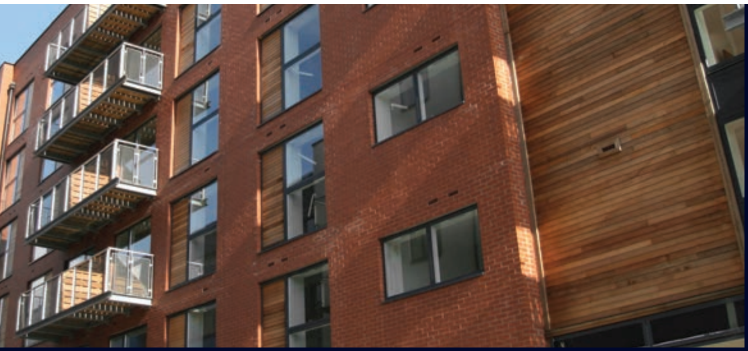
AcoustiTECH

PERFORMANCE CREDIBILITY EXPERTISE



Demystify the acoustics of the building

“ Soundproofing is becoming a major concern. Before buying a housing unit, consumers are more than ever asking about the acoustical performance. “

Yves Joli-Cœur,
Distinguished lawyer and general secretary
of the Quebec condo-boards association.

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DEMYSTIFY THE ACOUSTICS OF THE BUILDING

FINITEC CANADA's team is proud to present this document developed especially to answer the needs of the different players in the field of new construction and renovation of condominiums, such as architects, developers, contractors and condo board associations. This document reflects the expertise and credibility that we have in the acoustics of buildings.

We hope this tool will enhance your understanding of the acoustics of buildings. It was developed to accompany you in the completion of your projects, help you make better decisions and choose materials that can provide all the occupants of your building with peace of mind and increased acoustic comfort.

Do not hesitate to contact us. We will be pleased to collaborate with you and guide you in the success of your projects !

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1. GENERAL PRINCIPLES OF ACOUSTICS

A. Definition of architectural acoustics

Architectural acoustics is the scientific and technological field that seeks understanding and control of sound quality of buildings such as :

- Concert halls (arrived late 1800s and early 1900s)
- Theaters
- Recording studios
- Movie theatres
- Buildings (office buildings, hotels, apartments and condos)

This sphere of competence is more and more related to multi-story homes because the quality of acoustics could have important implications in terms of quality of life and well-being.

Picture 1. Ancient Roman theater.

Picture 2. The Boston *Symphony Hall*, widely considered to be one of the best concert hall in the world for the quality of its acoustics.

Picture 3. Evolo project, highrise condominium, Montreal, Qc, Canada.

Picture 4. Ritz-Carlton Hotel, Montreal, Qc, Canada.

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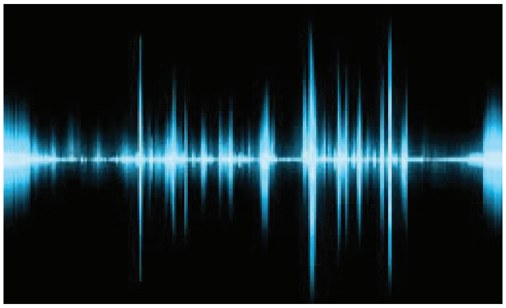
B. What is a sound wave?

Sound waves are longitudinal mechanical waves that occur when the vibration of a body propagates in a surrounding space. Indeed, the sounds we hear are generally produced by the vibrations of the air which affect the eardrum and cause it in turn to vibrate.



Picture 5. Example of a sound wave propagation.

C. What is the difference between noise and sound?

A sound is a physical phenomenon of vibration in a surrounding space, perceptible, depending on the strength and frequency, by the entire body and especially by the sense of hearing. A sound is usually described as harmonious, soft and pleasant. (i.e.: soft music)

A noise is a complex sound produced by various vibrations, often diffused and not harmonic. A noise is usually disturbing and unpleasant, whether the amplitude is high or low. (i.e.: noise from a mechanical system, impact noises, loud music, etc.)

D. How to measure the acoustics

The **sonometer** measures the intensity (Sound Pressure Level) of a sound perceptible by the human ear by expressing it in decibels (dB). The decibel is not a precise intensity measure because it is determined depending on how human beings react to the sound. The intensity gap hearing by a human being varies from 0 dB to 150 dB and more, depending on the person's hearing acuity. The instrument's precision is about 0,1 dB and whereas the human ear is less than 3 dB.

Picture 6. Sonometer brand Brüel and Kjaer.

E. Sum of decibels

The sum of decibels is not caculated by mathematics but rather by a logarithmic progression. Two different sound sources of 70 dB each will not give a final sound result of 140 dB but 73 dB. Indeed, two equivalent sound sources which occur at the same time will only add 3 dB to the sound level. To double the sound level sensation, adding 10 dB would be necessary.

Sum of two different sound sources	
Difference between the two sound sources	Adding to the highest value
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10 or + dB	0 dB

Table 1.
Example 1: If we add 50 dB + 50 dB, the difference between the 2 sound sources is 0, so we add 3 dB to the highest value and the result will be 53 dB.
Example 2: If we add 50 dB + 60 dB, the difference between the 2 sound sources is 10, so we add 0 dB to the highest value and the result will be 60 dB. The loudest sound completely hides the lowest.

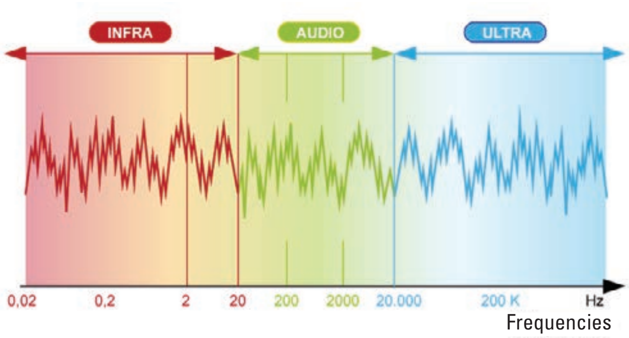
Increasing sound level vs. changing in auditory perception	
Increasing sound level	Auditory perception
1 to 2 dB	Not perceptible
+ 3 dB	Barely perceptible
+ 5 dB	Audible difference
+ 10 dB	Sensation is doubled
+ 20 dB	Sensation is quadrupled

Table 2.

F. Audible frequencies

The sound intensity is not the only thing that can vary as the sound itself can also have different tones and therefore be more or less bass. The tone depends on the **frequency** of the sound wave. The measuring unit used for the frequency is the Hertz (Hz). A bass sound has a low frequency while high frequencies characterize the treble sound.

A human being can hear sounds of frequencies from approximately 20 Hz to 20 000 Hz. An **infrasound** is a sound wave with a frequency lower than 20 Hz and an **ultrasound** is a sound wave with a frequency higher than 20 000 Hz. Even if those sounds are not perceptible by the human ear, many animals use it as a means of communication. This explains why we can call dogs by using ultrasonic whistles that only some animals can perceive. The range of perceptible sounds varies for every animal species.



Picture 7. Sound frequency spectrum.

G. The human ear auditory perception

The human **auditory acuity** is a bandwidth of frequencies perceptible by the human ear and the threshold perceptibility. The range of sound perception varies according to the person's age, heredity and the ear abuse of intense suscitations, which makes the ear more sensitive to sound. The hearing threshold of the human ear is 0 dB and the threshold of pain around 120 dB.

Sound level vs. change in auditory perception, depending on the type of noise		
dB	Type of noise	Auditory perception
140	Airplane takeoff (50 ft)	Painful
130	Clap of thunder	
120	Gunshot	
110	Rock concert	Unbearable
100	Nightclub	
90 80	Lawnmower Mechanical room	Uncomfortable
70 60 50 40	Car traffic Busy office Normal conversation Radio on low volume	Noisy
30 20 10 0	Whispering Perception threshold Insect Threshold of hearing	Low

Table 3.

H. Acoustic comfort

To determine the acoustic comfort level, the popular idea is to impose a maximum noise level, that is to say, a decibel threshold not to exceed. On the other hand, the human ear sensitivity varies according to the frequency. Two sound sources of 60 dB can give completely different perceptions (i.e.: 60 dB at 1 000 Hz is more irritating than 60 dB at 250 Hz). At same sound level, one will be unbearable and the other one quite tolerable. It will depend on the dominant frequencies that have passed through the inner wall of the room.

2. TYPES OF NOISE

A. The impact noise (often viewed as "impact sound")

Caused by a shock or a vibration: foot steps, moving furniture, falling objects, etc. The impact noise, also known as the structure-borne noise or shock noise, is transmitted by the vibration of the structure, walls and floors of the building. We need to understand that impact noises that are transmitted directly through the wall inevitably become airborne noises.

B. The airborne noise (often viewed as "airborne sound")

The vibrations that come from radio, voices, televisions, sound systems, etc. These sounds are transmitted by the structures (floors or walls) or through openings in the room's inner wall and the outside shell of the building.

Although there are some similarities between the factors for attenuating airborne noises and those that mitigate the impact noise, these are far more complex to measure, classify and reduce.

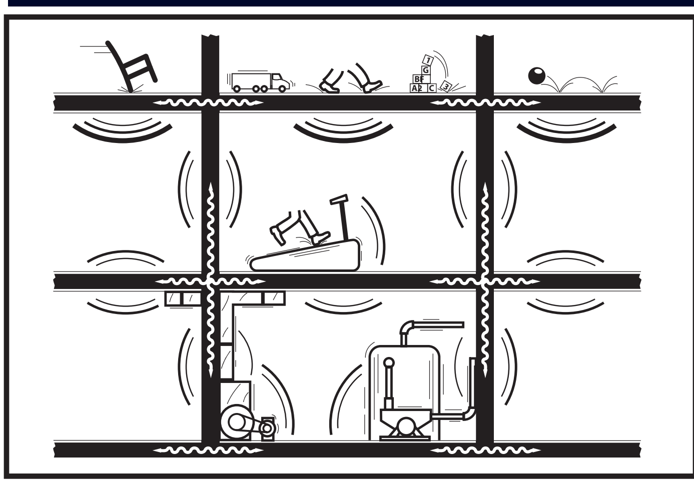
3. QUANTIFY THE ACOUSTICS

A. IIC and FIIC: Measurement of impact noise insulation in a building

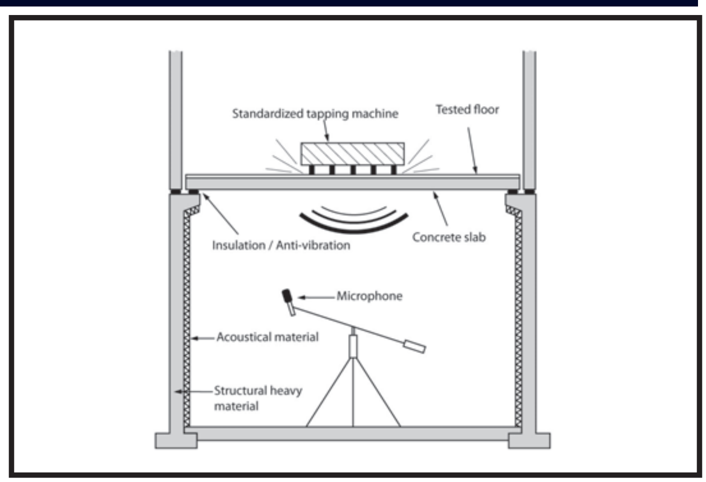
The IIC is the measurement index used to compare the acoustical values of an assembly in a building (floors or walls). The IIC (*Impact Insulation Class*) is the **transmission coefficient of impact noise**. The IIC is an absolute value obtained by standardized acoustical testing.

In the industry, these values are presented in two forms: either by IIC or FIIC. They refer to the same extent, except that the IIC indicates that the tests were conducted in the laboratory whereas the FIIC, the addition of the letter "*F*" indicates the tests were conducted in the field (in the building).

Impact noise movement (IIC - Impact Insulation Class)



Picture 8. In a building (FIIC). The FIIC factor depends largely on the materials used during the building construction.



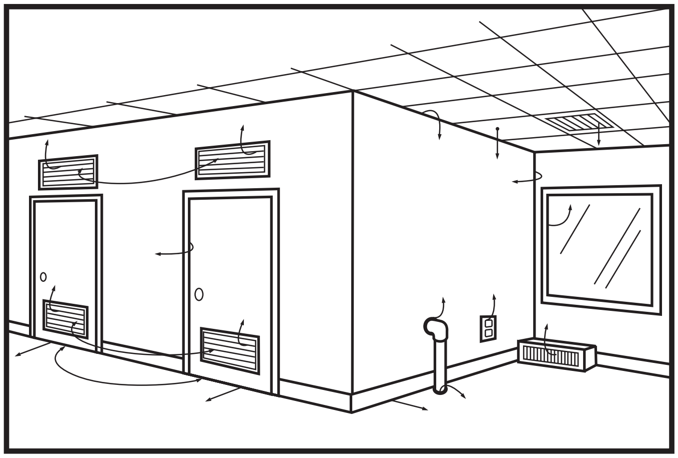
Picture 9. In a laboratory (IIC). Tests conducted in a laboratory tend to give more accurate values due to the quality of assemblies and overall environmental conditions.

B. STC and FSTC: Measurement of airborne noise insulation in a building

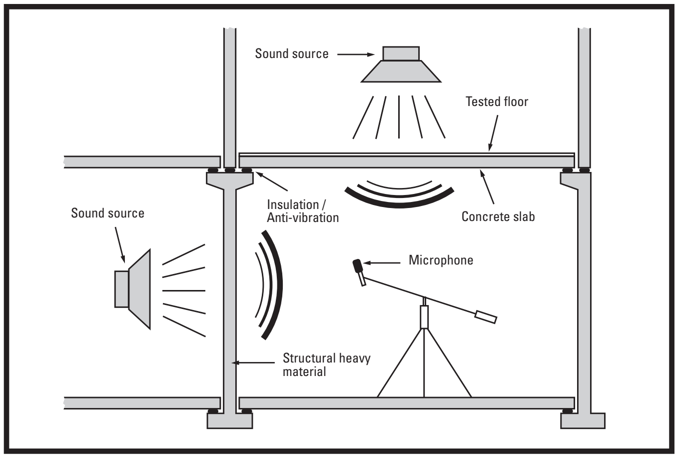
The STC is the index of measurement used to compare the acoustical values of an assembly in a building (floors or walls). The STC (*Sound Transmission Class*) is the **index of sound transmission**. The STC is an absolute value obtained by standardized acoustical testing.

In the industry, these values are presented in two forms: either by STC or FSTC. They refer to the same extent, except that the STC indicates that the tests were conducted in the laboratory whereas the FSTC, the addition of the letter "*F*" indicates the tests were conducted in the field (in the building).

Airborne noise movement (STC - Sound Transmission Class)



Picture 10. In a building (FSTC). The FSTC factor depends largely on the materials used during the building construction.



Picture 11. In a laboratory (STC). Tests conducted in a laboratory tend to give more accurate values due to the quality of assemblies and environmental conditions.

C. What is ASTM?

ASTM International, previously known as *American Society for Testing and Materials* (ASTM), is a globally recognized leader in the development and delivery of international voluntary concensus standards. Today, some 12 000 ASTM standards are used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence. The ASTM standards are elaborated following a process that includes technical barriers to the principles of the trade agreement of the World Trade Organization (WTO). The development process of ASTM standards is open and transparent, allowing individuals and governments to participate directly and equally to a global consensus decision.

D. How acoustical tests are conducted

Acoustical testing is conducted using methods recognized by the ASTM. They should take into account ambient noises and reverberation index, previously measured, specific to the time and place where the tests were performed.

FIIC TEST

The FIIC test is conducted with an automated device called a hammering standard tapping machine. This device is calibrated to provide the same ground impact and to reproduce sounds at the same frequency, regardless of its manufacturer. It is also necessary to have a sonometer to capture sounds. This device also needs to be calibrated to obtain results comparable to the standards. This involves using the tapping machine on the floor of the source room to create a sound and in turn collecting the sound that has crossed the inner wall in the receiving room. The collected data is then compiled according to the acoustical principles developed by the ASTM standards.

FSTC TEST

The FSTC test is conducted using a sound source, an amplifier and a frequency generator. This test will cover the full range of frequencies in the third octave which is necessary for acoustical analysis. As for the FIIC test, it is necessary to have a well calibrated sonometer to capture sounds. The test is conducted by generating a specific sound (pink or white noise*) in the source room and collecting data. The test is repeated using the same sound, but this time through the inner wall between the source room and the receiving room. The data collected during these two readings will be compiled and compared according to ASTM standards. The differences between data will indicate the amount of sound that has passed through the inner wall of the room.

*A pink noise is a standardized noise that get an acoustical energy distributed uniformly in frequencies 125, 250, 500, 1000, 2000 and 4000 Hz. A white noise is an embodiment of a random process wherein the power spectral density is the same for all frequencies.

The data analysis gives the final results, expressed in dB, for example FIIC 58 dB. This result indicates the amount of sound that the complete ceiling / floor structure (with the acoustical membrane, if appropriate) mitigated. Thus, a higher score means a higher acoustical performance.

Although acoustics are a precise science, the acoustical performance of a building is difficult to predict. Various floor / ceiling structures vibrate at different frequencies. Changes in the density of materials used may occur, quality of contact between these and the order in which they are placed may change. These factors can certainly change the results.

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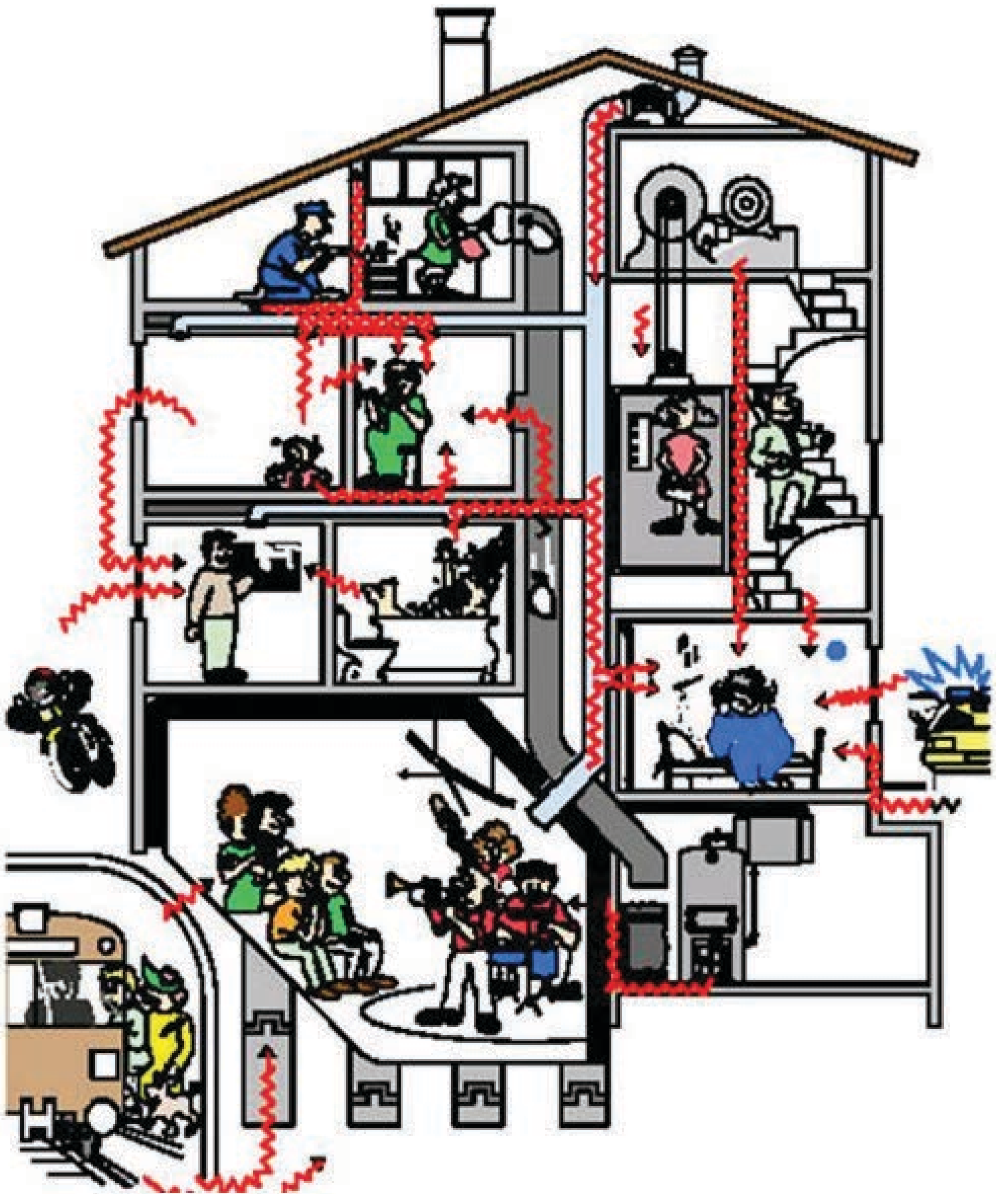
4. THE BUILDING STRUCTURE AND ITS ROLE IN THE TRANSMISSION OF IMPACT NOISES AND AIRBORNE NOISES

A. The movement of sound

As previously mentioned, noises are sound vibrations that can move through materials or be transported in the air. Speed of sound and the ease at which it will spread will vary with the type of structural assembly and the density of materials that composes it.

Because the sound moves easily through the air, all openings, ducts, spacing between the structure itself and non-sealed mechanical parts of the building will allow sound to pass through.



Picture 12. The movement of sound in a building (picture provided by Brüel & Kjaer).

B. Four factors that influence the acoustics of the building

- **Material density**

The density of the materials influence the sound transmission speed. The more dense the material (hard and compact), the further and faster sound travels. The influence of steel for example, the higher the vibration frequency of these materials will be and will more easily carry sound. On the other hand, the more porous the material, like wood for example, the less the vibration which slows the transmission of sound. These porous materials have, to some degree, the ability to absorb vibrations and sounds.

- **The mass**

The mass of the building structure influences sound absorption. The heavier, thicker and bigger the materials are, like concrete for example, the less they will vibrate and the more they will block sounds and provide inertia to the building. The mass plays an important role in acoustics, which is alternating “ mass-spring-mass “. Such configurations allow both absorption and vibration resilience. The acoustical membrane acts as a spring between two masses.

- **Cavities and hard surfaces**

Unprotected cavities of the building structure amplify sound transmission. Moreover, smooth and hard surfaces reflect these sounds. These factors would act as a sounding board or an amplifier.

- **The uncoupling**

Direct contact between rigid materials of the structure or floors causes transfer, transportation and even amplification of sounds, as appropriate, mechanical and acoustical vibrations. Making sure that high-density materials that compose the building are dissociated from each other by resilient materials, drastically reduces the movement of vibrations.

C. Flanking

Flanking is the lateral transmission of sound in the receiving room by the vibration of construction materials which constitute the supporting elements of the floor (load bearing walls). Ideally, the load bearing walls should not be in contact with the floor they support. Most of the time, inner surfaces of load bearing walls act as a sounding board.

D. The building structure vs. the performance

There are different types of building structures such as concrete (generally 8 in or 9 in thick), timber frame structure (with or without a concrete slab), hambro system, CLT «*Crossed Laminated Timber*», etc. Each of these structures yield acoustical performance which are different from each other, consequently it goes without saying that the acoustical performance of the building will also be different from one structure to another.

> «Acoustical performance can also vary for a similar structure. The impact sound insulation that provides a concrete slab of 200 mm (8 in) thick varies significantly from one building to another. Indeed, the impact sound insulation class measured on 35 concrete slabs from 200 to 250 mm (8 to 10 in) thick vary from FIIC 24 to FIIC 39 with an average result of FIIC 33.»
>
> Reference:
> This is from a recent article of Mr Michel Morin, MJM Acoustics Advisors, published in the Journal of the Canadian Association of Acoustics (Volume 37 - Numero 2, P.21 to 24).

No matter what acoustical solutions are used there are always some variations in the results from one building to another.

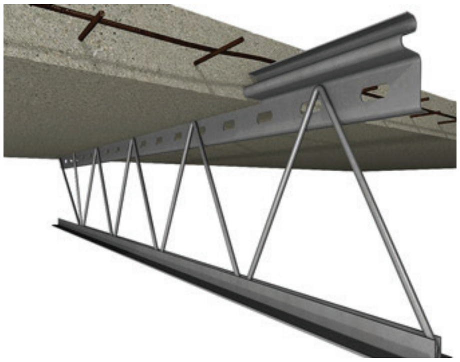
Despite the adding of acoustical materials, a building with a timber frame structure could rarely compete in FIIC and FSTC with a building made of concrete. Concrete inner walls incorporated into those structural assemblies provide a better performance against the transmission of airborne sound.

Not only the type of material and method of construction chosen influence the acoustical results, but also the quality of the construction itself, in its every details, plays an important role in obtaining superior results.

Picture 13. Example of a building with a **concrete** structure.

Picture 14. Example of a building with a **timber frame** structure.

Picture 15. Example of a building with a **Crossed Laminated Timber (CLT)** structure. *The University of British Columbia Earth Sciences Building.* Architects: Perkins+Will Canada Architects Co. Picture by K. K. Law.



Picture 16. Example of a building with a **Hambro** structure. Illustration from www.canam-construction.com

E. Velocity of sound propagation in materials

The velocity of a sound wave in a material, called speed velocity (c), is determined by the magnitude of the forces that bind the molecules together.

Velocity of vibration waves propagation of a material

Material	Speed (m/second)
Steel	5000
Concrete	3000
Wood	1500
Cork	1200
Water	1000
Rubber	350
Air	340
Carpet or equivalent	150 and less

Table 4.

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5. ACOUSTICAL STANDARDS

A. What are the standards of the National Building Code (NBC)?

The National Building Code (NBC) sets out technical provisions prepared by the Canadian National Research Council (CNRC) to describe the construction minimum standards in Quebec. The NBC describes the types of materials, their specifications and minimum performances they must reach when used in construction.

In the case of acoustics, for a floor / ceiling assembly in multi-family buildings of more than one floor or in co-ownership, the NBC requires 50 for the FSTC as the minimum acoustical performance. On the other side, for impact noises, the NBC recommends a FIIC of 55, but does not require it.

B. What are your requirements in acoustics?

Despite the fact that there are no requirements in the NBC about mitigation of impact noises, a certain level is necessary for the occupants comfort and satisfaction. Although it is impossible to completely soundproof a condominium unit, it is possible to procure a certain acoustical comfort that allows the occupants to live comfortably without the apprehension of disturbing neighbors or being bothered by them.

Co-ownership associations requirements

In acoustics, carpet will always remain a superior material. An engineered wood floor installed over an acoustical membrane does not provide an equivalent acoustical performance to a carpet. However, carpet is becoming a less popular compared to hardwood, so it is important to identify acoustical solutions specific to each building in order to provide an optimum acoustical performance for the condominium occupants.

Occupants expectations and values projected by developers

The NBC acoustics recommendation of FIIC 55, now seen as a standard in the construction industry, was not determined based on the satisfaction of condominimum occupants. In a building offering an impact insulation class between FIIC 55 and FIIC 60, foot steps and other sounds like moving furniture, could be heard in the lower unit.

People’s tolerance to the noise transmitted to their condominium unit may vary depending on many factors independent of the building such as the level and frequency of sound, the hearing acuity of the occupants, their lifestyle and their relationships between neighbors.

Expectation and satisfaction level of condominium unit owners compared to the acoustical performances of their building therefore vary. These expectations are, obviously, greatly influenced by the information given at time of sale. This information needs to be fair, honest and realistic. A good acoustical performance is certainly a serious sales argument.

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6. PUBLISHED ACOUSTICAL VALUES

A. What is not said

Unfortunately, some companies are taking advantage of the fact that the acoustics are a very complex science to manipulate consumers. They try to take advantage of the situation by not presenting their product in a simple, comprehensive and honest manner.

In most cases, manufacturers will try to give particularly high values, while failing to mention under what conditions the tests were performed.

For example :
- The type of floor / ceiling assembly tested
- The presence of a suspended ceiling in the assembly tested (A suspended ceiling can add 10 to 14 points to the published result.)
- Other acoustical materials involved in the assembly tested

B. How to read and compare the results

Besides the fact that the tests can be performed in a laboratory (IIC) or on the field (FIIC), there are two major trends in the market in the way of hiding the actual acoustic values of a product.

The **first** is to publish "marketing" documents with very high values without specifying the assembly tested. Most people will be impressed, but fooled by these numbers. Manufacturers of acoustical products often lead people to believe that the acoustical performance comes from their product, while the assembly itself contributes to, in some cases, up to 90% of the published value.

The **second** is to fail to mention that the acoustical results were achieved by tests conducted in a laboratory (IIC), and under perfect controlled conditions. The results obtained in a laboratory (IIC) are always higher than those obtained on the field (FIIC) for the simple reason that the laboratory's construction quality is superior and will prevent sound transmission better than a conventional building.

In short, we cannot associate an acoustical result to a membrane without indicating in which conditions the membrane has been tested. For example, a membrane "x" with a value of FIIC 60 obtained on a concrete slab of 9 in thick will not get the same result with a concrete slab of 4 in thick, or another type of structure. Thus, the acoustical result published is the result of the ceiling / floor assembly with this "x" membrane and not only the potential result obtained with this membrane only.

It is important to ALWAYS compare the published values for similar assemblies and tests performed in similar conditions (laboratory or field + similar assemblies) and to ask yourself «Does it represent my own reality ?».

C. Acoustical results of a test performed on a surface portion vs. a fully covered surface

«According to researcher M. Alfred Warnock, PH D. who conducted the study of the Canadian National Research Council (CNRC) on small samples of floor, the FIIC ratings measured with samples of 4 ft x 4 ft should be similar or slightly conservative compared to the rating that would be measured if the entire surface of the floor was completely covered with the covering tested». According to our experience, in such cases we often get a FIIC result from 1 to 3 points superior on the complete surface.

7. THE SELECTION OF AN ACOUSTICAL MEMBRANE

A. Choosing an acoustical adhesive instead of a membrane

One of the new trends in the industry is to choose an adhesive referred to as "acoustical" instead of an acoustical membrane, usually for financial reasons. However, we cannot believe that an adhesive could be effective enough to replace a membrane, unless the structure itself is already very powerful (adding soundproofing wool, etc.). During tests performed on the field on a concrete slab of 8 or 9 in, without a suspended ceiling, with an engineered glued floor, the average results obtained on different "acoustical" adhesive types are around FIIC 50, which is under the NBC recommendation of FIIC 55.

B. Summary of the typical features of a membrane

- **Soundproofing**

-Does the acoustical capacity of the membrane in IIC meet the NBC minimum requirements and yours ?

- **Health**

-Is it healthy for the occupants and the environment ?
-Does it contain VOCs or cancer-causing chemicals ?

- **Resistance**

-Can it be easily damaged before, during or after the final installation ?
-Is this membrane considered to be resistant and practically indestructible ?

- **Properties**

-Will it retain its acoustical properties over time ?
-Will it retain its acoustical properties under pressure ?
-Will it retain its physical properties over time (thickness, structural stability, etc.) ?

- **Added value**

-Does it provide a thermal value as "Novoclimat standard" (warmer for the feet) ?
-Is it more comfortable ? (Is it softer when you walk on the floor ? (Less tired / sore legs))
-Is it compatible with the flooring products ? Will it simplify the flooring choice ?
-Will it enable installing flooring at the same height as the other floor coverings in the building? (Does not require transition moldings, minimum thickness)
-Will the total thickness of the assembly require that you modify existing doors and stairs ?
-Is it compatible with radiant heating systems ?
-Does it offer a warranty equivalent to your flooring ?

- **LEED®**

-As part of building a LEED® structure, will the acoustical membrane contribute getting LEED® credits?
-Is the selected acoustical membrane truly green? Is the manufacturer eco-friendly ?

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8. SOME TIPS FOR SUCCESS IN ACOUSTICS

A. Construction / renovation recommendations

- Make sure that the building design meets the recognized design principles of acoustics. Hire a qualified acoustician that will guide you throughout the project and avoid significant costs of demolition and reconstruction. Determine, with the help of the acoustician, realistic and achievable acoustical values that can be obtained for the building.

- Limit the use of ceramics in kitchens and bathrooms. Otherwise, take specific measures to reduce sound for the benefit of the neighbors.

- Require the use of a door sweep seal at the bottom of the corridor doors and appropriate seal around the door to minimize sound transmission.

- Seal any openings where the sound could infiltrate, especially in and around the plumbing and ventilation.

- Make sure the building envelope is as air tight as possible. If air can penetrate the envelope, the sound can as well.

- Whenever possible avoid perforating the gypsum ceiling with recessed lighting or other systems that reduce the integrity and air tightness of the ceiling.

- Do not forget to disassociate the dense elements of the building (floors, baseboards, walls, pipes, etc.) from one another.

- Do not limit the use of acoustical membrane to hardwood floors, it can also be used with ceramic, marble and natural stone floors.

- Install ceramic before the cabinets are installed to have a full coverage of acoustical membrane over the entire room.

NOTES

For more information on the acoustics, please contact the Customer service at 1.888.838.4449 or visit our website www.acousti-tech.com

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