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Quiet in the Classroom

ANSI Standard S12.60 and Classroom Acoustics

Armstrong

On any given school day, thousands of students across the country are unable to understand 25 to 30 percent of what's said in their classroom.

The reason: excessive noise and reverberation within the classroom interferes with their ability to clearly hear their teacher.

The result: a decreased level of concentration, an increased level of stress, and an overall reduction in the level of learning.

Considering that the primary mode of teaching involves speech and listening, is it any wonder that good speech intelligibility is required in classrooms?

Yet, a survey of school officials conducted by the General Accounting Office to determine the physical conditions of their facilities showed that "acoustics for noise control" was the most frequently mentioned "unsatisfactory environmental condition." The problem was reported by 28% of the schools surveyed.[1]

The quality of the acoustic environment in a classroom is vital to all students because all must understand the teacher, but it is of particular importance to:

Students with hearing impairments or learning disorders — Children who suffer from mild-to-severe hearing disabilities or learning disabilities such as Attention Deficit Disorder (ADD) are at a significant disadvantage in a noisy classroom. High noise levels and excessive reverberation can quickly frustrate and discourage these students.

Very young children – These students require good acoustic conditions because much of the material and vocabulary is new to them. Since these children have smaller vocabularies, they are less able to fill in the missing words or phrases not heard clearly.

Students taking English as a second language – Non-English-speaking students represent a growing segment of the American scholastic population. These students are at more of a risk in a noisy classroom because they are often learning English at the same time they are learning the regular academic curriculum.

Students with temporary hearing impairment – Many children with normal hearing have temporary losses caused by illness. For example, research has identified middle ear infection as the most frequently-occurring medical disorder in young children, with an estimated incidence as high as 25% among kindergarten and first grade children. [2]

In addition to these hearing concerns, there are also the speaking concerns of teachers to consider. When teachers must continually raise their voices to overcome noise, vocal chords can become fatigued. Working in an environment of this type on an ongoing basis can contribute to voice strain, teacher frustration and even burnout.

To help remedy problems caused by inadequate acoustic design, the American National Standards Institute (ANSI) approved a new standard in 2002 that provides an enhanced learning environment for students and teachers alike by improving speech intelligibility.

Titled "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools," the standard (ANSI S12.60-2002) is intended to help school planners and designers by identifying the acoustical qualities necessary in classrooms for good speech communication between students and teachers.

While the catalyst for the standard was, initially, an effort to improve acoustics in schools for children with impaired hearing, the result is a standard that benefits all children.

Sound in the Classroom

Before taking a look at the new standard, and at the guidelines for designing classrooms to meet its requirements, it's important to be familiar with the attributes of sound found in the classroom that affect a student's ability to hear and learn.

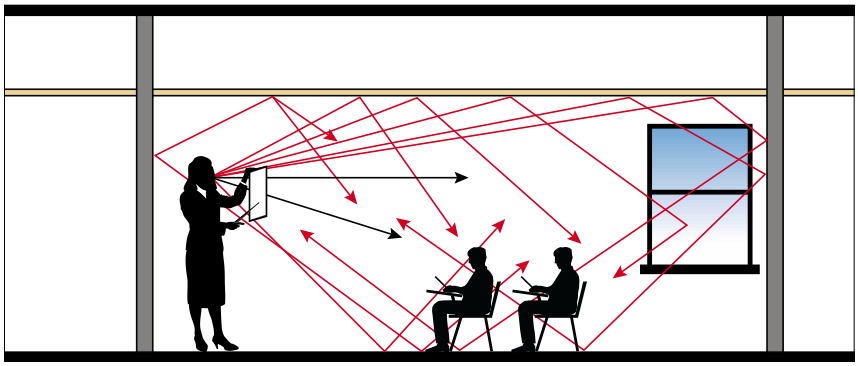
First, there is sound that is generated within the room itself, such as the teacher's voice or the sound of students moving around the room. The sound heard at any student's desk will always be comprised of a combination of both direct and reflected sounds.

The sound of a teacher's voice traveling directly from the teacher to the student is direct sound. Direct sound is always beneficial in terms of speech intelligibility because it is not affected by anything in the room, and thus is clear and distinct.

[1] *Sound and Communications*, 2002

[2] S. Schappert, "Office Visits for Otitis Media; United States, 1975-1990," Vital and Health Statistics, 214, 1-15 (1992).

HARD SURFACE CLASSROOM



Black arrows represent direct sound, with a clear path from teacher to student. Red arrows represent reflected sound. Note the many red arrows which indicate the longer, more indirect path taken to reach the student.

Eventually, direct sound will expand within the room and contact surfaces such as the walls, floor and ceiling. Some portion of this sound will become reflected sound. Reflected sound takes longer to reach the listener than direct sound, because its path to the listener is longer. Reflected sound can be good or bad depending on the time delay.

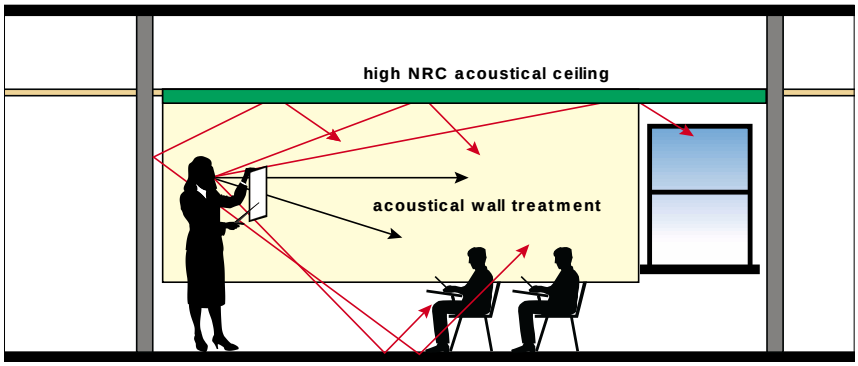
For example, at the back of a room, the level of direct sound will be much lower than at the front, simply because sound spreads out over the distance it must travel. In order to attain a sound level high enough for good speech intelligibility, it's often necessary to take advantage of reflected sound, as long as the time required for that reflected sound to reach the listener is short, usually less than 0.5 seconds.

Late arriving reflected sound is called an echo. Echoes become detrimental to speech intelligibility when their level becomes high enough to interfere with the word currently being spoken. In general, teachers speak several words within one second, so the sound from both current and previous words will be present in the sound heard by the students, and in different proportions for each student depending on where they are in the classroom.

The overall effect of reflected sound is called reverberation, and the time required for reflected sound to become inaudible is called **reverberation time**. In general, short reverberation times are good for speech intelligibility while long reverberation times reduce intelligibility.

There are two ways to reduce reverberation time: either decrease the volume of the room or increase the amount of sound absorbing materials. Decreasing the volume is generally not an option. Increasing absorption through the use of acoustical ceilings, wall panels and carpeting is a more common and less costly solution.

ACOUSTICALLY TREATED CLASSROOM



The addition of sound absorbing materials reduces late arriving reflected sound, lowers reverberation time, and improves speech intelligibility.

Background Noise

Any sound that is generated outside the building, such as that of playground activity, traffic, and even planes flying overhead can be considered background noise. This type of noise generally intrudes into the classroom by way of the windows.

There is also noise generated within the building, but not within the classroom itself. This usually takes the form of noise from an HVAC system, as well as noise from the corridors and adjacent rooms.

Taken together, the noise generated both outside the building and outside the classroom is called **background noise**. In essence, background noise is the effect of all sound sources intruding into the classroom. High levels of background noise can mask speech sounds, reducing speech intelligibility. In addition, teachers must speak louder to overcome the background noise, risking vocal fatigue.

Sound absorptive materials will absorb some of the background noise in the room. However, the best way to reduce it is to keep it from intruding into the room in the first place through the use of quiet HVAC systems, better wall constructions, and ceilings that act as a barrier to intruding sound from adjacent spaces.

The New ANSI Standard

ANSI Standard S12.60 for Classroom Acoustics addresses the issues of both

reverberation time and background noise and their effect on speech intelligibility by placing maximum permissible levels on each.

Under the new standard, the maximum reverberation time in an unoccupied, furnished classroom with a volume under 10,000 cubic feet is 0.6 seconds, and 0.7 seconds for a classroom between 10,000 and 20,000 cubic feet. The maximum level of background noise allowed in the same classrooms is 35 decibels (dBA).

The standard's acoustical performance criteria and design requirements apply during the design and construction of all new classrooms or learning spaces of small-to-moderate size, and, as far as is practical, to the design and reconstruction of renovated spaces.

At the present time, the new ANSI standard is voluntary unless referenced by a code, ordinance or regulation. However, school systems may require compliance with the standard as part of their construction documents for new schools.

A number of school districts are already putting the standard into action. The District of Columbia is one of them. Donna Ellis, a design project manager with the school district's Planning & Construction Division, notes that the district is currently working to implement the standard in its capital plan, which calls for the modernization or construction of ten schools per year for the next ten to fifteen years.

Signal-to-Noise Ratio

Speech intelligibility in a classroom depends on the level of speech relative to the level of background noise. To be heard, speech must prevail over background noise.

A convenient and easily determined indicator of speech intelligibility in a room is called the Signal-to-Noise Ratio or SNR. The signal or sound level of the teacher's voice in decibels, minus the background noise level in the room in decibels, equals the SNR in decibels. The larger the SNR, the greater the speech intelligibility.

Studies show that, in classrooms having a signal-to-noise ratio of less than +10 decibels, speech intelligibility is significantly degraded for children with average hearing. To ensure that children with hearing impairments and language disabilities are able to achieve high speech intelligibility, the American Speech-Language-Hearing Association recommends an SNR of at least +15 decibels.

Meeting ANSI Standard S12.60 Requirements

Designing a classroom to meet the acoustical requirements of the ANSI standard is neither difficult nor costly. The key is including acoustic concerns early in the planning and design stages.

To increase the signal-to-noise ratio, and thereby increase speech intelligibility, either the signal must be increased, which is accomplished by increasing good reflections and reducing undesirable late reflections, or the background noise must be decreased.

The latter is accomplished by either reducing the noise coming into the room through the ceiling plenum, through the walls and from the HVAC system, or decreasing the noise in the room by adding sound absorbing materials. Ideally, both halves of the ratio are addressed.

With this in mind, general guidelines for reducing reflected sound as well as background noise are described below.

Reducing Reflected Sound – The level of reflected sound and the reverberation time can both be reduced by adding sound absorbing material to a room. As a result, the locations of sound absorption treatments are important considerations for good acoustical characteristics in learning spaces.

For classrooms where there is no fixed lecture position for the teacher, such as those for lower grades, and where ceiling heights are less than ten feet, the best option is to place most, if not all, of the sound-absorbing material on the ceiling.

To reduce reverberation, choose a ceiling panel that has a Noise Reduction Coefficient or NRC of at least 0.70. The NRC indicates the average percentage of sound that a ceiling absorbs and is expressed as a number between 0.00 and 1.00. For example, an NRC of 0.80 indicates that the ceiling absorbs 80% of the sound that strikes it.

When ceiling heights are greater than ten feet, which is generally discouraged for classrooms, an increasing amount of the sound-absorbing material will need to be placed on the walls, as the wall height increases above ten feet. Acoustical wall treatments frequently take the form of one-to-two-inch thick, vinyl or fabric covered fiberglass panels.

If the bulk of the installed sound-absorbing material is on the ceiling and there is no possibility for wall treatment, installed furnishings such as bookshelves, assure that sound waves traveling across the room are scattered, thereby reducing the possibility of distinct echoes.

Carpeting can also help reduce reflected sound, although not nearly as much as the ceiling, because it is generally poor at lower frequencies and because most carpets used in schools have an NRC lower than 0.25. Thus, carpeting alone usually does not provide enough sound absorption for classrooms. What it can do is help reduce background noise from chair and foot impacts or scuffling. Carpeting can also reduce the transmission of this impact noise to the room below.

Reducing Noise Traveling Through the Plenum – Walls do not always extend all the way up to the finished deck of the floor above. Instead they often stop at the suspended ceiling line. As a result, noise in an adjacent space can reflect off the deck and bounce back down through the ceiling into an adjoining classroom.

To help reduce this type of noise intrusion, choose an acoustical ceiling panel that has a high Ceiling Attenuation Class or CAC value. The CAC indicates a ceiling's ability to block sound between two rooms that share a common plenum. The higher the number, the better the ceiling acts as a barrier to airborne sound transmission.

In addition to higher CAC ceiling panels, other solutions include backloading the suspended ceiling with fiberglass insulation batts, or installing a gypsum board plenum barrier between the adjacent rooms.

Reducing Noise Traveling Through the Walls – In the past, interior school walls were built of brick or concrete block, so intrusion of sound through a partition wall was not much of a problem. Today, the use of thinner, more lightweight wall materials are the norm and noise intrusion must be addressed.

According to the new ANSI standard, the minimum Sound Transmission Class or STC of a wall separating two adjacent classrooms is 50. The STC indicates the ability of a wall construction to block sound. The higher the number, the better the performance.

Most non-movable walls today are constructed of a layer of gypsum board, an air space and another layer of gypsum board on the other side. Adding fiberglass insulation in the cavity between the layers will reduce noise transmission, as will adding a second layer gypsum board to each side. Sealing all gaps between the walls and the floor and ceiling, as well as any openings in the wall such as piping, electrical outlets, and HVAC registers will reduce noise transmission even more.

Reducing HVAC Noise – The main source of background noise in classrooms is usually an HVAC system. In terms of acoustical design, a centralized system is much better than window or room units. Room units contain fans that are usually loud and difficult to treat with sound absorbing materials due to their position in the classroom.

It is also important to locate air handlers and rooftop mechanical equipment away from critical listening spaces such as classrooms. It is best to locate them over spaces that are inherently noisy, such as corridors, cafeterias and gymnasiums. Positioning units over hallways and then running ducts to nearby classrooms is also a good practice.

Retrofitting Existing Classrooms

A classroom designed without regard to good acoustics will often include a tall plaster or drywall ceiling, drywall or other masonry walls and a hardwood or tile floor. Unfortunately, numerous classrooms of this description were built in the past before the days of acoustical concern. In this type of classroom, reverberation and echoes may significantly reduce speech intelligibility, especially for younger children.

Acoustical problems in existing classrooms can be solved, but the options are often limited. That's because little can be done to change the architectural infrastructure without great expense. For example, it's difficult to reduce the transmission loss of walls inexpensively, other than sealing as many openings as possible.

Other than replacing the system, the ability to reduce HVAC noise is also limited. Installing silencers in the ductwork, and vibration silencers under the equipment, are two possible solutions. Consequently, the most common and affordable solution is to control reverberation time through the addition of sound absorptive materials.

Installation of an acoustical ceiling in a classroom that does not already have one will greatly reduce reverberation time. As noted earlier, reverberation time is affected by the volume of the room and the amount of absorptive surfaces within it. The addition of an acoustical ceiling decreases the volume of the room and increases the amount of absorptive materials at the same time.

If a suspended ceiling is already in the room, check the acoustical values of the ceiling panels. Replacing them with panels with a higher NRC value will improve the acoustical environment. The addition of appropriate wall treatment will further improve it, as will the addition of carpeting. And, if possible, adding a pane of glass to the windows will help block exterior noise.

If a classroom is designed correctly at the time of construction, the addition of these acoustic treatments does not add significantly to the construction cost. When they are included as part of a retrofit is when additive costs usually apply.

Acoustical Treatment Earns an A+

case study

A test conducted by Armstrong with architect Micaelina Campos illustrates the effect of acoustical treatment in an existing classroom. Teachers in a local school were complaining about the vocal effort required to teach. The problem was a very high reverberation time and a high level of background noise from the street. Campos recommended an acoustical treatment, and offered to conduct a test to see if the proposed solution would work.

She selected four essentially identical classrooms. The design of the rooms was typical for the area, namely, hardwood floors, masonry walls, high masonry ceilings and tall windows. Campos treated two rooms acoustically, and left the other two untreated to function as "control" rooms.

To improve the acoustical environment in the treated rooms, Campos employed a three-step solution: installation of a suspended ceiling with an NRC of 0.70; application of a wall treatment across the top portion of the back wall; and a reduction in the size of the windows followed by the installation of a second pane of glazing.

The acoustical results of the treatment were dramatic: Reverberation time went from 2.6 seconds to 0.6 seconds, and the level of background noise went from 66 decibels during peak street noise hours to a low of 38 decibels.

However, acoustical results were not the only measures of success. A number of subjective factors were also investigated. For example, teachers were asked how they felt after teaching in the treated classrooms. There was an 80% increase in the level of satisfaction. Fewer voice problems was one of the most common reasons given.

Reinforcing this finding was the fact that school officials noted that before acoustical treatment, 57.5% of total teacher absences were due to voice/throat problems. After treatment, only 34.7% were due to the same problem.

However, the most telling measure of success came from parents, who, after moving their weekly association meetings from one of the non-treated classrooms to a treated one, decided to conduct all their subsequent meetings in the treated classroom, and to install acoustical treatments in the remainder of the classrooms.

Quiet in the Classroom

The need for good classroom acoustics and the methods for attaining them have been known for decades. However, in the absence of standards, far too many schools have been built with little or no concern for good hearing.

The establishment of ANSI S12.60 fills that void by providing clear design goals for both school planners and designers.

The information and building materials needed to design classrooms for high acoustical performance now exist. Apply them to ensure that any newly constructed classroom provides an acoustic environment that positively enhances the learning experience for students and teachers alike.

Ceilings Can Provide More Than Just Acoustics

The proper choice of an acoustical ceiling goes a long way toward creating a better learning environment. There are numerous other features incorporated into today's ceilings that can help optimize school design even further. They include:

Better indoor air quality – Due to intermittent use, school facilities may have to shut down their air handling systems, causing increased humidity levels. As a consequence, mold and mildew can appear on surfaces such as ceiling panels. However, acoustical ceilings are now available that include, as a standard feature, a special anti-microbial paint on the front and back of the panels that inhibits the growth of mold and mildew on the ceiling surface.

High light reflectance – Proper lighting is a critical contributor to effective learning. Poor lighting can cause eyestrain and fatigue, which can hamper a student's ability to concentrate. High light reflectance ceilings, meaning those that have a Light Reflectance (LR) value of 0.83 or higher, can help improve this situation by creating brighter, more evenly lit, spaces.

Connectivity – Ceiling systems are now available that have technology embedded in the ceiling panel to provide in-building wireless connectivity and "3-in-1" sound systems.

Sustainability – Mineral fiber ceilings, the most commonly used ceilings in schools, are made with recycled material, some containing as much as 79%. Moreover, landfill disposal can be reduced through a unique ceiling recycling program from Armstrong.

The information on classroom acoustics and ANSI Standard S12.60 has been provided by Armstrong Ceiling Systems. There are additional resources available to you for all of your school needs that include:

- Classroom Acoustics CEU course at armstrong.com
- Armstrong Ceiling Recycling Brochure (CS-3238) and www.armstrong.com
- Reverberation Calculations through TechLine™ at 1-877-ARMSTRONG
- Reverberation Calculation Form at www.armstrong.com
- "Classroom Acoustics, a resource for creating learning environments with desirable listening conditions"; Acoustical Society of America, asa@aip.org
- Your Armstrong Ceiling Systems representative at 1-877-ARMSTRONG

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