) values.
6. Provide examples and recommendations of materials and specifications selection in the form of various case studies in residential, office, educational and healthcare environments.
7. Assist consultants, building designers, contractors and project owners on specifications and estimated ambient noise level and its controls.

2.0 The Problem of Noise in the Built Environment

Excessive level of noise causes us to suffer from distraction, fatigue and other unhealthy consequences. Noise from all kinds of sources invades our homes and workplaces, whether coming from the traffic, aircraft, barking dogs or human voices.

Within the workplaces, we have office machines and equipment such as telephones, ventilation system and even conversations between office cubicles causing unwanted noises which can be very distracting and lead to loss of concentration and productivity level.

Noise from within the homes typically comes from household appliances, footsteps sound, and television sound that travel across rooms, turning our homes into a hectic environment instead of a place to rest and recuperate. The scenario for healthcare sector is also very similar; where a good and controlled acoustic environment is needed so that patients can rest well with less stress for faster recovery.

In the educational environment, such as classrooms in schools or auditoriums in educational centres, excessive noise impedes the learning process and degrades the learning experiences of its occupants, especially for kids and young adults.

In addressing the noise problems of the built environment and recommending effective solutions, it is important that we understand the basic physics of acoustics and how noise is produced and then seek ways to control it. Some common standpoints for this approach will be the source of the noise, the path it travels and the point of receiving the noise. This manual includes information on how to solve specific noise problems using ROCKWOOL acoustical products and proprietary systems that are both safe and efficient.

3.0 Fundamentals of Acoustics

3.1 How is Sound Created?

Vibrating surfaces such as engine housings, loudspeakers and rapidly moving like turbulent water and jet engine exhausts produce minute fluctuations in the pressure of the surrounding air. These pressure fluctuations spread out from the source in the form of expanding waves in the air, much as a water wave on a pond spreads out from the point where a pebble has been dropped in – their intensity steadily decreasing with distance from the source. Our ears, acting like microphones, sense these tiny air pressure fluctuations and create equally tiny electrical signals that our brain then interprets as sound.

The words 'sound' and 'noise' are often used interchangeably. However, from the viewpoint of its effects on people in the community or the workplace, sound is considered to be noise when it is 'unwanted' – either because it interferes with essential human activities (such as speech, sleep, concentration or relaxation) or causes annoyance.

3.2 Basic Terminologies Defined (Frequency, Wavelength, Amplitude)

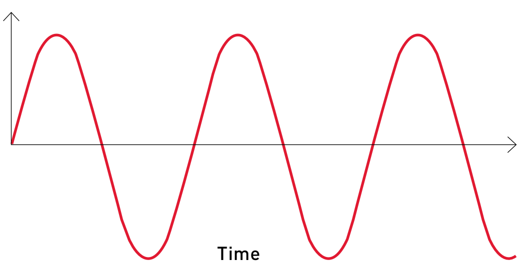
The basic properties of sound need to be understood to enable us to control sound effectively in today's built environment. The common terminologies associated with the subject of sound are:

- Frequency, also known as the pitch of the sound
- Wavelength of sound
- Amplitude of sound, also known as the loudness

Frequency (Pitch)

Sound is a form of energy transmitted by vibration of the molecules in a medium that passes the energy through one end to another. The speed of sound in air is approximately 344m/s, in solid object it is about 5000m/s,

Diagram 1: Pure tone (sine wave)



and in fluid about 1500m/s. The denser the medium, the faster sound travels in the medium. A pure sound wave of a single frequency takes the shape of a sinusoidal wave form.

Based on the wave form, the number of cycles per second made by a sound wave is called the Frequency, expressed in Hertz (Hz). Sound radiates in all directions from a vibrating medium. However, most sounds that we hear are a combination of many different frequencies like a spectrum. Healthy young human beings normally hear frequencies as low as about 20 Hz and as high as 20,000 Hz.

For purposes of noise control, the audible sound spectrum is then divided into octaves, and these divisions are expressed as octave bands and are referred by their centre frequencies. Each centre frequency is twice that of the one before it. When a more detailed sound spectrum is required, octave bands are further divided into thirds.

Wavelength

The wavelength of a sound wave is the distance between the start and end of a sound wave cycle or the distance between two successive sound wave pressure peaks. Numerically, it is equal to the speed of sound in the

Table 1: Octave Band Centre Frequency and One Third Octave Centres

Octave Band Centre Frequency	Band Width	One Third Octave Centres	Band Limits
	22		22
31.5		25	28
		31.5	35
	44	40	44
63		50	57
		63	71
	88	80	88
125		100	113
		125	141
	176	160	176
250		200	225
		250	283
	353	315	353
500		400	440
		500	565
	707	630	707
1K		800	880
		1000	1130
	1414	1250	1414
2K		1600	1760
		2000	2250
	2825	2500	2825
4K		3150	3530
		4000	4400
	5650	5000	5650
8K		6300	7070
		8000	8800
	11300	10000	11300
16K		12500	14140
		16000	17600
	22500	20000	22500

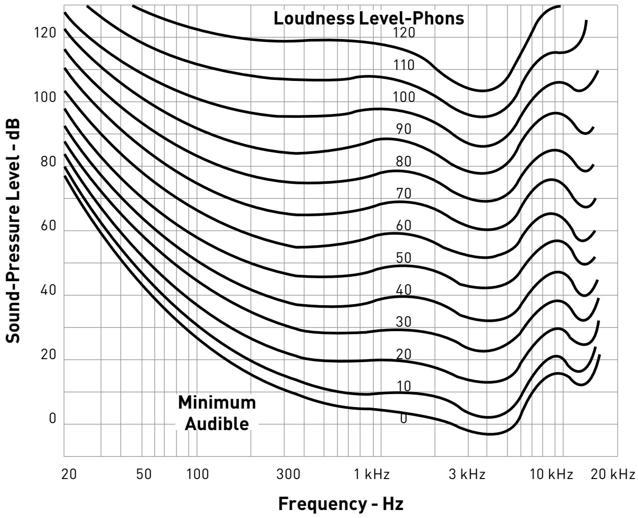
material such as air divided by the frequency of the sound wave. For example, a wavelength of a 100 Hz tone at room temperature is 500m/s divided by 100 Hz is equal to 5m.

Amplitude (Loudness)

The amplitude or loudness of a sound wave is expressed as Sound Pressure Level (SPL). Sounds having the same wavelength (equal frequency) may have differing loudness.

The pressure (Pa) term which is used to describe an audible loudness varies within a huge range (which runs

Diagram 2: Equal Loudness Curve



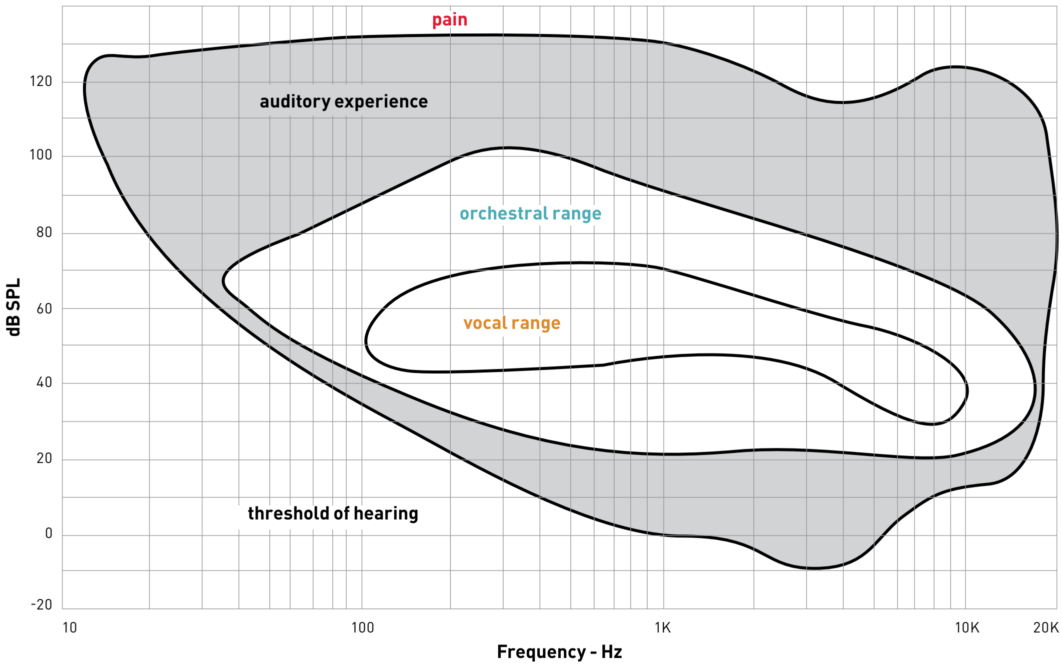
in couple of thousands of a unit). Hence a term which is based on logarithm scale was introduced so that the numerical value of sound pressure level can be more manageable - this is called Decibel (dB).

Within this scale, a sound pressure level (SPL) of 0 decibels (dB) represents the threshold of hearing in the normal human ear's most sensitive frequency range, while the thresholds of pain in the ear occur at 150 dB.

The decibel (dB) is then commonly used to measure the ratio between a given sound pressure and a reference sound pressure, or known as the threshold of hearing.

This relationship is expressed by the following equation:
$(L_p) = 10 \log (P/P_{re})^2$
Where: L_p is the Sound Pressure Level
P is the Sound Pressure (Pa)
P_{re} is the sound pressure at the threshold of hearing (0.00002 Pa)

Diagram 3: Human Hearing Range - Threshold of Hearing and Threshold of Pain



Above diagram 3 shows the SPL in dB and in Pascal (Pa) for various sounds within the human ear's hearing range. It is worth noting for example that a sound pressure level of 60 dB is 1,000 times that of the sound pressure level at 20 dB, instead of 3 times in normal mathematical logic as the quantum is represented in a logarithmic manner.

As a rule of thumb, every 10 dB increase in sound level corresponds to a "doubling of subjective loudness" so that, for example, a jackhammer noise at 110 dB would typically be judged to be 2 x 2 x 2 x 2 = 16 times as loud as the inside of a house at 70 dB.

The human ear is sensitive to a wide range of sound intensity (loudness); from ticking of a watch to jet engine noise in rather close proximity, would typically result in a pain sensation in the ears. The human ear is also sensitive to a wide range of sound frequencies, ranging from very low (like the sound from a sub-woofer, around 20-30 hertz) to very high (aircraft sound, about 18000 to 20000 Hertz). However, the ears are more sensitive to middle and higher-frequency sounds, around 500 Hertz to 8000 Hertz than to low frequency ones.

Different individuals will perceive sound intensities in relation to frequencies differently as a matter of biological make up although it is common that one's ability to receive and interpret sounds will decrease with advancing age as hearing range could decrease to about 70 Hz to 14,000 Hz. Human also tends to hear a 4000 Hz tone as being louder than a tone at some other frequency, even though the acoustical energy, or sound power could be the same.

In order to mimic and normalise the ear's sensitivity, weighting system or correction factor is introduced. The common correction factor that is used to represent noise level in relation to human perception is called A-weighting; there are also several other weightings available but they are more suitable for other purposes and studies.

The A-weighting factor is commonly embedded into sound level meters for noise measurement as a form of electronic filter. This weighting is used when measuring sound in the community or the workplace and the resulting sound levels are expressed in units of A-weighted decibels, or dBA.

In general the correction factor results in noise level with suppression to low frequencies sound; and due to frequencies dependent, overall noise level measured is typically lower compared to noise level expressed in dB.

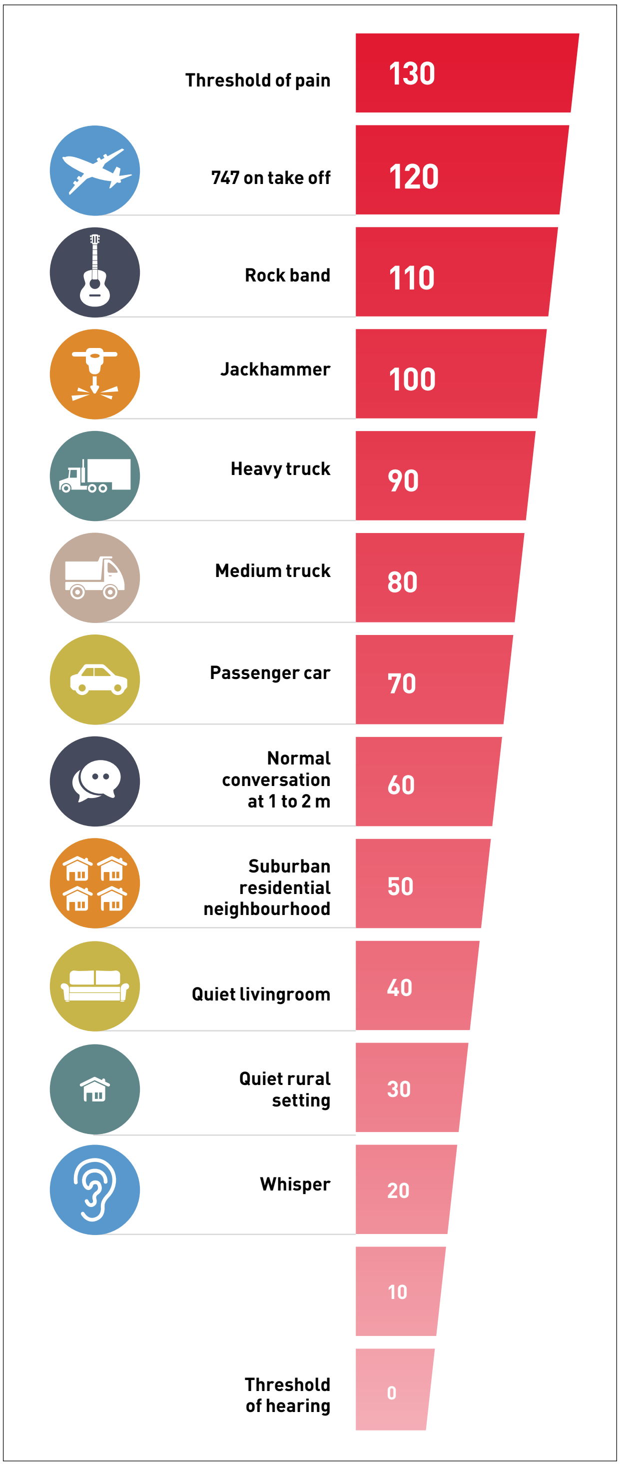
Table 2 below shows the typical sound levels in dBA commonly found in our homes and workplaces.

Table 2: A Comparison of Sound Pressure and Sound Pressure Level

Sound Pressure, Pa		Sound Pressure Level, dB	
	20	120	Pneumatic Chipper (at 5ft.)
	10		
Rock-n-Band	5	110	Textile Loom
Power Lawn Mower (at operator's ear)	2	100	
	1	90	Newspaper Press
Milling Machine(at 4ft.)	0.5		Diesel Truck 40 mph (at 50ft.)
Garbage Disposal (at 3ft.)	0.2	80	
	0.1	70	Passenger Car 50 mph (at 50ft.)
Vacuum Cleaner	0.05		
Air Conditioning Window Unit (at 25ft.)	0.02	60	Conversation (at 3ft.)
	0.01		
	0.005	50	
	0.002	40	Quiet Room
	0.001		
	0.0005	30	
	0.0002	20	
	0.0001	10	
	0.00005		
	0.00002	0	

Diagram 4 is a Decibel Scale showing sound levels typically created by familiar sources of noise in the home and community.

Diagram 4: Decibel Scale (dBA)



3.3 How Do We Hear Sound?

Under perfect listening conditions, human ear is able to detect changes in sound level as low as just 1 dB. A change of minimum 3 dB is usually required in order to be noticeable, whereas the change of 10 dB in sound level is perceived as twice as loud of one-half as loud.

As noise levels are commonly expressed in logarithm scale of decibel, any calculation regarding sound level shall be undertaken correspondingly to logarithmic principles. Addition of noise level from two sound sources can be estimated by empirical guidelines such as Table 3 below.

Table 3: Adding dB to Sound Levels for Second Source

If the difference between the two sound levels is:	Add to the higher sound level:
1 dB or less	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 dB or greater	0 dB

For example, two motors may be located at the source, one operating steadily and the other intermittently. However, the total sound pressure level when both motors are operating will not be the total number of decibels produced by each, because decibels are not calculated by normal addition.

If both motors are emitting 65 dB, when the second motor is operating, the total sound pressure level will be 65 + 3 = 68 dB. If one motor is emitting 65 dB and the other 70 dB, when both motors are operating the total sound pressure level will be 70 + 1 = 71 dB. If one motor is emitting 65 dB and the other 75 dB, when both motors are operating the total sound pressure level will remain at 75 dB, the sound level of the noisier motor.

3.4 Propagation of Sound

Sound travels and fluctuates with time, and is therefore an important influence on the degree of how it effects and is perceived by humans. Normally the sound fluctuation takes place with one or combination of the following forms:

a. Steady Sound

- With little fluctuations or remain constant most of the time.
- Example such as noise produced by a table fan
- Occupants eventually become accustomed to the steady sound that they almost cease to hear it after a while

b. Intermittent Sound

- Occurring once in a while, transient event and rather random with time
- Interrupts repeatedly between periods of relative quiet
- Example such as low flying airplane
- More annoying than steady sound

c. Impulsive Sound

- Unusually loud sound that is startling or shocking to the listeners
- Noise generated in an impulse or very short period of time
- Example such as sound of an explosion
- If loud enough, impulsive sound can cause hearing damage

4.0 The Need for Solutions

To differentiate sound from noise involves personal subjective judgement based on the individual's sensitivity and tolerance towards sound, coupled with the attitude and experience or exposure of the individual to sound. For one person the sound may be perceived as soothing and comfortable but by another perceived as noise or unwanted sound.

It is difficult to completely eliminate the characteristics of sound like pure tones such as whines and humming or impulsive components such as gun-shot sound or barking dogs that is continually coming on and off. Such undesirable sound interferes with our quality of life during rest and sleep, our ability to converse clearly or even when listening to music or other natural sounds. The unwanted sound creates unpleasant feelings or fears, so much so that sometimes we find it difficult to express our discomfort when we are experiencing it.

Therefore, the unwanted sound or noise is widely recognised as a form of environmental pollution. Even though noise is created from human activities, we must weigh the rights of others to enjoy peace and quietness in their residential space, within neighbourhoods, and at public areas such as educational and healthcare centres.

The noise annoyance is also subject to other factors when viewed from the degree of impact it brings and how much it influences one's lives. These factors include the following:

- Age and state of health of the individual
- Activities that the individual is engaged in, relative to the ambient noise level
- Previous experiences with the same or similar type of noise
- Perceptions with regards to the usefulness of the activity creating the noise
- Type of noise sources
- Attitude towards the noise maker

4.1 The Effects of Noise

As mentioned in the previous section on basic terminologies, sound travels as pressure waves through the air. The wavelength of a sound is the distance that sound travels during one pressure cycle (i.e. the time taken for an air pressure fluctuation to go from maximum to minimum and back to maximum again). With the same speed of sound in the air for all frequencies, the wavelength decreases as the frequency increases.

Sound with long wavelengths (low-pitched sounds) tend to diffract around objects more readily than sound with short wavelengths. This makes shielding a noise receiver from low-frequency sounds more difficult compared to shielding noise of other frequencies. Low-pitched sounds also pass through solid materials easily. However, high-pitched sounds with short wavelengths can pass through small cracks and gaps more easily than low-pitched sounds.

Hearing Loss

At high sound intensities, noise can cause temporary or permanent hearing loss. This can be due to very loud sound like lightning thunder or a gun-shot from a short distance. When we are exposed to such occupational noise environment it can cause damage to our hearing over time. Therefore, as part of occupational safety requirement it is recommended that a person should not be exposed to noise level more than 85 dBA for a continuous of 8 hours a day. Hearing damage could be in the form of not being able to hear certain frequency or not being able to listen to sound lower than certain loudness.

Speech Intelligibility

The impact of noise on speech communication is huge. This happen when intrusive noise exceeds the normal speech sound levels and when the noise 'mask' the speech sound, causing loss of speech intelligibility. The recommended practical noise level threshold for the onset interference with speech intelligibility is capped at 45 dBA for steady noises and 55dBA for intermittent peak levels.

Interference with Sleep

Intrusive noise interferes with our sleep and quality of rest by causing shifts to lighter sleep stages or actual awakenings. It is said that in a residential environment, the normal night time ambient noise level is recommended at 45dBA for intermittent noises and 30 dBA for steady noises. Any noise level received above this level will cause discomfort and significantly degrade the quality of sleep, causing tiredness and lack of concentration at work and deterioration in health over time.

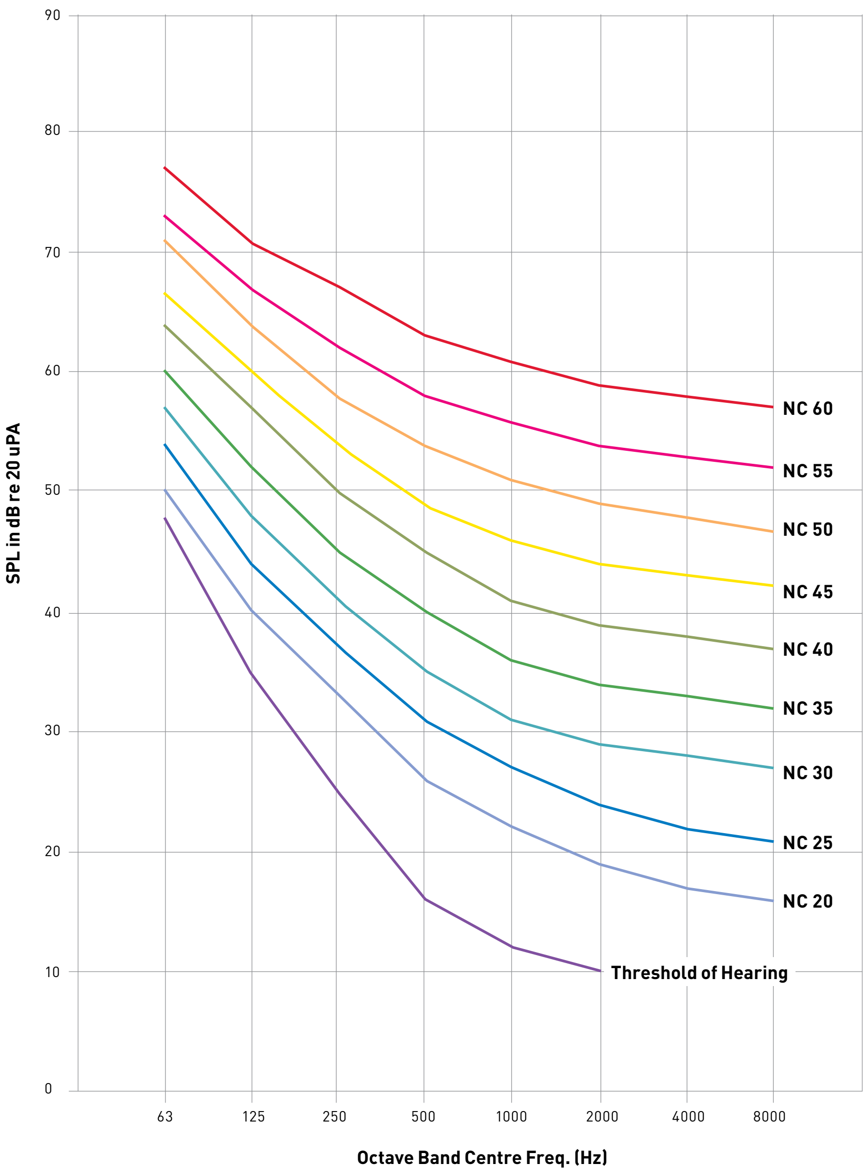
5.0 How Much Sound is Acceptable?

Noise is generally defined as unwanted sound. Our homes and workplaces are subjected to certain level of background noises which are also known as ambient sound. Under normal circumstances, we can determine the acceptable level of ambient noise level before we deploy the solution to solve this problem. It is important to take note that we can reduce ambient noise to a desired designed level, but we cannot completely eliminate ambient noise.

The question is, how much sound is acceptable so that the ambient noise will not become too loud or too soft that deter the activities for occupants within a given space?

For example, moderate ambient sound level can be helpful in order to prevent private conversations from being overheard by others; yet the level should not make it difficult for the occupants within the same room to

Diagram 5: Noise Criteria (NC) Curve



converse clearly with each other. Low ambient sound can also contribute to good quality sleep when it is not interrupted by impulsive noise.

Depending on the usage of space and type of building, background noises or ambient noise levels need to the designed and checked with good sound control to enable good indoor comfort and clear speech intelligibility.

5.1 Noise Criteria (NC)

Noise Criteria (NC) is one of the important parameters used in measuring the allowable ambient sound level for various types of interior spaces. NC rating is determined through plotting measured ambient noise level spectrum over an NC Chart; where NC rating curves is pre-plotted. By referring to the NC curves, the NC rating is taken at the nearest curve that the plotted ambient noise curve did not cut through. This is the lowest NC rating possible for a particular interior space.

Referring to the Diagram 5, the NC rating curves are plotted in such a way that the sound pressure level is adjusted to reflect the behaviour of human ear in response to the respective octave band centres of frequencies.

The recommended NC sound level for various interior spaces is shown in Table 4.

Table 4: Recommended noise criteria range for various interior spaces

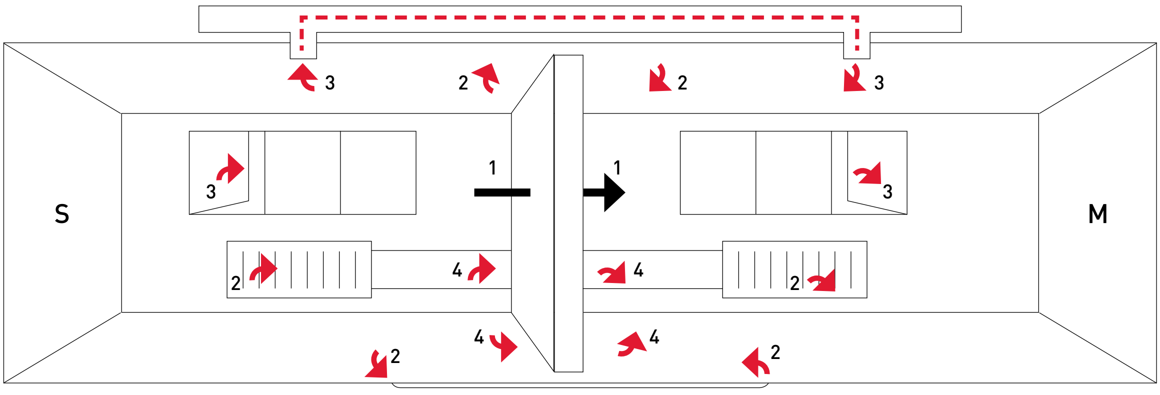
Type of Space	Acoustical Considerations	NC value
Concert and recital halls	Listening to both loud and faint sounds	10 - 20
Broadcast and recording studios	Distant microphone pick-up	15 - 20
Broadcast, television, and recording studios	Close microphone pick-up	20 - 25
Large auditoriums, theaters, churches	Listening to speech and music	20 - 25
Small auditoriums, theaters, churches	Listening to speech and music	25 - 30
Meeting, conference, and classrooms	Clear speech communication among a group	25 - 30
Bedrooms, apartments, hotels, motels	Clear conversation with speech privacy	25 - 35
Living rooms and family roos	Clear conversation among a small group	35 - 45
Private offices	Clear conversation with speech privacy	30 - 35
Large offices, reception areas, retails shops	Clear speech communication	35 - 50
Lobbies, engineering rooms, secretarial areas	Clear speech communication	40 - 45
Kitchens, laundries, laboratories	Clear speech communication	40 - 45
Light maintenance shops, equipment rooms	Clear speech communication	45 - 60

6.0 Sound Paths – Airborne and Structure Borne

Sound waves travel through mediums such as air, fluid and solids. Depending on the medium that the sound energy travels through, sound paths can be airborne or structure borne.

Empirically, the ambient noise can be controlled and attenuated at the location of the source and receiver, or along the path it travels from the source to the receiver.

This can be done by replacing the sound source with a quieter one which is often difficult to do; or to block the sound with a solid and heavy material to resist and isolate the transmission of the sound waves. One important method to control the ambient noise level is to use absorptive material that is light and porous, thereby preventing the sound energy from being reflected as reverberation.



1. Direct sound transmission 2. Flanking transmission 3. Overhearing 4. Leakage

7.0 Airborne Sound Transmission

Sound that is emitted from its source directly into the air is called airborne sound. It travels through the air and reached the human ear and then is interpreted by the brain as of a certain loudness of pitch. Examples of airborne sound are sounds from adjacent meeting rooms, sounds of traffic passing near our homes and the noise from a barking dog.

To measure how much a particular building element is able to attenuate sound from one space to another, the airborne sound transmission loss is used. Typically, heavy and solid materials provide better sound transmission loss than light and porous material. Materials used in modern buildings are designed to be light and flexible such as drywall systems with lightweight framing; which are not only environmentally friendly, but also flexible in design and cost saving making it the preferred choice compared to conventional construction materials such as bricks and mortar. These lightweight products and materials are able to provide good acoustical performances. Therefore, it is important to select the right type of materials in order to achieve the desired acoustic level and effective designed ambient noise.

Sound transmission loss, also known as STL, measures from the one-third octave band frequencies of 125 Hz to 4000 Hz, and is expressed in the form of Decibel (dB). The sound transmission loss (STL) is tested and measured in test laboratories in accordance to the ASTM E90 standard.

7.1 Sound Transmission Class (STC)

The sound transmission class (STC) is referred to as the sound transmission loss value expressed as a single number rating. It is obtained by comparing the noise reduction performance of a building element at various frequencies against a standard noise reduction curve.

Field measured STC values need to cater for losses in the STC performance due to the nature of the installation flaws and unintended ambient noise that exist on site, influencing the measurement of the on-site transmission loss. Field STC is denoted as FSTC. For the design of FSTC, it is estimated at approximately a difference of 5-8 rating of STC from the actual STC value.

For example, where the sound source noise level is 75 dBA and the wall element provides an STC 35, then the receiving space will be roughly 40 dBA. Originally developed to address the transmission for interior sounds such as speech, radio and television noise, the STC is also now used to compare both interior and exterior building elements and to select the appropriate construction details such as windows, doors and walls. This is expressed as Outdoor-Indoor Transmission Class (OITC).

Mass-Spring-Mass

One of the most effective ways to reduce and attenuate sound transmission from one interior space to another is by adopting the mass-spring-mass assemblies.

For example, a double-leaf drywall with front and back facing fixed to metal studs. This lightweight assembly enables equal or even better STC rating compared to solid walls such as concrete or brick walls.

By adding in insulation material such as the ROCKWOOL Safe'n'Silent Pro into the cavity enables a significant incremental value in transmission loss or STC. To get the optimal performance out from the insulation, it is best to fill the cavity completely with ROCKWOOL Safe'n'Silent Pro. By having the insulation in the cavity, it is empirically estimated that the sound transmission loss of the said drywall system in the mass-spring-mass assembly can provide additional sound insulation between 3-5 STC ratings.

In the mass-spring-mass system, by adopting a double independent stud system with the ROCKWOOL Safe'n'Silent Pro in the cavity will also improve the STC rating of the drywall system, by eliminating the acoustic bridging of the mechanical connections between both sides of the drywall.

The best practice of maintaining a reasonable good sound level within an interior space is to enclose or encase the source with housing that is constructed with materials of high STC ratings. The enclosure should be designed and built with caution so that there are no air gaps that will cause sound leakage from the enclosure through these small gaps.

7.2 Consideration on Flanking Paths

To determine the sound transmission loss in relation to the desired ambient sound, careful consideration must be given to flanking paths. The flanking path is defined as the route or the path that sound travels from one space to another space which is not through the main separating element. Any gap or small opening in an acoustically designed space will lead to sound leakage and this will increase the ambient noise level.

Examples of flanking paths include door and window gaps and improperly sealed joints between wall panels and sockets and openings for mechanical and electrical service fittings. In order to reduce the flanking noises, below measures are recommended:

Table 5: Measures to Reduce Flanking Noises

Doors	■ Made from solid wood, solid or with insulated cores
	■ With seal or gasket to prevent sound from passing through door jamb
	■ With airtight seals along top, bottom and sides of door
	■ Adding a second storm door separated by airspace of 100 to 150mm with perimeter seal on both doors
Windows	■ Double glaze window, floated glass or laminated glass window
	■ Reduce window size
	■ Add airtight perimeter seals
	■ Reduce windows that are directly facing exterior noise, or have larger size windows on the quiet side of the space
	■ Add a layer of heavy glass with large airspace to existing windows (storm window)
	■ Close all windows tightly
Wiring and piping works	■ Conduit holes must be properly sealed
	■ Cut-outs from drywall should be as small as possible and should be caulked
	■ Avoid back to back socket positioning
	■ Locate openings at the quiet side of the space
	■ Cut holes and opening should be staggered
	■ Stuff holes with insulation material such as ROCKWOOL Safe'n'Silent Pro
Wall panels	■ Insulate wall cavities using ROCKWOOL Safe'n'Silent Pro
	■ Increase the mass of the lightweight constructions through thickness of lining material
	■ Use double or staggered studs

8.0 Sound Absorption

Sound absorption is defined as the ability of a material to transform acoustical energy to other forms of energy, typically heat. Some materials will absorb sound energy differently; materials such as concrete and brick wall absorb very little to none acoustical energy and reflect most of the sound energy that strike its surfaces, whereas porous material such as ROCKWOOL stone wool products absorb most of the sound energy that it comes in contact with.

8.1 Noise Reduction Coefficient (NRC)

The sound absorption criteria is usually expressed in terms of percentage or as the decimal fraction of the sound energy absorbed and not reflected by the materials. Different materials will behave differently in absorbing sound energy at different frequencies. Building materials are generally rated with a single number rating called Noise Reduction Coefficient (NRC).

It is calculated with the average sound absorption coefficient at specific frequencies of 250, 500, 1000 and 2000 Hz.

In order for a material to be considered as having sound absorption properties, a minimum NRC value of 0.50 is required.

Table 6 shows the typical values of NRC for various types of materials.

The NRC values of a material is used to calculate the sabin of absorption which is the unit of measuring sound absorption that equals to the sound absorption coefficient of a material multiply with the coverage surface area that is used. The sabin of absorption is then used in calculating the noise reduction in an interior space and reverberation time, RT60.

Table 6: One third- octave sound absorption coefficients of typical building materials

Product	Octave Band Center Frequencies, Hz						NRC
	125	250	500	1000	2000	4000	
Brick, unglazed	0.03	0.03	0.03	0.04	0.05	0.07	0.05
Brick, unglazed, painted	0.01	0.01	0.02	0.02	0.02	0.03	0.00
Brick, unglazed, painted	0.10	0.05	0.06	0.07	0.09	0.08	0.05
Carpet, 1/8" pile height	0.05	0.05	0.10	0.20	0.30	0.40	015
Carpet, 1/4" pile height	0.05	0.10	0.15	0.30	0.50	0.55	0.25
Carpet, 3/16" combined pile and foam	0.05	0.10	0.10	0.30	0.40	0.50	0.25
Carpet, 5/16" combined pile and foam	0.05	0.15	0.30	0.40	0.50	0.60	0.35
Fabric, light velour, 10 oz./sq. yd. hung straight in contract with wall	0.03	0.04	0.11	0.17	0.24	0.35	0.15
Fabric, medium velour, 14 oz./sq. yd. draped to half area	0.07	0.31	0.49	0.75	0.70	0.60	0.55
Fabric, heavy velour, 18 oz./sq. yd. draped to half area	0.14	0.35	0.55	0.72	0.70	0.65	0.60
Floors, concrete or terrazzo	0.01	0.01	0.01	0.02	0.02	0.02	0.00
Floors, linoleum, asphalt, rubber or cork tile on concrete	0.02	0.03	0.03	0.03	0.03	0.02	0.05
Floors, wood	0.15	0.11	0.10	0.07	0.06	0.07	0.10
Floors, woo parquet in asphalt or concrete	0.04	0.04	0.07	0.06	0.06	0.07	0.05
Glass, 1/4", selaed, large panes	0.05	0.03	0.02	0.02	0.03	0.02	0.05
Glass, 24oz. operable windows, closed	0.10	0.05	0.04	0.03	0.03	0.03	0.05

From "Acoustical Ceilings — Use and Practice," Ceilings and Interior Systems Contractors Association (1984). p.18.

8.2 The Need and Properties for Sound Absorbers

Porous materials have interconnecting air pockets and are an effective sound absorber. ROCKWOOL Safe'n'Silent Pro when coupled with thin or perforated surfaces such as fabric lining and perforated panels, is a good sound absorber that performs well to reduce unwanted noise in a space. This can be achieved by placing the materials on the surface of the walls within an interior space.

8.3 Sound Level Reduction Calculation

The reduction of sound level in a room is related to the amount of sound absorption surfaces in the room itself. The reduction of sound level can be expressed as:

Reduction in sound level = 10 log A_a/A_b dB,

Where A_a is the sound absorption in sabins in the room after correction

A_b is the sound absorption in sabins in the room before correction

In instances where an interior space is noisy due to occupant activities such as a music hall or auditorium, and the sound level may need to be controlled and minimised to a low level, the equation above can be used to determine the amount of acoustical absorption materials needed in order to meet such requirements.

For example, for wall absorbers using ROCKWOOL Safe'n'Silent Pro with sound absorption coefficient of 0.70 at 250 Hz, with a coverage surface area of 1000 sq. meters, we assumed the total sabins of absorption in the room from all other absorptive surfaces at 250 Hz is 200 sabins. The wall absorber contributes total sabins of 0.70 x 1000 = 700 sabins so when added to the room is 200 + 700 = 900 sabins.

The sound level reduced in the room by calculation is:
10 log (900/200) = 6.5 dB

And this is achieved by adding 1000 sq. meters of wall absorber with ROCKWOOL Safe'n'Silent Pro.

8.4 Reverberation Time

Reverberant sound or also known as echo in an interior space will fade away with time as the sound energy is absorbed multiple times and reflected within the surfaces of the room itself. If the surfaces of the room are all made of hard and non-absorptive materials, it takes longer time for the echo to die off, thereby causing disturbance to the occupants, reducing speech intelligibility and affects concentration.

Reverberation time of RT60 is defined as the time needed for the sound to reduce by 60 dB from its original sound level. It is then calculated and modelled through the usage of absorptive materials in the interior space. In room acoustics, it is important to have a good reverberation time to ensure occupants' activities are not impaired or affected.

The Reverberation time is expressed as:
RT60 = 0.161 (V/A) in seconds, where
V = Volumetric size of the room
A = Sabins of absorption in the room

The example uses a room volumetric size of 5000 cu. meters with amount of sabins of absorption at 200 sabins at 250Hz. After installation of wall absorbers with total sabins of 1000 sabins, this gives a total of 1200 sabins.

The RT60 before the acoustical correction is calculated as 4.0 seconds whereas after adding in wall absorbers, the RT60 becomes 0.67 seconds.

This lower reverberation time provides a comfortable and clear speech intelligibility to the occupants using the room.

9.0 Noise Control Solutions

This manual has so far discussed about how sound propagates and the means of calculating the effects of sound whether it is being reflected or absorbed in a room. Hence, we should now consider ways of how to control the sound via its sound paths, from the sound source, the travel path and the receiver end of the sound.

The acoustical consideration range takes into account all the way from the starting point where the sound originates to everything in between, until it reaches the receivers' ears.

Controlling Noise at the Source

The following measures can be considered in order to control the noise at the source itself. It is the least costly way of reducing noise, but often is limited by the site condition or the activities in the room itself, sometimes making it impossible to make changes to the sound source.

- Move the source to another location at a certain distance away, so that the noise level is lower.
- Change the acidity related to the generated noise so that the sound level is reduced; for example reducing motor power or speed of rotating drum of equipment.
- Repair faulty equipment that generates noise such as loose bolts and nuts from vibration.
- Replace equipment with a quieter type or model.

Another method of containing and reducing the sound from its source is by having an acoustical housing that encloses the sound generating activity or equipment. The housing needs to be designed with high sound transmission loss properties. It also needs to be covered with high sound absorptive material to increase the overall noise reduction level.

Controlling Noise Along its Path

As mentioned in sound absorption topics, reverberant sound resulting in echo can be reduced by placing sound absorbing materials on the surfaces which reflects the sound. This contributes significantly to the final outcome of the acoustical correction in order to produce a desired comfortable environment. It is also one of the least expensive ways to design and construct noise controlling mechanisms compared to controlling the sound source.

Controlling Noise at the Receiver

When the first two methods fail to meet the noise controlling criteria, we can also find ways to fix the noise problem at the receivers end.

9.1 Noise Control Mistakes to Avoid

Thinking That There is No Noise Problem

In an industrial environment of a factory, if workers are exposed to ambient noise level of more than 85 dBA it is considered hazardous. Ear protectors should be used as a temporary measure while the use of actual enclosure for the loud noise must be deployed. Another example is in the educational environment where a 55 dB sound in a learning centre will cause difficulty in listening and poor speech intelligibility that can impair the learning process.

Not Considering Noise Control Before a Project is Started

It is estimated that the cost to correct the acoustic performance of a room is almost double or the measures are only half as effective if done after the completion of a construction. We therefore recommend that the acoustic performance be determined at design stage and the installation starts during the design and specification stage before the sound source is introduced or the occupant activity occurs.

Not Conducting a Detailed Study of Noise Equipment

Equipment and machineries always emit noises that can cause uneasiness to the users and occupants and these must be addressed and considered when controlling the ambient noise level. The spectrum of noise in terms of frequencies should be analysed and the octave band noise levels obtained and studied beforehand. By doing so we can better understand the overall noise generated by the equipment and thereafter design the control mechanism to reduce the ambient noise.

Not Using a System Approach to Noise Control

Noise control involves a system approach rather than just one single material or product. All possible noise paths and solutions that could lead to higher noise level need to be considered whether before, during or after the construction works are carried out. In this case, airborne and structure borne sound must be studied and understood thoroughly.

Not Sealing Air Leaks

Sound will pass through even from the smallest gaps or cracks whether they are from the construction itself or the architectural finishes. Wherever there are air leaks, sound can pass through from one space to another, causing higher ambient noise thereby defeating the purpose of having high acoustic performance solutions. So it is important that air leaks are sealed properly to avoid such problems.

9.2 Case Studies – Assumptions and Presets

The following sections of this manual include several simulated case studies where ambient noise levels are recommended for various categories of room/space functions. Examples are provided showing the various acoustics elements combined to achieve the desired ambient noise level. Relevant acoustics design elements and other related elements are described hereafter as well. It is assumed that the external noise source of related room/space is in the range of 70 to 80 dB(A). Examples of such external noise sources are passing traffic, student activities, music or announcements from portable sound reinforcement.

The partitioning elements of the room/space were designed based on estimated calculation of commonly used Mass Law equation which is an empirical estimation method. Elements such as doors, ceiling panels, carpets and others are generally available in the market.

The simulated case studies are for reference and to provide general understanding; other design and construction details may not been listed herein and may require further attention. It is recommended that the partitioning elements be laboratory tested before implementation on site.

10.0 Case Study - Residential

A residential unit is a place where people lives and spend a good amount of time in. Typically it consists of several bedrooms, a living area, toilets and kitchen; and is designed to provide comfort to those living in it. Some houses have additional rooms or spaces that serve as audio visual room, leisure and games room/space, library, study room and so on. These additional luxury of room and space means that the residential unit becomes a common place for both dwelling and leisure.

10.1 Use of Space and Occupancy

Different rooms have a different function and require different conducive ambient noise level. Table 7 recommends conducive ambient noise level and noise criteria for various rooms and spaces for a residential unit.

Generally, rooms or spaces for resting and relaxing is expected to have lower ambient noise; while activity room/space could tolerate higher ambient noise.

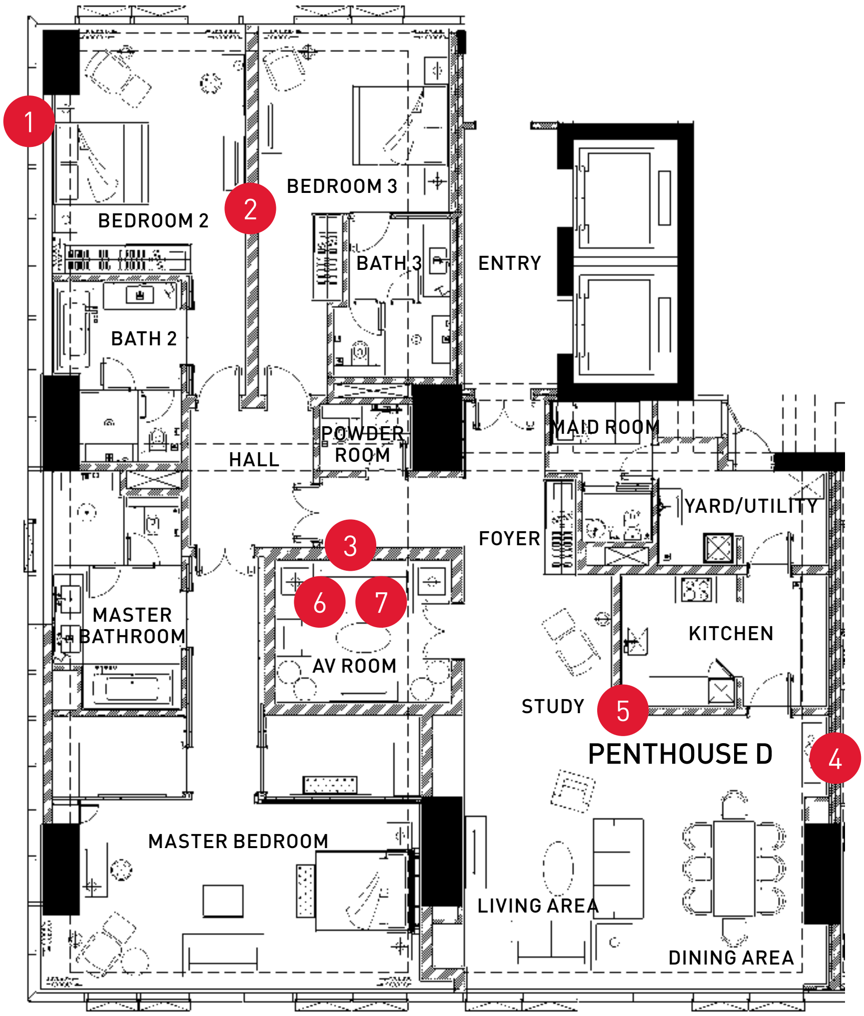
In order to achieve the recommended ambient noise level, appropriate airborne sound isolation performance for various partying elements, noise control on mechanical equipment and introduction of interior finishes with acoustics enhancement properties/elements would be required where appropriate.

10.2 Ambient Noise Level Consideration

Residential unit typically requires reasonable airborne sound isolation performance; apart from isolating external noise, it is also for isolating noise intrusion or cross-over between rooms/spaces.

More importantly a good sound isolation is needed between units, such as between terrace houses, semi-detach houses, condominiums, apartments and other similar housing configurations.

Diagram 6: Example of a layout of a high rise residential unit



Tolerance to sound crossover between rooms and spaces within the same unit is usually higher; but not between 2 connecting units. Also, additional consideration is needed for residential estate or project which is situated next to a busy expressway, railway line, transit line, and/or airport.

Indoor ambient noise of these residential estates are likely to be affected by traffic noise, train noise and/or air craft noise. Hence provision for high airborne sound

Table 7: Recommended NC/NR rating and Ambient Noise Level for various room/space for a residential unit

Space / Room	Recommended Rating	
	NC	Noise Level
Bedrooms	30 – 40	35 – 45 dB(A)
Study Area	30 – 40	35 – 45 dB(A)
Av Room	35 – 40	40 – 45 dB(A)
Living Area	35 – 45	40 – 50 dB(A)
Kitchen	45 – 50	50 – 55 dB(A)
Yard / Utilities	50 – 55	55 – 60 dB(A)

isolation performance should be considered for facade glazing or external wall of the building; apart from setting building orientation and layout as part of the effort to keep external noise intrusion to a minimal.

Ideally, noise crossover between internal spaces and rooms of a unit is to be kept to a minimal in order to meet proposed ambient noise level. A person sleeping in the bedroom should not be disturbed by the television sound in the living room; or the audio sound from the AV Room should not leak and disturb other family members carrying out their activities in other parts of the unit.

Unfortunately, often sound leaks and intrusion happens through the door gap; even though partitioning wall and door has been carefully designed and selected. This compromises the overall airborne sound isolation performance of the partitioning elements. So, whenever possible door seals are recommended.

As to limiting noise intrusion, ambient noise level of a residential unit is also dependent on other noise generating sources typically by long running period equipment such as the ACMV system.

High end high rise residential units are likely to be equipped with centralized ACMV system which generally allows noise mitigation to be introduced within the system to ensure resultant noise propagated would not compromise the desired ambient noise level.

Mitigation measures include sound isolation box of a Fan Coil Unit, internally lined duct, acoustics silencer, low noise air-grille and others.

On the other hand, general residential units utilise stand-alone systems such as ceiling fan, stand fan, split-unit air conditioning unit and air cooler as part of the home cooling. Special selection would be required to ensure that noise emission does not compromise the desired acoustics environment.

Notwithstanding the ACMV system, the operations of electrical or mechanical products that emit noise and run for long periods of time should also be reviewed when a certain ambient noise rating needs to be achieved.

10.3 Bedrooms and AV Room

Common residential unit's interior finishes are for example plaster ceiling, plaster and paint walls and homogenous tiles. Acoustics ceiling, absorptive wall panels and/or diffusive panels which are used to enhance the acoustics environment would likely be seen in an AV Room only; unless otherwise intended for other areas.

Sound reverberation and flutter echoes can be reduced to a minimal with built-in and loose furniture; and other decorative items. These items diffuse noise energy and breaks noise reflection path. At the same time, the shape, dimensions and volume of a residential unit generally does not further encourage flutters and echoes.

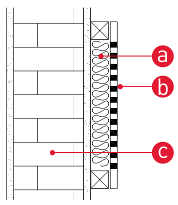
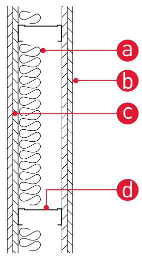
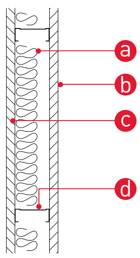
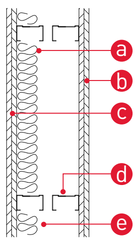
Introduction of acoustics elements in an AV Room is essentially to enhance its acoustics environment; resulting in a pleasant aural experience coupled with the audio visual system.

Elements introduced here could be absorptive, diffusive and/or mixed of the two. The common idea is to create a well sound distributed environment and at the same time with minimal sound reverberation, echo and flutter. This will boost the audibility and speech intelligibility which further enhances the experience. Elements such as acoustics absorptive wall panels with fabric and/or perforated timber finish, acoustics absorptive ceiling, timber raised floor with vibration isolators and carpet are typically seen as part of AV Room design.

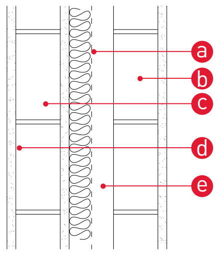
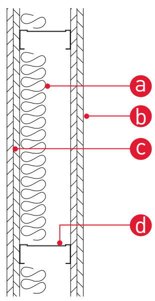
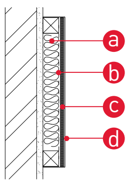
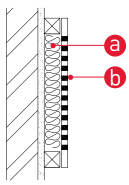
As AV Room often operates under high sound level condition; consideration on improving the sound isolation performance of the perimeter walls and doors would be essential to reduce noise impact to other areas within the unit or even to other connecting units.

The following section proposed construction details and recommendation on ACMV which serves as a guide in order to meet desired ambient noise level as prescribed above.

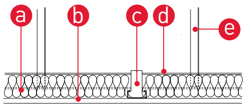
10.4 Recommended Specifications

Items	Elements	Example and Details		Remarks
1	Building Envelope or Facade		a) 50mm ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimum opening area of 15 - 20% c) 100mm thick brick wall, with 20mm thick plastering on both sides and 8mm thick casement window Curtain glass wall could be in form of double glazed for better sound isolation performance.	Perforated panel finish on the internal side of the facade (brickwall) provides sound absorption performance and prevent thermal heat transfer, lowering U-value of building envelope.
2	Party Wall between Bedrooms		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 12 mm thick Plasterboard (min. density 650 kg/cu.m) c) 2 x 12 mm thick Plasterboard (min. density 650 kg/cu.m) d) 92 mm deep stud	Wall to construct to full height
			a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 1 x 19 mm thick impact resistant plasterboard (min. density 750 kg/cu.m) c) 1 x 19 mm thick impact resistant plasterboard (min. density 750 kg/cu.m) d) 75 mm stud	Wall to construct to full height For Non Critical room
3	Party Wall between AV Room and other spaces/ rooms		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 12 mm thick Plasterboard (min. density 650 kg/cu.m) c) 2 x 12 mm thick Plasterboard (min. density 650 kg/cu.m) d) Separated Stud e) 150 mm deep air cavity	Wall to construct to full height Separated or twin studs are sized according to maximum height of wall system.

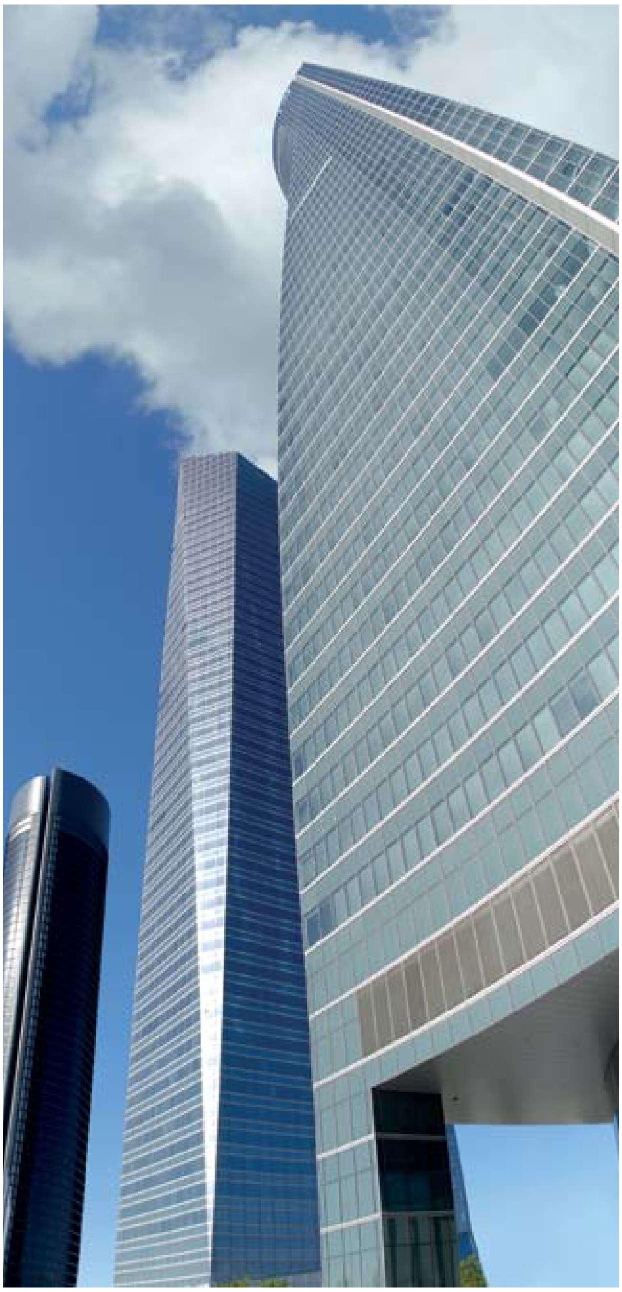
10.4 Recommended Specifications (continued)

Items	Elements	Example and Details		Remarks
4	Party Wall between Residential Units		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 100 mm thick clay brick (min. density 1500 kg/cu.m) c) 100 mm thick clay brick (min. density 1500 kg/cu.m) d) 20 mm thick plastering (on 3 sides) e) 100 mm deep air cavity	Wall to construct to full height
5	Party Wall for Kitchen		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 15 mm thick moisture resistant plasterboard (min.density 650 kg/cu.m) c) 2 x 15 mm thick moisture resistant plasterboard (min.density 650 kg/cu.m) d) 92 mm deep stud	Wall to construct to full height Wall choices to suit requirements in wet areas by using moisture or water resistant board, and installation to cater for additional loadings from wall tiling and penetrating services. Installation with heavy fixtures to be designed and considered separately.
6	Acoustics Wall Panel	Fabric Finish 	a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) Wire mesh to support ROCKWOOL layer c) 5 – 10 mm foam d) Acoustics transparent fabric	NRC 0.6- 0.8 Sound absorption will increase with additional 50 mm air cavity behind insulation layer
		Perforated Panel Finish 	a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimum opening area of 15 - 20%	NRC 0.6- 0.8 Typically to treat 60 – 75% of side and rear wall areas

10.4 Recommended Specifications (continued)

Items	Elements	Example and Details		Remarks
7	Acoustics Ceiling		**Concealed Ceiling System:** a) 50mm ROCKWOOL Safe'n'Silent Pro b) Ceiling panel or perforated panels c) Ceiling clip and lock system d) Furring channels e) Ceiling hanger rod/channel	NRC 0.6- 0.9 Available in various brands and system for selection to suit ID preference
*	Door		Solid wood core door with well-designed door frame and ironmongery, STC rating 30-32.	Bottom door seals will improve sound intrusion or sound leakage – best use for AV Room
*	Centralized Air Conditioning with delivery ducts	Air Handling Unit/ Fan Coil Unit	To select fan with low noise unit as stated in laboratory testing (by manufacturer's testing)	FCU may require acoustics box up if installed within sensitive room or space
		Ducting	Internal lining of 50 mm thick ROCKWOOL ThermalRock S60 with GI sheets of min. 30% opening areas	
		Silencer	To select by calculation which refer to AHU/FCU noise level, duct size, duct length, duct path, internal lining, diffusers and room/space's acoustics condition. Silencer selection based on ASHRAE recommendation and calculation procedure with consideration of above mentioned parameters.	
		Diffusers	To select diffusers with low regeneration noise; especially for noise sensitive room	Noise will generate when excessive air and/or high velocity air flows through diffusers blades; hence the selection Air speed and volume per diffuser are essential

11.0 Case Study - Office



An office is the place where a commercial establishment has its work and conduct related matters. It is not a place for manual hard labour; employees mainly work on administrative, design related and/or sales related work.

Employees typically spend more than 8 hours in an office thus it is important for office workers to have a conducive environment with good acoustics climate.

It has been confirmed by researches that an office with good acoustics climate and low ambient noise level could actually boost employees' concentration and thereby their productivity as well.

Hence a well-designed acoustics environment is beneficial for both employees and employers.

11.1 Use of Space and Occupancy

Table 8 recommends the conducive ambient noise level and noise criteria for various rooms and spaces for an office.

Generally, rooms or spaces use for the purposes of office work, meeting and productivity related work are recommended to have low ambient noise level; while supporting facilities which deals with other types of activities which can tolerate moderately higher noise level.

In order to achieve the recommended ambient noise level, appropriate airborne sound isolation performance for various partying elements, noise control on mechanical equipment and introduction of interior finishes with acoustics enhancement properties/elements would be required where appropriate.

Table 8: Recommended NC/NR rating and Ambient Noise Level for various room/space for an office unit

Space / Room	Recommended Rating	
	NC	Noise Level
CEO, CFO, COO Room	35 - 40	40 – 45 dB(A)
Meeting Room / Board Room	35 - 40	40 – 45 dB(A)
Executive Office	40 - 45	45 - 50 dB(A)
Open Office	40 - 45	45 - 50 dB(A)
Lift Lobby, Foyer and Circulation	45 – 50	50 – 55 dB(A)
Pantry	45 – 50	50 – 55 dB(A)
Toilets	50 – 55	55 – 60 dB(A)

11.2 Ambient Noise Level Consideration

Office is usually by choice located in a prime commercial zone, among all the hustle and bustle of commercial and human activities. It is also likely to be surrounded by heavy trafficked roads, train stations, bus routes and possibly even close to an airport. This places the office in an environment of high noise level.

Hence, in order to maintain the desired interior ambient noise level, design of an office tower or commercial building has to provide for sufficient airborne sound isolation between the external and internal of the building, between floors and adjacent office units.

Also equally important is to provide internal partitioning elements with reasonable airborne sound isolation, as part of the effort to contained noise/sound at its source. This is highly relevant as it relates to sound crossover and speech privacy issues; apart from maintaining the desired ambient noise level.

An interview or confidential discussions are not appropriate to be overheard by other employees outside of the interview or meeting room. Private tele-conversation among employees which could be heard in the adjacent room could also prove to be inappropriate and may spark disagreement or lead to privacy intrusion issue.

Unfortunately, often sound leaks and intrusion happens through the door gap; even though partitioning wall and door has been carefully designed and selected. This compromises the overall airborne sound isolation performance of the partitioning elements. Thus, whenever possible door seals are recommended. Sound crossover could happen due to partitioning wall not being constructed to full height from floor to soffit. It is therefore proposed that the wall be constructed to full height.

As for limiting noise intrusion, ambient noise level of an office could be dependent on noise generating sources typically by long running period equipments; such as the ACMV system.

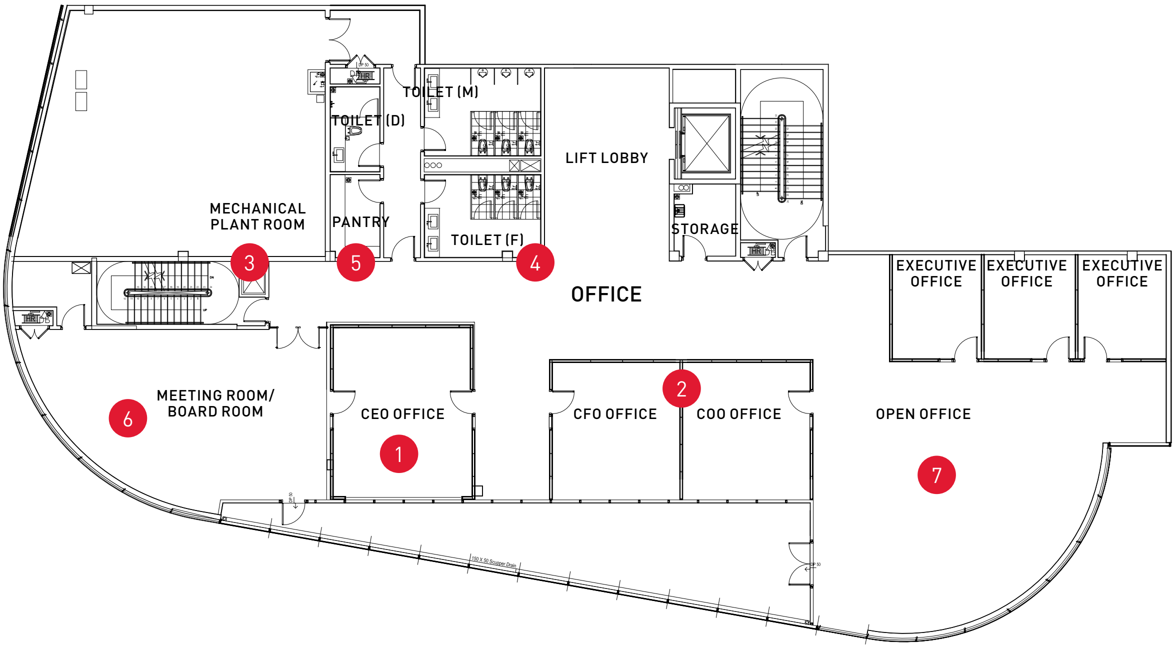
Office in a commercial or office tower is likely be equipped with centralized ACMV system which typically allows noise mitigation to be introduced within the system to ensure resultant noise propagated would not compromise the desired ambient noise level.

Mitigation measures includes selection of quieter air handling unit (AHU), sound isolation box of a Fan Coil Unit, internally lined duct, acoustics silencer, low noise air-grille and others.

On the other hand, smaller offices or home offices that utilises stand-alone system such as ceiling fan, stand fan, split-unit air conditioning unit and air cooler as part of its home cooling. Special selection would then be required to ensure that noise emission does not compromise the desired acoustics environment.

Notwithstanding the ACMV system, the operations of electrical or mechanical products that emit noise and run for long periods of time should also be reviewed when a certain ambient noise rating needs to be achieved.

Diagram 7: Example of a layout of an office



11.3 Meeting Rooms and Workstations

Meeting rooms or board rooms are commonly regarded as critical rooms. This is a place where a company direction, policy, commercial and financial related matters are discussed and decisions are made. Hence contents of any meeting or discussion can be considered as highly confidential and should always be regarded as "only within the four walls ". Apart from its privacy needs, meeting rooms should be a place where speech intelligibility should not be compromised.

Hence acoustics input towards its construction includes providing good sound isolation performance, good interior acoustics and also sound mitigation to control ACMV noise. Equipment used within the meeting room should also be considered in terms of its noise intensity.

With all these measures, a meeting room's ambient noise level could be preserved, would be annoyance free, and able to maintain its role in providing privacy of space for discussions.

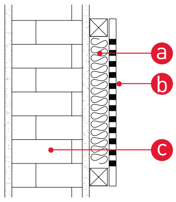
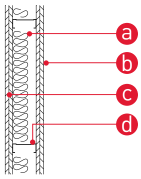
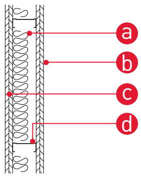
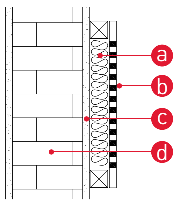
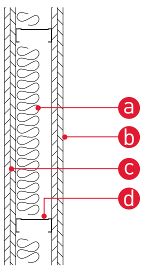
It is common that a meeting room is finished with plaster ceiling, mixture of glass and timber panelling works as interior design input and maybe with carpets as well. To improve the acoustics absorption through noise reverberation control, acoustics panelling of either absorptive or diffusive type can be introduced. This will boost the audibility and speech intelligibility and further enhances the listening experience.

Employees are typically placed in an open office space with individual workstation which commonly does not provide for intensive acoustics environment. In an open office concept, acoustics inputs would be in the form of providing acoustics ceiling panels, carpet, and providing for low noise ACMV system.

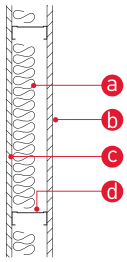
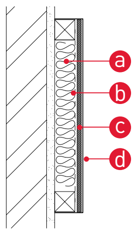
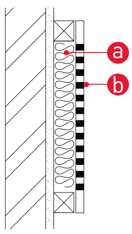
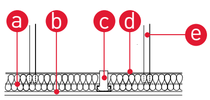
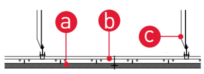
Acoustics ceiling panels are to control sound reverberation and carpets to reduce walking and impact noise from heels. Whereas a controlled ACMV system would also help in not compromising the desired ambient noise level.

The following section proposed construction details and recommendation on ACMV which serves as a guide in order to meet desired ambient noise level as prescribed above.

11.4 Recommended Specifications

Items	Elements	Example and Details		Remarks
1	Building Envelope or Façade		a) 50mm ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimum opening area of 15 - 20% c) 100mm thick brick wall, with 20mm thick plastering on both sides and 8mm thick casement window Curtain glass wall could be in form of double glazed for better sound isolation performance.	Preferred as it could be implemented to most areas while providing reasonable sound isolation performance.
2	Meeting Room Wall/ CEO, COO, CFO Office Wall		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 16 mm thick Plasterboard (min. density 650 kg/cu.m) c) 2 x 16 mm thick Plasterboard (min. density 650 kg/cu.m) d) 92 mm deep stud	Wall to construct to full height
3	Executive Office Wall		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 12 mm thick Plasterboard (min. density 650 kg/cu.m) c) 2 x 12 mm thick Plasterboard (min. density 650 kg/cu.m) d) 75 mm deep stud	Wall to construct to full height
4	Mechanical Plant Room Wall		a) 50mm ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimum opening area of 15 - 20% c) 20 mm thick plastering (both sides) d) 210 mm thick clay brick	Wall to construct to full height All round or all 4 sides ofthe room should be full height Wall choices to suit requirements of building fire codes and other related installation requirements.
5	Toilet Wall		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 15 mm thick moisture resistance plasterboard (min. density 650 kg/cu.m) c) 2 x 15 mm thick moisture resistance plasterboard (min. density 650 kg/cu.m) d) 92 mm deep stud	Wall to construct to full height Wall choices to suit requirements in wet areas by using moisture or water resistant board, and installation to cater for additional loadings from wall tiling and penetrating services. Installation with heavy fixtures to be designed and considered separately.

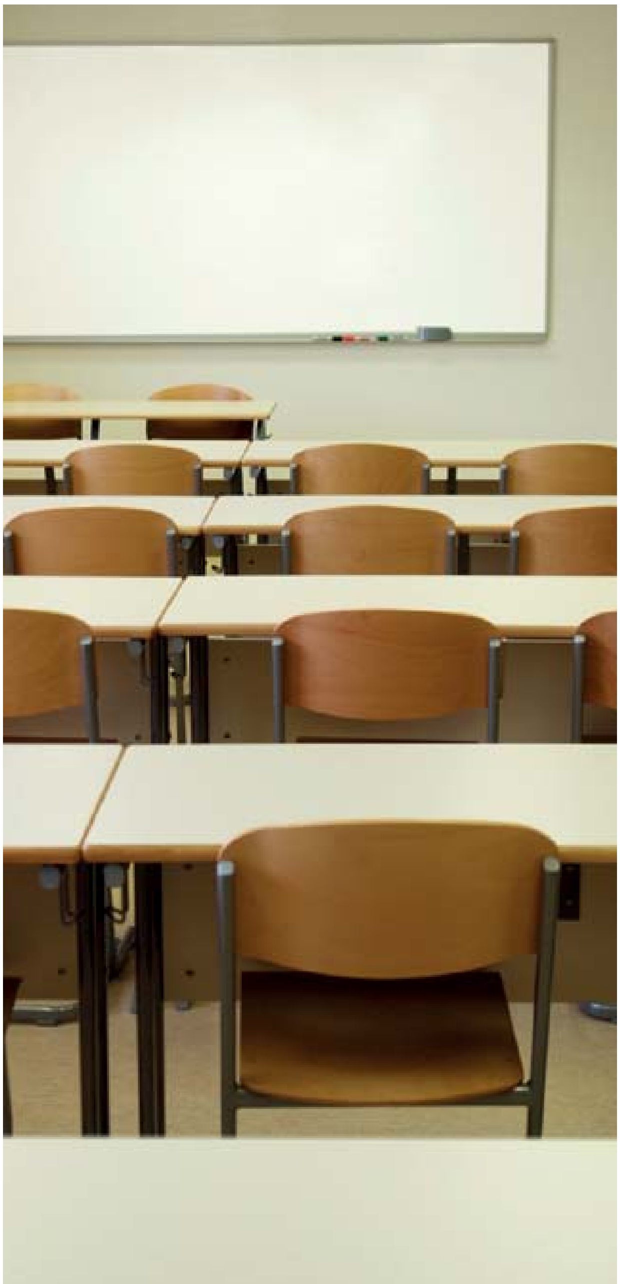
11.4 Recommended Specifications (continued)

Items	Elements	Example and Details		Remarks
6	Pantry Wall		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 12 mm thick Plasterboard (min. density 650 kg/cu.m) c) 12 mm thick Plasterboard (min. density 650 kg/cu.m) d) 75 mm deep stud	Wall to construct to full height Where dry wall is suitable for construction Plasterboard with water resistance treatment preferred
7	Acoustics Wall Panel	Fabric Finish 	a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) Wire mesh to support ROCKWOOL layer c) 5 – 10 mm foam d) Acoustics transparent fabric	NRC 0.6- 0.8 Sound absorption will increase with additional 50 mm air cavity behind insulation layer Typically to treat 60 – 75% of side and rear wall areas
		Perforated Panel Finish 	a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimal opening area of 15 - 20%	NRC 0.6- 0.8 Sound absorption will increase with additional 50 mm air cavity behind insulation layer Typically to treat 60 – 75% of side and rear wall areas
8	Acoustics Ceiling		**Concealed Ceiling System:** a) 50mm ROCKWOOL Safe'n'Silent Pro b) Ceiling panel or perforated panels c) Ceiling clip and lock system d) Furring channels e) Ceiling hanger rod/channel	NRC 0.6- 0.9 Available in various brands and system for selection to suit ID preference Suitable for all office room and open office space
			**T-grid Ceiling System:** a) Rockfon Sonar dB35, thickness 25mm, NRC 0.85, or Rockfon Sonar dB40, thickness 30mm, NRC 0.90, or Rockfon Sonar dB44, thickness 50mm, NRC 0.90 b) Ceiling main runner c) Adjustable hanger and clip	Rockfon comes in range of dimensions in A, E and X edges, with ISO Clean Room Class 3 and 5 classification.

11.4 Recommended Specifications (continued)

Items	Elements	Example and Details		Remarks
*	Door		Solid wood core door with well-designed door frame and ironmongery, STC rating 30-32.	Bottom door seals will improve sound intrusion or sound leakage
*	Carpet			Carpet is proposed for office as it provides good dampening for impact noise especially from shoes and dragging of chairs.
*	Centralized Air Conditioning with delivery ducts	Air Handling Unit/ Fan Coil Unit	To select fan with low noise unit as stated in laboratory testing (by manufacturer's testing)	FCU may require acoustics box up if installed within sensitive room or space
		Ducting	Internal lining of 50 mm thick ROCKWOOL ThermalRock S60 with tissue facing or GI sheets of min. 30% opening areas	
		Silencer	To select by calculation which refer to AHU/FCU noise level, duct size, duct length, duct path, internal lining, diffusers and room/space's acoustics condition. Silencer selection based on ASHRAE recommendation and calculation procedure with consideration of above mentioned parameters.	
		Diffusers	To select diffusers with low regeneration noise; especially for noise sensitive room	Noise will generate when excessive air and/or high velocity air flows through diffusers blades; hence the selection Air speed and volume per diffuser are essential

12.0 Case Study - Educational Institution



Educational institution, a place where teaching and learning takes place; places great emphasis on speech intelligibility and minimal sound disturbance.

This includes government schools, private schools, libraries, colleges and universities.

Acoustics elements are typically introduced to critical rooms/spaces of an institution; especially to improve interior acoustics environment which includes:

- Auditorium / Lecture Theatre / Seminar Room
- Library
- Video Room, Music Room
- Studio (music or recording)

These spaces are usually used to carry out critical or important activities.

12.1 Use of Space and Occupancy

Different room functions require different conducive ambient noise level; but fundamentally it is intended to create an environment with good speech intelligibility and minimal nuisance.

Table 9 recommends conducive ambient noise level and noise criteria for various rooms and spaces of a typical educational centre.

In principle, education centre is a place where teaching and learning takes place and ideas are communicated to the audience or students via aural and visual medium.

Hence a room or space utilized for such activities is expected to have lower ambient noise so as not to compromise speech intelligibility and to maintain concentration of students. However, other types of activity room/space could tolerate higher ambient noise.

Referring to Table 9, in an auditorium where lectures are delivered, ambient noise level is expected to be in the range of 35 to 45 dBA. Auditoriums are often equipped with sound reinforcement system where lectures can be delivered to the audience at 65 to 75 dBA. The difference of average 30 dB would provide good amount of clarity which would not compromise speech intelligibility.

If the ambient noise level is as high as 60 dBA and the speech delivery volume is at 65 to 75 dBA, the 5 to 15 dB difference may contribute to speech being masked occasionally by ambient noise level and the 60 dBA ambient noise level can be deemed to be high and not comfortable for a room requiring high level of concentration.

In order to achieve the recommended ambient noise level, appropriate airborne sound isolation performance for various partying elements, noise control on mechanical equipment and introduction of interior finishes with acoustics enhancement properties/elements would be required where appropriate.

Table 9: Recommended NC/NR rating and Ambient Noise Level for various room/space for an educational centre

Space / Room	Recommended Rating	
	NR / NC	Noise Level
Lecture Theatre / Auditorium	30 – 40	35 – 45 dB(A)
Seminar Room	30 – 40	35 – 45 dB(A)
Quite Zone	30 – 40	35 – 45 dB(A)
Library	35- 45	40 – 50 dB(A)
Tutorial Room / Classroom	35- 45	40 – 50 dB(A)
Computer Room	45 - 50	45 – 55 dB(A)

12.2 Ambient Noise Level Consideration

As discussed in previous section, conducive acoustics environment with reasonable level of ambient noise is essential for a teaching and learning facility.

Airborne sound isolation performance of partying elements for each room/hall/theatre/space hence becomes important to avoid external noise intrusion and/or noise cross over between them.

Additional consideration would need to be taken for an Educational Institution that is situated next to a busy expressway, railway line, transit line, and/or airport. Indoor ambient noise is likely to be affected by traffic noise, train noise and/or air craft noise. Provision of high airborne sound isolation performance should be considered for facade glazing or external wall; apart from setting building orientation and layout, as part of the effort to keep external noise intrusion to a minimal.

Ideally, noise crossover between rooms is to be kept minimal, or at best none at all, in an effort to meet proposed ambient noise level and also to avoid annoyance.

It would be annoying if during a lecture the person could listen to another lecture being conducted in the adjacent lecture theatre. Apart from being a nuisance, the crossover also disrupts the teaching and learning process. Hence under such building layout configurations, additional acoustics considerations, input, design and construction effort would be required.

As for limiting noise intrusion and crossover, ambient noise level of an educational institution could also be dependent on the noise generating sources typically from long running period equipments such as ACMV system.

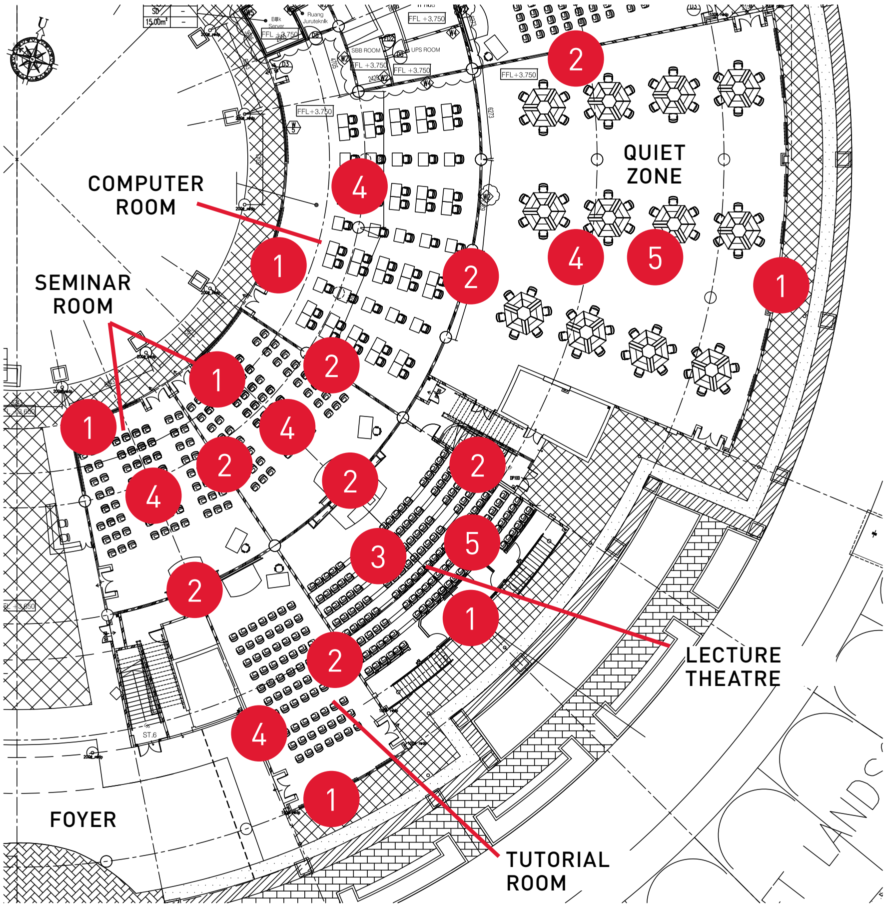
Large rooms, for example auditoriums, lecture theatres and library are likely to be equipped with centralized ACMV system which typically allows noise mitigation to be introduced within the system to ensure resultant noise propagated would not compromise the desired ambient noise level.

Mitigation measures include selection of quieter Air Handling Unit, sound isolation box of a Fan Coil Unit, internally lined duct, acoustics silencer, low noise air-grille and others.

On the other hand, smaller rooms such as class room, tutorial rooms and reading room could be utilising stand-alone system like ceiling fan, stand fan, split-unit air conditioning unit and air cooler for cooling. Special selection would then be required to ensure that noise emission does not compromise the desired acoustics environment.

Not withstanding to the ACMV system, the operations of electrical or mechanical products that emit noise and run for long periods of time should also be reviewed when a certain ambient noise rating needs to be achieved.

Diagram 8: Example layout of part of an educational institution



12.3 Lecture Hall and Auditorium

Lecture Hall or Auditorium typically is large volume room with rake floor design; which could cater to hundreds of audience. Due to its large space and crowd, modern day design also includes sound reinforcement system.

With the presence of high delivery sound level and the large volume which encourages echoes and sound reverberations, interior acoustics treatment then becomes part and parcel of an auditorium design.

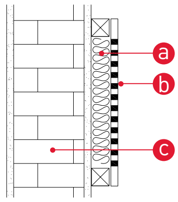
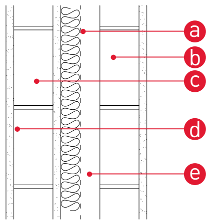
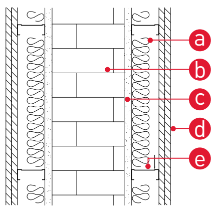
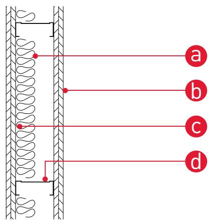
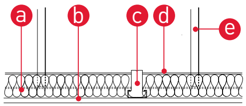
Common finishes includes plaster ceiling, profile ceiling with acoustics treatment, acoustics absorptive and/or diffusive panels; and some even come with carpet.

The elements introduced could be absorptive, diffusive and/or mixed of the two. The common idea is to create a well sound distributed environment and at the same time with minimal sound reverberation, echo and flutter. This will boost the audibility and speech intelligibility which further enhances the experience. Elements such as acoustics absorptive wall panels with fabric and/or perforated timber finish, acoustics absorptive ceiling and carpet are typically seen as part of auditorium design.

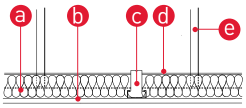
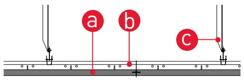
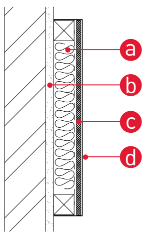
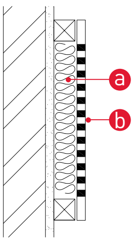
As speech intelligibility is critical in an auditorium and also in order not to disturb adjacent teaching and learning facilities, consideration on improving the sound isolation performance of the perimeter walls and doors would be essential.

The following section proposed construction details and recommendation on ACMV which serves as a guide in order to meet desired ambient noise level as prescribed above.

12.4 Recommended Specifications

Items	Elements	Example and Details		Remarks
1	Building Envelope or Façade		a) 50mm ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimum opening area of 15 - 20% c) 100mm thick brick wall, with 20mm thick plastering on both sides and 8mm thick casement window Curtain glass wall could be in form of double glazed for better sound isolation performance.	Preferred as it could be implemented to most areas while providing reasonable sound isolation performance.
2	Teaching and Learning Room - Lecture Theatre, Seminar Room		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 100 mm thick clay brick (min. density 1500 kg/cu.m) c) 100 mm thick clay brick (min. density 1500 kg/cu.m) d) 20 mm thick plastering (on 3 sides) e) 100 mm deep air cavity	Wall to construct to full height
3	- Lecture Theatre, Seminar Room		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 210 mm thick claybrick (min. density 1500 kg/cu.m) c) 20 mm thick plastering (on 2 sides) d) 2 x 16 mm thick Plasterboard (min. density 750 kg/cu.m) e) 75 mm stud	Wall to construct to full height Suitable for Party Wall between 2 connecting Theatre or Auditorium
4	Other Teaching and Learning Rooms (Tutorial Room, Discussion Room)		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 16 mm thick Plasterboard (min. density 750 kg/cu.m) c) 2 x 16 mm thick Plasterboard (min. density 750 kg/cu.m) d) 92 mm deep stud	Wall to construct to full height For areas which requires frequent change of space design or functions
5	Acoustics Ceiling (Auditorium, Lecture Theatre)		**Concealed Ceiling System:** a) 50mm ROCKWOOL Safe'n'Silent Pro b) Ceiling panel or perforated panels c) Ceiling clip and lock system d) Furring channels e) Ceiling hanger rod/channel	NRC 0.6 - 0.8 Typically for lecture theatre and auditorium could be in form of profiled ceiling with combination of plaster ceiling and specific acoustics tiles

12.4 Recommended Specifications (continued)

Items	Elements	Example and Details		Remarks
6	Acoustics Ceiling Panels (Library, Reading Area, Quiet Zone, Tutorial Room, Seminar Room)		**Concealed Ceiling System:** a) 50mm ROCKWOOL Safe'n'Silent Pro b) Ceiling panel or perforated panels c) Ceiling clip and lock system d) Furring channels e) Ceiling hanger rod/channel	NRC 0.7 - 0.9 Typically in the form of acoustics ceiling tiles to suit ID
			**T-grid Ceiling System:** a) Rockfon Sonar, thickness 20mm, NRC 1.00, or Rockfon Tropic, thickness 15mm, NRC 0.90 b) Ceiling main runner c) Adjustable hanger and clip	Rockfon comes in range of dimensions in A, E and X edges, with ISO Clean Room Class 3 and 5 classification.
7	Acoustics Wall panel (eg. Auditorium, Lecture Theatre, large Seminar Room etc)		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) Wire mesh to support ROCKWOOL layer c) 5 – 10 mm foam d) Acoustics transparent fabric	NRC 0.6- 0.8 Typically introduce to large room/hall with sound reinforcement system and where speech intelligibility is emphasised.Sound absorption will increase with additional 50 mm air cavity behind ROCKWOOL layer. Typically to treat 60 – 75% of side and rear wall areas
		Perforated Panel Finish 	a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) Perforated panel finish with minimal opening area of 15 - 20%	NRC 0.6- 0.8 Typically introduce to large room/hall with sound reinforcement system and where speech intelligibility is emphasised.Sound absorption will increase with additional 50 mm air cavity behind ROCKWOOL layer. Typically to treat 60 – 75% of side and rear wall areas

12.4 Recommended Specifications (continued)

Items	Elements	Example and Details		Remarks
*	Door		Solid wood core door with well-designed door frame and ironmongery, with STC rating 30-32. 2 hours fire rated doors with STC rating 32-35. Acoustic solid wood core door with steel sheet, and with well designed door frame and ironmongery of STC rating 35-38.	Bottom door seals will improve sound intrusion or sound leakage – best introduce to critical rooms such as Lecture Theatre, Auditorium, Seminar Rooms, Meeting Rooms etc.
*	Centralized Air Conditioning with delivery ducts	Air Handling Unit/ Fan Coil Unit	To select fan with low noise unit as stated in laboratory testing (by manufacturer's testing)	FCU may require acoustics box up if installed within sensitive room or space
		Ducting	Internal lining of 50 mm thick ROCKWOOL ThermalRock S60 with tissue facing or GI sheets of min. 30% opening areas	
		Silencer	To select by calculation which refer to AHU/FCU noise level, duct size, duct length, duct path, internal lining, diffusers and room/space's acoustics condition. Silencer selection based on ASHRAE recommendation and calculation procedure with consideration of above mentioned parameters.	
		Diffusers	To select diffusers with low regeneration noise; especially for noise sensitive room	Noise will generate when excessive air and/or high velocity air flows through diffusers blades; hence the selection Air speed and volume per diffuser are essential

13.0 Case Study - Healthcare Centre

Healthcare Centre usually refers to public hospital, private medical centre, specialist and clinics. It is a place where medical treatments are offered and administrated to patients. Apart from seeking medical advice and treatment, it is also a place where patients recuperate from treatment or surgeries.

Due to its modus operandi and function, a healthcare centre, ideally, should have some form of acoustics input in order to create an environment which is conducive for medical consultation, administrating medical treatment, surgeries and recuperation to take place.

It is widely known that chaotic and high ambient noise environment would induce more stress to patients and does not help with the healing and recovery process. Furthermore under such environment, medical consultation which emphasise on speech intelligibility and privacy may be compromised as well.

13.1 Use of Space and Occupancy

Table 10 recommends conducive ambient noise level and noise criteria for various room and space for a typical healthcare centre.

Generally, patient wards are recommended to have low ambient noise in order to provide a conducive and stress free recuperation environment; while low ambient noise is also recommended for consultation room to support need for speech intelligibility.

High concentration rooms and facilities are proposed to have low ambient noise level to minimise distraction - especially for operating theatres or treatment rooms. Distraction may not just be damaging to patients but may also lead to unnecessary emergency. Environments that are free from distraction and stress help healthcare provider to be more efficient.

Supporting facilities which deal with other types of activities can tolerate moderately higher ambient noise level.

In order to achieve the recommended ambient noise level, appropriate airborne sound isolation performance for various partying elements, noise control on mechanical equipment and introduction of interior finishes with acoustics enhancement properties/elements would be required where appropriate.

Table 10: Recommended NC/NR rating and Ambient Noise Level for various room/space for a healthcare centre

Space / Room	Recommended Rating	
	NC	Noise Level
Wards	30 - 35	35 - 40 dB(A)
Consultation Room	35 - 40	40 - 45 dB(A)
Operating Theatre	35 - 40	40 - 45 dB(A)
Delivery Suites	40 - 45	45 - 50 dB(A)
Waiting Area	35 - 45	40 - 50 dB(A)
Lobby, Foyer, Corridor and other circulations	45 - 50	50 - 55 dB(A)

13.2 Ambient Noise Level Consideration

Healthcare centres consider hygiene and bacteria/ virus/allergen free as of utmost importance. Hence, sterilisation is undertaken every now and then, and at the same time healthcare centres do not encourage the use of building elements that could potentially be breeding grounds for such threats.

Therefore, very often, general areas and medical treatment and consultation related areas do not have any form of extra acoustics treatment to it. Typically they are nice and flat surface. This also means healthcare centres are typically more reverberant.

For example a reverberant ward corridor or waiting area does not have acoustic wall panels and are only mainlyusing acoustics rated ceiling panels.

Thus ambient noise level at various part of a healthcare centre could be different depending on the emphasis on providing good sound isolation whether between the external and internal part of the building, wards, consultation rooms, treatment rooms, operating theatres; and other such critical rooms as well as other areas such as corridors, waiting areas, mechanical plant room and so on.

As for limiting noise intrusion and crossover, ambient noise level of a healthcare centre could also be dependent on other noise generating sources typically from long running period equipments; such as the ACMV system.

Well established healthcare centres are likely equipped with centralized ACMV system which typically allows noise mitigation to be introduced within the system to ensure resultant noise propagated would not compromise the desired ambient noise level.

Mitigation measures include selection of quieter Air Handling Unit, sound isolation box of a Fan Coil Unit, internally lined duct, acoustics silencer, low noise air-grille and others.

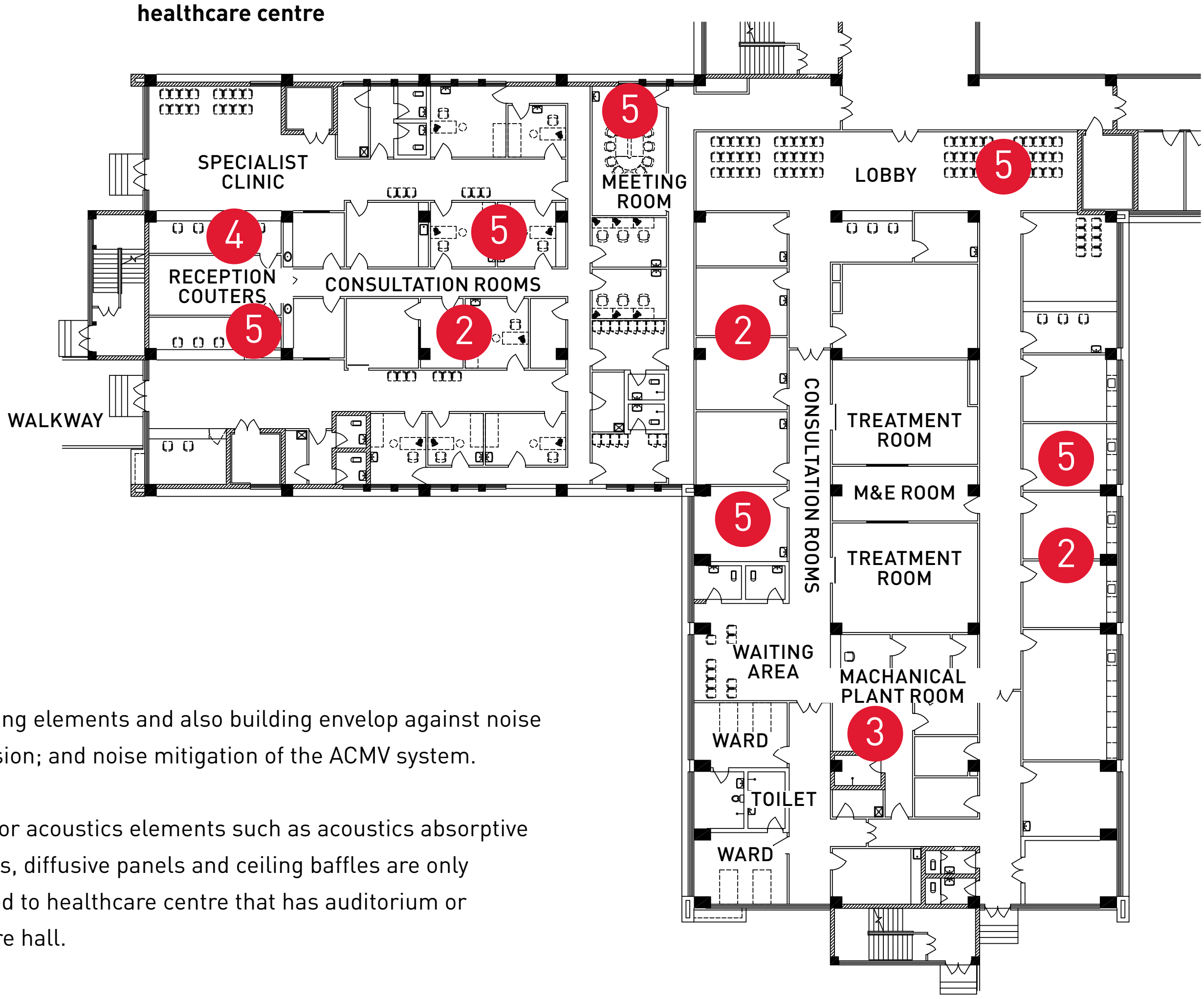
On the other hand, smaller establishments such as specialist clinic, general clinic, physiotherapist, could be utilising stand-alone system like ceiling fan, stand fan, split-unit air conditioning unit and air cooler for cooling. Selection on quieter units would then be required to ensure that noise emission does not compromise the desired acoustics environment.

Not withstanding the ACMV system, the operations of electrical, mechanical and also medical equipment that emit noise and run for long periods of time should also be reviewed when a certain ambient noise rating needs to be achieved.

13.3 Patient Wards and Common Areas

As discussed in previous section, acoustics provision and consideration for a healthcare centre is typically limited to providing good sound insulation performance for internal

Diagram 9: Example layout of part of a healthcare centre



partying elements and also building envelop against noise intrusion; and noise mitigation of the ACMV system.

Interior acoustics elements such as acoustics absorptive panels, diffusive panels and ceiling baffles are only limited to healthcare centre that has auditorium or lecture hall.

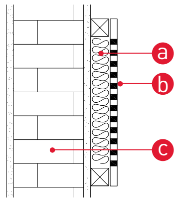
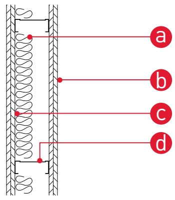
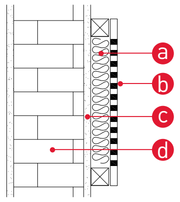
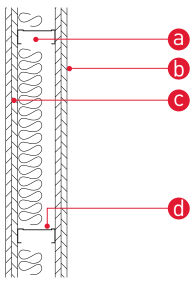
Internal partitioning of a healthcare centre space is important as to provide speech privacy, minimise sound leakage, minimise sound intrusion and ensuring certain ambient noise level could be achieved.

Rooms such as patient wards, consultation rooms, operating theatres, surgical rooms, treatment rooms, and critical facilities are recommended to have partitioning elements with higher sound isolation rating. However, other general and less critical facilities could adopt a more common construction.

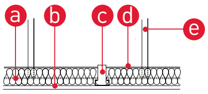
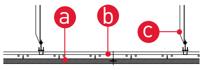
Due to the absence of acoustics absorption elements at most area of a healthcare centre, introduction of noise mitigation on mechanical, electrical, ACMV and medical equipment which generates high noise level becomes important. Residual noise energy could not be further absorbed and sound tends to have longer decay time resulting in rooms and spaces being perceived to be more reverberant.

The following section proposed construction details and recommendation on ACMV which serves as a guide in order to meet the desired ambient noise level as prescribed above.

13.4 Recommended Specifications

Items	Elements	Example and Details		Remarks
1	Building Envelope or Façade		a) 50mm ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimum opening area of 15 - 20% c) 100mm thick brick wall, with 20mm thick plastering on both sides and 8mm thick casement window Curtain glass wall could be in form of double glazed for better sound isolation performance.	Preferred as it could be implemented in most areas while providing reasonable sound isolation performance. Common construction.
2	Consultation Rooms/ Wards		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 16 mm thick Plasterboard (min. density 750 kg/cu.m) c) 2 x 16 mm thick Plasterboard (min. density 750 kg/cu.m) d) 92 mm deep stud	Wall to construct to full height For areas which require frequent change of space design or functions
3	Mechanical Plant Room Wall	Perforated Panel Finish 	a) 50mm ROCKWOOL Safe'n'Silent Pro b) Perforated panel with minimum opening area of 15 - 20% c) 20 mm thick plastering (both sides) d) 210 mm thick clay brick	Wall to construct to full height All round or all 4 sides of the room should be full height Wall choices to suit requirements of building fire codes and other related installation requirements.
4	Toilet Wall		a) 50 mm thick ROCKWOOL Safe'n'Silent Pro b) 2 x 15 mm thick moisture resistance plasterboard (min. density 650 kg/cu.m) c) 2 x 15 mm thick moisture resistance plasterboard (min. density 650 kg/cu.m) d) 92 mm deep stud	Wall to construct to full height Wall choices to suit requirements in wet area and other related installation requirements such as wall tiling and penetrating services

13.4 Recommended Specifications (continued)

Items	Elements	Example and Details		Remarks
5	Acoustics Ceiling		**Concealed Ceiling System:** a) 50mm ROCKWOOL Safe'n'Silent Pro b) Ceiling panel or perforated panels c) Ceiling clip and lock system d) Furring channels e) Ceiling hanger rod/channel	NRC 0.6 - 0.9 Foyer, Corridor, Waiting Areas, Wards Consultation Rooms, Meeting & Discussion Rooms, Office, Receptions, Nurse Stations
			**T-grid Ceiling System:** a) Rockfon Medicare Standard, thickness 12mm or 15mm, NRC 0.90, or Rockfon Medicare Plus, thickness 20mm or 22mm, NRC 0.95, or Rockfon Medicare Air, thickness 25mm, NRC 0.90 b) Ceiling main runner c) Adjustable hanger and clip	Rockfon comes in range of dimensions in A, E and X edges, with ISO Clean Room Class 3 and 5 classification.
6	Door		Solid wood core door with well-designed door frame and ironmongery 2 hours fire rated doors	Bottom door seals will improve sound intrusion or sound leakage – best introduce to critical rooms For Operation Theatre and critical facilities
7	Centralized Air Conditioning with delivery ducts	Air Handling Unit/ Fan Coil Unit	To select fan with low noise unit as stated in laboratory testing (by manufacturer's testing)	FCU may require acoustics box up if installed within sensitive room or space
		Ducting	Internal lining of 50 mm thick ROCKWOOL ThermalRock Slab with tissue facing or GI sheets of min. 30% opening areas	
		Silencer	To select by calculation which refers to AHU/FCU noise level, duct size, duct length, duct path, internal lining, diffusers and room/space's acoustics condition. Silencer selection based on ASHRAE recommendation and calculation procedure with consideration of above mentioned parameters.	
		Diffusers	To select diffusers with low regeneration noise; especially for noise sensitive room	Noise will generate be when excessive air and/or high velocity air flows through diffusers blades; hence the selection Air speed and volume per diffuser are essential

14.0 ROCKWOOL Safe'n'Silent

ROCKWOOL Safe'n'Silent is developed to form the mass-spring-mass assembly of building elements that provides superior performance in building and room acoustics. By applying the suitable specifications of Safe'n'Silent Pro coupled with building systems, the ambient noise level can be reduced according to recommendations hence giving better indoor acoustic comfort.

The usage and application of Safe'n'Silent Pro is very wide, ranging from drywall partitions and acoustic ceiling in residential houses to workplaces such as offices, as well as wall lining application specially for areas with concerns on reverberant noise. Its application provide a quieter environment by eliminating intrusion sound and background noise that causes nuisance and discomfort to the occupants in a particular interior space, thereby contributing to a better Noise Criteria (NC) rating. The ultimate aim is to give occupants better concentration in places of study or work, better speech intelligibility, comfort in hearing and comprehending conversations.

The Safe'n'Silent solutions in this manual are provided as recommendations to building designers, architects, interior designers, consultants, engineers and property owners; providing possible measures to achieve an optimal indoor acoustic comfort for various environments. The manual does not limit itself to the listed recommendations, other design assemblies and construction details that are not listed may be acceptable through the recommendations of ROCKWOOL representatives or acoustic professionals before actual installation is being carried out. For further information, kindly contact your local ROCKWOOL representatives for assistance.

With the unique and natural properties of ROCKWOOL Safe'n'Silent Pro, the product is safe and sustainable to use and no CFCs, HFCs, HCFCs or asbestos were used in its manufacture. It can be easily cut to size for a fast and simple installation between studs, around electrical boxes, pipes, wiring, ductwork and even in drywall partitions between studs and joists of non-standard widths.

Safe'n'Silent Pro does not slump or sag when used in the wall cavity, assuring there will be no gaps that may compromise the performance of the system and providing lifetime protection against noise and fire.
The technical parameters and performance of Safe'n'Silent Pro are given in Table 12.

Table 12: Technical Parameters of Safe'n'Silent Pro

Product Name	Safe'n'Silent Pro330	Safe'n'Silent Pro350	Safe'n'Silent Pro370	Standards
Noise Absorption Co-efficient at 50mm (NRC)	0.90	1.00	1.00	EN ISO 354 / ASTM C 423-01
Fire Performance	Non-combustible / A1 Fire Classification	Non-combustible / A1 Fire Classification	Non-combustible / A1 Fire Classification	EN13501-1
Melting Point	More than 1000°C	More than 1000°C	More than 1000°C	ASTM E794
*Thermal Conductivity 20°C λ Value (W/mK)	0.036	0.035	0.034	ASTM C518
R-value at 50mm thickness (m^2K/W)	1.389	1.429	1.471	
Water Absorption (partial immersion)	1.0kg/m^2	0.5kg/m^2	0.5kg/m^2	EN1609.97
Water Vapor Absorption	Less than 0.04 Vol %	Less than 0.04 Vol %	Less than 0.04 Vol %	ASTM C1104/C1104M
Thickness	50, 64, 75, 90mm	50, 64, 75, 90mm	50, 64, 75, 90mm	EN 822
Applications	Recommended for commercial applications such as retail and office partition walls	Recommended for all drywall partition applications	Recommended for fire-rated partition system	

** Thermal conductivity values are based on testing conducted in external accredited laboratory in accordance to ASTM C518 : 1991. Test reports are available upon request. For design, it is recommended to use a safety factor of 20% as design value.*

Notes

Notes

ROCKWOOL IN ASIA

FACTORIES:

ROXUL-ROCKWOOL INSULATION INDIA PVT. LTD.
Plot-Z/4, Dahej SEZ, Dahej
District Bharuch-392 130
Gujarat-India
T (+91) 2641 619400
F (+91) 2641 256292

ROCKWOOL MALAYSIA SDN BHD
Lot 4, Solok Waja 1
Bukit Raja Industrial Estate
41050 Klang, Selangor, Malaysia
T (+60) 3 3341 3444
F (+60) 3 3342 7290

175 A&B,
Kawasan Perindustrian Air Keroh
Jalan Lingkungan Usaha
75450 Melaka, Malaysia
T (+60) 6 233 2010
F (+60) 6 233 2012

ROCKWOOL (THAILAND) LIMITED
Hemaraj Eastern Industrial Estate
(Map Ta Phut) 1 Soi G 2
Pakornsongkrohraj Road
Huaypong, Muang, Rayong 21150, Thailand
T (+66) 3868 5110
F (+66) 3868 4938

OFFICES:

ROXUL ROCKWOOL TECHNICAL INSULATION INDIA PVT. LTD.
705, Center Point, J.B.Nagar
Andheri-Kurla Road
Andheri (East), Mumbai-400 059 India
T (+91) 22 6715 7700
F (+91) 22 6715 7710

Office No-238, Regus Business Center
2nd Floor, Prestige Omega
No. 104 EPIP Zone, Whitefield
Bangalore - 560066 Karnataka

240, Elegance Tower, 2nd Floor
Regus Business Center
Jasola Delhi - 110025

ROCKWOOL MALAYSIA SDN BHD INDONESIA REPRESENTATIVE OFFICE
Wisma Pondok Indah Tower 3,
17th Floor, Jl. Sultan Iskandar Muda V
Jakarta 12310 Indonesia
T (+62) 21 2965 9071
F (+62) 21 2953 8998

ROCKWOOL BUILDING MATERIALS (SINGAPORE) PTE. LTD.
No. 8, Tuas Avenue 2, Jurong Town
Singapore 639448
T (+65) 6861 4722
F (+65) 6862 3533

3 International Business Park
Unit No. #02-24
Nordic European Centre
Singapore 609927
T (+65) 6933 7110
F (+65) 6933 7124 / 6933 7129

ROCKWOOL (THAILAND) LIMITED
B.GRIMM Building 11th Floor
88 Krungthepkreetha Road
Huamark, Bangkapi
Bangkok 10240 Thailand
T (+66) 2731 7511–14
F (+66) 2731 7510

VIETNAM REPRESENTATIVE OFFICE
9th Floor, Maritime Bank Tower
180-192 Nguyen Cong Tru Street, District 1
Ho Chi Minh City, Vietnam
T (+84) 8 6288 2009
F (+84) 8 6288 4691

13th Floor, Hanoi Tower
49 Hai Ba Trung Street
Hoan Kiem District
Hanoi Vietnam
T (+84) 4 3934 3958
F (+84) 4 3934 3966

710 401-07/15_V1 (EN)

Disclaimer: ROCKWOOL Asia provides the information in this document with the considerations for the most accurate information available with regards to ambient noise control using ROCKWOOL Safe'n'Silent Pro in various system assemblies. The installation of systems, use of space and occupancy within a space are subjected to changes that may influence the final outcome of the noise control. Therefore ROCKWOOL Asia shall not hold liability in the event of differences in actual application. ROCKWOOL Asia shall provide no warranty on any of the performances of the recommendations stated in this manual.

ROCKWOOL®
FIRESAFE INSULATION

SAFE'n'SILENT

www.rockwoolasia.com