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Designing Stone Wool Ceiling Assemblies

by Cory Nevins

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SPECIFIERS HAVE AN INCREASING NUMBER OF CHOICES FOR COMMERCIAL CEILING SYSTEMS. AMONG THE PERFORMANCE CONSIDERATIONS FOR SELECTING THE MOST APPROPRIATE FOR A PARTICULAR APPLICATION ARE ACOUSTICS, FIRE PERFORMANCE, HUMIDITY RESISTANCE, HYGIENIC PROPERTIES, DIMENSIONAL STABILITY, INDOOR AIR QUALITY (IAQ), AND LIGHT REFLECTION. ADDED TO THESE ARE VARIOUS CHOICES THAT PERTAIN TO DESIGN AESTHETICS, EASE OF INSTALLATION, MAINTENANCE, DURABILITY, SUSTAINABILITY, AND COST.

Stone wool ceiling panels and metal suspension systems meet these selection criteria for both new construction and renovation projects throughout North America. The material was discovered on the islands of Hawaii, where it occurs naturally as a by-product of volcanic activity. The primary rock involved is basalt, the earth's most abundant bedrock. The igneous material forms by the rapid cooling of lava from eruptions on the sea floor. Seismic activity, including the earth's volcanoes, produces 38,000 times more rock material than is used by the world's largest producer of stone wool.

The typical production process for stone wool begins with the fusion of this volcanic rock at a temperature of 1500 C (2732 F). Emerging from the furnace, the melt runs

out of the bottom and onto a spinning machine, where wool is whipped into thin strands, similar to making cotton candy. The strands form 'wool,' held together with minor amounts of organic binders.

Now a fleecy web, the material is gathered and formed; the number of layers varies depending on the final product's desired structure and density. The layered fibers then move to a curing oven. Once cured, the wool emerges with non-directional fibers that contribute to its multiple performance characteristics of the stone wool products. In addition to ceiling panels, stone wool's unique combination of thermal, fire, and acoustic properties make it suitable for:

- blown insulation in cavity walls;
- rolls of loft insulation;
- pre-formed and faced pipe sections; and
- wall slabs.

A mineral fleece and water-based paint are layered on top of the stone wool to produce the finished ceiling panels. The stone wool products proceed to cutting saws, finishing and packing equipment, or are led to off-line equipment for special treatment. The majority of the waste created during the production is fully recyclable.

Use of suspended ceilings

Since the 1950s, drop ceilings have been the preferred method for concealing HVAC vents, electrical wires, plumbing pipes, phone cables, and security lines in interior commercial buildings. These suspended, interconnected ceiling systems consist of a metal grid comprising cross-tees and main runners.

The main runners are suspended by hanger wires from the structure above, and wall channels or angles provide a clean look throughout the perimeter. Panels are used to conceal the plenum—hiding the visible structure, suspension system, HVAC, and other equipment, while providing simple access for future maintenance.

The suspension ceiling system is selected for aesthetics, maintenance, and specialized performance such as fire resistance, seismic mitigation, or limited accessibility in security applications. For all ceiling designs, specifiers should check the suspension systems are manufactured to ASTM International standards. On request, suspension manufacturers may provide reports from the International Code Council (ICC) and third-party seismic performance testing and certification reports.

Stone wool ceilings offer good sound absorption, high light reflectance, fire protection, and humidity resistance. These panels are well-suited to create modular ceiling designs, such as long corridors.

Corrosion resistance is also a priority for metal suspension systems supporting stone wool and other ceiling panels. The industry standard is 23.8-mm (15⁄16-in.) galvanized steel for suspended metal ceiling grids; most may be specified with a minimum of 25 percent recycled content.

While the ceiling panel's size, orientation, color, finish, and edge largely determine the overall aesthetic, changing the size of the grid's face also changes the appearance.

For example:

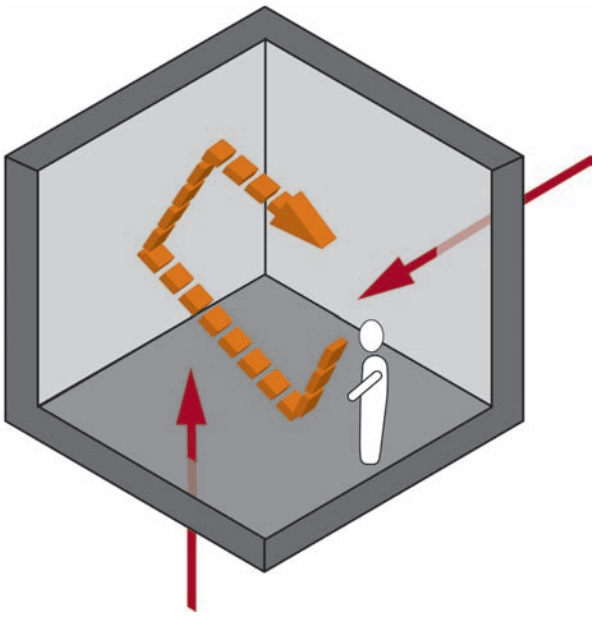
- a 14.28-mm (9⁄16-in.) narrow face diminishes the distinction between grid and panel for a more monolithic look;
- adding a 3.17-mm (1⁄8-in.) slender, center regress with a 'bolt-slot' design accentuates the shadow between panel and grid;
- mitered intersections provide crisp, continuous lines for a uniform ceiling plane;
- wide-face 34.92-mm (1 3⁄8-in.) ceiling suspension offers bolder expression of the ceiling grid modules, especially at high elevations; and
- in curved drywall applications, radius systems create concave and convex shapes, including barrel-vaulted ceilings.

Specifying acoustic comfort

According to the World Health Organization (WHO):

noise seriously harms human health by causing short- and long-term health problems. Noise interferes with people's daily activities at school, at work, at home and during leisure time. It can disturb sleep, cause cardiovascular and psychophysiological effects, hinder work and school performance and provoke annoyance responses and changes in social behavior.[1]

Therefore, it could be argued design professionals have a duty to create acoustic comfort and well-being for the occupants of their buildings. Stone wool can help with two primary components of acoustic comfort: speech intelligibility and noise reduction.



When a sound wave hits a surface, part of the energy is reflected, part of it is absorbed by the material, and the rest is transmitted. Undesired sound from various potential sources can include noise transmitted into the building from the exterior, or coming in from other interior spaces.

The material's airflow resistance and density contribute to its high noise absorption properties. The fibers' size and non-directional orientation lead to stone wool's inherent sound-absorbing qualities. The measures and concepts discussed in this article provide a foundation for understanding the relationship between stone wool's characteristics as a material and achieving acoustic comfort.

Speech intelligibility

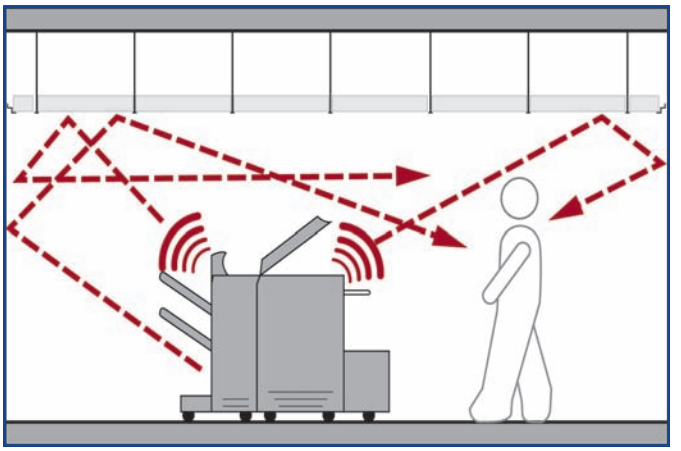
One important component of acoustic comfort and sustainability, speech intelligibility refers to a listener's ability to hear and understand a speaker in a room or space. It is measured as a signal-to-noise ratio, expressed in decibels (dB). For this application, the signal typically is speech and the noise usually is everything else in the background.

Reverberation time

An important factor for creating speech intelligibility, it is defined as the time it takes for the sound pressure level to decrease 60 dB below its original level. In most situations (excluding unamplified music performance), a lower reverberation time improves speech intelligibility and acoustic comfort. For most rooms requiring speech intelligibility, mid-frequency reverberation time should be between 0.50 and 1.00 seconds when the room is unoccupied.

Noise reduction coefficient

The noise reduction coefficient (NRC) indicates a surface's ability to reduce noise by absorbing sound. It is calculated by averaging the absorption coefficients from the 250-Hz, 500-Hz, 1-kHz, and 2-kHz octave bands. It varies between 0.00 (*i.e.* absorbs very little sound) and 1.00 (*i.e.* absorbs a lot of sound). NRC is one of two important variables in determining reverberation time (the other being room volume). A higher NRC indicates more noise reduction (or sound absorption) and leads to lower reverberation times and greater speech intelligibility. Stone wool ceiling products typically have an NRC of 0.85 or higher.



The noise reduction coefficient (NRC) refers to a surface's ability to reduce noise by absorbing sound. NRC is important in areas where high levels of noise (like a photocopier) are present.

Background noise

Undesired sound from various potential sources can include noise transmitted into the building from the exterior, or coming in from other interior spaces. It can also include sounds generated by the building's systems or even those reverberating too long inside the room.

Speech intelligibility

Factors influencing speech intelligibility include:

- speech signal's strength and clarity;
- sound source's direction;
- level of background noise;
- room's reverberation time and shape; and
- listeners' hearing acuity and attention span.

Reverberation time depends on two main variables: the volume of the room and the amount of sound-absorbing materials. As volume decreases or as the amount of sound-absorbing materials increases, reverberation time decreases and speech intelligibility generally increases. Since the volume of the room often depends on functional and aesthetic criteria, reverberation time is often solely dependent on the amount and efficacy of sound-absorbing materials.

In many cases, placing sound-absorbing materials on the walls is not desirable due to its tendency to get damaged, dirty, or worn because of occupant contact. As a result, whether speech intelligibility is poor, fair, or good can highly depend on the ceiling specified. This is why acoustic standards and guidelines

for schools, hospitals, offices, and other types of facilities have minimum NRCs of 0.70 and up to 0.90. Stone wool ceiling panels, more than other panels made of less-absorbing materials, help ensure projects comply with acoustic performance requirements in these standards and guidelines.

Even if reverberation time is appropriate, speech intelligibility can be low if the background noise in the room is too loud. Speech intelligibility equates to a high signal to noise ratio. Consequently, it is also important to ensure noise from the exterior, other interior spaces, and from the building's systems is controlled.

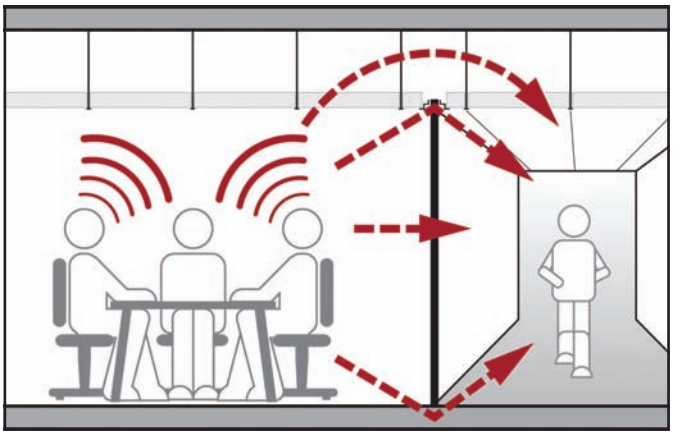
Noise reduction

In other rooms or spaces like open offices, cafeterias, libraries, and gymnasia, speech intelligibility is not the primary acoustic goal; rather, the push is for overall noise reduction for stress relief and concentration. Noise reduction equates to an overall decrease in sound pressure level from loud continuous noise (*e.g.* traffic noise transmitting into the building), as well as event-specific noise (*e.g.* a crying baby). The sound pressure level in a room depends on the strength of the sound source, the room's size, and the quantity and quality of sound-absorbing surfaces.

Just 30 decibels of periodic noise can be disturbing to sleep or concentration. Conversational speech is generally between 50 to 70 dB. Noise with sound levels of 35 decibels or more can interfere with speech intelligibility in smaller rooms. This is demonstrated by a phenomena known as the 'cocktail party effect,' whereby as noise levels get louder and louder, people try to talk louder and louder to be understood. Despite their efforts, speech intelligibility decreases and acoustic stress increases. It is not until someone leaves the 'party' that they realize just how agitated they were as their muscles begin to relax, heart rate slows, and respiration deepens. Stone wool, because of its high noise-absorbing characteristics, also helps achieve the overall noise reduction goals.

Whether sound reduction is needed for speech intelligibility or overall acoustic comfort, blocking noise that could be in the plenum above the ceiling can also be important in some instances. As more acoustics standards and guidelines place minimum noise control criteria on wall constructions (*i.e.* sound transmission class [STC]), the need for ceilings to block noise from adjacent spaces traveling via the overhead plenum is becoming less frequent. This is because achieving the minimum STC wall requirements necessitates the walls be extended up to, and sealed against, the underside of the deck above them. However, in the cases where the walls do not extend full height, or where there may be noisy mechanical equipment in the plenum, the ceiling also may need to block noise from transmitting into the space below them.

Ceiling attenuation class (CAC) indicates the ceiling's ability to prevent airborne sound from traveling between adjacent rooms when the demising walls do not intersect with the structural deck above. CAC is also a good measure to judge how much protection is offered against noisy mechanical equipment in the plenum. The higher the CAC value, the greater the ceiling's blocking capacity. A CAC value of 35 dB is considered to be moderately high and may be specified for stone wool ceiling panels. When even higher sound-blocking capacity is required, stone wool ceiling panels can be specified with a CAC value up to 43 dB in combination with a high NRC of 0.85.



Insulation influences the sound level in the receiving space, helping provide more privacy between rooms and better concentration in the adjacent room.

Fire performance

Every second counts once a fire has started. Specifiers know choosing the right building materials can delay the spread of fire and provide the vital extra minutes needed to save the occupants and limit the damage.

Given its volcanic origins, stone wool can withstand temperatures up to 1177 C (2150 F). It is non-combustible, will not develop toxic smoke, and does not contribute to the development and spread of fire even when directly exposed to fire.

Ceiling panel products are required to be tested for surface burning characteristics to Underwriters Laboratories (UL) 723/ ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*. Testing requires 7.31 m (24 ft) of material to be exposed to a flame ignition source in a Steiner Tunnel Test to determine how far the fire will spread during 10 minutes, and how much smoke is developed during this period.

The test was developed by Al Steiner of UL and has been incorporated as a reference into North American standards for materials testing. The progress of the flame front across the test material is measured by visual observation, while the smoke emitted from the end of the test assembly is measured as a factor of optical density. A Flame Spread Index and a Smoke Developed Index are calculated from these results. Both indices use an arbitrary scale in which asbestos-cement board has a value of 0, and red oak wood has a value of 100.

Many commercial applications require a Flame Spread Index of 25 or less and a Smoke Developed Index of 50 or less. Products labeled "FHC 25/50" (Fire Hazard Classification 25/50) or "Class A" (ASTM E1264, *Standard Classification for Acoustical Ceiling Products*) fulfill these requirements. Stone wool ceiling panels may be specified to meet the most stringent requirements with a maximum Flame Spread Index of 0 and a maximum Smoke Developed Index of 5.

Humidity and hygienic attributes

Humidity can weaken the structure of certain ceiling materials, causing them to sag and, in extreme cases, even fall out of the suspension system. This often happens in buildings under construction where the building is not yet temperature- and humidity-controlled, or materials have not yet dried. Additionally, humidity levels are naturally high in wet rooms like kitchens and sanitary areas, and moisture problems may occur.

The stone-wool core in acoustic ceiling panels can be specified as hydrophobic, which means it neither absorbs water nor holds moisture. This makes the ceiling panels 'sag-resistant,' even up to 100 percent relative humidity (RH) and in temperatures ranging from 0 to 40 C (32 to 104 F). The material is dimensionally stable and does not warp, curl, or cup. It also neither rots nor corrodes. Further, its characteristics remain unaltered over time, maintaining its dimensions and physical characteristics throughout a building's lifecycle.

Since stone wool is inorganic, it also does not promote the growth of mold or bacteria. North American studies show a relationship between mold and damp conditions, and an increase in allergic reactions, along with eye, nose, and throat irritation.[2] They have also been associated with litigious concerns that some commercial building owners have termed 'sick building syndrome.'

Twenty-three percent of office workers experience frequent symptoms of respiratory ailments, allergies, and asthma. The impact has been an increased number of sick days, lower productivity, and increased medical costs. The economic impact is enormous, with an estimated decrease in productivity around two percent nationwide, at a cost of $60 billion annually.[3]

Helping maintain cleanliness, stone wool ceiling panels may be specified with a smooth, non-textured finish that can be vacuumed with a soft brush attachment. Specially treated hygienic and medical surface finishes allow cleaning with water and some diluted disinfectants, such as chlorine, ammonia, and quaternary ammonium. In some cases, specially treated surface finishes on stone wool ceiling panels allow for more intensive cleaning, such as steam cleaning twice a year following a defined protocol.

Stone wool, the core material of stone wool ceiling products, can withstand temperatures up to 1177 C (2150 F). It is made from basalt rock and is non-combustible; it will not contribute to the development and spread of fire.

Stone wool acoustic ceiling products that have been certified to GreenGuard Gold certification standards for low chemical emissions into indoor air during product usage are suitable for environments such as schools and healthcare facilities.

Sustainability

In addition to being composed from the earth's most abundant bedrock, stone wool ceiling panels can contain up to 42 percent recycled content. When removed, undamaged stone wool products may be reused or recycled for other projects. However, if recycling, one should be observant of recycling plant locations.

Stone wool is an excellent thermal insulator and contributes to energy-efficient buildings. Stone wool ceilings' reflective, smooth surface also can play a significant role in enhancing energy efficiency through better light distribution. The health benefits of natural light include a more positive mood, improved productivity, and lower absenteeism.[4] Maximizing use of natural daylight may allow a reduction in the number of lighting fixtures. The subsequent lowering of electric loads may reduce cooling costs.

Further contributing to sustainable goals, stone wool ceiling panels may be specified with UL Environment's Greenguard Gold Certification for low-emitting products. Certification is only given to products compliant with the associated requirements, which among others include stringent limits on emissions of more than 360 volatile organic compounds (VOCs).

UL Environment states indoor air can be two to five times more polluted than outdoor air. Greenguard Gold criteria incorporate health-based emissions requirements as denoted by the U.S. Environmental Protection Agency (EPA), the State of California Department of Public Health's Section 01350, and others.

More than 400 green building codes, standards, guidelines, procurements policies, and rating systems give credit for Greenguard products. Certification also fulfills the low emission requirements of the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) v4 program, and the Collaborative for High Performance Schools' Criteria (CHPS) for low-emitting materials.

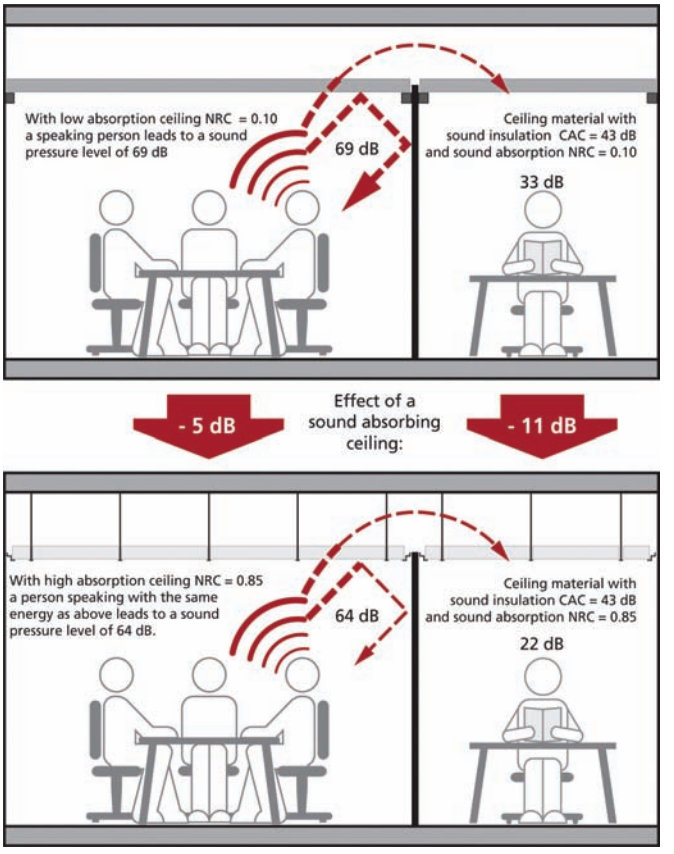
Aesthetic design

Beyond sustainability and performance, there are numerous aesthetic considerations in selecting the best stone wool ceiling panels to achieve the desired architectural expression.

Shape

The shape of a stone wool panel's edge significantly contributes to the ceiling's overall appearance. Demountable options include:

- square lay-in—cost-effective, provides easy access to the plenum, and mounts in standard suspension systems;
- tegular—square or angled, hangs on a visible and recessed suspension system that creates a shadow between the tiles, and mounts in standard suspension systems;
- semi-concealed—appears to float under the suspension system, the profiled edge and deeply recessed grid profiles presents an elegant shadow (an effect emphasized by specifying the suspension system in black); and
- concealed—hides the suspension system to create a monolithic appearance, but only some concealed panels are demountable.



In practice, there is a strong link between sound absorption and room-to-room sound insulation. This link may not be accurately reflected in laboratory testing. In practice, two ceilings with the same ceiling attenuation class (CAC), but different NRCs, produce different levels of perceived sound insulation. The ceiling with the highest NRC will do a better job of lowering the sound pressure in both the sending and the receiving room.

Another option is the direct-mount assembly, where ceiling panels are directly bonded to the structural soffit or an existing ceiling surface. These systems are for areas where ceiling heights do not permit the use of the suspension setup.

Panels are not limited to two dimensions of squares and rectangles; they may be three-dimensional cubes. Baffles and clouds provide an alternative for rooms where contiguous ceilings are unsuitable. They are suited to thermal mass applications where the soffit needs to be left exposed. They can be used as as a retrofit or to create a design feature.

A wide range of sizes contributes to the design freedom and flexibility offered with stone wool ceiling panels. By combining different module sizes, even small rooms may seem larger and long corridors can seem less distant. The line of a ceiling

impacts the perception of a space and creates focal points that may show direction, outline an object, or divide a large space into more comfortable zones.

Horizontal lines convey stability, grounding, and direction. Vertical lines, on the other hand, also communicate stability, as well as pillar-like attributes of strength and balance. Diagonal lines are perceived as dynamic and transformational with overtones of freedom, while curves are considered playful, organic, and soothing.

Texture and color

Based on today's design styles, stone wool ceiling panels are preferred in smooth and lightly textured surface finishes. This gives the impression the ceiling is lighter in texture, weight, and color. White and neutral tones are the most popular color choices for interior ceilings. For more vibrant spaces, stone wool ceiling panels can be specified in a breadth of other hues.

A viewer's perception and relation to a color changes depending on whether it stands alone, is dominating a space, or if it is in play with other colors. It also is influenced by the quality and quantity of light hitting it.

Colors evoke physical and psychological reactions, and the brightness or color temperature creates different moods and ambiance: Warm colors—such as red, orange, and yellow—are considered stimulating. Cool colors—like blue, purple, and light green—generally have a calming effect.

Spatial perception is also affected by color. Lighter hues tend to make spaces seem bigger, while darker ones make spaces feel intimate. A dark ceiling will seem lower than it really is, or—when installed high enough—simply disappears.

Color schemes also can indicate the purpose and usage of a space through the creation of boundaries and transitions. Consideration should be given to how the visual stimulation in a space will be perceived by the brain to evoke a desired response. This is of utmost importance in environments where varied spaces have different tasks and functions, to avoid any confusion that can cause stress in the occupants.

Segment-specific demands

Color certainly has a place in educational settings, but aesthetics may need to be secondary to performance requirements. Fire performance and indoor air quality are top-of-mind, and acoustics also need to be of primary importance. Classrooms in the U.S. typically have speech intelligibility ratings of 75 percent or less, meaning every fourth spoken word is not understood.[5] Loud or reverberant classrooms may cause teachers to raise their voices, leading to increased teacher stress and fatigue.[6]

In school activity areas, stone wool ceiling panels may be specified with both a high acoustic performance and impact-resistance. The panel's reinforced surface withstands tougher-than-average wear and tear, as well as the stress of frequent mounting and demounting.

Along with durability and flexibility for future redesign, health care facilities seek products with easy-to-clean surfaces to support infection control. Most Methicillin-resistant Staphylococcus Aureus (MRSA) infections occur in people who have been in hospitals or other health care settings and are resistant to the antibiotics commonly used to treat ordinary staph infections.[7]

Stone wool ceiling panels designed for medical use have been classified Class 5, or better, in accordance with International Organization for Standardization (ISO) 14644-1, *Cleanrooms and Associated Controlled Environments–Part 1: Classification of Air Cleanliness*. Those that have specially treated medical and hygienic surface finishes also help mitigate:

- MRSA bacteria resistant to antibiotics and responsible for post-surgery infections and septicaemias;
- Candida Albicans, which is yeast responsible for skin infections and pneumonias; and
- Aspergillus Niger, which is mold responsible for pneumonias.

Noise also contributes to patients' slower recovery times. Studies show high levels of sound have negative physical and psychological effects on patients by disrupting sleep and increasing stress.[8]

With respect to auditory privacy, acoustic performance not only is relevant to patient decency and respect, but also to the protection of corporate intellectual property, and to increased concentration levels in working environments. After surveying 65,000 people over the past decade in North America, Europe, Africa, and Australia, researchers at the University of California-Berkeley reported more than half of office workers are dissatisfied with the level of speech privacy, making it the leading complaint in offices everywhere.[9]

Conclusion

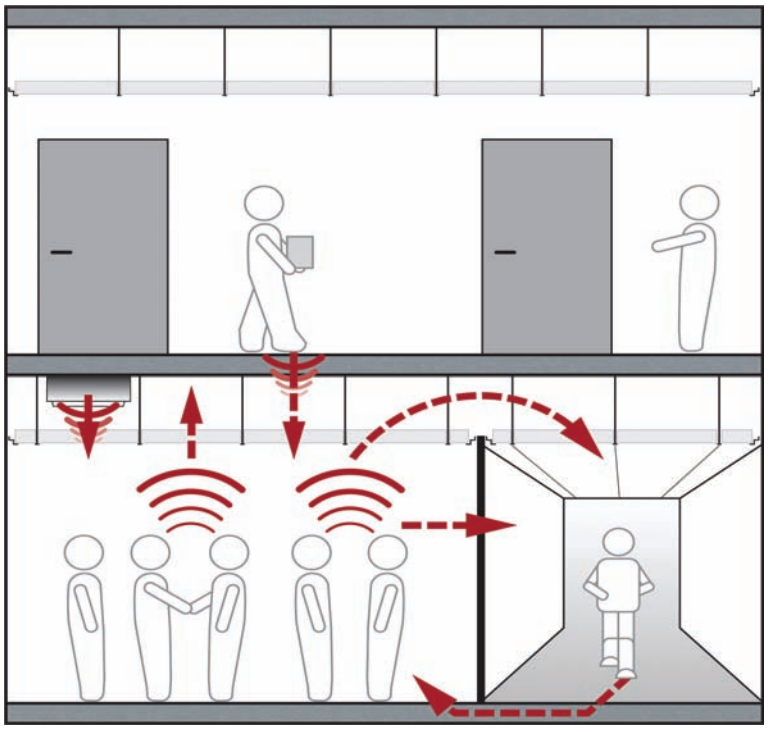
From acoustics to fire performance and aesthetics to sustainability, stone wool ceiling systems provide the versatility and attributes to meet the varied requirements of commercial and institutional buildings' new construction and renovation projects. **CS**

Notes

[1] Visit www.euro.who.int/en/health-topics/environment-and-health/noise.

[2] For more information, visit www.hc-sc.gc.ca/ewh-semt/air/in/poll/mould-moisissure/effects-effets-eng.php.

[3] See William J. Fisk's "Health and Productivity Gains from Better Indoor Environments," from the 2000 edition of *Annual Review of Energy and the Environment.* Visit www2.



Total sound insulation is the ability of a total construction (*e.g.* partitions, ceiling, floor and all connections) to prevent sound from traveling through the ceiling void and through building elements. Sound insulation of ceilings is measured using CAC, while walls are measured using the sound transmission class value (STC).

bren.ucsb.edu/~modular/private/Articles/Fisk%20HealthandProductivity%202000.pdf.

[4] For more, see Vanessa Loder's article, "Maybe Money Really Does Grow on Trees," in the May 4, 2014 edition of *Forbes*. Visit www.forbes.com/sites/vanessaloder/2014/05/04/maybe-money-really-does-grow-on-trees/2.

[5] See *Classroom Acoustics*, by Seep et al, published in 2000 by the Acoustical Society of America (ASA).

[6] See Tiesler & Oberdörster's 2008 article, "Noise: A Stressor? Acoustic Ergonomics of Schools," in *Building Acoustics* (15 [3]).

[7] Visit www.mayoclinic.org/mrsa.

[8] See the white paper, "Sound Practices: Noise Control in the Healthcare Environment?" published by HermanMiller Healthcare in 2009, and "Sound Control for Improved Outcomes in Healthcare Settings," by Joseph Ulrich, published in 2004 by the Center for Health Design.

[9] See John Tierney's article, "From Cubicles, Cry for Quiet Pierces Office Buzz," in the May 19, 2012 edition of the *New York Times*. Visit www.nytimes.com/2012/05/20/science/when-buzz-at-your-cubicle-is-too-loud-for-work.html. Also, visit www.cbe.berkeley.edu/research/index.htm.

ADDITIONAL **INFORMATION**

Author
Cory Nevins is Rockfon's director of marketing, leading the company's continuing education and training programs to keep commercial building team members updated on acoustic stone wool ceiling panels, specialty metal ceiling panels, and ceiling suspension systems. He has nearly 20 years of experience in the building products industry, the majority of which has focused on ceiling systems, and a bachelor's degree in marketing from Miami University in Oxford, Ohio. Nevins can be contacted at cory.nevins@rockfon.com.

Abstract
Stone wool's various attributes are making the material attractive for use in suspended ceilings in educational, office, and healthcare projects. This article touches on such assemblies' acoustics, air quality and light reflection impacts, along with information about fire performance, humidity, and dimensional stability. Design professionals must also understand the aesthetic possibilities, including flexibility with edges, sizes, colors, surfaces, shapes, and textures.

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ROCKFON, LLC 4849 SOUTH AUSTIN AVE., CHICAGO, IL 60638 / USA and Canada: 800-323-7164