Technical Commentary

Acoustical Properties of the OneStep Building System

OneStep-Midwest LLC
www.onestepbuildingsystem.com

TC 1-3
CFMU (2002)

INTRODUCTION

The word acoustic is derived from the Greek root akouein, meaning to hear. Acoustics is essentially the study of sound and its behavior within various media and environments. The broad field of acoustics covers those waves and vibrations within the audible range of human hearing. Sounds falling outside the human range fall within the acoustical study of sonics. For our purposes however, we are most concerned with architectural acoustics, which refers to the study and design of sound transmission and reception in enclosed spaces. Good architectural acoustics is essential in providing a habitable and useful building space. For example many studies have concluded that good acoustical design of classrooms can increase test scores among students. As a result most building codes require that structures be designed and constructed so that noise experienced by occupants is low enough not to threaten their health or interfere with their daily activities such as sleep, rest or work. Tests show exposure for more than 8 hours a day to sound in excess of 85 dB is potentially hazardous. After exposure to a typical hazardous industrial sound for an 8-hour workday, the ear tires and hearing is temporarily impaired. In 1990 about 30 million people were exposed to a daily occupational noise level above 85 dB, compared with more than nine million people within the U.S. in 1981. Currently 120 million people around the world have hearing difficulties or disabilities.

This issue is of such concern that the World Health Organization (WHO) has published a series of guidelines for community noise. Soon organizations such as the European Union (EU) will become involved in setting more stringent standards for acoustical design to prevent such disabilities from continuing. This technical note will explain how the OneStep Building System provides superior sound insulating capabilities as well as basic principles in acoustical design.

For more detailed information on acoustical design, a list of references has been provided at the end of this technical note.

MEASUREMENT OF SOUND

Sound is a pressure variation within a medium such as air, water or material substance that the human ear can detect. The number of pressure variations is called the frequency of the sound. Essentially the frequency is a measure of how many vibrations or cycles occur per second. We measure these frequencies in Hertz (Hz). One cycle per second is defined as one hertz.

Sound travels through a material at a specific speed, which we can measure. The two methods of measurement are the decibel scale (dB) and the Pascal scale. The decibel scale is considered a better approximation to the human perception of relative loudness or intensity and is therefore more commonly used. For each 20 dB increase in sound there is a tenfold increase in pressure. The human ear can perceive sounds as low as 16. As the decibel range reaches 120 dB + the human threshold for pain occurs. We find sounds at this level unbearable for any extended period of time. Exposure to such sounds for long durations can lead to permanent damage to our hearing. However, continuous exposure to sounds in the moderate range can also affect our hearing capability over time. Therefore it is very important to design structures that not only prevent high frequency noises from penetrating the space but also block continuous moderate frequency ranges as well.

Representative Sound Levels

LOUDNESS	DECIBEL RANGE	SOUND
Deafening	110-150 dB	Jet Plane Takeoff Siren at 100 ft (30 m) Thunder Hard Rock Band
Very Loud	90-100 dB	Power Lawn Mower Pneumatic Jackhammer
Loud	70-80 dB	Noisy Office Average Radio
Moderate	50-60 dB	Normal Conversation
Faint	30-40 dB	Library
Very Faint	3-20 dB	Rustling Trees Normal Breathing Whisper at 4 ft (1.2m)

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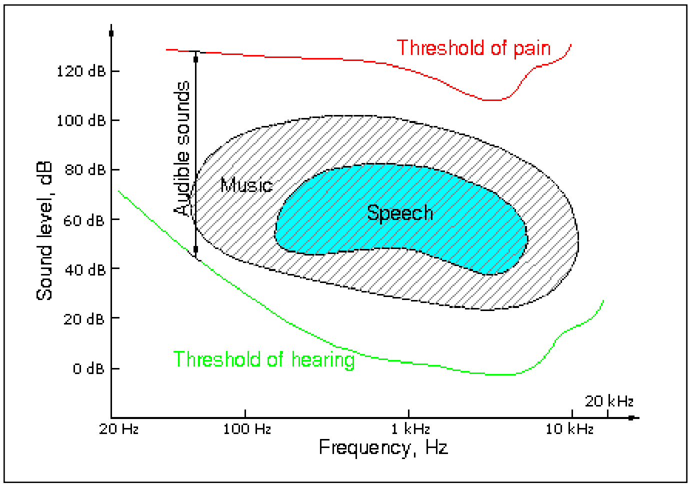

Fig 2

SOUND PROPERTIES

Sound travels in a straight line and will either transmit through a material, reflect off the material or become absorbed. **Absorption** is the loss or dissipation of sound energy in passing through a material or on striking a surface, usually through conversion to heat energy. The term may also refer to the property of a medium material or object to dampen sound energy. The absorption process can be measured in units of Sabins and is expressed as an absorption coefficient. One Sabin is the absorption power of one square foot of window space. This is because a window is considered to have no sound reflecting capability. We express the absorption capabilities of a building material by its noise reduction coefficient (NRC). The NRC is calculated by taking a mathematical average of the sound absorption coefficients, obtained at frequencies of 250, 500, 1,000 and 2,000 cycles per second. NRC is dependent of the porosity of a materiaL as well as its texture. The more porous and open textured a material the more able to absorb sound and thus will have a higher NRC rating. The OneStep Building System is very good at absorbing noise within a room and thereby diminishes noise intensity, because of the concrete and masonry materials used in its construction.

Reflection occurs when the sound wave bounces off the material at an angle. Different surfaces have different reflecting capability. Typically concave surfaces focus sound waves, thereby concentrating the sound in specific areas. Convex surfaces scatter the waves thereby promoting good diffusion of sound. We measure the reflective capability of a material by its reflective coefficient and express this data as a measure of the materials reverberation or diffusion. Reverberation time is the time required for the sound level in the room to decay 60 dB, or in other words, it is the time needed for a loud sound to be inaudible after turning off the sound source (refer to fig 3). Reverberation time is proportional to the volume of the room space and inversely proportional to the sum of each surface area multiplied by its absorption coefficient. Reverberation will also increase the ambient noise level and apparent loudness of sounds within a space, this is a very important consideration for many types of building such as classrooms. School Gymnasiums need reverberation control to allow reasonable speech communication, and to suit the other typical multi-purpose applications such as school assemblies, music concerts dances etc. Controlling the reverberation time helps control the noise levels, reducing the impact on surrounding rooms. Lower background noise and controlled reverb reduces the strain on speaker's voices within the room.

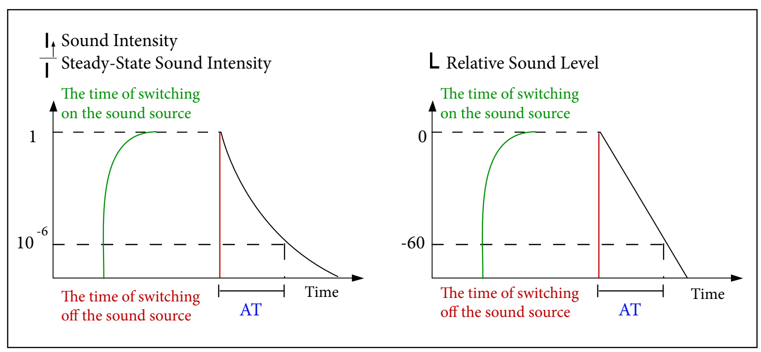

Fig 3

Transmission of sound through air or other medium is determined by the density and stiffness of the material. We measure the transmission properties of a material by its Sound Transmission Class (STC). STC is determined by comparing the decrease in sound energy as airborne sound passes through a material. We call this decrease sound transmission loss. By plotting transmission loss values at various frequencies one can determine the STC rating of a particular material. The standard process for conducting this test is ASTM E-90 Airborne Sound Transmission Loss of Building Partitions. This test measures the sound isolating properties of a wall panel or window by comparing sound energy in two adjacent chambers when the test sample is mounted in an opening between them. Broadband noise is generated in one chamber and sound pressure levels are measured simultaneously in both. After correcting for room losses and the area of the sample, the difference between the two sets of data is the transmission loss in decibels for each test frequency. An easy estimation of STC ratings for a wall assembly is the following formula as discussed in NCMA technical note 13-2A.

STC = .18w + 40
Where W = wall weight in lb/ft2

This quick calculation when used to determine the STC rating for the OneStep Building System produces the following results.

Split Face ext. finish/ Smooth int. finish:	36.00 lbs/unit
Insert Connectors/Insulation:	0.67 lbs/unit
Ready Mix Concrete Fill:	65.00 lbs/unit
Total:	101.67 lbs/unit

101.67 x 1.12= 113.87 lbs/ft2

.18(113.87) + 40 = 60.5

STC RATING: 61

Concrete and masonry materials have the ability of reducing the transmission of the natural frequency of vibration in all but some low frequency sounds. This makes the CFMU system extremely effective in reducing unwanted noise, which is why the STC ratings for the technology are so high. Most building standards indicate that rooms constructed of materials with an STC of 70 are considered perfectly quiet. The OneStep Building System building system therefore has provided the maximum technological capacity for sound reduction while also providing economical value.

MASS - SPRING - MASS MODEL

The OneStep Building System has two very important attributes for reducing sound transmission. First, as has already been discussed, it has a tremendous mass which naturally eliminates much of the natural frequency vibrations that occur at the audible range. The other attribute however is that the system is a layered sandwich wall. These multiple layers within the structure of the CFMU system are referred to in acoustical design as a mass-spring-mass model. This model provides an additional benefit in dampening the effects of unwanted noise within an architectural space.

When a single layered wall assembly is bombarded by sound energy, the wall resonates at a certain frequency. This frequency is referred to as the critical frequency (fc). Concrete, wood and masonry wall assemblies have critical frequencies close to that of common speech ranges. Therefore the transmission loss in such an assembly at the critical frequency is minimal, because most of the sound is heard on the other side of the wall. Concrete and masonry materials tend to compensate for this disadvantage by providing high mass within the thickness of the wall. However in single layered walls some low frequency noises will still penetrate the structure.

In multi-layered walls such as the OneStep Building System, the middle layer acts as a spring, while the two outer layers act as masses. This causes the sound to vibrate out of phase within the spring layer. This frequency is called the respiration frequency (fr). The Mass-Spring-Mass model is very effective at damping unwanted noise particularly at the lower frequency ranges. The two outer layers of concrete/masonry provide the mass and the insulation insert and air/weep cavity within the CFMU system provides the spring. The heaviest layer within the system, its concrete fill material, which determines the critical frequency (fc), while the weep cavity and insulation layer provides the respiration frequency (fr). Taken together the OneStep Building System will provide a damping coefficient as measured by the energy loss, which occurs in a given layer due to the multiple internal reflections of sound waves. The damping coefficient is an intrinsic property for many materials and will vary between 1-20% depending on how a wall assembly is built and what materials are used. This makes the OneStep Building System building system an extremely effective technology for the construction of classrooms, auditoriums and theaters.

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ARCHITECTURAL ACOUSTICS

Good acoustical design is dependent on a number of factors such as room size, shape, materials used in construction, even the furniture and number of occupants can affect the acoustics of a space. All of these factors must be taken into consideration on a case-by-case basis when designing a space for proper acoustics. There are reference publications however, that can help in establishing certain standards. Architectural Acoustics", by M. David Egan (McGraw-Hill, Inc., 1988), a standard reference work for design professionals, recommends a background noise level of less than 20 dB (NC-20) for critical music performance (including broadcast and recording studios); a range of NC-20 to NC-30 for less demanding, lecture halls, and NC-30 to NC-35 for classrooms. The recommended reverberation limits for these spaces range between 0.6 and 0.8 seconds. The author notes, however, that NC curves to provide satisfactory listening environments for persons with hearing impairments need to be lower by 5 (resulting in a recommendation of NC-25 to NC-30 for classrooms serving adults with hearing loss). Egan recommends that reverberation time in such rooms should not exceed 0.5 seconds.

For more information on the OneStep Building System, contact your local representative toll free at: (800) 332-5298 or visit our website at www.onestepbuildingsystem.com

References:

1. National Concrete Masonry Association Technical Note 13-1
2. National Concrete Masonry Association Technical Note 13-2A
3. www.sfu.ca/sonic-studio/handbook
4. EU Construction Products Directive 89/106/EEC
5. “HVAC Noise in Classrooms”, School Planning & Management, July 2000