Ceilings account for about a third of interior surface areas in most buildings and are often a building's largest and most visible interior surface. As a result, ceiling design and specification decisions are among the most important prerogatives of design professionals.

A plethora of ceiling systems is available to contemporary designers. While each type may have its place in the contemporary palette, it is arguable that perforated ceilings most fully express the adventurous spirit of contemporary architecture.

Consider:
• Advances in computer-aided design and manufacturing (CAD/CAM) techniques make it affordable to create ceilings of almost any size and shape, ending the aesthetic tyranny of the 2 x 4 feet grid.
• High-speed and versatile perforating equipment allows designers to create an almost unlimited range of visual textures and patterns.
• A new type of wood panel makes it practical to perforate wood, creating exciting new design and performance options for wood ceilings.
• Perforated ceilings can meet the objectives of sustainable construction and are being used in LEED certified buildings.
• New acoustical technology makes it possible to use perforated panels to satisfy the need for improved acoustics in architectural projects.

Form-Giving Potential
Rapid advances in computer-aided manufacturing (CAM) and product engineering have made it possible to fabricate customized perforated panels. Ceiling panels can now be fabricated to almost any size and shape, with design information from architectural drawings used to produce the automated fabrication instructions. This new design process allows architects to break away from the regimentation of traditional grids by using larger panels that better fit the scale of a room and by creating panels with radii and compound curvatures that can flow throughout a freeform space.

Automated punches can make as many as 7,000 perforations per minute. To satisfy the designer’s vision, each hole can be in a unique size, shape, and location. This allows panels to be perforated with an unlimited variety of patterns and unique designs. For example, perforations can be slots, polygons, and oblongs, as well as more traditional circles and squares. Custom perforation patterns can create corporate logos or graphic motifs on the ceiling, and the density of holes can vary from one end of a panel to another to create the illusion of motion.

The planetarium in the Rose Center at the American Museum of Natural History, New York, established a benchmark for perforated acoustical panels. Designed by Polshek Partnership, the 87 ft. diameter sphere is clad with pearlescent metal panels and perforated to absorb noise in the resonant glass-box enclosure. Fabricating the precise compound curvature of the panels was only possible with recent advances in computer-assisted manufacturing.
The same machinery that punches the perforations can also be used to create openings for the installation of lighting and other ceiling-mounted fixtures.

Perforation size, layout, and spacing can vary to create an open area as large as 50 percent or more of a panel. In addition to affecting appearance, this open area has practical implications such as whether fire sprinklers can be installed above a ceiling or whether panels can be backlit to create a luminous ceiling.

Automated equipment can perforate panels at 7,000 holes per minute.

Perforations are also the key to boosting the acoustical performance of panels. In a post-occupancy evaluation of over 180 workplaces, the Center for the Built Environment found that building occupants reported more dissatisfaction with acoustics in their workplaces than any of the other parameters measured. Architectural acoustical demands are higher today due, in part, to the challenges of improving employee satisfaction in open workplaces more than any of the other parameters measured. Architectural acoustical demands are higher today due, in part, to the challenges of improving employee satisfaction in open workplaces than any of the other parameters measured. Architectural acoustical demands are higher today due, in part, to the challenges of improving employee satisfaction in open workplaces than any of the other parameters measured. Automated equipment can perforate panels at 7,000 holes per minute.

Researchers found building occupants report more dissatisfaction with acoustics than any other parameter measured.

Perforated ceiling systems deliver outstanding acoustics. Perforated panels typically achieve noise reduction coefficients (NRC) of NRC .75, and even as high as NRC .95 with additional insulation. More importantly, perforated panels can be tuned to satisfy the acoustical requirements of different rooms, such as providing speech privacy in an open office, clarity in a meeting room, and rich sound in a concert hall. Tuning an installation is accomplished by changing the perforation pattern, the type and placement of any acoustical insulation, and the distance from the panels to the structure above the ceiling. Noise reduction characteristics can vary significantly among similar ceiling products. When specifying ceiling products, architects should review test reports and available information to assess performance qualities. On complex projects, an acoustical consultant can be an invaluable member of the design team.

Recent advances in perforating wood ceilings expand design options still further. Until recently, wood panels were made with wood veneers laminated to wood or particleboard cores. The resulting panels were heavy, especially where large panels were required. The acoustical performance of wood panels was limited by the cost to drill holes in the panels. Even with "gang-drilling," making holes in wood panels was slow. The heat from high speed drilling could char a wood core. This meant that perforated wood panels were practical with only limited design options and a relatively small percentage of the open area necessary for a full range of noise control options. Drilled panels, for example, are typically limited to NRC .45, far below the NRC .75 to .95 required in rooms with critical noise control requirements.

This has changed, however, with the development of wood panels with wood architectural veneers laminated to lightweight cores of sheet aluminum. Until recently, it has been difficult to get enough adhesion between wood and aluminum to meet the challenges of architectural service. This problem has been overcome through the use of new wood panel systems.

A new type of architectural wood panel is made by laminating 1) real wood veneer to 2) light gauge sheet aluminum. For acoustical performance, panels can be perforated and used in combination with 3) an non-woven acoustical fabric insulation.

High levels of noise reduction and glare-free illumination were required in the First Alliance call center in Irvine, CA. To satisfy both requirements, a white non-woven acoustical fabric was attached to the top of perforated ceiling panels and backlit to create a soft, luminous ceiling.

Perforated Metal and Wood

Most perforated ceilings are made of sheet metal. While perforated steel panels are available, the trend is towards the use of aluminum panels that are lighter in weight and can have higher recycled-material content. Metal ceilings are available pre-painted in a wide spectrum of colors, with mirrored or anodized surfaces, and with other unique finishes to fit almost every style or taste.
Wood panels are increasingly used on walls for wood paneling. They have book, slip, or random matched leaves of veneer. In addition to use on ceilings, these new wood panels can be pulled away from the grid so that the springs can be squeezed and released from the grid. Panels can then be removed or swung out of the way for maintenance.

Despite these innovations, new wood panels still meet the quality standards of traditional architectural woodwork. For example, veneers have different grain characteristics depending upon whether they are plain sliced, rotary, quarter, or rift cut. Different visual effects can also be achieved by specifying the panels to have book, slip, or random matched leaves of veneer. In addition to use on ceilings, these new wood panels are increasingly used on walls for wood paneling.

The new wood-metal hybrid panels can be fabricated on the same machinery used to perforate and shape metal panels. The result is panels that weigh as little as one pound per square foot, a fraction of the weight of panels with conventional wood cores. Their light weight makes them easy to handle and install, reduces the cost of the substructure from which a ceiling is suspended, and makes it possible to use wood ceilings in remodeling projects where the existing structure could not carry the weight of conventional wood panels. While the weight of conventional wood panels typically requires them to be mounted permanently in place, hybrid panels can be mounted with torsion springs or other simple connections that allow panels to snap into place and to be removed as required for convenient access above a ceiling. The new type of perforated wood panels also display the same high acoustical performance and design flexibility as metal panels.

**SUSTAINABLE CEILINGS AND LEED**

Environmental characteristics can be critical to the design of a building seeking to comply with the U.S. Green Building Council’s (www.usgbc.org) Leadership in Energy and Environmental Design (LEED) program. LEED provides a framework for achieving sustainability. The program is based upon a checklist of criteria that, if met, earn credits toward LEED certification of the project as a sustainable building.

Over a dozen LEED prerequisites and credits can be impacted by a building’s ceilings. Ceiling systems can contribute directly towards LEED credits. This analysis is based upon LEED for New Construction, Version 2.1. Version 2.2 is scheduled for release in 2006.

**Recycled Material Content (LEED Credit MR-4):**

Ceilings are now manufactured with a wide range of recycled materials, including metal, paper, glass, and slag. Of these, metal ceilings can have the greatest recycled content; some ceilings are now produced with up to 85 to 98 percent recycled aluminum, including as much as 75 percent post-consumer recycled content primarily from beverage containers.

Steel used in ceiling suspension systems can have between 25 percent and 30 percent recycled material content.

There are ready markets for scrap aluminum, and the material can be recycled repeatedly without degradation of its metallurgical properties. Recycled aluminum requires only five percent of the energy needed to make aluminum from bauxite ore. Recycling is a relatively clean process that produces little pollution other than that associated with the energy used to melt and process the metal.

**Perforated Metal and Wood Ceilings: Sustainability, Acoustics, and Aesthetics**

Going beyond tradition, however, the wood-metal hybrid panels offer superior sustainable qualities, such as finishes with zero volatile organic compounds (VOCs) and, when specified, veneers from sustainable forests or rapidly-renewable sources, in addition to the recycled content of their aluminum cores. And while urea formaldehyde, considered a “probable human carcinogen” by the Environmental Protection Agency, is still used in many conventional wood products, the new wood panels have no added formaldehyde.
Perforated ceilings made with rapidly renewable bamboo and recycled aluminum helped earn a LEED Silver Rating for the recently completed Clinton Presidential Library in Little Rock, Arkansas. Designed by Polshek Partnership, bamboo in the 9,000 sq. ft. ceiling was carbonized by heat-treating until it obtained the rich amber color desired by the architect. The bamboo was laminated to recycled aluminum and custom perforated to provide the desired appearance and a high noise reduction coefficient. And because the panels are so lightweight, they could be provided in sizes up to twelve feet long by four feet wide to fit the large scale of the Library’s exhibit halls.

**Rapidly Renewable Materials** (LEED Credit MR-6): Bamboo can grow to harvestable size in as little as three years, regenerates without replanting, and requires minimal fertilization or pesticides. As an ecologically-friendly material, bamboo enjoys growing acceptance as an architectural finish and an alternative to wood in products such as flooring. Recently, bamboo has been introduced as a finish for ceiling panels. Veneers of bamboo are laminated to recycled aluminum cores in the same way described above for wood panels.

**Certified Wood** (LEED Credit MR-7): To encourage environmentally responsible forest management, wood ceilings can be made with veneers from sources certified to maintain sustainable forests. For assurance that wood products delivered to a project are actually from sustainable forests, the ceiling fabricator must be listed with the Forest Stewardship Council (FSC) and must prepare a chain-of-custody certificate for wood building components.

**Low-Emitting Materials, Composite Wood** (LEED Credit EQ-4.4): Whether made from trees or bamboo, the new wood panels contain no added urea-formaldehyde resins in either the aluminum core or the glue used to laminate the veneers.

**Other LEED Credits**

The performance of a ceiling system has a significant impact on a number of other criteria within the LEED program, even if the ceiling itself is not the direct basis for evaluating claims for LEED credits. For example:

**Building Systems Commissioning, Measurement and Verification** (LEED Prerequisite EA-1 and Credit EA-5): For optimum energy efficiency, HVAC and other building systems must be readily accessible for adjustment and maintenance. This means that ceilings must allow access to mechanical or electrical equipment located above the ceiling and that ceiling panels must be easily removable and resilient enough to be handled without damage.

While lay-in grid ceilings allow panels to be removed and replaced, conventional mineral fiber panels are fragile and can be easily damaged. And traditional wood ceilings allow only limited access because such panels are heavy.

These limitations have been overcome by the new generation of metal and wood ceilings. These ceiling systems have exceptionally lightweight panels that reduce the effort required for installation and handling. Their light weight also makes it practical to use larger-than-normal panels to permit improved access to above ceiling equipment. They are mounted onto a concealed grid with torsion springs that allow panels to swing out of the way or to be removed and replaced without special tools.

**Improved Energy Performance** (LEED Prerequisite EA-2 and Credit EA-1): Lighting accounts for an estimated 20 to 25 percent of annual energy consumption in the United States. Improving the light reflectance of ceilings can help conserve this energy. Depending on the finish selected, metal ceilings can provide outstanding light reflectance values. The highest levels of reflectance are provided by polished metals with mirror-like finishes. While these are visually exciting, they create too much glare for use in most spaces. Instead, a light-colored matte finish should be used to diffuse light and create conditions for better visual acuity.

Indirect lighting can often provide better-quality, glare-free illumination than old-style troffer luminaires. Their performance, however, depends upon having a reflective ceiling that will diffuse light uniformly. In addition, a ceiling must be easy to clean to prevent degradation of the lighting.
Minimum IAQ Performance and Ventilation Effectiveness (LEED Prerequisite EQ-1 and Credit EQ-2): Indoor air quality (IAQ) depends, in part, on having air diffusers and ventilation devices that distribute air efficiently and effectively. CAD/CAM fabrication allows metal and wood panels to be fabricated to incorporate diffusers and ventilation devices into an integrated ceiling that offers both high performance and a tailored appearance.

Another IAQ approach is to minimize the potential growth of mold, mildew, and other microorganisms within a building. The new breed of perforated panels has smooth, dense surfaces that minimize opportunities for growth of microorganisms and can be easily cleaned. Conventional mineral fiber ceiling panels often contain cellulose that can provide nourishment for microorganisms. And both mineral fiber panels and glass fiber insulation can retain moisture necessary for microorganism growth. Perforated panels, however, do not have either of these drawbacks since they use a new type of non-woven acoustical fabric that does not support microorganisms.

Construction IAQ Management Plan (LEED Credit EQ-3): Perforated panels contribute only minimally to indoor air contamination during construction because they are fabricated off-site, reduce on-site cutting and finishing, typically do not contain frangible materials that release fibers or dust, and have smooth, dense surfaces that are easy to clean.

Daylight & Views (LEED Credit EQ-8): One of the most useful strategies for bringing daylight into a space is to locate windows as high as possible along exterior walls. This can be at odds with the desire to drop ceilings so that ducts and other utilities can be run above the ceilings. The new generation of ceilings accommodates both needs through the innovative use of curved ceiling panels to create light scoops or accommodate clerestory glazing and high window walls. Equally important are reflective panel finishes that can help make the most of natural lighting.

Perforated Metal and Wood Ceilings: Sustainability, Acoustics, and Aesthetics
Penn State Building Uses Unique Panel System

Penn State University’s new Information Sciences and Technology Building demonstrates that metal ceiling panels can deliver unprecedented precision and customization yet still remain affordable. An S-curve in the building’s plan requires panels that appear to curve, an effect heightened by cantilevered, sloping soffits. The shimmering metal soffit and ceiling panels are contiguous, creating a visually continuous sweep across the 102 foot width of the building. Designed by Rafael Vinoly Architects, the 680 foot long sinusoidal ribbon of ceiling is the building’s dominant visual element.

As the building houses an incubator for the advancement of computerization, it is only appropriate that the ceilings in the project were produced with newly hatched computerized design and manufacturing techniques. Each of the project’s 7,500 panels had to be fabricated in a different size. Calculating the dimensions of the system was “intensely mathematical” says Al Kiechle, senior project engineer at Ceilings Plus, the Los Angeles-based ceiling fabricator. Panels are tapered on both ends and the dimensions of the inclined soffit panels had to be calculated in three dimensions. They vary from 72.6037” in length at the outside curves of the building to 63.2844” on the inside edge of the building’s curves. Kiechle says, “With conventional metal forming techniques, we couldn’t even measure panels with this degree of precision.” Instead, Ceilings Plus used automated high-speed, precision CAD/CAM punch presses and brake forms. “This enabled us to fabricate components with a tolerance measured in ten-thousandths of an inch. The differences were minute, but an error in even one panel would have appeared as a flaw in the geometry of the building.” Kiechle says.

For acoustical control, interior panels have perforations and a non-woven acoustical fabric to create a noise reduction coefficient (NRC) of .75. The factory installed acoustical fabric is gray to match the panel color and reinforce the monolithic appearance of the “inside-outside” plane. Stainless steel torsion springs allow 100% access to the cavity above the ceiling to permit easy access to cables and ductwork serving the computer labs located on the top level.

Special software was used to convert the architects’ digital drawing files into a format that could be read by numerically-controlled perforating and metal-forming equipment, significantly reducing the time and costs required for CAD/CAM fabrication of panels for the project.
BEYOND LEED

While the LEED program incorporates many strategies for greening a building, it is hardly comprehensive. Fortunately, it allows credits for innovation in design. Here are a few sustainability strategies that apply to ceilings yet are not included in the LEED program:

Prefinishing to Eliminate Total VOCs: LEED credit EQ-4.2 can be earned for the use of paints and coatings with low levels of volatile organic compounds (VOC) emissions. As currently written, however, the LEED credit applies only to job-site applied materials. For example, a coating that is field-applied to a wood ceiling must not exceed the VOC limits established by the Green Seal program (www.greenseal.com). If the wood is factory prefinished, however, it does not qualify for the credit even though it does not release VOCs in the field.

Consider the case, too, of a factory-applied coating with a chemistry that releases zero VOCs. For example, UV coatings are cured with high-intensity ultraviolet light that causes polymers in the coatings to crosslink without the release of VOCs. While UV coatings have been used for many years in the furniture industry, it is only recently that a low-sheen UV coating suitable for architectural panels has been developed. The coating produces a durable, non-yellowing, and washable finish that is smoother and more consistent than field-applied coatings.

A similar observation can be made about factory-applied paints. Applicators that roller-coat metal coil, for example, use solvent recovery systems and then burn the vapors to fuel their paint curing ovens, reducing total energy used to paint panels and preventing the release of VOCs into the atmosphere.

Zero VOCs in the factory would seem to be better for the environment than a low-level of VOCs on the jobsite, irrespective of any LEED credits. This means that a designer must sometimes look beyond LEED to see the big picture necessary for sustainable construction.

Prefabrication to Reduce Construction Waste: LEED Credit MR-2 recognizes projects that divert waste materials from the construction job site. Construction waste and demolition debris generates as much as 25% of the solid waste stream in this country. While managing construction waste is important, wouldn’t it be better to eliminate jobsite waste altogether?

Prefabricated metal and wood ceiling systems can be cut to size and for penetrations in the factory where it is usually easier to collect and recycle trimmings. Prefabrication also simplifies installation and coordination at the job site. Where field cutting can not be avoided, aluminum panels are still advantageous for construction waste management. Whereas mineral fiber ceilings can now be recycled at a growing number of collection points, there is no redemption value to the material. Recycled aluminum, on the other hand, has significant salvage value and a ready market, powerful incentives to encourage installer participation in a recycling program.

Designing for Resource Recovery and Reuse: LEED Credit MR-3 addresses the reuse of salvaged or reused materials within the current project. But LEED does not currently recognize the environmental importance of planning for future reuse of building components. In other industries, such as automotive and contract furniture, attention is being given to designing products that can be readily disassembled so that resources can be recovered and reused at the highest possible level.

While it is easy enough to demolish most ceilings systems, reuse of ordinary ceiling materials is unlikely. Mineral fiber panels, for example, are typically discolored after years of use, repainting them reduces their acoustical performance, and panels are too frangible to be collected for reuse. On the other hand, perforated panels resist damage, can be cleaned or repainted without loss of acoustical properties, and can be salvaged intact for any number of reuses.

Life-Cycle Assessment: Another step beyond LEED’s checklist approach is to conduct a rigorous analysis of all environmental consequences of using a product. The Building for Environmental and Economic Sustainability (BEES) program developed by the National Institute of Standards and Technology, for example, attempts to measure “the environmental performance of building products by using the life-cycle assessment (LCA) approach specified in ISO 14000 standards. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management.”

While industry standards for evaluating ceilings are still being developed, perforated ceilings are expected to have a favorable LCA due to the material, energy, and service life factors discussed above.

Optimized Acoustical Performance: It has been said that the most important factor in greening a building is to provide an environment in which people can perform at their optimum level. The California Department of General Services, for example, has found that personnel salary and benefits account for 89 percent of the operational cost of an office building, and any gain in occupant productivity translates into enhanced building sustainability. The widespread dissatisfaction with the acoustics in workplaces referred to earlier leads to costly errors in communication and reduced productivity due to distractions.

ACoustics and sustainability

Perforated panels provide a spectrum of solutions for these acoustical problems. While other types of ceiling panels can reduce, transmit or reflect sound, perforated panels can be designed to function in all three of these acoustical modes.
Sound is the auditory perception of vibration or pressure oscillations that occur in the air around us. The pitch of a tone can be analyzed in terms of frequency and is expressed in hertz (Hz), the number of vibrations or pressure oscillations that occur per second. Humans can generally hear from 20 Hz (low pitch) to 20,000 Hz (high). While we enjoy this full spectrum when listening to a symphony, the critical frequencies for understanding speech typically occur at mid-range frequencies between 125 Hz and 4,000 Hz. Most noises contain a combination or range of frequencies occurring simultaneously.

The intensity or loudness of a sound is related to sound pressure and is expressed in decibels (dB). Because decibels are logarithmic units, a change of 3 dB will be barely noticeable but a 10 dB change will appear twice (or half) as loud. Zero dB represents the threshold of audibility and sound pressures above 100 dB are loud enough to cause deafness and pain. Our ears are an increasingly noisy society, and occupational health and safety regulations limit the duration for which a person may be exposed to very loud noise. Even in less noisy environments, however, attention must be given to noise control if we are to provide optimum living, working and listening conditions.

Noise is propagated and travels in waves in much the same way as ripples spreading out from a pebble tossed in water. Visualizing this can help to understand how sound is reflected when it encounters a hard dense surface, absorbed when it enters a resilient or porous material, or transmitted through a lightweight construction. Sound waves can be also focused or dispersed depending on whether they reflect from a concave or convex surface.

When designing the acoustical environment of a room, one begins by identifying the sources and characteristics of sounds in the space and by defining the acoustical criteria (such as loudness, reverberation, speech intelligibility, etc.) that are required by its occupants. The acoustics of an open office or restaurant, for example, must enable occupants to have intelligible yet private conversations. And in auditoria and conference rooms, sound must be carefully distributed so that performers or speakers can be clearly heard throughout the room. Once these project parameters are determined, ceiling and wall systems can be designed to reinforce performers or speakers can be clearly heard throughout the room. Once these project parameters are determined, ceiling and wall systems can be designed to reinforce

The following formula is used to predict a room’s reverberation time:

\[ T = \frac{0.05}{V} \]

where:

- \( T \) = reverberation time, the time required for a sound to decay 60 dB, in seconds
- \( V \) = room volume in cubic feet
- \( a \) = the total amount of sound absorbing material in a room, measured in Sabins (A Sabin is equal to one square foot of surface that absorbs 100% of the sound falling on it. For example, a window with one square foot of open area would have one Sabin since all of the sound energy impinging on the window would leave the room.)

Based on this, the reverberation time can be decreased by using perforated panels with acoustical insulation to increase the sound absorption \( a \) in a space. Alternatively, reverberation time can be increased by using acoustically transparent perforated panels to increase the volume \( V \) of the space.

Noise reduction is tested at six frequencies, but only four mid-range values are averaged to obtain a Noise Reduction Coefficient (NRC). The graph shows two panels with the same NRC; however ‘A’ has better overall performance, especially in the lower frequencies that are critical for speech.

The noise reducing potential of panels is determined with ASTM C 423 - Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method. Note that test results can vary depending upon how panels were mounted in the test chamber; a test report that replicates the installation conditions expected on the job site should be used. The percent of noise absorbed is typically calculated at six frequencies from 125 Hz to 4000 Hz. To simplify comparisons between acoustical products, the noise reduction coefficient (NRC) is the average of sound absorption tests at 250, 500, 1000, and 2000 Hz, rounded to the nearest multiple of 0.05. These mid-range frequencies are used because they cover the spectrum most important for spoken communication.

While an NRC is useful for preliminary product screening, it should not be relied upon for final product approval. When test data are plotted on a graph, they usually form a gradual curve; a peak in the curve indicates that the tested material is especially efficient at absorbing certain frequencies. This could be desirable if, for example, one needs to dampen the whine from a machine operating at that particular frequency. But if the same insulation were used in a music hall, it would have the disconcerting effect of hushing certain notes. For this reason, it is good practice to ask panel manufacturers to furnish complete product test reports prepared by qualified, independent acoustical laboratories, especially when designing spaces where high quality acoustics are essential.

**ARCHITECTURAL ACOUSTIC FUNDAMENTALS**

**CONTINUING EDUCATION Series**

**ARCHITECTURAL RECORD**

**Perforated Metal and Wood Ceilings: Sustainability, Acoustics, and Aesthetics**

8

**File Name:** AR_Ceilings_Plus

**Writer/Designer:** Angela Hallaki/Alison DelFilippis

**Issue Date:** Dec 05

**Last Revision:** 11-28-05
Noise Reduction: The traditional approach to reducing noise with perforated panels is to use them as a covering over sound-absorbing materials such as glass fiber batts. Perforations allow noise to pass through the panels and into the acoustical insulation while providing a durable and attractive finish system. When sound contacts the fibers in the acoustical insulation, the fibers vibrate and convert mechanical energy into friction and minute quantities of heat. Glass fiber insulation batts with a density of three pounds per cubic foot can deliver NRC .95 in a one-inch thick installation, and an outstanding NRC > 1.00 (equal to absorbing all sound impinging on the ceiling) is even possible when two inches are used.

It is not always practical to use glass fiber batts, however. Installing batts on the backside of a panel, for example, raises concerns about the appearance of a perforated panel. The weight of the batt factors into installation labor. The potential for condensation within the insulation rules them out in moist environments. And the possibility that fibers will slough off the batts makes them unacceptable in certain occupancies.

Fortunately, a new type of non-woven acoustical fabric provides a welcome alternative for use in most perforated ceilings. These paper-thin fabrics, only 0.2 mm thick, can produce an impressive NRC .75 when used with selected perforated panels—performance equal to many conventional acoustical ceiling tiles. The engineered fabrics reduce noise by creating resistance to the air flow caused by the oscillating air pressure of a sound wave. To be effective, perforated panels with acoustical fabric should be installed with at least 16 inches of airspace behind them. This is because air is an elastic medium; if the air cavity behind the panels was shallower, the air would be too “stiff” and would interfere with the air pressure oscillations.

The fabric is available in colors to create visual options: light-colored fabrics can also be backlit to create luminous ceilings. They are self-extinguishing when exposed to flame and are compatible with the Class A flame spread ratings of metal and wood/metal hybrid panel systems.

Acoustical Transparency: A perforated panel must be acoustically transparent for noise to pass through it. Transparency is determined primarily by the percentage of open area in a panel. However, a panel with a single large hole will pass less sound than would a panel of equivalent open area but with many small perforations distributed across its face.

Ceilings are often considered to be boundaries that form a barrier across the top of a room. With perforated panels, however, another paradigm is available: Ceilings are also membranes that connect spaces and filter or modulate sound, light, and air. This makes perforated panels an important component in the acoustical designer’s palette.

The following examples suggest how perforated ceilings can be used as pervious membranes:

1. Perforated metal allows varying degrees of physical separation without creating barriers to sound, light, and air. For example, a perforated ceiling in an atrium can provide visual screening and partial shade for the lower levels while permitting the free flow of sound, light, and air throughout the full height of the atrium.

2. Reverberation time is directly linked to the volume of a space. Where a longer reverberation time is required, a perforated metal ceiling allows the space above the ceiling to be included in the room’s volume. In the Schuster Performing Arts Center, for example, perforated panels allowed the space above the ceiling to contribute to the longer reverberation time required for orchestral performances.

Alternatively, perforated panels can be used to decrease reverberation time by making a space more sound absorbing.
3. Perforated metal panels can be used as a visual screen for speakers and other audio equipment. This approach allows public address speakers and noise masking devices to be inconspicuously located above perforated metal ceilings to maintain a clean and uncluttered overhead appearance.

Acoustical Reflectors: In many rooms, it is useful to have ceilings that absorb noise in certain areas while reflecting or reinforcing sound in other areas. In a conference room, for example, the ceiling over a conference table should be reflective to help a speaker’s voice project across the table, while the perimeter of a room should be absorptive to reduce potentially distracting noise. In addition, reflective ceilings are often required in auditoria where it is necessary to project sound from a stage to the back of an audience.

When a concave ceiling is required, the designer must consider whether it will focus the sound in undesirable ways; if so, perforated ceiling panels can be used to reduce acoustical reflections.

THE NEXT NEW THING

The past decade has been a time of rapid evolution in ceiling designs. This trend appears to be continuing unabated into the foreseeable future. Evidence of this is a recently introduced extensible ceiling system that ships in a nested configuration but slides open in the field to match the width of a room or corridor.

Architects continue to explore more complex geometries for ceilings. Scientists are experimenting with ways to eke greater performance from acoustical materials. Product designers continue their search for more aesthetic opportunities. And the criteria for sustainable construction will undoubtedly become more stringent. Clearly, there is no ceiling on the innovations yet to come.

Author Bio:
Michael Chusid, RA, FCSI is an architectural consultant to Ceilings Plus. His firm, Chusid Associates, specializes in developing and marketing innovative building products.
Program title: “Perforated Metal and Wood Ceilings: Sustainability, Acoustics, and Aesthetics.” (05/12)

AIA/CES Credit: This article will earn you one AIA/CES LU hour of health, safety, and welfare credit. (Valid for credit through December 2006.)

Directions: Select one answer for each question in the exam and completely circle appropriate letter. A minimum score of 70% is required to earn credit.

1. a  b  c  d  e  
2.  
3. a  b  c  d  e  
4. a  b  c  d  e  
5. a  b  c  d  e  

6. a  b  c  d  e  
7. a  b  c  d  e  
8. a  b  c  d  e  
9. a  b  c  d  e  
10. a  b  c  d  e  

Last Name   First Name   Middle Initial or Name

Firm Name

Address   City   State   Zip

Tel   Fax   E-mail

AIA ID Number   Completion date (M/D/Y):

Free! Fee will be paid by Ceilings Plus - mail to: Architectural Record /Continuing Education Certificate, PO Box 682, Hightstown, NJ 08520-0682. For Customer Service, call: 877-876-8093.

Check below:

☐ To register for AIA/CES credits: Answer the test questions and send the completed form with questions answered to above address or fax to 609-426-5592.

☐ For Certificate of Completion: As required by certain states, answer test questions, fill out form above, and mail to above address or fax to 609-426-5592. Your test will be scored. Those who pass with a score of 70% or higher will receive a certificate of completion.

Material resources used: Article: This article addresses issues concerning health and safety.

I hereby certify that the above information is true and accurate to the best of my knowledge and that I have complied with the AIA Continuing Education Guidelines for the reported period.

Signature   Date

Free! Fee will be paid by Ceilings Plus - mail to: Architectural Record /Continuing Education Certificate, PO Box 682, Hightstown, NJ 08520-0682. For Customer Service, call: 877-876-8093.
LEARNING OBJECTIVES

After reading this article, you should be able to:

• Recognize how advances in computer-assisted fabrication techniques create new options for the design of customized ceilings.
• Understand how perforated ceilings contribute toward Leadership in Energy and Environmental Design (LEED) credits and environmental considerations beyond the scope of LEED.
• Know about new hybrid wood panels using wood or bamboo veneer on recycled aluminum cores.
• Understand how the acoustical characteristics of perforated panels can be used to meet a variety of architectural challenges.

INSTRUCTIONS

Refer to the learning objectives above. Complete the questions below. Go to the self report form on page 11. Follow the reporting instructions, answer the test questions, and submit the form.

QUESTIONS

1. Which of the following is not true about the new generation of perforated ceilings?
   a. They allow designers to break away from the regimentation of the 2 x 4 foot grid ceiling
   b. Panels can be curved to create a third dimension as part of the ceiling design
   c. They allow for easy access for maintenance of above-ceiling equipment
   d. Panels are easily damaged by changes in humidity

2. Perforated ceilings may help a project qualify for which of the following LEED credits?
   a. Recycled Material Content (LEED Credit MR-4)
   b. Certified Wood (LEED Credit MR-7)
   c. Daylight & Views (LEED Credit EQ-8)
   d. All of the above

3. Which of the following is an environmental benefit of perforated ceilings that go beyond current LEED criteria?
   a. Restoration of strip mined landscapes
   b. Designed for salvage and reuse
   c. Radio-frequency shielding
   d. All of the above

4. Automated, high-speed manufacturing techniques create which of the following benefits?
   a. Customized fabrication of ceilings at more affordable prices
   b. Factory preparation of openings for light fixtures and other ceiling penetrations to reduce installation time and costs
   c. Less waste due to field cutting to simplify job-site recycling
   d. All of the above

5. Which of these statements is true about the new hybrid wood panels on an aluminum core?
   a. They are heavier than conventional panels
   b. They are difficult to curve
   c. They can be perforated in a wide range of whole sizes, shapes, and patterns
   d. The adhesives used to produce them contain urea-formaldehyde

6. Which is not an acoustical use for metal panel systems?
   a. Amplify sound
   b. Reflect sound
   c. Attenuate sound
   d. Allow transmission of sound

7. Which type of acoustical panel can be repainted without losing acoustical performance?
   a. Acoustical tile
   b. Glass fiber insulation
   c. Perforated metal panels
   d. All of the above

8. What type of acoustical insulation is increasingly being used instead of traditional glass and mineral fiber insulation to increase the noise reduction of perforated panels?
   a. Wheat straw agriboard
   b. Non-woven fabric
   c. Lead sheet
   d. Autoclaved aerated concrete

9. In which building type might a long reverberation time be desirable?
   a. Lecture hall
   b. Open plan office
   c. Church
   d. Broadcast and recording studio

10. Why is it good practice to select acoustical products based upon test reports and not just an NRC?
   a. NRC results are difficult to interpret
   b. Testing is required by building codes
   c. Idiosyncrasies at certain frequencies could be obscured by an NRC’s averaging
   d. Test laboratories guarantee the acoustical performance of a building

www.ceilingsplus.com  800-822-3411

Ceilings Plus (www.ceilingsplus.com) is the leading specialty ceilings producer. Using computer-assisted design and manufacturing, the company fabricates ceilings and walls that are architectural, functional, and affordable. Products include curved Radians™ and extensible Runways™ panels, plus Arboreal® panels with wood veneers on aluminum cores. Panels can be almost any size or shape and perforated to enhance appearance and acoustics.

For sustainability, Ceilings Plus panels can have recycled content as high as 85 to 98%. Arboreal veneers can be FSC-Certified or rapidly-renewable bamboo. Panels have no-added formaldehyde and zero VOCs. Ceilings Plus products are durable, easy to maintain, accessible and offer outstanding life-cycle value.

Advertising Supplement Provided By Ceilings Plus