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Classroom Acoustics CEU
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Classroom Acoustics

Enhancing the learning environment through better speech intelligibility.

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.

Acoustic Environment

The quality of the acoustic environment in a classroom is vital to all students because all need to understand the teacher, but it is of particular importance to students who have hearing impairments or learning disorders; to very young students with limited vocabularies; to students for whom English is a second language; and to students with a temporary hearing loss due to illness such as a head cold.

In addition to the hearing environment for students, there are also issues of vocal strain and fatigue for teachers. When teachers must continually raise their voices to overcome noise, they can become fatigued. Working in a poor sound environment on an ongoing basis can contribute to vocal strain, teacher frustration, and even "burnout."

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

Letter Was Catalyst

Titled "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools," ANSI Standard S12.60 for Classroom Acoustics was initiated by a letter from the parent of a 10-year-old boy with a hearing impairment to the U.S. Architectural and Transportation Barriers Compliance Board (Access Board) of the Americans with Disabilities Act (ADA).

Case Study: Retrofitting an Existing Classroom

An evaluation conducted by Dr. Kenneth Roy, senior principal research scientist for Armstrong Ceilings, demonstrates the difference a high performance acoustical ceiling can make in a classroom renovation.

The acoustic test took place in a sixth grade classroom at the Robert E. Lamberton Public School in Philadelphia, PA. Built in 1949, the 24' x 44' x 11' classroom had a spray-applied 1/2" fiber-on-plaster ceiling, concrete block walls, and a vinyl tile floor.

The NRC of the existing ceiling was estimated to be 0.25. The reverberation time in the existing room was 1.1 seconds averaged over the frequency range specified by ANSI S12.60, far exceeding the maximum acceptable reverberation time of 0.6 seconds.

An Armstrong School Zone™ Fine Fissured suspended ceiling with an NRC of 0.70 was then installed. This ceiling is designed specifically for educational facilities and features greater impact resistance and more uniform sound absorption than most conventional ceiling panels commonly used in these applications.

Following the change in ceilings, measurements were re-taken and the average reverberation time was now 0.56 seconds, within the acceptable limit.

However, objective test results were not the only measures of success. A number of subjective factors were also observed. The teacher, for example, indicated there now appeared to be less fidgeting and talking during her lessons. She also said her students seemed to be paying more attention.

An even more telling measure of success may have come from the students themselves. When asked if they noticed any changes, their most common response was the improvement in the sound level. Several others also commented that the room was brighter. As one student, who sat in the back of the room, summed it up, "I can hear (my teacher) a lot better today."

As the parent noted, "A poor acoustical environment is an architectural barrier to children with hearing impairments as much as a set of stairs might be a barrier for the child in a wheelchair."

Commenting on the impact of the letter, Lois Thibault, the Board's Coordinator of Research, said, "What we really need is a resolve to make sure that acoustics are dealt with as seriously as other problems. Because people can't see this problem, they often don't want to pay for it, so acoustical considerations are among the first expenses to be cut. But this issue may be affecting how well all children – not just those with hearing or learning disabilities – perform in school. It's important not to let that happen."

So, while the catalyst that initiated ADA's examination of classroom acoustics and its effect on learning was initially an effort to improve schools for children with impaired hearing, the result is a standard that benefits all children.

ANSI Standard S12.60

ANSI Standard S12.60 for Classroom Acoustics addresses both the issues of reverberation time and background noise as they affect speech intelligibility by setting maximum permissible levels on each.

Under the standard, the maximum acceptable reverberation time in unoccupied but furnished classrooms with volumes up to 10,000 cubic feet is 0.6 seconds, and 0.7 seconds for classrooms between 10,000 and 20,000 cubic feet. Reverberation time is the time required for sound reflections within a room, such as from a loud hand clap, to become inaudible.

The maximum acceptable background noise allowed in these classrooms is 35 decibels (dBA). By comparison, the loudness of a normal face-to-face conversation is about 60 dBA.

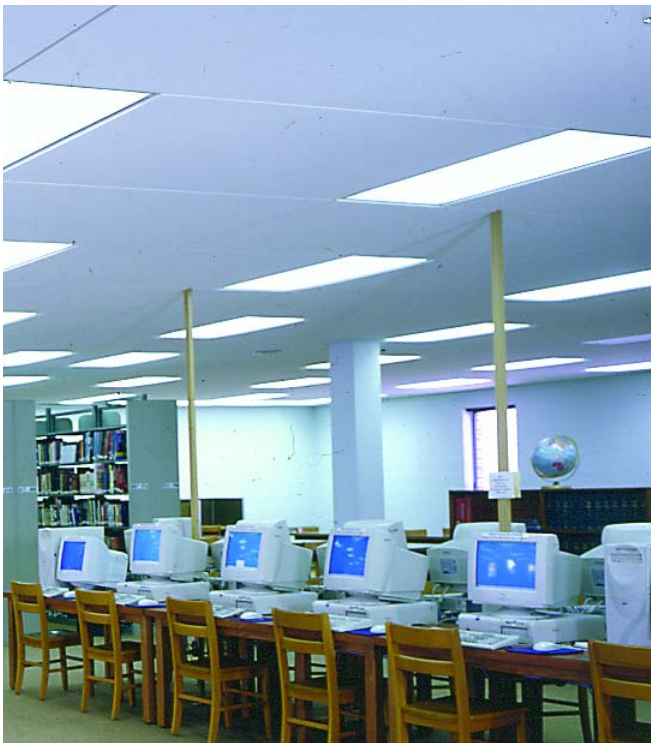
These acoustical performance requirements apply to the design and construction of new classrooms of small-to-moderate size, and, as far as is practical, to the renovation of existing classrooms.

Voluntary Standard

Acoustical standards like ANSI S12.60 are by no means new. Similar performance standards covering school construction are already in place in a number of European countries, including the United Kingdom, Sweden, Italy and Switzerland.

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

Although little consideration has historically been given to acoustic design in classrooms – compared to lighting and ventilation – the situation is beginning to change.



A number of states have already adopted the full standard, including Ohio, New Hampshire, New Jersey, Minnesota and Connecticut.

In addition, other classroom acoustics standards/ directives based on ANSI S12.60 are in use in the states of California, Washington and New York as well as in the Los Angeles, Philadelphia, Minneapolis and Washington, DC school districts.

New Classrooms

ANSI Standard S12.60 is a performance specification in that it states desired results but not how to attain them. However, it does include a number of appendices that are prescriptive in nature, with specific design suggestions, including choice of materials.

Designing a classroom to meet the acoustical requirements of the standard is neither difficult nor costly. The key is to include acoustic concerns early in the planning and design stages. With this in mind, general guidelines are described below.

Reverberation Time – For any given room, reverberation time decreases as additional sound absorptive materials are added in the space. Both the amount of sound absorptive materials and its location in the space are important considerations that affect the quality of sound within the room.

For classrooms with ceiling heights of approximately 10 feet, place most, if not all, of the sound-absorbing material on the ceiling. This is usually the easiest and lowest cost solution. For best results, choose an acoustical ceiling panel that has a Noise Reduction Coefficient (NRC) rating of at least 0.70.

Acoustical Terms

The acoustical properties of building materials and systems are vital contributors to the functional success of most educational spaces. As a result, it's important to be familiar with three primary measures of acoustical performance.

Noise Reduction Coefficient (NRC) – Indicates the ability of a ceiling or wall treatment to absorb sound. It is expressed as a number between 0.00 and 1.00, and indicates the average percentage of sound that a material absorbs. For example, an NRC of 0.60 means a ceiling absorbs 60% of the sound that strikes it. A ceiling with an NRC of less than 0.50 is considered a poor absorber.

Ceiling Attenuation Class (CAC) – Indicates the ability of a ceiling to block sound in one room from passing up into the plenum and transmitting back down into an adjacent room that shares the same plenum. The higher the number, the better the ceiling acts as a barrier to sound transmission. A ceiling system with a CAC of less than 25 is considered low performance.

Sound Transmission Class (STC) – Indicates the ability of a wall construction to block the transmission of sound through it and into an adjacent space. The higher the number, the better the construction acts as a barrier to sound transmission. A wall system with an STC less than 35 is considered low performance.

For rooms with ceilings between 12 and 15 feet high, it may be advantageous to place some of the absorptive material on the walls as well as on the ceiling.

For ceiling heights over 15 feet, it is usually necessary to utilize wall absorption. Acoustical wall treatments usually consist of 3/4" to 1" thick mineral fiber or fiberglass backer board with a vinyl or fabric covering.

If there is no possibility of acoustical wall treatment, try to ensure that three-dimensional furnishings such as bookshelves are distributed around the room to diffuse sound reflections, thereby reducing the possibility of echoes.

Carpeting may also help reduce reverberation, but not nearly as much as a good acoustical ceiling (NRC 0.70) because most commercial grade carpeting is generally a poor absorber (NRC of 0.25 or lower). However, carpeting can help reduce background noise caused by the sound of people walking, and desk and chair shuffling. It can also reduce the transmission of these impact noises to the room below in multi-floor school buildings.

Figures #1 and #2 show the difference in sound paths in a classroom that is not acoustically treated compared to one that is.

Background Noise – There are many sources of background noise that may intrude into a room. How these are handled depends on the path the noise takes in entering the room. The primary contributors to background noise are described below.

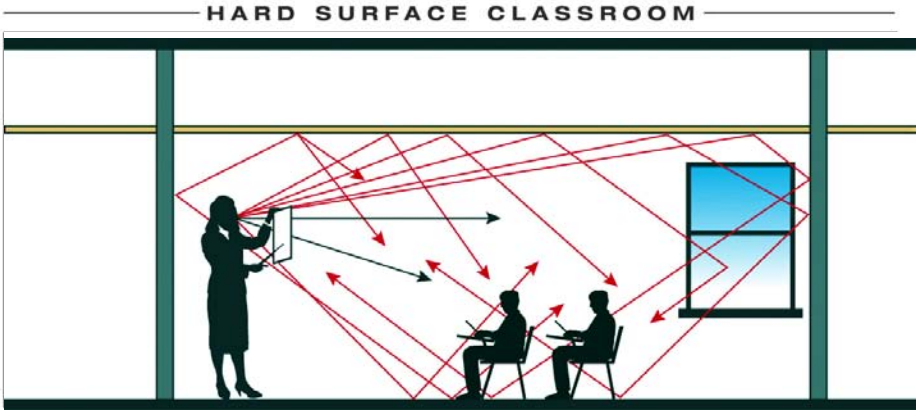


Figure 1:

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.

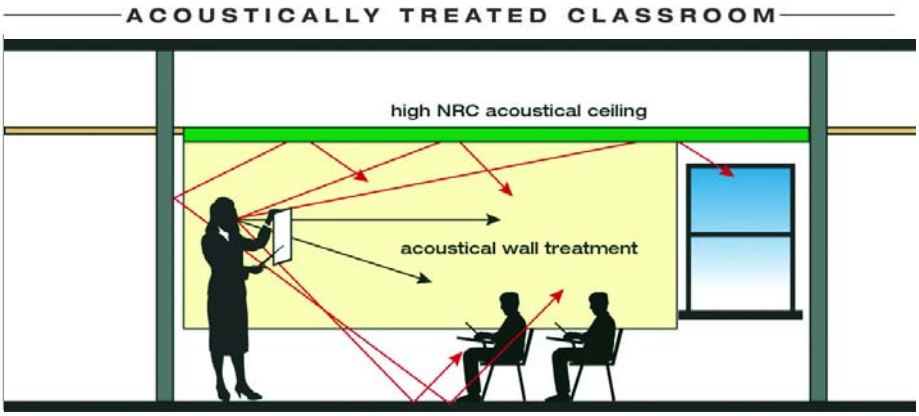
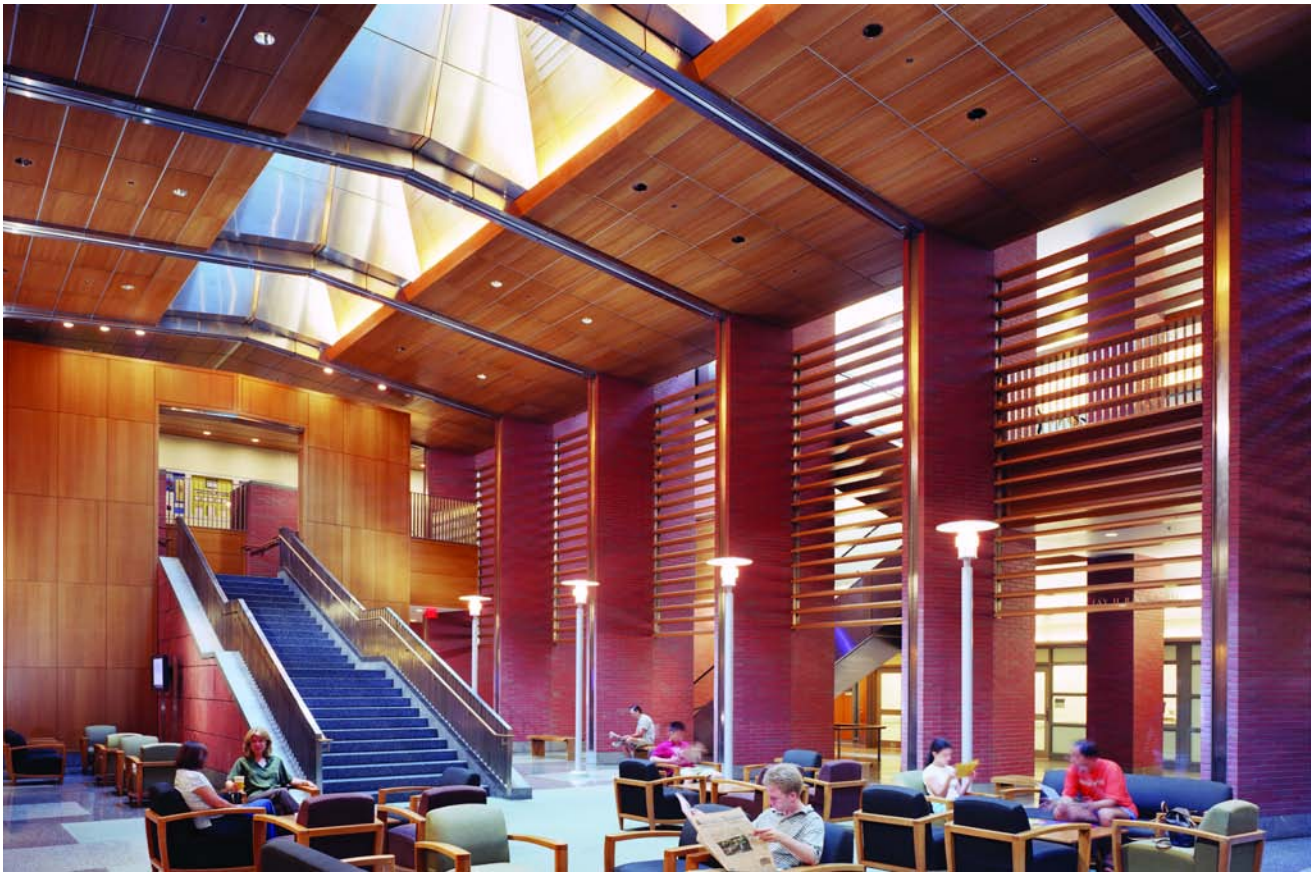


Figure 2:

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



Noise Traveling Through the Plenum – Some rooms are constructed with walls that are only as high as the suspended ceiling, rather than extending all the way up to the roof or floor deck above. As a result, noise from an adjacent room can penetrate the ceiling plane and move unimpeded throughout the ceiling plenum. Some portion of this plenum noise will pass back down through the ceiling into adjoining rooms, thereby adding to the background noise in each room.

To reduce plenum noise intrusion:

- Choose an acoustical ceiling panel that has a Ceiling Attenuation Class (CAC) rating of 35 or higher.
- Backload the suspended ceiling with R-11 fiberglass building insulation batts.
- Install a gypsum board plenum barrier between adjacent rooms, being sure to seal all penetrations such as pipes, ducts, cable runs, etc.

Noise Traveling Through the Walls – Years ago, 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, noise intrusion must be addressed because most walls are constructed using metal studs with a layer of gypsum wallboard on each side.

According to the ANSI standard, the minimum Sound Transmission Class (STC) rating of a wall separating two adjacent classrooms is 50.

To achieve this rating and reduce noise transmission between rooms:

- Add R-11 fiberglass insulation in the cavity between the gypsum board layers.
- Add a second layer of gypsum board to each side.
- Seal all gaps between the walls and floor and ceiling.
- Seal any openings in the wall such as piping, electrical outlets, and HVAC registers.

Metal, Wood Ceilings

Mineral fiber panels suspended in a metal grid are the most popular acoustical ceiling systems used in educational environments today. However, there is now a trend toward an increased use of other ceiling materials, especially in public spaces such as lobbies, and large spaces such as lecture halls and auditoriums. The reason is a desire to create more dramatic ceiling visuals. Two of today's more common alternatives to mineral fiber are metal and wood.

Metal Ceilings

One reason for the increasing use of metal ceiling systems is their durability. A metal ceiling panel will usually outlast a mineral fiber panel, especially in areas where access to the plenum is frequent.

Another consideration is aesthetics. Metal ceilings are available in a variety of sizes and finishes that can impart a very high tech look to a space. And, even though it is metal, this type of ceiling can provide very good acoustical control.

In order to achieve good sound absorption, the panels must be perforated. Perforations vary in size depending on aesthetic appeal, although today there are microperforated panels in which the holes are so small, they are essentially invisible.

Perforated panels are usually provided with a black, sound absorbing fleece liner or both a liner and an encapsulated fiberglass batt behind the perforations. The NRC of perforated panels can range from 0.65 to 0.90 depending on the backing used.

Wood Ceilings

Wood ceilings are increasing in popularity because of their beauty. They are perceived as upscale, even when used with a standard suspension system and standard light fixtures. They also impart a warm ambiance to a space.

As in the case of metal, wood ceilings are available in a variety of finishes and sizes. Perforated versions are also offered for better acoustical performance compared to non-perforated panels. The NRC of perforated panels can be as high as 0.75 depending on the backing used.

HVAC Noise – The main source of background noise in classrooms is usually the heating, ventilation and cooling (HVAC) system. A centralized system is usually much quieter than window or room units since air is supplied through ducts. Unducted window and room units usually contain high velocity fans that are usually very loud and difficult to treat with sound absorbing materials in the room.

To reduce HVAC noise:

- Locate air handlers and rooftop mechanical equipment away from critical listening spaces such as classrooms.
- Locate the equipment over spaces that are inherently noisy, such as corridors, cafeterias and gymnasiums.
- Position units over hallways and then run ducts to nearby classrooms.

Existing Classrooms

A classroom designed without regard to good acoustics will often include a high ceiling of plaster or gypsum board; masonry or gypsum board walls; and a hardwood or tile floor.

Unfortunately, numerous classrooms fitting this description were built in the days before sensitivity to acoustical needs. In such a classroom, long reverberation times tend to destroy speech intelligibility, especially for younger children.

Acoustical problems in existing classrooms can be solved, but the options are often limited. This is because little can be done to change the architectural infrastructure or HVAC system without great expense. Consequently, the most common and affordable solution is to control reverberation through the addition of sound absorptive materials.

To improve the acoustical environment of an existing classroom:

- Install a suspended acoustical ceiling in a classroom that does not have one.
- If an acoustical ceiling is already in the room, replace panels that have a low NRC (0.50 or lower) with panels that have a higher NRC (0.70 or higher).

- Add acoustical wall treatments and "space absorbers" (baffles).
- Add carpeting.
- Seal as many openings in the common walls as possible.
- Add a second pane of glass with an air gap to the windows, if possible, to help block exterior noise.
- Install vibration isolators under HVAC equipment, and silencers in the ductwork.

Solutions such as these do not add significantly to the construction cost of a new building. It is when they are included as part of a retrofit that additive costs usually apply.

Larger Spaces

The same basic recommendations to control reverberation time and background noise in classrooms also apply to larger rooms such as cafeterias, gymnasiums and auditoriums. However, it is usually prudent to employ the services of an acoustical consultant for the proper design of these spaces.

Two key considerations when acoustically treating larger spaces are the ceiling height and the relative importance of speech intelligibility to the space.

Cafeteria – The ceilings in a cafeteria are usually not overly high. And, speech intelligibility is not a primary concern, especially considering that the main source of noise in the space is usually the students themselves.

To reduce the level of noise in a cafeteria:

- Install an acoustical ceiling with a high NRC rating.
- Add acoustical wall treatments or "space absorbers," if practical.

Gymnasium – The most common problem in gyms is excessive reverberation time, since these are typically large spaces with high ceilings and plenty of hard surfaces. Speech intelligibility is somewhat of a concern because gymnasiums are frequently used for assemblies.

To reduce reverberation time in a gymnasium:

- Install sound absorptive ceiling and wall treatments, split approximately 50/50 in total area.
- Keep the wall treatment at least 8 feet high and distributed between all four walls.
- Make sure the acoustic ceiling and/or wall panels are impact resistant.

Quiet Classrooms

The need for good classroom acoustics and the methods for attaining them have been known for decades. However, in the absence of a standard, 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 administrators. It also raises awareness of the learning problems associated with poor acoustics and, hopefully, eventually eliminates design problems from being repeated as new schools are built.

The information and building materials needed to design and build classrooms for high acoustic 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: Key Element of High Performance Schools

The proper choice of an acoustical ceiling goes a long way toward creating a better learning environment. However, improved acoustics isn't the only benefit. There are numerous other features incorporated into today's ceilings that can help optimize school design even further.

High light reflectance – Proper lighting is critical 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. They also reduce glare and enhance daylighting in the room.

Sag resistance – School facilities often have to cycle or shut down their HVAC systems for extended periods of time, such as summer vacations, causing increased humidity levels. Humidity resistant ceiling panels specifically designed for these types of applications are available. These ceilings stay flat and can be installed in high humidity environments other than outdoors or where subjected to standing water.

Mold/mildew resistance – High humidity conditions can also lead to the growth of mold and mildew on any surface, including ceiling panels. To help remedy this situation, acoustical ceiling panels are available with a fungicide that inhibits the growth of mold and mildew on the painted surface on both the front and back of the panel when used in accordance with good design, construction and maintenance practices.

Sustainability – School districts are now more sensitive to the need to build environmentally friendly facilities. Many acoustical ceilings used in schools are made with recycled content, some containing as much as 82%. In addition, Armstrong offers a Ceiling Recycling Program that enables school districts to ship old ceilings from renovation projects to one of its plants as an alternative to landfill disposal.

Resources

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. They include:

- Classroom Acoustics CEU course at armstrong.com/ceu
- Armstrong Ceiling Recycling Brochure (CS-3238) at armstrong.com/environmental
- Reverberation Calculations through TechLine™ at 1-877-ARMSTRONG
- Reverberation Calculation Form at armstrong.com/schools
- "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

Reverberation Calculator

To help demonstrate the beneficial effect of acoustical treatment in a classroom, Armstrong Ceilings has developed a web-based, interactive Reverberation Calculator that allows users to actually hear the difference in sound quality both before and after treatment. It will even provide recommendations for a new space or an upgrade to an existing space.

To access the calculator, simply log on to armstrong.com/schools and follow the prompts regarding a description of the space and its surface materials. The program will first calculate the current reverberation time and allow users to hear the quality of the sound. Following selection of acoustical treatment options, the program will then allow users to hear the difference in sound quality with lowered reverberation time.

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