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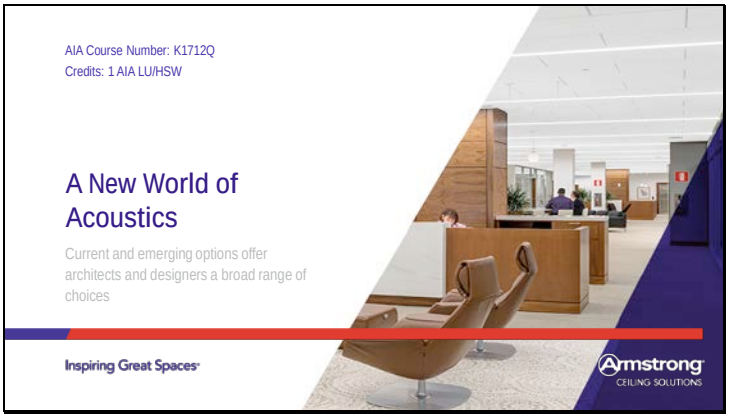
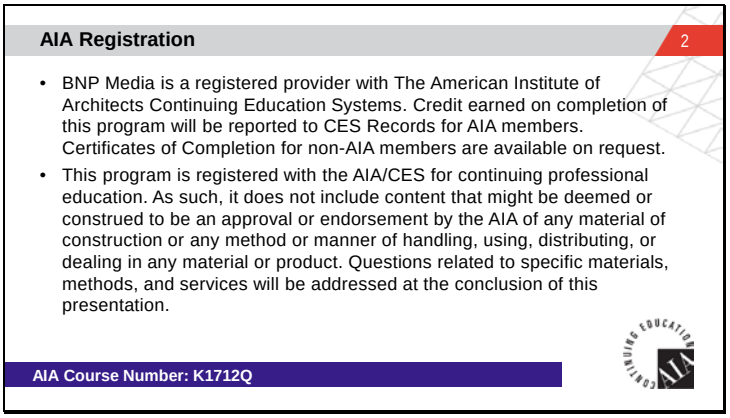

AIA Course Number: K1712Q
Credits: 1 AIA LU/HSW
A New World of Acoustics
Current and emerging options offer architects and designers a broad range of choices
Inspiring Great Spaces
Armstrong
CEILING SOLUTIONS

Slide 2



This slide outlines Armstrong participation in the American Institute of Architects Continuing Education program. You will receive one AIA Learning Unit (LU). Thank you for your attention and participation in this seminar.

Slide 3

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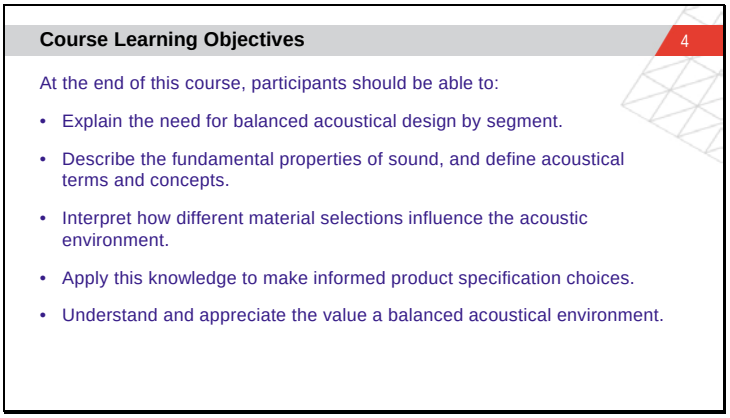
Slide 4



At the end of this course, participants should be able to:

- Explain the need for balanced acoustical design by segment.
- Describe the fundamental properties of sound, and define acoustical terms and concepts.
- Interpret how different material selections influence the acoustic environment.
- Apply this knowledge to make informed product specification choices.
- Understand and appreciate the value a balanced acoustical environment.

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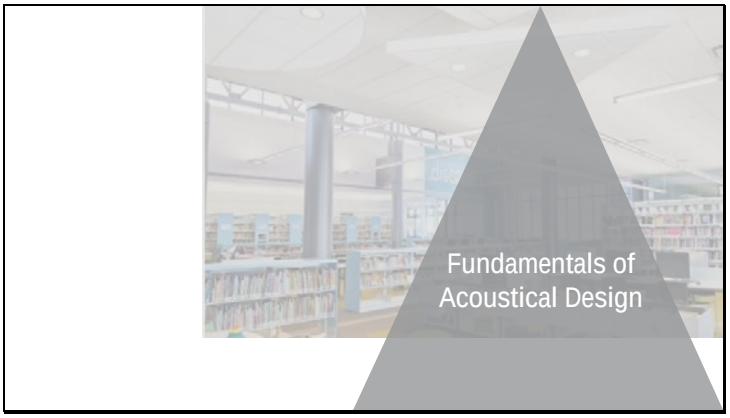

Slide 6

As architects and designers, we are all aware that people experience a building with our human senses. While designs often pay the most attention to what we see, our sense of hearing is also directly impacted as soon as someone or something makes a sound in a building. If the quality of sound is not a factor considered in a design, then it can result in poor acoustic quality, distracting noise, or an irritating experience. Poor architectural acoustics can be annoying or distracting such that it can impede concentration, comprehension, confidentiality, healing, or learning. By contrast, good sound qualities can add drama, vibrancy, and energy, creating a useful, inspiring, and helpful experience.

Overall, when visually appealing spaces and acoustically appropriate techniques come together, the end result is a fully successful building design. To achieve this positive balance of visual and acoustical performance, architects and designers have more material and system options than ever to choose from. This is particularly true when it comes to ceilings that have long been used for acoustic control in buildings of all types. Understanding the full range of options currently available from manufacturers allows design professionals to create ceilings that perform well acoustically, add to the visual aesthetics, and contribute to sustainable designs.

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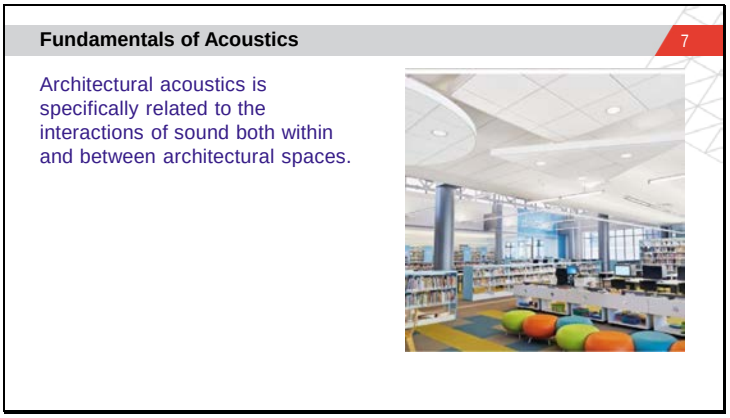

Acoustics is the scientific study of sound in all its forms, and architectural acoustics is specifically related to the interactions of sound both within and between architectural spaces. Professionals, specialists, and scientists have studied sound in terms of its generation, its transmission through space and objects, and its reception by people. In all cases, sound radiates outward from the source, of which there are many both inside and outside of buildings.

Sound is typically characterized by its loudness and frequency content, such that loudness is measured in decibels (dB) and frequency is measured in Hertz (Hz). The sound as heard within a space will be a combination of direct sound from the sources and sound reflected off the various surfaces within the space. Highly reflective surfaces will redirect sound without significant changes except for direction, which in very “hard” rooms can result in long delay times for arrival at the listener, causing echoes. Highly sound-absorptive surfaces, on the other hand, will diminish the reflected sound waves and reduce reverberation and echoes. Based on the sound behavior, people can experience different levels of speech intelligibility, speech privacy, or sound intrusion depending on the room size and shape and the acoustic treatments within or between spaces.

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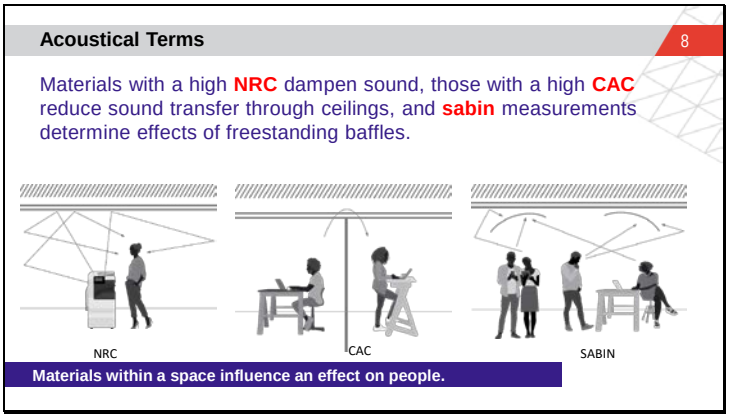

Sound radiates out in all directions, but materials within a space will influence its effect on people. Materials with a high NRC (top image) dampen sound, those with a high CAC (middle image) reduce sound transfer through ceilings, and sabin measurements (bottom image) determine effects of freestanding baffles.

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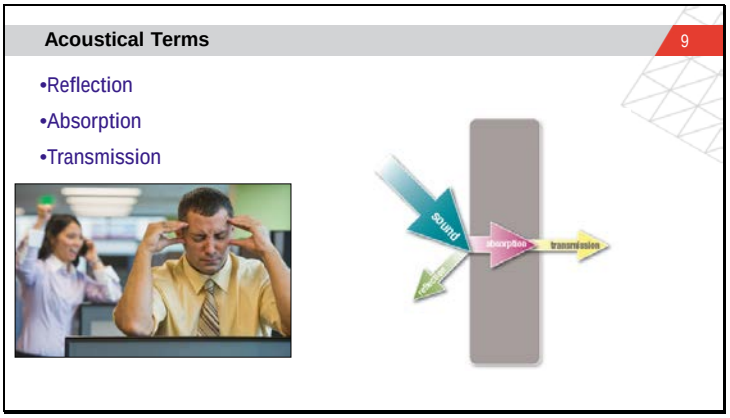

Finding the right combination of sound absorption/reflection and sound transmission for a given space is a matter of using several well-developed tools to balance the acoustic characteristics within that space.

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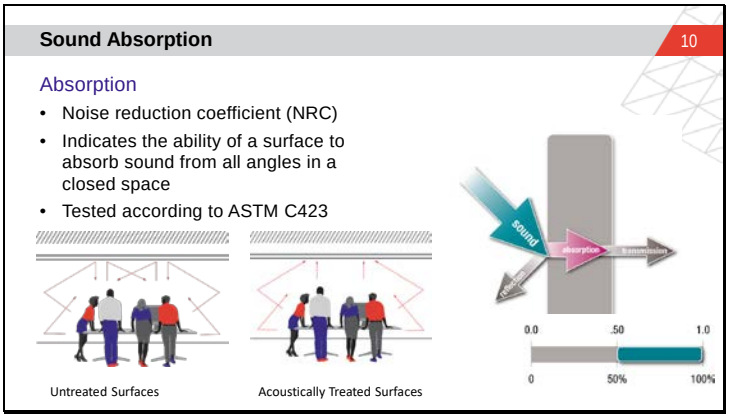

Sound absorption is the ability of a material or surface to deaden sound and is always frequency dependent. The sound absorption coefficient is measured on a scale of 0.0–1.0 over a frequency range, and the single number rating for a material is called the noise reduction coefficient (NRC).

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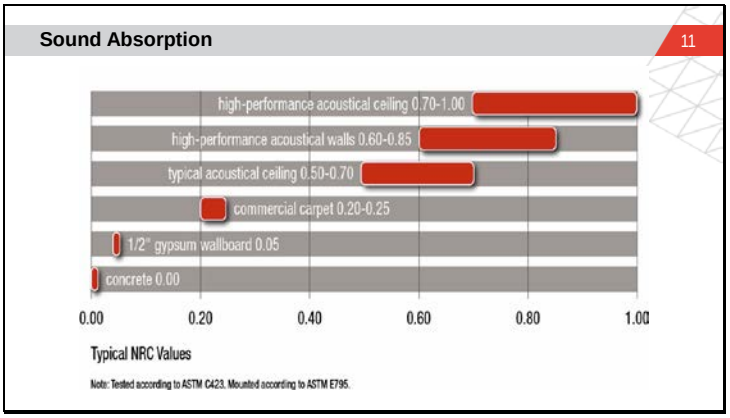

The higher the NRC rating, the higher the overall (averaged over frequency) sound absorption of the material being measured. The NRC values published in ceiling manufacturers' data represent the percent of sound absorption per square foot of material used in continuous ceilings.

If discontinuous ceilings are being installed or only partial areas have acoustic treatment (considered “unit” absorbers), then the overall sound absorption of the entire space can be measured and published as sabins of absorption.

Since we need to know the total sound absorption (sabin) within a space, we can multiply the NRC by the number of square feet of continuous ceiling or we can add up the unit sabins for the number and type of partial acoustical treatments that are in place.

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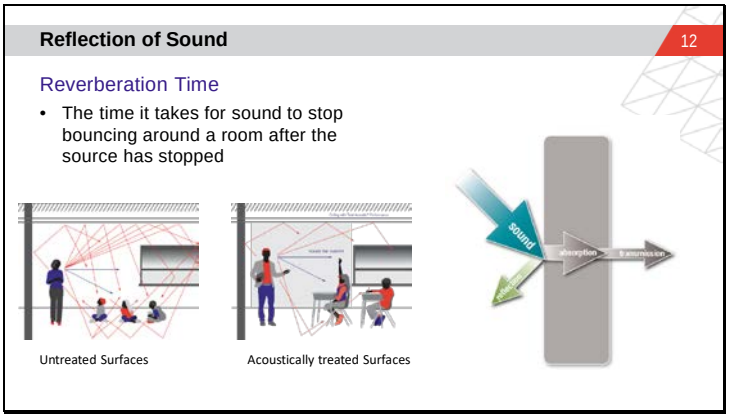

The opposite of sound absorption is sound reflection, which is also measured in the same way. A material with an NRC of 0.0 will reflect back all of the sound striking it and not absorb any. Typically, materials with NRC < 0.5 are considered sound reflectors.

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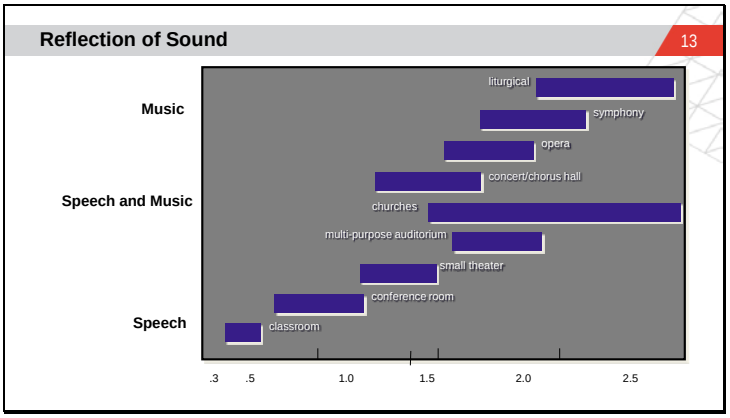
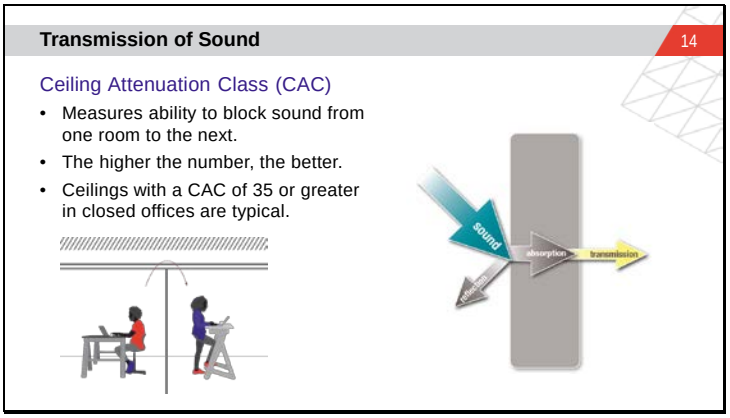


The use of too many sound-reflective materials, especially in large spaces, can create echoes and excessive reverberation of sound, which may be desirable in some cases, but not in others. A measure of reverberance is the reverberation time (RT), which is indicative of the persistence of sound after it was made and is measured as the time it takes for sound to decay by 60 dB in level.

Controlling or minimizing RT is particularly important in situations where people are listening to someone speaking since it directly affects the ability to understand the spoken word, which is referred to as “speech intelligibility.” Long reverberation times mean that the listener will be subjected to reflected sound with long delay times relative to the direct sound from the talker, and these late reflections will result in “overlaps” of spoken words, making it more difficult to understand.

Slide 14



When assessing the sound transfer through ceilings, the specific measurement is the ceiling attenuation class (CAC).

This rating is essentially the equivalent of an STC rating for walls but is specific to the ceiling conditions where a dividing wall is constructed only to the ceiling height, allowing sound to pass through a plenum space above the ceiling.

This is a “two pass” test in that the sound can transmit up through the ceiling in one space, across the ceiling plenum, and back down through the ceiling in an adjacent space. The higher the CAC rating, the more sound that is attenuated, meaning that less is transferred between spaces.

Slide 15

Transmission of Sound

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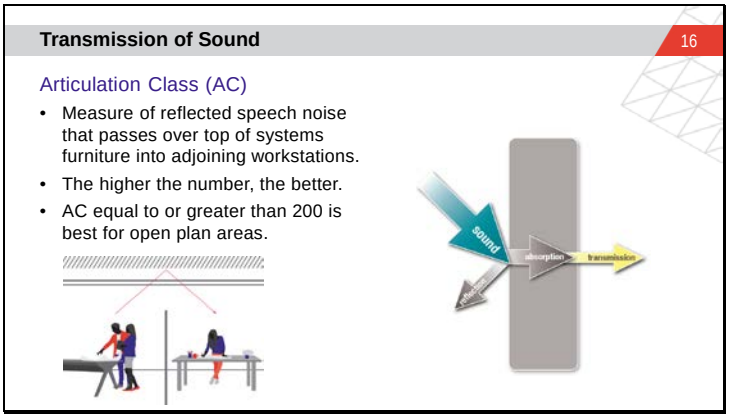
CAC Measurements for Typical Ceilings	
High CAC mineral fiberboard	40 CAC
Typical mineral fiberboard	35 CAC
Fiberglass with CAC backing	25 CAC
Non-backed fiberglass	15 CAC

A CAC value of 35 or higher is recommended for spaces where speech privacy or confidentiality is a requirement. Specification of ceilings with CAC of 35 or higher contribute by blocking sounds from adjacent spaces from traveling into other areas when walls do not go to the deck.

Slide 16



In cases where the walls of a space do not extend all the way to the ceiling, such as with movable office partitions or partial height furniture, the appropriate measure is the articulation class (AC) rating. In this condition, it is speech privacy that is being rated so more absorption is being sought. Just like the CAC, a higher rating means that more sound is attenuated and less is transferred between office cubicles or similar spaces.

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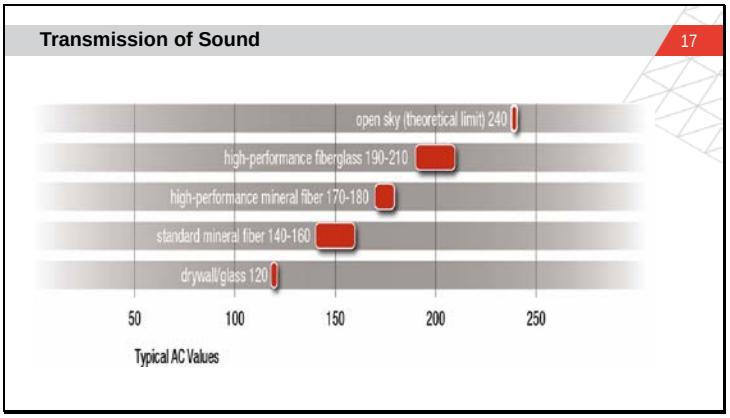

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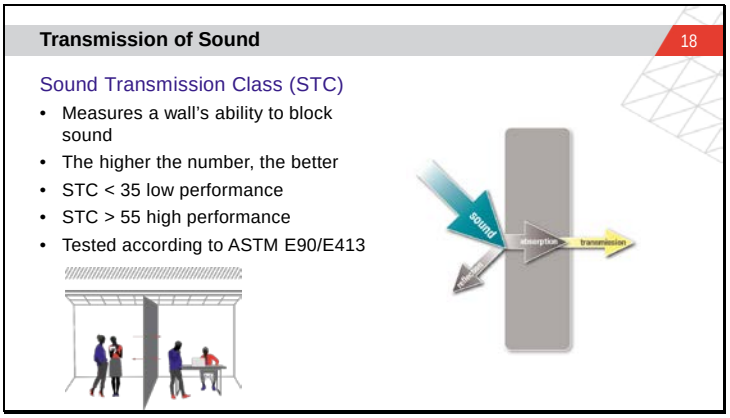
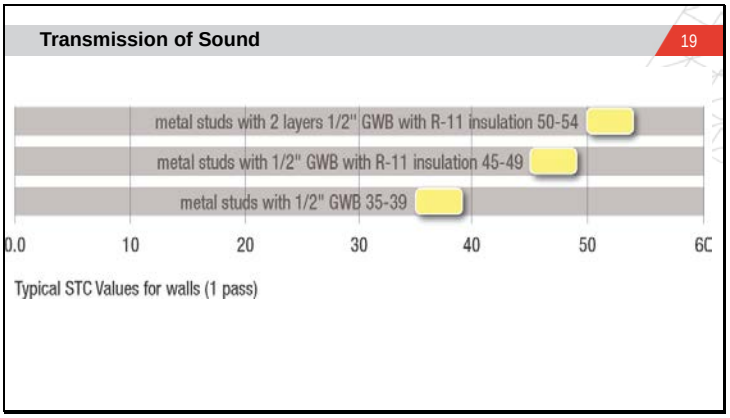


The most common method for measuring how much sound is being transferred between wall assemblies is the sound transmission class, or STC rating. A higher STC rating means that more airborne sound is blocked by the component or assembly. Lower STC ratings mean that more sound passes through the components or assemblies, adding to the background noise level in the space, degrading the ability to hear and understand speech.

Slide 19



It should be noted that, contrary to the popular notion that sound passes through a structure, such is not exactly the case. Sound generated on one side of a wall will energize the wall structure and set it in motion, much like a diaphragm. The wall itself becomes the transmitter of the sound energy which can be heard on the opposite side of the wall by the listener.

Hence, the ASTM test methods used to determine STC ratings have focused on this direct transmission process, and the STC number is derived from sound attenuation values tested at 16 standard frequencies from 125 Hz to 4,000 Hz. The subjective perceptions of the STC ratings are generally accurate for speech sounds but less so for amplified music, mechanical equipment noise, transportation noise, or any sound with substantial low-frequency energy below 125 Hz.

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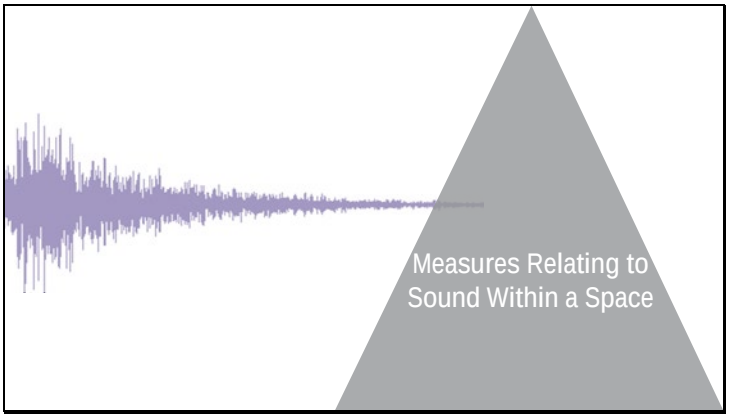

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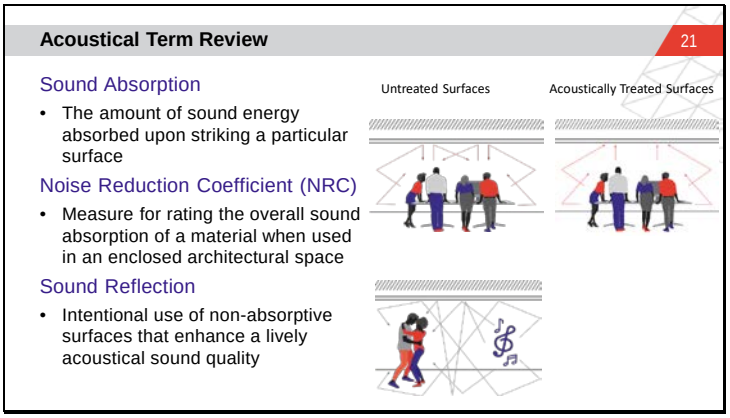

Measures Relating to Sound Within a Space

• **Sound Absorption** The amount of sound energy absorbed upon striking a particular surface. The more sound energy that is absorbed then the less that is reflected back as reverberation or a possible echo

• **Noise Reduction Coefficient (NRC)** A measure for rating the overall sound absorption of a material when used in an enclosed architectural space where sound is reflected at many angles of incidence. An NRC of 0 indicates perfect reflection while an NRC of 1 indicates perfect absorption. Generally, a ceiling system with an NRC < 0.50 is considered low performance, and an NRC > 0.70 is high performance. NRC is important in any space where reverberation time and noise levels are an issue. NRC is measured according to ASTM C423 and is generally used in the Americas – European countries may use the weighted sound absorption coefficient W.

• **Sound Reflection** The intentional use of non-absorptive surfaces that enhance a lively acoustical sound quality, such as in nightclubs or music venues.

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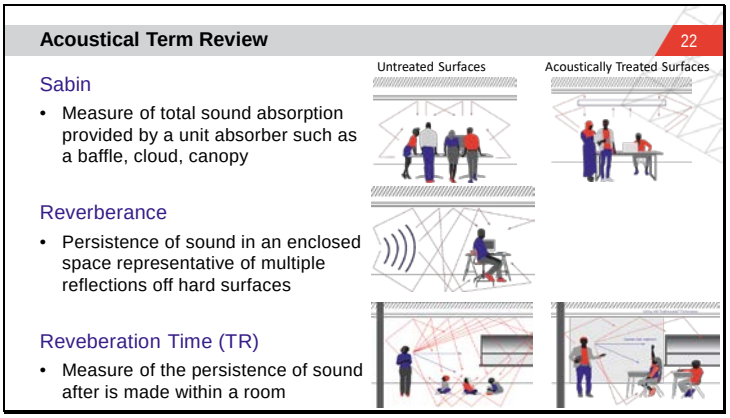

Sabin: A measure of the total sound absorption provided by a unit absorber such as a baffle, cloud, canopy, etc. when installed within an architectural space. Sabin per unit is preferred to characterize the absorption provided by an individual "space absorber," in open offices, retail spaces, open plenum areas, or corridors/lobbies. Absorption in Sabin is measured according to ASTM C423 The number of Sabin per unit is approximately equal to the total surface area of the unit (in square feet) that is exposed to sound, multiplied by the absorption coefficient of the material

• **Reverberance** The persistence of sound in an enclosed space representative of multiple reflections off hard surfaces which can give a feeling of spaciousness, warmth, and envelopment. . Higher levels are generally good for music listening spaces, but not so good for speech intelligibility. Higher levels are characterized by longer reverberation time and higher sound levels. The level of the reverberant sound within a room is dependent on both the volume of the room and the amount of sound absorption within the room, such that small hard surfaced rooms sound "louder" than large well-treated rooms.

• **Reverberation Time (RT)** RT is the measure of the persistence of sound after is made within a room, and is measured as the time in seconds that it takes for the sound level to decay by 60 dBs. Long reverberation can impair "speech intelligibility" since it creates garbled sounding words and poor verbal communication. Instructional spaces, such as classrooms, are best with short RTs—less than 0.6 second to ensure clarity and high speech intelligibility. Auditoriums, theaters, and other musical spaces will typically benefit from longer RTs, typically greater than 1.2 seconds. In schools, RT limitations are required according to ANSI S12.60.

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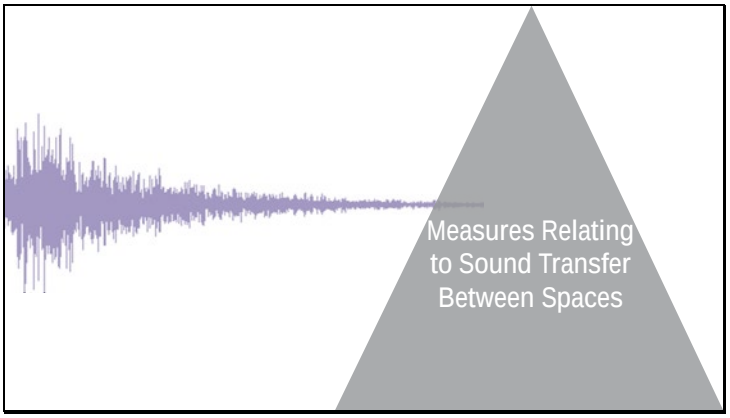

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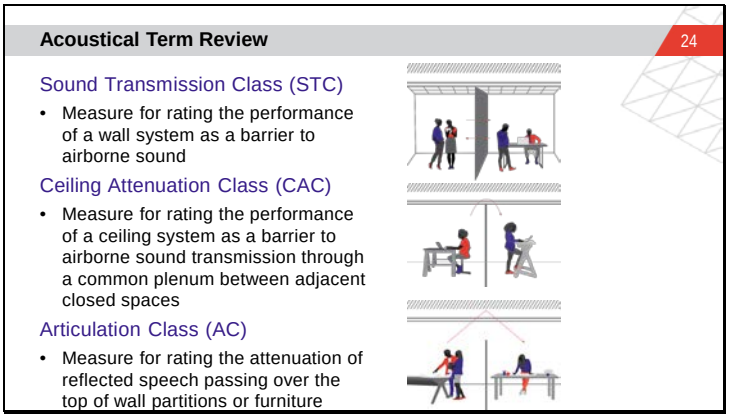

Sound transmission class (STC): A measure for rating the performance of a wall system as a barrier to airborne sound transmission between adjacent closed spaces, such as offices. A wall system with an STC ≤ 35 is considered low performance, whereas one with an STC ≥ 55 is high performance. STC is the wall equivalent of CAC. STC is important between closed spaces and in many open plan spaces, closed offices, corridors, open offices with dividers, etc. STC is measured according to ASTM E90.

Ceiling attenuation class (CAC): A measure for rating the performance of a ceiling system as a barrier to airborne sound transmission through a common plenum between adjacent closed spaces, such as offices. A ceiling system with a CAC ≤ 25 is considered low performance, whereas one with CAC ≥ 35 is high performance. CAC is important between closed spaces and from closed rooms to adjacent spaces such as corridors and closed offices, conference, health-care exam rooms, doctors' offices, etc. CAC is measured according to ASTM E1414.

Articulation class (AC): A measure for rating the attenuation of reflected speech passing over the top of wall partitions or furniture into the adjoining work stations. A ceiling system with AC ≤ 150 is low performance, whereas one with AC ≥ 180 is high performance. AC is measured according to ASTM E1110 and E1111.

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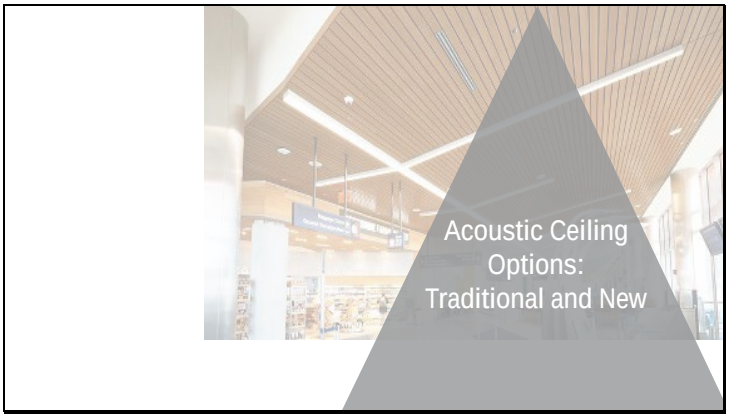

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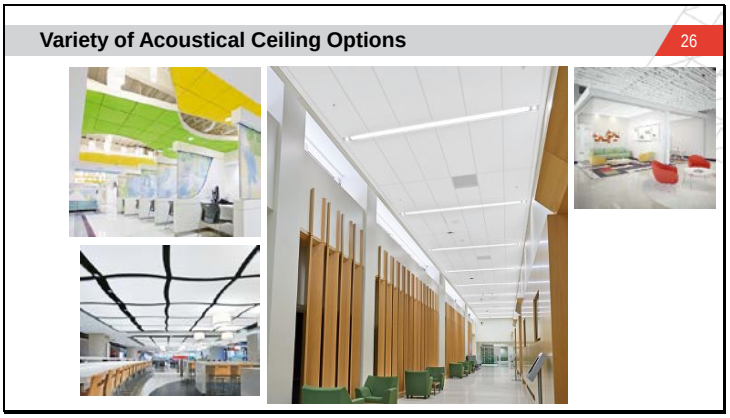

Using the principles of acoustics and the measurement processes available, ceiling manufacturers have been able to advance and refine their product offerings to provide architects and designers with a variety of choices. This variety allows for designs to be optimized for acoustic performance while still addressing visual and other aspects of the spaces.

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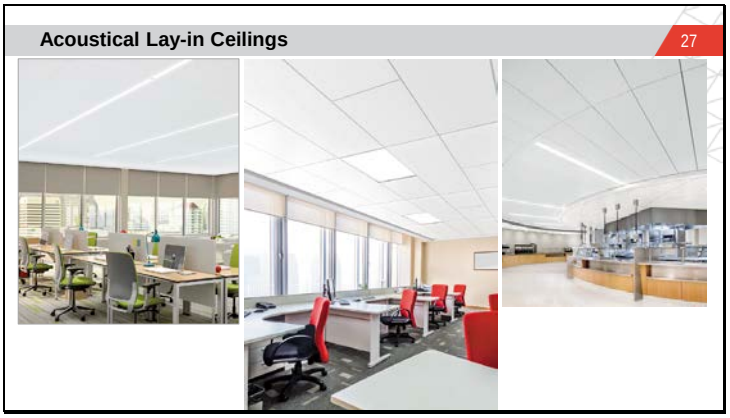

Lay-in acoustical ceiling panels with a suspended grid system have been a traditional choice for many commercial and institutional buildings. They have commonly been available in standard 24-inch square or 24-inch by 48-inch rectangular sizes and made from mineral fiber or fiberglass materials. While these continue to be available and are a rather standard option, a whole new palette of ceiling panels and grid systems are now available.

Ceiling panels are currently available in a wide range of sizes, patterns, and acoustical properties to suit a variety of design conditions. Long, narrow sizes such as 48 or 60 inches long by 6 inches wide are available as well as large 30-inch square panels, among others. It is even possible to specify panels in trapezoidal shapes for situations where the ceiling radiates out visually from a rounded central area or stagger panels to create an Ashlar pattern. To complement new linear lighting layouts, many are available with on center spacing to maintain a more consistent linear visual and move beyond traditional 2-foot by 2-foot and 2-foot by 4-foot modular layouts. Additionally, concealed panels are available in more options than ever before, offering larger panels and visually hiding the grid systems.

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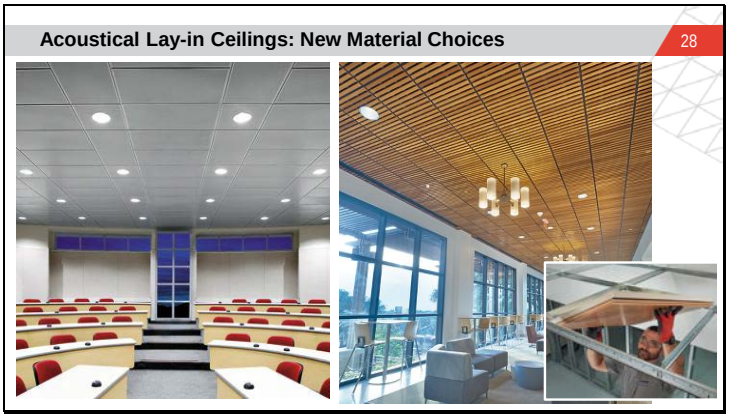

The choice of materials used for lay-in ceiling panels has also been significantly increased. In addition to mineral fiber or fiberglass, panels are also available in wood, metal, plastic, and translucent material with a variety of smoothness or textures. While the variety of materials contributes to the visual appearance and overall “feel” of a space, manufacturers have also included very good acoustic qualities into these ceiling panels. In some cases, that is achieved by using a pattern of very small (even ultra-small) perforations that are not visible when viewing the ceiling from below. Absorbent material is then added behind the panel that deadens the sound that passes through the perforations. The size and spacing of the perforations plus the reflectance of the panel material all combine to create desired NRC and CAC ratings. The ideal balance of NRC and CAC attributes within a single ceiling system create the most flexible performance so that as layouts in buildings change, the performance of the ceiling can cover all requirements, from speech privacy to concentration or collaborative spaces.

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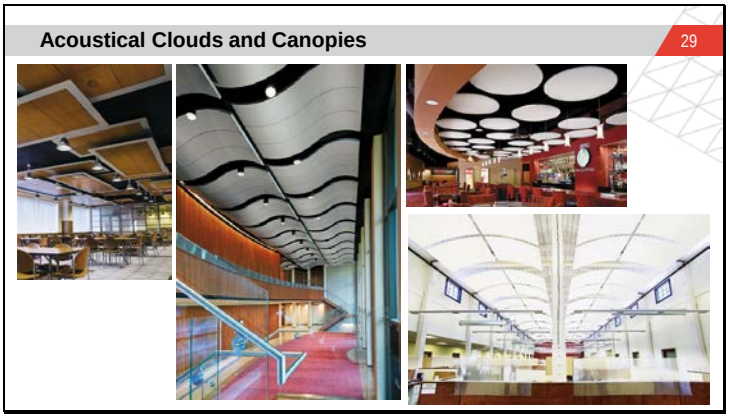

A free-form approach to ceiling design has prompted the use of isolated panel formations that visually float below the structure above, hence promulgating the term “clouds.” While commonly available in square or round formations, the actual size, shape, and material are all variable. In this way, they can be designed to add a degree of acoustic control as well as visual appeal to a space. Similarly, a canopy can be added that is curved such that it adds a true three-dimensional aspect to a space and contributes to the acoustical performance at the same time. Depending on the material, some of these absorb sound from both top and bottom, enhancing control of sound. These canopies are available from manufacturers in a variety of materials as well as a variety of acoustical properties.

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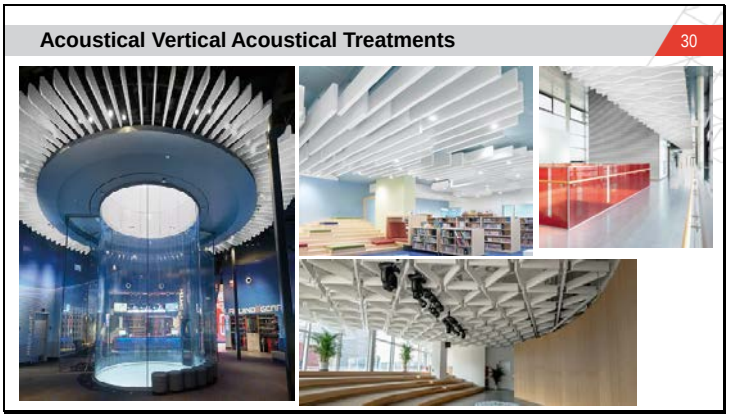
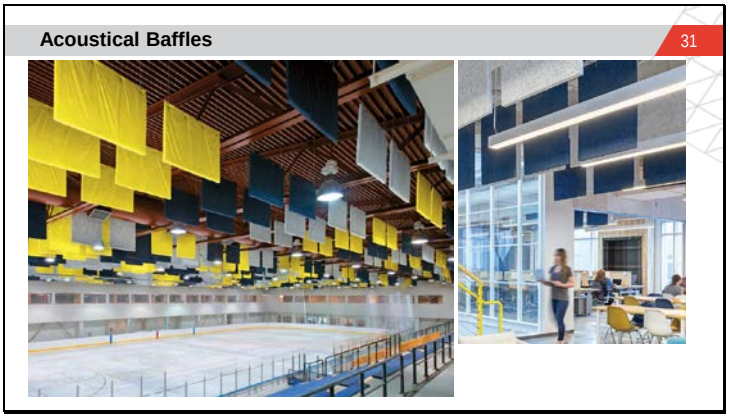


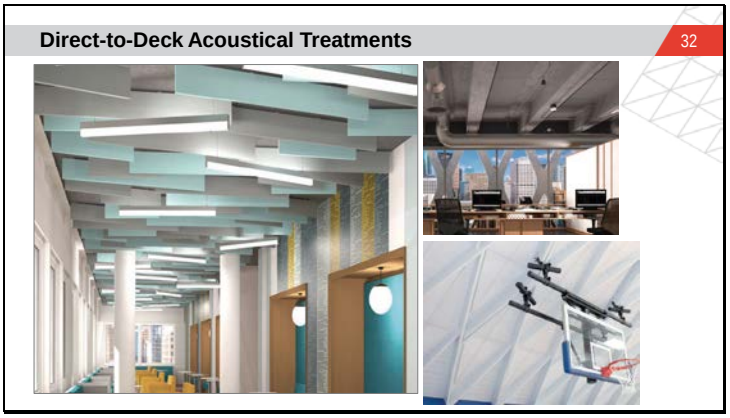
In design situations where the horizontal plane of the ceiling is not desired but acoustic control is, then an alternate ceiling design can be created using vertically hanging acoustical treatments. In some cases, these treatments are long, linear acoustical elements that can be hung in unique configurations to aesthetically define spaces. They are generally available in rectangular standard sizes along with both standard and custom colors. These long, linear treatments can be suspended from a traditional 15/16-inch ceiling suspension system or hung individually from the structure above. Properly designed and installed, they are approved for use in seismic areas and come with many options to achieve exceptional acoustical performance by reducing reverberation time in spaces.

Slide 31



The term “acoustical baffles” applies to vertical hanging acoustical treatments that are commonly larger and shaped closer to squares than rectangles. Baffles are a very good acoustical solution in large spaces open to the roof structure. Tests have shown that it is possible to achieve a 50 percent average reduction in reverberation time with only about 25 percent coverage of baffles in the space. This type of treatment comes in a wide variety of material choices, colors, textures, edge details, and even shapes. They can include up to 100 percent post-consumer woven fabric content or even be made from rapidly renewable bio products. Baffles are also readily seismic approved and easy to install with adjustable aircraft cables. Overall, they add acoustical control to spaces with an exposed structure or roof deck and readily add visual benefits of color and texture to the space.

Slide 32



Another approach to providing noise reduction in exposed structure spaces where your design intent is to maintain a very open plenum look is to use acoustical panels that attach directly to the deck and can be sprayed out in the same color as the deck so the treatment is visually unseen from below. The combination of the coverage area percentage as well as the NRC values play a role in overall reverberation time improvements. Panels with an NRC value of 0.75 or higher would have the greatest impact to provide noise absorption and reduce reverberation time in exposed structure spaces. Some manufacturers provide services to assist you in identifying panel requirements and calculate reverberation times or make reverberation time calculators available tailored to their products. As to installation, these direct to deck materials enable a a fast installation using self-stop screws, so retrofitting spaces is simplified.

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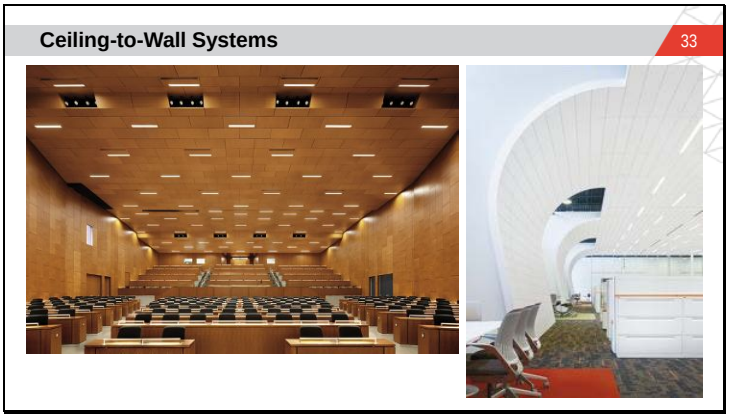

Using the same or similar material on a wall as the one used on a ceiling can make a strong visual statement when it comes to enclosing a space. It can also create a strong acoustic control, depending on the NRC rating of the material used. Seamless, integrated, and flowing transitions between ceilings and walls can be achieved using standard manufactured components. From crisp, 90-degree angles to active, inviting curves that ebb and flow with a particular design, a wide variety of three-dimensional enclosures can be achieved. The material choices are varied as well, including wood with a warm inviting look, metal with a cooler more sophisticated appearance, translucent materials that can add intrigue, or textured fabrics that can do many different things. Together, the combination of material and shape can be very dramatic or simple and understated.

From an acoustical standpoint, the materials used can have a very low NRC rating to create a sound reflective environment that may be required in a nightclub or other active environment. By contrast, a high NRC rated material could be chosen to absorb sound and create a quieter space. Fleece and other backing materials offer this capability and manufacturers offer a package along with tested ratings to ensure reliable performance.

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Use of ceiling materials on walls is often a welcome contributor to absorb sound and improve reverberation time in spaces, therefore improving acoustics. Manufacturers offer tested materials and installation methods to achieve added acoustical benefits in a variety of shapes, colors, and sizes. Selection of systems from the same manufacturer of ceilings and walls often creates a desired uniformity in design of spaces.

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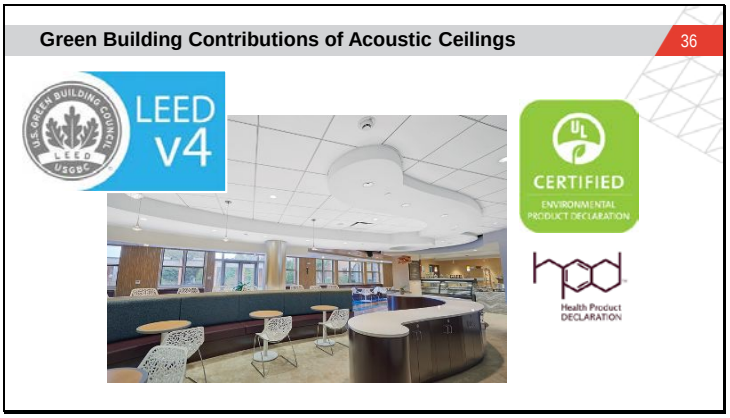

Ceilings are a big part of any building interior so it only makes sense that their sustainability should be addressed. The U.S. Green Building Council's (USGBC's) LEED® rating system contains a number of areas where ceilings can contribute to a higher rating and more sustainability overall. This is true in both current versions of LEED that are in use, namely, LEED 2009 and LEED v4. Availability of manufacturer environmental product declarations (EPDs) and health product declarations (HPDs) has grown in recent years. Other standards have emerged, including The Well Building Standard and The Living Building Challenge. If you are following any of these standards, manufacturers should be able to provide required documentation, with many making a commitment to these sustainability standards.

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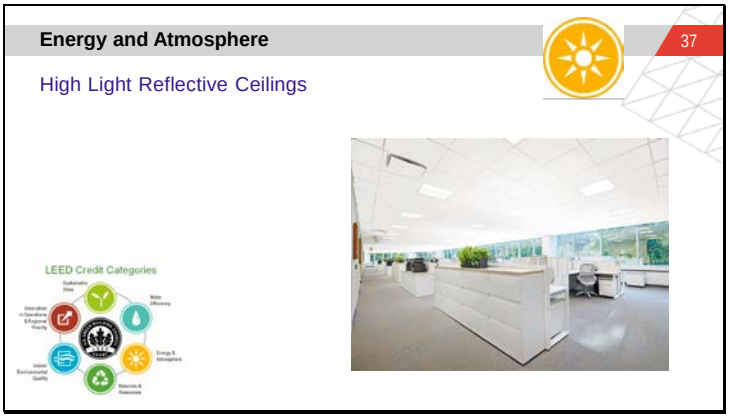

When designing an energy-efficient building, there is a tendency to focus on things like insulation and windows, but ceiling systems can also play a role in effective energy conservation. By using a ceiling system that has higher levels of light reflectance, less artificial light may be needed. Typical acoustical ceilings have a light reflectance (LR) rating of 0.75, meaning that they reflect 75 percent of the light striking is surface. High LR ceilings are made to reflect up to 90 percent of the light striking their surface. This means that the light coming from either natural daylighting systems or electrical lighting systems can be dispersed and spread farther with a high LR ceiling, thus making the space appear brighter with less light needed. This improves space illumination allowing for fewer light fixtures, a reduced electrical light output, lower maintenance costs, and reduced cooling load.

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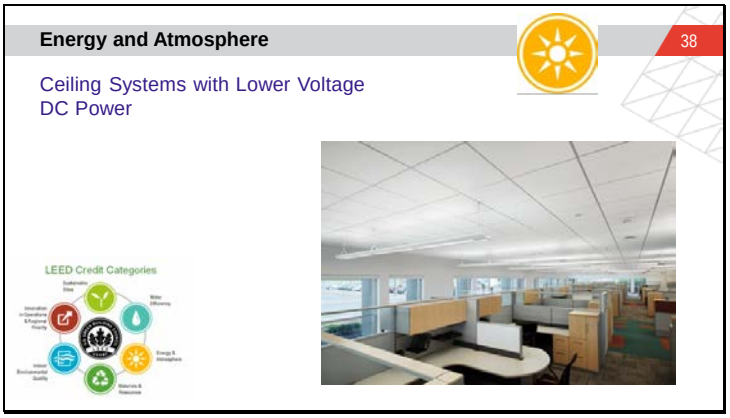

An innovative and emerging trend in energy efficiency related to ceilings is the use of lower voltage direct current (DC) power distributed through the ceiling suspension system to power electric lights. This concept is being actively promoted by the EMerge Alliance®, an open, not-for-profit industry association leading the rapid adoption of safe DC power distribution in commercial buildings through the development of standards. In particular, the EMerge Alliance standard for commercial interiors integrates interior infrastructures (like ceilings), power, controls, and peripheral devices, such as lighting, in a common platform. This is all particularly significant on buildings where on-site solar or wind energy is being generated since the electricity produced in such systems is in DC form. Typically, it would then be converted to alternating current (AC) for use in buildings. However, a DC-based grid system can eliminate energy lost from conversion and help accelerate use of DC-based LED lighting that is easy to locate, connect, and operate.

In LEEDv4, there is now a credit in the Interior Design and Construction (ID&C) system for Design Flexibility which recognizes and rewards different strategies that increase the useful life of the project space. Interior ceiling systems that are movable or demountable can directly contribute to this credit along with accessible ceiling systems. The DC powered ceiling system can also contribute to this credit since it offers the ability to safely alter and reuse interior spaces since the lighting can be repurposed and reconfigured without the need for rewiring.

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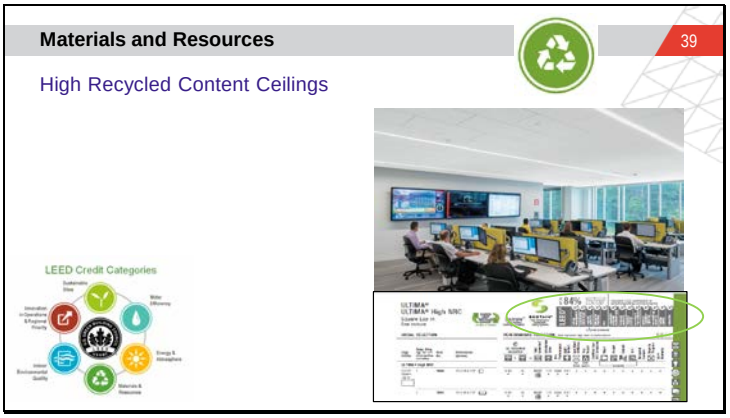

Under LEED 2009, MR Credit 4: Recycled Content allows points for recycled material content in a new or renovated building. Mineral fiber, fiberglass, and wood ceiling products have a recycled content from 47 percent to 92 percent depending on the material specified. Additionally, high recycled content suspension systems and grids made from metals are also available. There are also a growing number of ceiling products that are being made from bio-based rapidly renewable materials, meaning they may qualify under MR Credit 6 for one point. Similarly, if wood ceilings are specified, they may also qualify for an additional point if certified wood is used under MR Credit 7. And of course, when any of these ceiling products are manufactured in the USA that means regional material contribution may be possible under MR Credit 5. If LEEDv4 is being used, there is a new section of credits on Building Disclosure and Optimization. This new area rewards products that have EPDs disclosing the manufacturers life-cycle inventory of a product. The formerly single attributes such as recycled content, FSC certification, recyclable content, etc. are now all part of this life-cycle assessment/EPD process. Currently, EPDs are available for some, but not yet all, ceiling system products.

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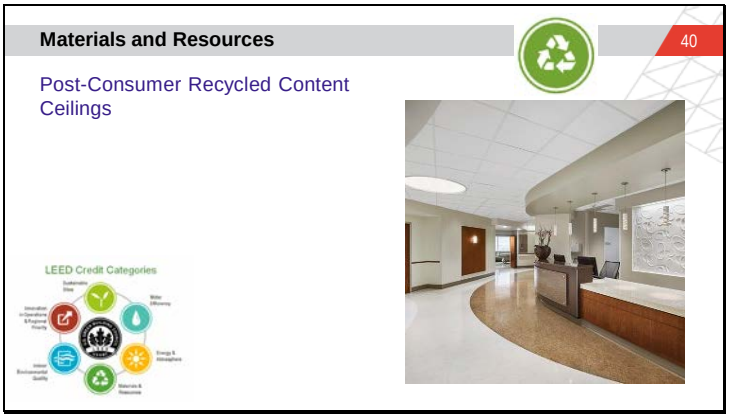

In cases where an existing building is being remodeled, MR Credit 3: Materials Reuse allows either 1 or 2 points based on thresholds of 5 percent or 10 percent of material being reused. Many of the ceiling systems discussed already are long lasting and durable or have built-in flexibility, meaning that they should be considered for ongoing use as part of a renovation project. However, where that is not practical or consistent with other design parameters, then look for a manufacturer that will take back the existing ceilings for recycling and reuse. That will not only be the most appropriate thing for the total life cycle of the ceilings, it can also contribute to 1 or 2 points under MR Credit 2: Construction Waste Management by diverting this material from a landfill.

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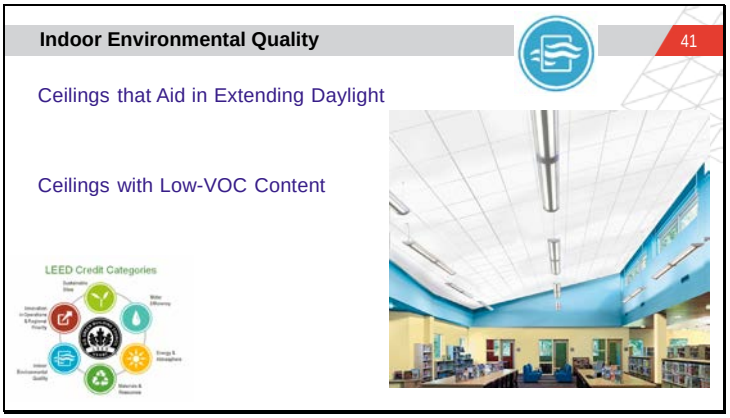

There are a number of ways that ceilings can contribute to improved indoor environmental quality (EQ). We have mentioned the higher light reflectivity option that can aid in extending daylighting into the space. Recent independent studies have shown a 10–15 percent increase in the effectiveness of daylighting designs with the use of these ceilings. That means that indirect lighting is spread further providing higher visual comfort and improving the effectiveness of people working. Beyond this EQ trait, most ceiling products are prefinished and qualify as low-emitting materials due to low or no VOC content in the ceiling panels. Further, no paints, coatings, adhesives, or harmful sealants are typically needed for ceilings so those concerns are eliminated.

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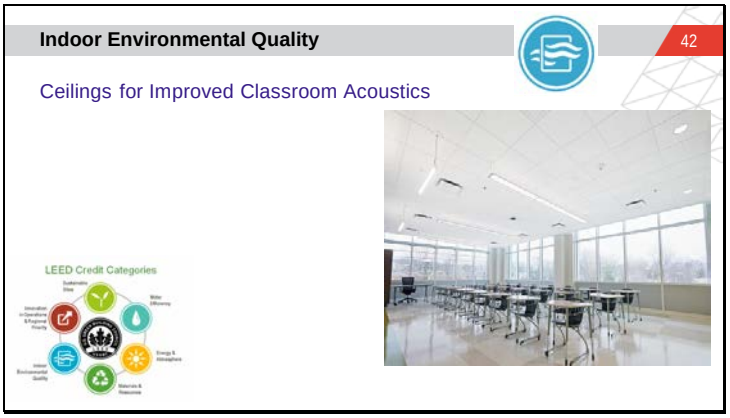

One of the growing concerns in green building design is the role that acoustics can play in terms of indoor environmental quality. In particular, LEED for Schools contains both a prerequisite and a credit possibility for improved classroom acoustics using ANSI Standard S12.60 as the basis for performance. This standard and the IEQ inclusion comes from studies that have demonstrated that excessive reverberation and noise in a classroom interferes with a student's ability to clearly hear their teacher, which obviously affects a student's ability to learn. The standard addresses direct sound, which, in this case, is the sound of a teacher's voice traveling directly from the teacher to the student. This is always beneficial in terms of speech intelligibility because direct sound is not affected by anything in the room, making it clear and distinct. The standard also addresses reflected sound and reverberation time, as they are specifically related to speech intelligibility. Finally it addresses, background noise defined as any sound that is generated outside the building, such as playground activity, traffic, planes, etc. that generally intrudes into the classroom by way of the windows or as noise from within the building, such as HVAC system noise and corridor noise. Using ceiling systems that have appropriate NRC, CAC, and STC ratings plus proper RT measurements for different areas of school building will be necessary in order to meet the prerequisite and the credit point in a LEED for Schools building.

While LEED for Schools is the only version of LEED v4 that has a minimum acoustic performance prerequisite, other LEED rating systems now include a credit for acoustic performance based on acoustic design. These include 1 available point for LEED for New Construction, Data Centers, Hospitality, Warehouses and Distribution Centers, plus up to 2 points in LEED for Health Care. Ceilings can obviously be used to contribute to the overall acoustic design and earning LEED points in this category.

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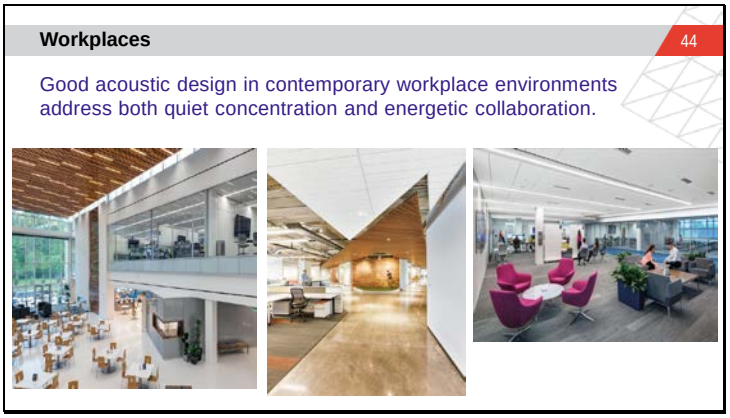

Good acoustic design in contemporary workplace environments address both quiet concentration and energetic collaboration. Studies have shown that noise at the office reduces worker effectiveness, raises stress, and lowers employee satisfaction. To address these issues, speech privacy and excessive reverberation time can be directly addressed using appropriate acoustical design solutions.

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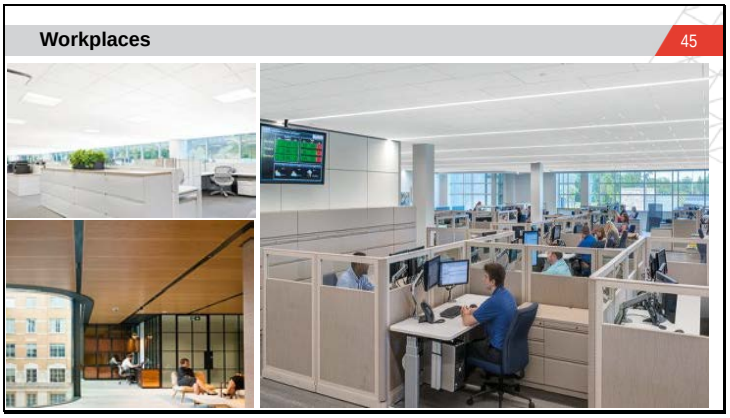

In open-plan offices, contributors of noise can include employee conversations, benching workstations, speaker phones, and also plenum noise from equipment and adjacent private offices and collaboration areas. To counteract this noise, a balanced acoustical design requires high CAC and high-NRC products that absorb sound and keep it from spreading very far from its source. Closed-plan offices will help contain sound within each office, but there is still sound transfer from room to room if walls are built to ceiling height only. In this case, high CAC product, with a minimum of CAC 35, are a must to prevent sound transfer through the ceilings of adjacent offices. Higher STC ratings are needed in the walls for the same sound containment reason.

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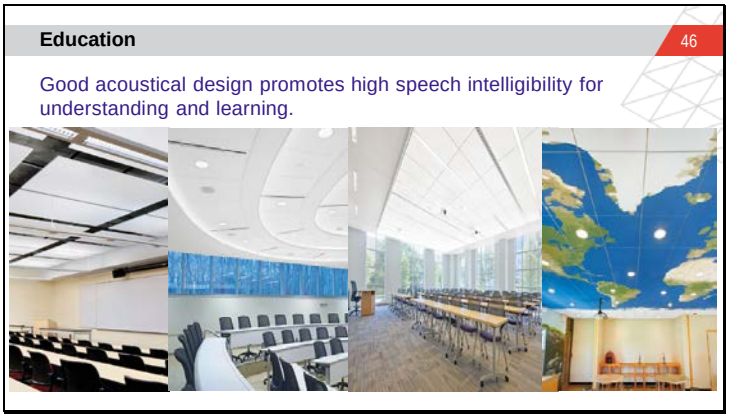

Good acoustical design in schools address high-performing learning environments for students and for teachers. Excessive reverberation and noise in a classroom interferes with a student's ability to clearly hear their teacher. In fact, studies indicate that students typically hear only three out of every four words in the classroom. Good acoustical design promoting high speech intelligibility is key to understanding and learning from all of the words.

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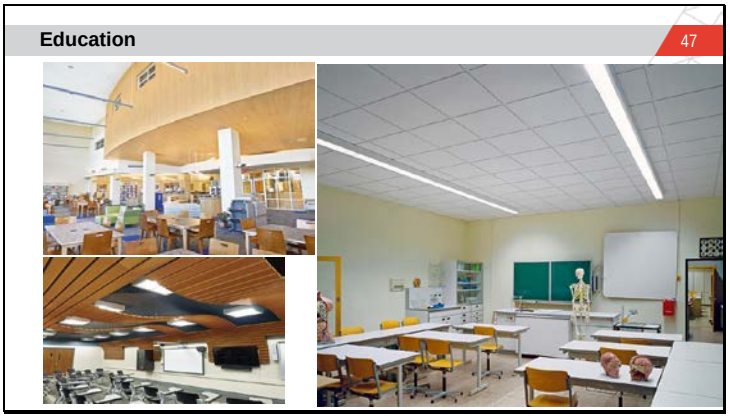

As in workplace situations, acoustical considerations for schools vary by space although all will benefit by being acoustically separated from each other. Classrooms and libraries will generally need to be quieter with higher NRC, CAC, and STC ratings than larger open spaces, such as cafeterias, gymnasiums, or auditoriums that may accept more reverberation. As mentioned earlier, ANSI Standard S12.60 is used as a performance standard in the LEED for schools rating system, but it is a useful standard even if the building is not seeking LEED certification. Among the things that this standard establishes is the need to first design the architecture for good speech clarity using acoustically appropriate materials and systems within the space. Then, in order to protect that clarity and high speech intelligibility, it sets standards for low background noise from neighboring spaces and outdoor sources that can also be addressed by acoustical design principles. Altogether, students and teachers who function in an acoustically designed school will be more effective and happier without the distractions of unwanted sound.

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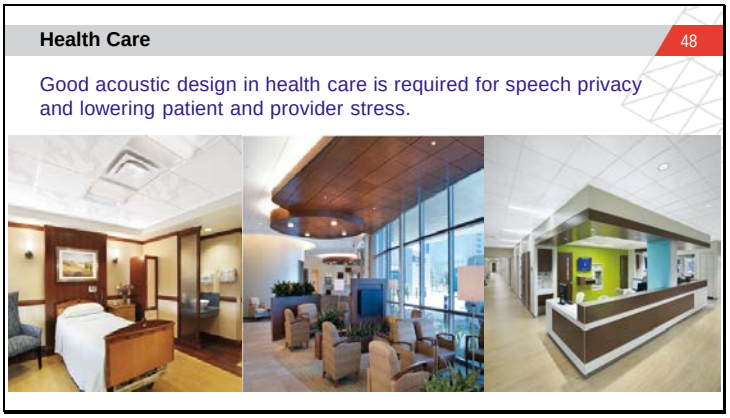

Health-care facilities are increasingly requiring good acoustic design as a functional requirement for speech privacy under the federally mandated HIPAA privacy rule. That means that anywhere patient information is being discussed and there are other people in the vicinity, speech sound must be controlled or absorbed. Hence administrative areas where multiple patients are seen will require areas to meet and talk that have high NRC, CAC, AC, and STC ratings to prevent the unwanted and unlawful dissemination of a patient's private information.

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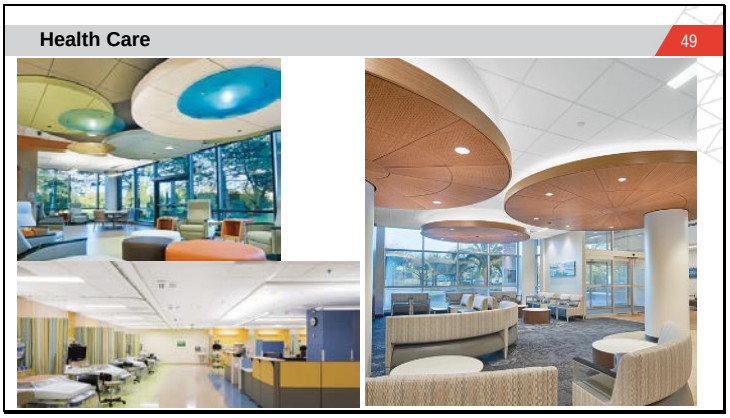

Beyond this basic sound-control need, there is evidence to indicate that optimum patient recuperation occurs when acoustics are taken into account in the design. Excessive noise is created by the 24/7 environment of corridor activity, busy nurses' stations, equipment, alarms, and activity in treatment rooms among other things. Studies indicate that on average, hospital noise levels from all of this activity exceed those set by the World Health Organization.

The significance is that these elevated noise levels are attributed to increasing patient stress and having an adverse effect on patient comfort. The design of health-care spaces can sometimes make this worse by using hard, sound-reflective surfaces by not building walls all the way to the deck above or by failing to treat and isolate high noise areas. Hence, designing to acoustically separate patient rooms from sources of noise and using sound-absorptive materials in areas that are generating the sound can directly contribute to the success of the hospital operations. This will not only help patients but also the health-care staff who can benefit from a more pleasant work environment while reducing the possibility of missed communication due to better speech intelligibility.

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Let's Review!

In this course, we have discussed:

- The fundamental properties of sound.
- Acoustical terms, definitions, and concepts.
- The need for balanced acoustical design by segment.
- How different material selections can influence the acoustic environment.
- The value a balanced acoustical environment to the people in the space.

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Thank You

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This concludes the American Institute of Architects Continuing Education Systems Course.

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