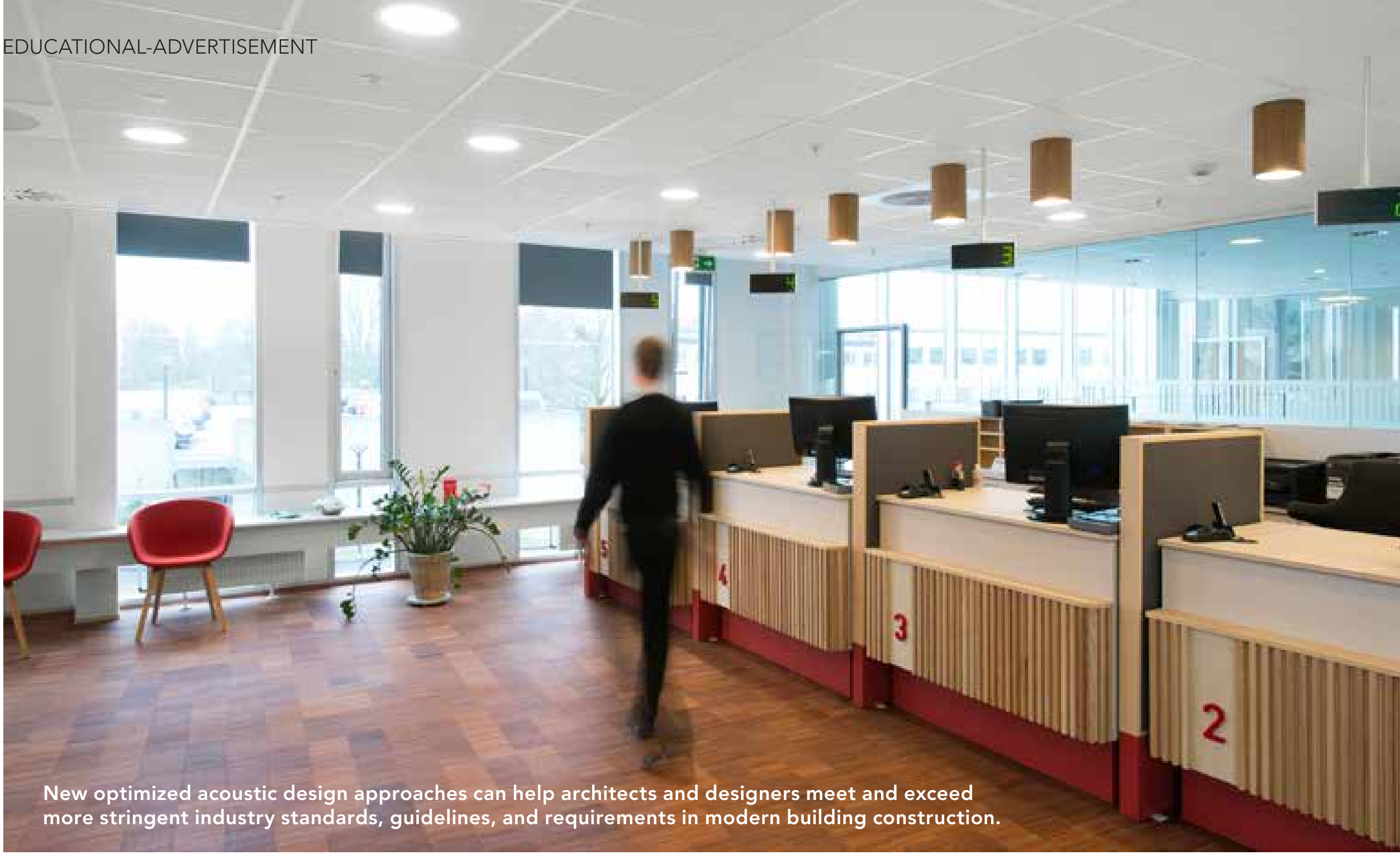

New optimized acoustic design approaches can help architects and designers meet and exceed more stringent industry standards, guidelines, and requirements in modern building construction.

*All images courtesy of ROCKFON*

# Optimizing Acoustics for Effective Sound Design and Performance

## High NRC-rated ceiling panels provide high-performance sound-absorption solutions—maximizing building function, occupant well-being, and compliance with building standards

Sponsored by ROCKFON | *By Robyn M. Feller*

Anyone who has ever tried to work in a busy office or get some sleep during a hospital stay knows that the noise surrounding us—whether it's your coworker's exuberant laugh or machines beeping down the hall—can affect our mental and physical well-being, not to mention productivity and general state of satisfaction with our environment. As awareness of the impact noise has on our daily lives increases, it's only logical that building standards and guidelines are becoming more stringent when it comes to acoustic requirements. In order to meet many of these higher-performance criteria, architects and designers need to make a concerted effort to consider how every structure, surface, fixture, material, and even gap plays a role in the way sound is experienced. For the best results, this means focusing on the true strength of acoustic ceiling panels: noise absorption.

Designers and architects are now tasked with the challenge of navigating the wide range of ceiling panel solutions available in the marketplace. Although some products attempt to absorb and block noise, there is actually a misconception that ceilings alone can block sound between rooms. The reality is, modular acoustic ceilings by themselves do not have enough mass to block sound. Additionally, ceiling systems will always have substantial noise leaks—created by installing light fixtures and air devices—making them even less effective at blocking sound.

In this course, we will look at the effects of noise, how to determine the type and level of noise mitigation required for a given project, as well as look at the factors that go into meeting and exceeding new industry standards, guidelines and requirements through the latest optimized acoustic design approaches.

### WHY ACOUSTICS MATTER

It is no surprise that noise affects physical and mental health, productivity, and overall well-being. The first step toward an optimized acoustic experience is to understand its importance for our daily lives.

### CONTINUING EDUCATION

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**Learning Objectives**

After reading this article, you should be able to:

1. Assess the impact of noise on physiology, comfort, health, mental capacity, behavior, and productivity.
2. Describe the myths and truths in the design world as they relate to acoustic building practices.
3. Recognize how ceiling panels with high noise reduction coefficient ratings (NRC), such as those made of stone wool, can lead to compliance with the building standards, guidelines, and rating systems from multiple perspectives.
4. Explain the mechanics of optimized acoustic design and differentiate between optimizing absorption and optimizing blocking using modular, suspended, acoustic ceilings, and other architectural components.

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### Impact of Noise on Physiology, Comfort, and Health

The National Institute for Occupation Safety and Health asserts that ambient noise levels affect people's health by increasing general stress levels. Continued exposure does not lead to habituation; in fact, the effects worsen. More specifically, according to the World Health Organization:

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 psycho-physiological effects, hinder work and school performance, and provoke annoyance responses and changes in social behavior.[1]

The clinical manifestations of stress occurring with noise, that is, negative physical impacts on the human body from noise, are numerous and should not be taken lightly. They include:

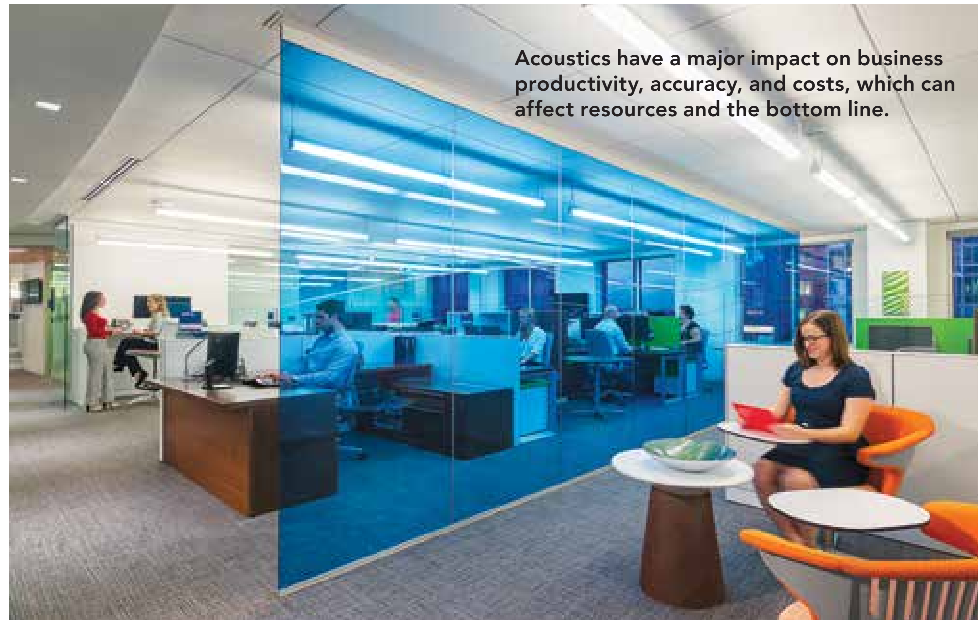
- Increased heart rate
- Elevated blood pressure
- Dilation of pupils
- Increased respiration rate
- Increased muscle tension
- Fatigue and nausea
- Heart attacks
- Increased ulcer formation
- Intestinal motility changes
- Increases in adrenaline

The effects go beyond the physical. Additionally, the negative mental and behavioral effects of noise include:

- Increased aggressiveness
- Impatience and nervousness
- Decreased helping behaviors
- Lowered attention span
- Decreased problem solving
- Memorization problems
- Comprehension problems
- Neurotransmitter deficiencies
- Interpersonal problems
- Social behavior problems

### Impact of Noise on Productivity and the Bottom Line

With all that in mind, it is essential to recognize the potential productivity and financial impact of bad acoustics. While some people still view noise as only a minor, short-term annoyance, appreciating the major impact of acoustics on business productivity, accuracy, and costs can affect resources in a big way.



Acoustics have a major impact on business productivity, accuracy, and costs, which can affect resources and the bottom line.

The numbers speak for themselves. Studies have shown that 90 percent of business operation costs are tied to staff or employees, compared to only 1 percent for energy usage. Those employees spend 62 percent of their time needing to do quiet work. In other words, good or bad acoustics affect 90 percent of an organization's resources 62 percent of the time.[2,3]

## ACOUSTICS IN BUILDING POST-OCCUPANCY SURVEYS

As we begin to assess the progress made in attenuating negative impacts of noise in buildings, the question to ask is, "How have we done over the past 10 years as an industry?" To find the answer, we can evaluate the data from post-occupancy building surveys to determine if the past acoustic design approach has been providing adequate results.

The Center for Built Environment at UC Berkeley (CBE) has the most extensive ongoing building occupant survey database in the world, giving us the resources to determine whether or not the industry needs to change direction. The CBE published a status report in 2012, which looked at almost 53,000 occupant surveys for 351 buildings over a 10-year survey period. What the data revealed was that overall, occupants were somewhat satisfied with their buildings, with a satisfaction rating of almost 1 (on a scale from -3 to +3) from dissatisfied to satisfied.

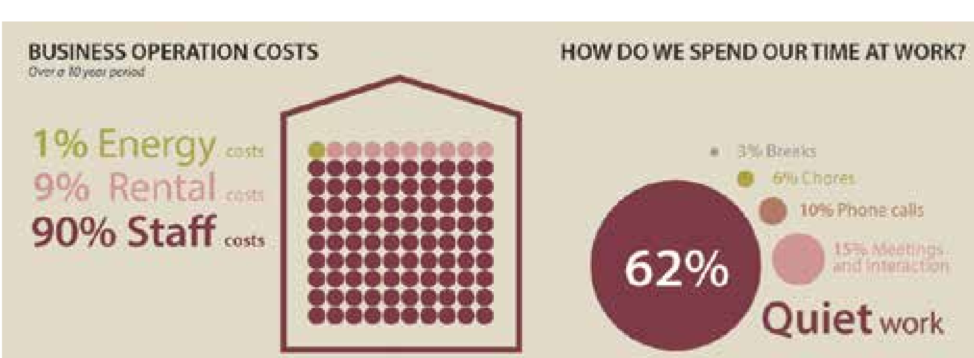
While certain categories get high ratings for satisfaction (e.g., ease of interaction, amount of light, comfort of furnishings, cleanliness), there are a few metrics that are anchoring the satisfaction ratings down. The surveys show the highest levels of dissatisfaction surround privacy, temperature, and noise level.[4]

With this data in hand, it's hard to conclude that the industry should continue the same acoustic design approach in future buildings, compelling us to look at options for a better route to optimal acoustic design.

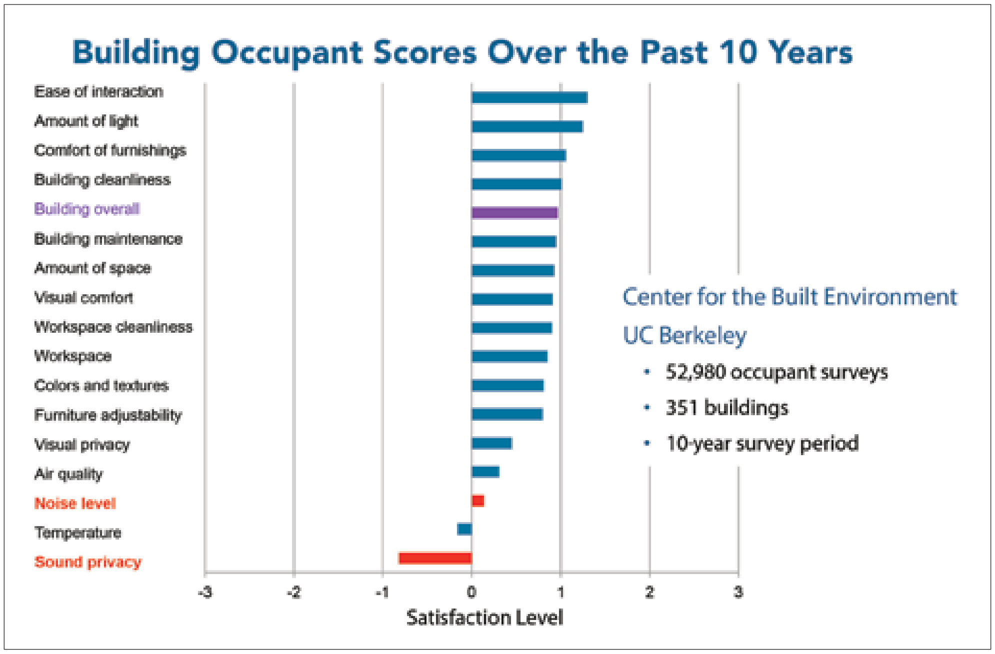
## OVERVIEW OF ACOUSTICS STANDARDS AND GUIDELINES

In recent years, there has been a noticeable increase in standards, guidelines, and building rating systems with acoustics sections in them, governing what architects need to do, and making acoustics and noise control more important within the context of the whole building design.

For an increasing number of project types, you may not have the choice whether or not you're going to take a different acoustic design approach in the future. The main trend we're seeing in the standards, guidelines, and rating systems is more stringent acoustic requirements, both in absorption and blocking/isolation.




*Sources: "Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building." World Green Building Council. 2014. Brill, Michael et al.* Disproving Widespread Myths About Workplace Design. *BOSTI Associates. 2001.*




*Source: Frontczak, M. et al. "Quantitative relationships between occupant satisfaction and aspects of indoor environmental quality and building design."* Indoor Air Journal. *Center for the Built Environment UC Berkeley. 2012.*

### CODES, STANDARDS, GUIDELINES, AND BUILDING RATINGS SYSTEMS WITH ACOUSTICS CRITERIA BY BUILDING TYPE

Schools
- American National Standards Institute (ANSI)/Acoustical Society of America (ASA) S12.60 Classroom Acoustics
- Collaborative for High Performing Schools (CHPS) National Core Criteria 2013
- Leadership in Energy and Environmental Design (LEED) v4
- Green Building Initiative (GBI) Green Globes

Health Care
- Facility Guidelines Institute (FGI) guidelines
- Evidence-Based Design (EBD) – The Center for Health Design
- LEED v4
- GBI Green Globes

Offices
- The WELL Building Standard
- LEED v4

Note: A number of industry associations have acoustic standards or guidelines—or contribute to their development—that are universal over all building types. These include: ANSI, ASA, Institute of Noise Control Engineering (INCE), National Council of Acoustical Consultants (NCAC), LEED, and FGI.

### Overarching Trends

Most of these current codes, standards, guidelines, and building ratings systems that include acoustics sections are building-type specific (see sidebar), and an optimized acoustic design approach can lead to compliance from multiple perspectives, specifically in the following areas:

- Helping to meet maximum permissible reverberation times or minimum NRC ratings
- Helping to attenuate exterior noise that has transmitted through the building envelope
- Helping to attenuate mechanical, electrical, plumbing, fire protection (MEPF) system noise that has entered the occupied rooms of the building
- Helping to control sound transmission between rooms

While in general there are differences in the requirements among various building types, let's now take a closer look at three of the main trends we're seeing in all of the acoustic standards, guidelines, and building rating systems.

**1. Many more building types now have some sort of acoustic criteria or performance metrics applied to them.** As noted in the sidebar, these include offices, schools, health-care facilities or sustainable buildings, etc.

**2. As absorption requirements are becoming more stringent, ceiling products, such as stone wool ceiling panels with high noise reduction coefficient ratings (NRC), are a primary way for the building to comply with the latest acoustics criteria.** NRC is a measure of how much noise is absorbed by a ceiling or other interior finish. The higher the NRC, the less noise propagation and disturbances there will be. When lower NRC ceiling panels are used (below 0.70), additional sound absorption on the floor and walls might be needed—an avoidable cost. (We will discuss this in more detail later in this article.)

The other way that the need for increased absorption is expressed in the standards is shorter reverberation time ($RT_{60}$), which is the length of time required for reflected sound to decrease 60 dB or a loud sound to become inaudible as it dissipates in the room. You achieve shorter $RT_{60}$ through higher NRC values, resulting in better speech intelligibility. In other words, the room reflects sound less when you have higher absorption that results in greater speech intelligibility, lower noise levels, and better sound privacy.

**3. We are also seeing higher blocking required in the standards. With the more stringent standards, higher sound privacy between enclosed rooms is required.** Typically, you'll see this expressed as sound transmission class (STC), which is a measure of how much noise transmits through the walls (or other assemblies). The higher the STC value, the more privacy you'll experience. To meet the higher sound-privacy requirements, full-height walls or plenum barriers must be used. The old practice of stopping the wall at the ceiling level and relying on the ceiling to block noise transfer does not comply with the new, higher requirements in the standards. In a nutshell, in the past, when both absorption and blocking criteria were less stringent or not defined at all, stopping the wall at the ceiling and relying on less-absorptive ceiling panels to block noise was more common. Now that the acoustic standards apply to more types of buildings and both the absorption and blocking criteria are more stringent, that old design approach fails to meet both the absorption and blocking criteria. In other words, a total failure.

### What About CAC?

Another question we need to ask is, "Where is ceiling attenuation class (CAC) in all of the new acoustics standards, guidelines, and ratings systems?" The basic answer is, it's not used. CAC is a measure of how much noise transmits through the ceilings over a partial-height wall, via a common plenum. CAC is associated with a subpar acoustic design approach because when you don't run the wall past the ceiling plane to block sound, you are relying on the ceiling alone, which doesn't produce good results. This is why we are not seeing CAC as a performance metric and it's not used in most current standards, guidelines, and ratings systems.

## DEBUNKING MYTHS AND TELLING TRUTHS

Some designers still stop the walls at the ceiling level, creating a plenum above, and then poke the ceiling system full of holes with return air grilles, supply diffusers, lights, speakers, sprinklers—the list goes on and on. Sometimes they even sacrifice

**As standards and guidelines have become more stringent, more building types need to meet acoustics criteria or specific performance metrics.**

ceiling panel absorption performance (NRC) for slightly higher blocking performance (CAC). This is called the "old compromise."

Let's explore some myths behind the old compromise as they perpetuate the dissatisfaction with acoustics we see with building post-occupancy surveys. Then we'll discuss the truths.

## Debunking Acoustic Myths

- It is alright to sacrifice ceiling NRC (absorption), even in open spaces, for slightly higher CAC (blocking) capacity. *It isn't.*
- Suspended modular acoustic ceilings alone can be used for effective sound blocking, providing enough noise blocking between rooms. *They can't.*
- The performance of the ceiling (CAC) can be less than the performance of the demising wall (STC). *It can't. They should be equal.*
- The lights, speakers, diffusers, grilles, etc. that penetrate a ceiling system have no significant effect or can be ignored. *Not true. Noise flanking paths through the ceiling decrease blocking capacity.*
- The ceiling panel CAC rating can also be used as the ceiling system CAC rating. *It can't. It leads to disappointment after occupancy.*

## Truths: Getting to True Sound Experience

- **Truth: Sacrificing absorption (NRC) can result in noncompliance with performance metrics (standards, guidelines, and rating systems).**

NRC and $RT_{60}$ are inversely related. As NRC increases, $RT_{60}$ decreases, which is considered better in most cases and what we're trying to do. For instance, let's say we received a reverberation time requirement either from our consultant, a standard, or guidelines—or we happen to know what our desired reverberation time is. From there, it's a simple calculation (which we will discuss in detail later in this article) to get the minimum NRC for our ceiling. Anything below that minimum is going to result in noncompliance with the required performance level, regardless if it's a noticeable difference or not. Conversely, anything at or above that minimum is still going to result in compliance.

Additional absorption on the walls or the floors may be required to compensate for deficiency in the ceiling NRC.

- **Truth: Ceiling panels can't provide enough blocking on their own to achieve speech privacy and avoid annoyance.**

The STC rating of most walls vary from about 40 to 60 points. STC 60 is considered high, but it requires special and heavy construction. STC 40 to 50 walls are considered more commonplace for contractors as they build these assemblies every day, requiring nothing special or out of the ordinary. These STC ratings are based on decades of actual human perception and annoyance in real buildings. These are the blocking levels mandated in the standards, guidelines, and rating systems.

However, CAC ratings of most ceilings panels vary from about 20 to 40 points. That means that on a good day, the best-performing ceiling panels (CAC) might perform about the same as the worst performing walls (STC). But that's before we even start talking about all the penetrations in the ceiling system. So why the disparity? It's because what we regard as high and low STC ratings for walls is based on human perception and annoyance proven in real buildings. But that's not true with CAC. What we consider high and low CAC for ceiling panels is based only on what's available in the market.

- **Truth: Accepting lower absorption performance (NRC) for higher blocking (CAC) results in total failure.**

We discussed earlier not sacrificing NRC for CAC or blocking. To get CAC performance in the 30 to 40 range, you typically, but not always, have to drop your NRC down to as low as 0.50, 0.60 and 0.70. This means, though, you're simply sacrificing your absorption for what is still an inadequate level of blocking. As a result, you are failing to meet both the absorption and blocking requirements, going back to that idea of the "old compromise," or a total failure.

The most common wall performance required by the standards at STC 45 to 50 outperforms CAC 30 to 35 ceilings by 10 to 20 points, meaning the sound that comes through the ceilings is two to four times louder than what's coming through the wall. Once you then add in the effect of all the noise leaks resulting from lights, grilles and diffusers, the disparity grows even worse.

- **Truth: Overall, sound blocking and sound privacy between rooms is only as good as the weakest link.**

Neither the sound path through the wall or through the ceiling is more important than the other. Sound blocking provided by the ceilings (CAC) is insufficient relative to that provided by the walls (STC). The sound-blocking capacity of the ceiling (CAC) must match the sound-blocking capacity of the wall (STC = CAC), but it can't. Ceiling performance falls short of the wall performance so the ceiling cannot match the performance of the wall.

- **Truth: Noise-flanking paths through the ceiling will affect blocking capacity.**

The lights, speakers, diffusers, grilles, etc. that penetrate a ceiling system have significant effect and can't be ignored. These penetrations can decrease the performance of the ceiling system 10 CAC points and more than 20 dB in the important high frequencies, which make speech intelligible.

When ceiling manufacturers test their panel ratings for CAC, they only have their ceiling panels in the suspension grid.

Continues at ce.architecturalrecord.com

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They don't test a realistic ceiling system with devices for air distribution, lighting, fire suppression, security surveillance, etc. Recently, when one building manufacturer and NGC Testing Services tested a high-performance ceiling panel with a rating of CAC 43, the lights and air devices alone dropped the ceiling rating down by 9 points, to 34. When they tested another panel with a CAC rating of 37 and had the same leaks, the rating dropped by 10 points, to 27.

While CAC decreases 10 points due to holes in the ceiling, blocking of speech-privacy frequencies decreases 15 to 22 dB (see Table 1). Generally, neither of these can provide speech privacy between rooms. Now compare the CAC 27 and 34 ratings for these ceiling systems with leaks to STC 40, 45, and 50 wall performance. As mentioned earlier, the truth is that ceiling panel CAC ratings is not the same as ceiling system CAC ratings in a real building.[5]

| Table 1: Perception of Changes in Sound Loudness |
|---|
| **3 dB difference = barely perceptible** |
| **6 dB = plainly different** |
| **10 dB = twice as loud** |
| **20 dB = four times as loud** |

The first step to fixing a problem is understanding it. Now that we understand the truths and have dispelled the myths, we need to ask, "Where do we go from here, and how can we make things better?" Let's take a look at a new design approach: optimized acoustic design.

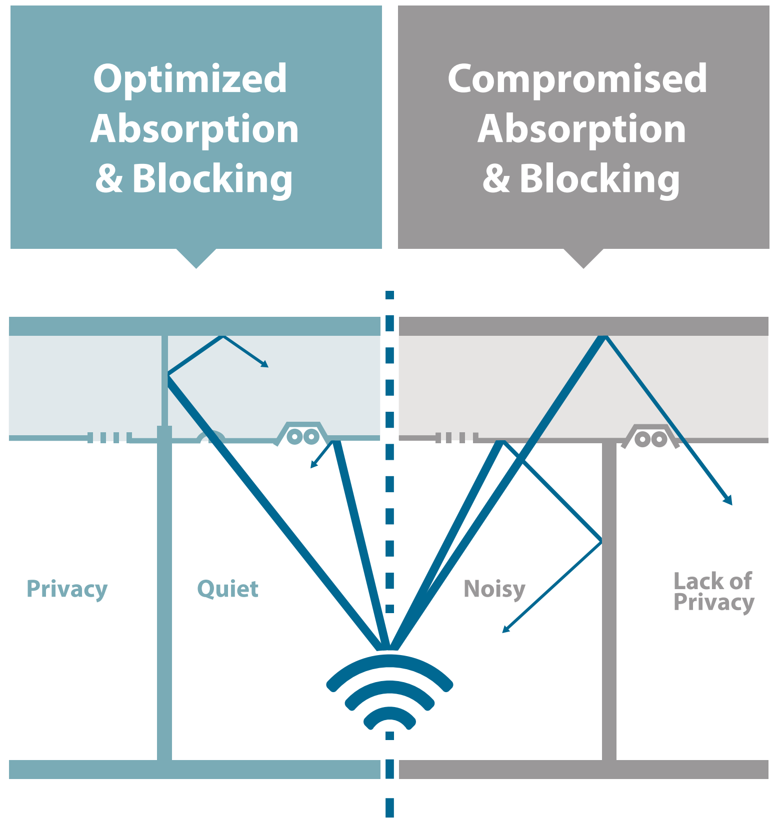
## OPTIMIZED ACOUSTIC DESIGN

Optimized acoustic design can be described as an effective, no-compromise acoustic approach that results in compliance with the industry's latest standards and achieves an optimal acoustic experience for people, all at a competitive price.

### Mechanics

The old acoustic design approach, which was based on myths, unfortunately led us to a compromised result, as evidenced by those poor survey scores discussed earlier. For example, when the ceiling NRC was not high enough, NRC was sacrificed, resulting in more noise reflecting off the ceiling and traveling further, disturbing more people. In other words, a noisy environment. We've also seen what happens when people rely on ceilings alone to block noise between rooms. Since the ceiling system is full of penetrations and there's a lack of privacy between rooms, you're inevitably compromising both absorption and blocking.

Now, let's compare that old model to an optimized acoustic design approach.




**More stringent standards call for an optimized acoustic design approach, moving away from an old compromised approach.**

First, you optimize the absorption of the ceiling to prevent noise from reflecting and traveling everywhere, thereby disturbing everyone. This is the main purpose of the ceiling and you take advantage of that strength.

Second, you decide if and where blocking is actually needed. If it is needed, there are multiple ways of providing it. For example, you could use a lightweight plenum barrier, but there are other methods as well.

Simply put, the old compromised method leads to noisy spaces and lack of privacy—exactly what we saw on the building occupant survey scores.

Enter the optimized acoustic design approach, which is based on good acoustic design and is consistent with the requirements in the standards, guidelines, and ratings systems.

## Optimizing Absorption

Let's focus first on optimizing absorption. To illustrate, look at the image below. Where is the sound absorption coming from in the building shown? Buildings like this are very common today—largely open, they have hard, sound-reflecting floors and glass in walls. In current architecture trends, the result is that most, if not all, of the absorption is provided by the ceiling. Optimal acoustic design must start with optimizing the sound absorption of the ceiling.

**The need for high NRC-rated ceiling panels is increased as spaces become larger and walls and floors remain sound reflective.**

When dealing with absorption you'll either be talking about minimum NRC ratings or maximum $RT_{60}$. We'll cover both.

According to Gary Madaras, Ph.D., ASA, INCE, Associate AIA, acoustics specialist at the ROCKFON Group, "High-performing absorptive ceiling panels of NRC 0.90 can improve the acoustic experience in open-plan offices, classrooms, retail shops, health-care patient recovery areas, as well as in multifunctional rooms, corridors, meeting rooms, lobbies, and reception areas." He adds, "NRC indicates the amount of noise absorbed by a ceiling material. Typically, the higher the NRC, the better. Ceilings lower than NRC 0.70 often require additional absorption on the walls. Look to your ceiling panels to meet the high absorption requirements you need and to your walls for blocking, when it's needed."

NRC is an average of the sound-absorption coefficients at four different octave bands: 250, 500, 1,000, and 2,000 Hertz. There is an ASTM standard for testing that (ASTM C 423), and the testing should come from an independent NVLAP-certified lab when reviewing these results. NRC values vary between 0.0 and 1.0 in 0.05 increments. Higher NRC ratings mean speech is more intelligible and noise is absorbed faster as it travels across an open space or down a corridor. To summarize:

**Based on the acoustic standards, NRC can be categorized as:**

**Best** = NRC 0.90 or higher

**Better** = NRC 0.80 or higher

**Good** = NRC 0.70 or higher

**Avoid** = NRC less than 0.70

You typically won't want to specify a ceiling with NRC less than .70 as they are too reflective.

The second way standards may show absorption criteria is as reverberation time ($RT_{60}$) instead of as NRC. It's more common to see the criteria expressed as reverberation time so it's good to know how to convert. The formula to convert reverberation time to NRC is:

$$NRC = \frac{0.05 \times \text{Room Volume}}{RT_{60} \times \text{Area}}$$

NRC: Noise reduction coefficient of the ceiling
Room Volume: Average length x average width x average height (all in feet)
Area: Area of the ceiling in length x width (both in feet)
0.05 is a constant when using feet as the units for volume and area

Note: The assumption is that there is no other significant absorption from other components in the room, such as wall panels or carpeting. If there are other factors, then this NRC value may be conservative.

If, you're not working with an acoustics consultant or for some reason your project doesn't need to comply with a building code or standard, you'll have to figure out what NRC you want to use. The following Optimizing Absorption matrix can lead a designer toward the right absorption performance (NRC) for his or her project:

**NRC: Optimizing Good, Better, Best***

| Sensitivity to Noise \ Amount of Noise Inside the Room | Low | Medium | High |
|---|---|---|---|
| High | **BETTER** NRC 0.80 | **BEST** NRC 0.90 | **BEST** NRC 0.90 |
| Medium | **GOOD** NRC 0.70 | **BETTER** NRC 0.80 | **BEST** NRC 0.90 |
| Low | **GOOD** NRC 0.70 | **GOOD** NRC 0.70 | **BETTER** NRC 0.80 |

***Values are based on the requirements of current acoustics standards, guidelines, and rating systems.**

**How to use the matrix:** Simply rate the user's sensitivity to noise as low, medium, or high, and then rate the potential for noise in the space as low, medium, or high. The matrix will then give you the NRC for the ceiling. The matrix values are based on today's acoustic standards. As an example, we can use an emergency room department admitting and triage area. In that kind of space, there's a lot of potential for noise and a high sensitivity to noise (ex: a missed clinical instruction or direction for medication could be life threatening). With a high sensitivity to noise and high potential for noise, the matrix leads to an NRC of 0.90 or higher for the ceiling in this application.

## Optimizing Blocking

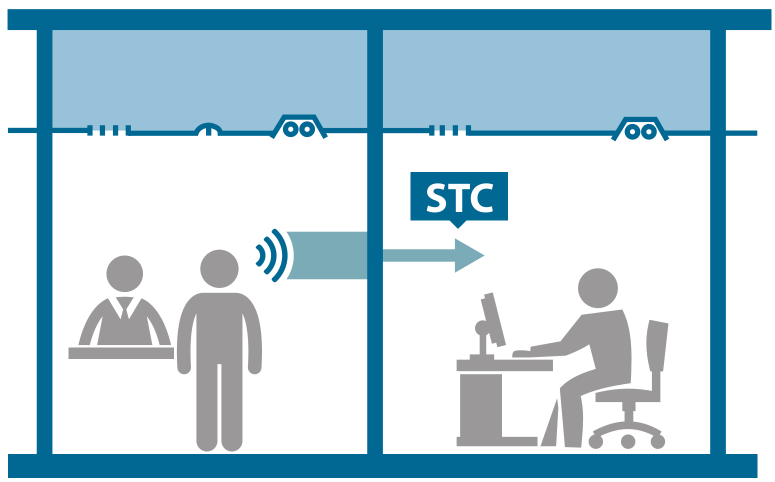
Now that we've optimized our absorption, we next have to decide where—and if—blocking is important for a specific project. If it is important, the question to ask is "which" sound-blocking design approach do we want to use?

**What is blocking?** Blocking is preventing sound in one room from entering the room next to it. It's different than absorption, which is controlling the sound generated inside the space you are in. Blocking is only important where you need privacy between two adjacent rooms.

**Determining if blocking is needed**. There are, in fact, many spaces where blocking is not required, such as in places where medium to large groups of people are in open spaces—open offices, airport concourses, restaurants, malls, retail stores, lobbies, atriums, waiting areas, gymnasiums, cafeterias, etc. As a caveat, it should be noted, though, that blocking may still be a factor for smaller rooms that abut these areas. When blocking is not relevant, optimizing sound absorption is the only important step.

**Criteria in the standards: STC**. When dealing with blocking, you mostly see sound transmission class (STC) in the standards. As previously discussed, STC is the most common blocking criterion overall. It applies to the noise-blocking capacity of the wall construction between rooms and to other assemblies as well. The building codes, standards, guidelines, and rating systems require sound blocking to be accomplished with full-height walls (from the slab to the slab above or the roof) and assumes all the penetrations, if any, are sealed.

Blocking can be categorized as best (STC 50 or higher), better (STC 45 or higher), or good (STC 40 or higher). You should avoid STC below 40 as it does not provide adequate sound privacy.




**Sound transmission class (STC) is the most common blocking criterion in standards and guidelines. Ratings of 45 and 50 are common.**

**Design approach options.** If you have determined that blocking is important between two adjacent spaces, there are a couple of options to choose from.

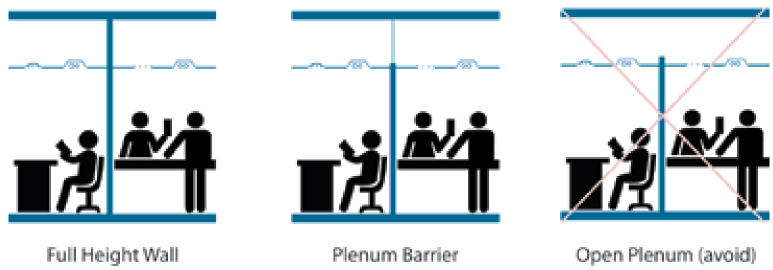
**Best option:** extend the demising walls full height up to the slab or roof above. This is the approach required by most standards and guidelines and leads to the highest level of blocking and achieving STC 45, 50+. As an added benefit, the noise leaks or flanking paths through the ceilings are mostly inconsequential, and you don't have to remediate them.

**Better/Good option:** Use a plenum barrier or partial wall, which will allow you to achieve STC 40, 45 or 50. In this option as well, ceiling flanking paths do not need to be remediated.

Note: Using ceiling systems alone to block noise is ineffective.

**Full-height walls vs. plenum barriers.** By full-height walls, we mean extending all of the lower wall construction up past the ceiling level so that it completely blocks off the plenum and seals up against the floor or roof above. This approach is typically mandated by the standards and guidelines. Any time you see a STC requirement, you know the wall is supposed to be full height and any penetrations through it sealed airtight. While this approach is best, it can be difficult to do in existing buildings that already have walls that stop at the ceiling level.

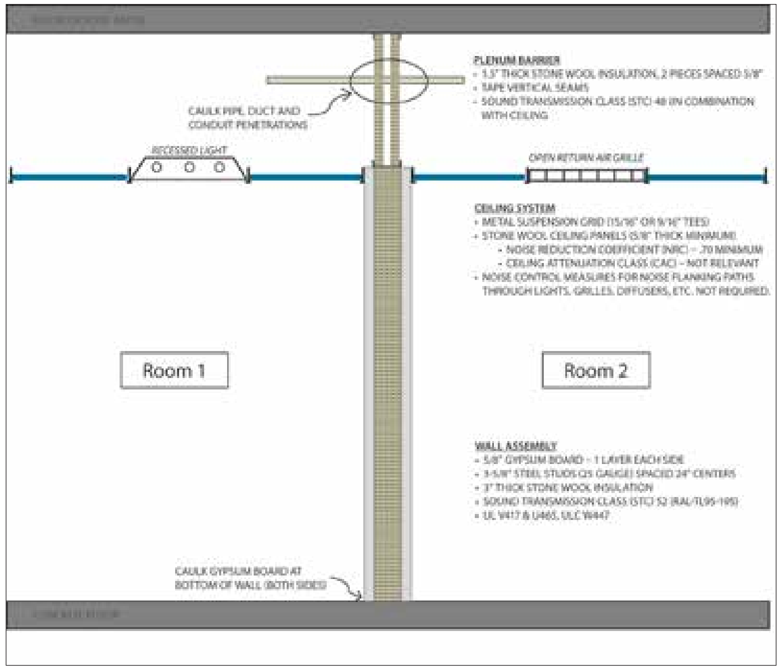
At times, in new construction, full-height walls can be overdesigned and unnecessarily costly when a suspended, modular, acoustics ceiling is also used. There is some sound-blocking value provided by the ceiling. When you combine that with the sound-blocking capacity of the upper wall, the total is far greater than what's being provided by the lower part of the wall alone. So the upper part of the wall—above the ceiling—does not always have to be the same construction as the lower part of the wall. Ideally, the blocking capacity up through the ceiling, through the upper wall, and down through the ceiling of the adjacent room is the same as that of the lower wall alone. That means the upper part of the wall can be simpler and lighter weight. These lightweight upper walls are called plenum barriers and can be far less costly than full-height walls.




**Both full-height walls and lightweight plenum barriers can provide effective sound blocking between rooms. Modular, acoustic ceilings cannot.**

Recent research shows that even when the main demising wall between two rooms stops at the height of the suspended ceiling, STC 40, 45, and 50 levels of isolation can be achieved by adding plenum barriers that begin at the top of the wall and extend up to the underside of the floor or roof above.[6] These plenum barriers can be made of stone wool insulation with foil face, standard gypsum board, or limp mass loaded vinyl. Other materials are possible as well. The studs from the lower wall do not necessarily need to extend past the ceiling level either. The plenum barriers can be friction fitted against the top of the wall and underside of the slab above or fastened in place using channels or angles. While higher levels of isolation (e.g., STC 50) require that penetrations through the plenum barriers be sealed airtight, lower levels of isolation (STC 40) can be achieved by just stuffing large openings with stone wool insulation and leaving gaps and cracks open. Taping and caulking, the time-consuming part of the installation, is not always required. Lastly, the plenum barriers only need to be used between the two rooms that require privacy. They do not need to extend horizontally all the way around the perimeters of both rooms. This permits return air to still move freely in the plenum in unducted systems.

For example, using just one layer of standard ⅝-inch gypsum board as a plenum barrier in combination with a stone wool, suspended, modular, acoustic ceiling, can result in STC 45, assuming the penetrations through the plenum barrier are sealed. And, the noise leaks or flanking paths through the ceiling system do not need to be remediated. This is a significant benefit because it saves on costs and permits easy access through the ceiling for maintenance. As another example, using two stone wool insulation boards (each 1 inch or 1½ inches thick) standing vertically and spaced apart ⅝ inch as a plenum barrier can come close to STC 50 without extending the walls full height. See the figure below for further details.




**This example detail utilizes a stone wool plenum barrier to achieve high sound blocking (STC 45–50) as required by standards and guidelines without requiring full-height walls.**

Similar to the NRC matrix for absorption, which we looked at earlier, designers may use the following Optimizing Blocking matrix when a standard or consultant is not providing the blocking performance requirement. This STC matrix can lead a designer toward the right blocking performance for his or her project when guidance is not otherwise given.

**STC: Optimizing Good, Better, Best***

| Sensitivity to Noise | Low | Medium | High |
|---|---|---|---|
| High | **BETTER** STC 45 | **BEST** STC 50 | **BEST** STC 50 |
| Medium | **GOOD** STC 40 | **BETTER** STC 45 | **BEST** STC 50 |
| Low | **GOOD** STC 40 | **GOOD** STC 40 | **BETTER** STC 45 |

Amount of Noise in Adjacent Rooms

***Values are based on the requirements of current acoustics standards, guidelines, and rating systems.**

**How to use the matrix:** Simply rate the user's sensitivity to noise as low, medium, or high, and then rate the potential for noise in adjacent room(s) as low, medium, or high. The matrix will give you the appropriate blocking level. Some adjacencies next to very loud things (ex: mechanical room, toilet room, band rooms, etc.) may require even higher STC ratings than shown in this matrix. Here are a couple of examples of the information this matrix could provide:

**Example 1:** Two regular patient rooms next to each other in a hospital setting

- Medium potential for noise and high sensitivity to noise because deep sleep is essential to the recovery process
- Blocking capacity should be STC 50

**Example 2:** A private office

- Medium sensitivity to noise coming from other offices and a medium potential for noise in adjacent rooms.
- The matrix tells us the STC should be 45

Note: The exact parameters don't apply to every situation. In this private office example, for instance, it's important to remember that not every office is the same.

## SUMMARY

**To achieve optimized acoustic design, choose a ceiling system to optimize absorption (NRC), and where needed, use walls or plenum barriers to effectively block sound (STC).**

You now know how an optimized acoustic design approach helps to achieve a true sound experience. This can be achieved by not compromising on quietness or privacy. You optimize the absorption for your specific application with a good NRC of 0.70, a better category being NRC of 0.80, or best NRC of 0.90. In addition, utilizing full-height walls or plenum barriers to achieve a good STC blocking rating of 40, a better STC rating of 45, or best blocking rating of STC 50.

This design approach will:
- Improve speech intelligibility
- Increase concentration and productivity
- Increase satisfaction and recovery
- Provide expected sound privacy
- Meet industry standards and guidelines

The bottom line to consider when looking to adhere to the widespread implementation of more stringent codes, standards, guidelines, and rating systems for acoustic design and to really optimize the acoustic systems in your projects' occupants is twofold: 1) ceilings are great at sound absorption; utilize it, don't sacrifice it; and 2) walls are much better at blocking sound than modular, acoustic ceilings.

The idea is simple. Select a ceiling system to optimize absorption (NRC), and, where needed, use walls or plenum barriers to effectively block sound (STC). This approach results in acoustic designs that comply with the standards and are optimized to achieve the best sound experience at the best price—moving the industry closer to raising satisfaction and increasing health and well-being for building occupants.

## END NOTES


[1]Summary of growing evidence of the impact of hazardous environments on human health. World Health Organization, Regional Office for Europe. <www.euro.who.int/en/what-we-do/health-topics/environment-and-health/noise>.

[2]"Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building." World Green Building Council. 2014. <http://www.worldgbc.org/activities/health-wellbeing-productivity-offices/>.

[3]Brill, Michael et al. *Disproving Widespread Myths About Workplace Design.* BOSTI Associates. 2001.

[4]Frontczak, M. et al. "Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design." *Indoor Air Journal*. The Center for the Built Environment UC Berkeley. 2012. <http://senate.ucsf.edu/2013-2014/mb1-eScholarship%20UC%20item%201wc7t219%20work%20environment%20article.pdf>.

[5]Madaras, G. and Heuer, A. "Effects of Noise Flanking Paths on Ceiling Attenuation Class (CAC) Ratings of Ceiling Systems and Inter-Room Speech Privacy." <http://awc.caa-aca.ca/index.php/AWC/AWC15/paper/view/129/86>.

[6]Madaras, G. and Heuer, A. "Optimizing Ceiling Systems and Lightweight Plenum Barriers to Achieve Ceiling Attenuation Class (CAC) Ratings of 40, 45, and 50." Canadian Acoustics. Vol. 44 No. 3 (2016). <http://jcaa.caa-aca.ca/index.php/jcaa/issue/viewIssue/272/AWC16>.


## QUIZ

1. Business productivity studies have shown that:
   a. acoustics have little to no effect on office productivity.
   b. good or bad acoustics affect 90 percent of an organization's resources 62 percent of the time.
   c. good or bad acoustics affect 62 percent of an organization's resources 90 percent of the time.
   d. None of the above

2. Building post-occupant surveys conducted by the Center for Built Environment at UC Berkeley in 2012 showed:
   a. dissatisfaction with past acoustic design approaches.
   b. that overall, occupants are very dissatisfied with their buildings.
   c. that past acoustic design approaches provide high levels of satisfaction for privacy.
   d. the highest level of satisfaction is related to noise level.

3. The main trend we're seeing in the standards, guidelines, and rating systems is:
   a. more stringent acoustic requirements, only in absorption.
   b. more stringent acoustic requirements, only in blocking/isolation.
   c. more stringent acoustic requirements, both in absorption and blocking/isolation.
   d. more stringent acoustic requirements in absorption and lowered requirements in blocking/isolation.

4. Most of the standards, guidelines, and building ratings systems with acoustics sections in them are building-type specific.
   a. True
   b. False

5. Which of the following is true of NRC and reverberation time?
   a. When NRC increases, so does reverberation time.
   b. As NRC increases, reverberation time decreases.
   c. NRC and reverberation time are both associated with optimized acoustic blocking.
   d. All of the above

6. Which of the following statements about acoustic design is TRUE?
   a. Suspended modular ceilings alone can be used for effective sound blocking, providing enough noise blocking between rooms.
   b. The blocking performance of a ceiling (CAC) is typically greater than the blocking performance of a demising wall (STC).
   c. The ceiling panel CAC rating can also be used as the ceiling system CAC rating.
   d. Noise-flanking paths through the ceiling will affect blocking capacity.

7. The standards and guidelines provide sound-absorption requirements in the following metric(s):
   a. NRC values only
   b. STC values only
   c. minimum NRC values or maximum reverberation time ($RT_{60}$) values
   d. STC and CAC

8. Based on the acoustics standards:
   a. NRC values less than .70 is considered good.
   b. the best NRC value is less than .80.
   c. you should avoid NRC values between .80 and .90.
   d. you should avoid NRC values less than .70.

9. Ceiling attenuation class (CAC) is an important criteria used in the current acoustic design standards.
   a. True
   b. False

10. Walls are much better at ____________ than modular, acoustic ceilings.
    a. blocking sound
    b. absorbing sound
    c. achieving high NRC values
    d. All of the above