

# Innovations in Sustainable Acoustic building material and Technologies

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**Abstract:** “Innovations in Sustainable Acoustic Building Materials and Technologies” explores the latest advancements in sustainable design practices within the field of architectural acoustics. In response to growing concerns about environmental sustainability, there is an increasing demand for eco-friendly solutions in acoustic design that prioritize both acoustic comfort and environmental responsibility. This research paper aims to address this need by examining emerging materials and technologies that offer high-performance acoustic properties while minimizing negative environmental impacts. The paper begins by reviewing the current state of sustainable acoustic building materials and technologies, highlighting the environmental drawbacks of conventional approaches and the urgency of adopting more sustainable alternatives. It then delves into the exploration of innovative materials derived from recycled, renewable, or bio-based sources, such as recycled rubber, glass wool made from recycled glass, and natural fibers like cork and bamboo. These materials offer promising acoustic properties while reducing resource consumption, energy use, and waste generation. Furthermore, the paper includes active noise control systems, which use advanced algorithms to cancel out unwanted noise, and biomimetic designs inspired by nature, such as sound-absorbing structures modelled after the properties of plants and animals.

## I. INTRODUCTION

In The built environment significantly impacts our daily lives, influencing everything from our productivity to our overall well-being. Within this context, architectural acoustics plays a crucial role in shaping our acoustic experiences, influencing how we perceive and interact with the spaces around us. However, traditional approaches to acoustic design often prioritize performance at the expense of environmental sustainability, relying on materials and technologies that have significant negative impacts on the planet.

In recent years, there has been a growing recognition of the need for more sustainable solutions in architectural acoustics. As concerns about climate change, resource depletion, and environmental

Case studies and real-world examples are presented to illustrate the practical application of these innovations in sustainable acoustic design. These case studies showcase successful projects that have integrated sustainable acoustic materials and technologies to achieve optimal acoustic comfort while minimizing environmental impact.

The paper concludes by discussing the challenges and opportunities associated with the adoption of sustainable acoustic building materials and technologies, emphasizing the importance of collaboration between researchers, architects, manufacturers, and policymakers to overcome barriers and accelerate the transition towards more sustainable practices in architectural acoustics. Overall, "Innovations in Sustainable Acoustic Building Materials and Technologies" provides valuable insights into the evolving landscape of sustainable design in architectural acoustics, highlighting the potential of innovative materials and technologies to transform the way we design and construct buildings with sound in mind.

**Keywords-** architectural acoustics, environmental sustainability, sustainable acoustic design, and technology advancements

degradation continue to escalate, architects, designers, and engineers are increasingly seeking eco-friendly alternatives that offer both high-performance acoustic properties and minimal environmental impact. This shift towards sustainability in acoustic design reflects a broader trend towards green building practices and sustainable design principles.

The introduction of this research paper sets the stage for exploring innovations in sustainable acoustic building materials and technologies. It begins by highlighting the environmental drawbacks of conventional approaches to acoustic design, such as the use of non-renewable resources, high energy consumption, and generation of waste. These issues underscore the urgent need for more sustainable alternatives that can help mitigate the environmental impact of building construction and operation.

Moreover, the introduction emphasizes the significance of integrating sustainability into acoustic design practices, not only to reduce environmental harm but also to create healthier and more comfortable indoor environments for occupants. By prioritizing The introduction concludes by outlining the objectives and structure of the research paper, providing a roadmap for the subsequent sections. Through an exploration of emerging materials and technologies, case studies, and real-world examples, this paper aims to showcase the potential of sustainable acoustic solutions to transform the way we design and construct buildings with sound in mind.

## 1. What is Acoustics?

Acoustics is the interdisciplinary science that deals with the study of all mechanical waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. A scientist who works in the field of acoustics is an acoustician while someone working in the field of acoustics technology may be called an acoustical engineer. The application of acoustics is present in almost all aspects of modern society with the most obvious being the audio and noise control industries.

## 2. Brief overview of some key acoustic materials used in the past:

### 2.1 Ancient Times to Middle Ages (up to 1500 AD):

**2.1.1. Stone and Earth:** In ancient civilizations, such as Mesopotamia and Egypt, thick stone walls and earthen structures were used to absorb and block sound.

**2.1.2. Tapestries and Textiles:** Textiles, such as tapestries and rugs, were hung on walls to help dampen sound reflections in large halls and chambers.

### 2.2 Renaissance to 19th Century (1500-1800 AD):

**2.2.1. Wood Panelling:** Wood panelling and wainscoting were commonly used in interiors to provide some level of sound absorption and diffusion.

**2.2.2. Tapestries and Draperies:** Tapestries and heavy draperies continued to be used for their decorative and acoustic properties, particularly in grand halls and theatres.

**2.2.3. Plaster and Stucco:** Plaster and stucco were applied to walls and ceilings, sometimes with decorative relief patterns, which also helped to absorb and diffuse sound.

### 2.3 Industrial Revolution to Early 20th Century (1800-1900 AD):

**2.3.1 Fabric-Wrapped Panels:** Fabric-wrapped panels made from materials like felt or cotton were introduced as a more controlled and consistent method of acoustic treatment.

**2.3.2 Horsehair and Wool:** Horsehair and wool were commonly used as filling for upholstery and padding, providing some degree of sound absorption.

sustainability in acoustic design, we can contribute to the broader goals of reducing carbon emissions, conserving natural resources, and promoting human well-being.

**2.3.3 Acoustic Tiles:** Porous ceramic tiles with intricate patterns were developed for use in ceilings and walls to absorb sound.

### 2.4 Mid-20th Century to Present (1900 AD - Present):

**2.4.1 Fiberglass Insulation:** Fiberglass became a popular acoustic insulation material due to its lightweight, flexible, and fire-resistant properties.

**2.4.2. Foam Panels:** Acoustic foam panels made from materials like polyurethane foam were introduced for their lightweight, porous structure, and high sound absorption coefficients.

**2.4.3 Mineral Wool:** Mineral wool, made from molten rock or slag, emerged as an alternative to fiberglass for acoustic insulation in walls and ceilings.

**2.4.4 Engineered Wood Products:** Engineered wood products, such as acoustic plywood and MDF (medium-density fibreboard), were developed with specific acoustic properties for use in construction and furniture.

## 3. Acoustic properties

Sound absorbers, sound diffusers, noise barriers, and sound reflectors are all different types of materials used in acoustic treatments. Sound absorbing acoustical panels and soundproofing materials are specifically designed to eliminate sound reflections, improve speech intelligibility, reduce standing waves and prevent comb filtering. These materials come in varying thicknesses and shapes to achieve different absorption ratings depending on the specific sound requirements. Acoustical foam panels are commonly used in applications ranging from recording and broadcast studios to commercial and industrial facilities. They can be applied directly to walls, hung as baffles, or used as freestanding absorbers. Anechoic wedges are ideal for controlling low frequency sound. To install acoustic treatment in a room, the space should be cleaned and cleared, and the space itself should be evaluated. Generally, acoustic treatment of a room will require one or all of three types of acoustic foam: bass traps, acoustic panels/tiles, and acoustic foam sheeting. Bass traps are used to absorb low frequencies, while acoustic panels/tiles are used to absorb mid-range and high frequencies and are usually self-adhesive for convenience. Acoustic foam sheeting can also absorb mid-range and high frequencies, but can cover a larger space or be cut to fit a specific space. Bass traps should be installed first, followed by treating the parallel walls, and then re-evaluating. White paintable panels are also an option for acoustic treatment. These panels have a soft textured appearance and the 2' by 1' dimension provides installers flexibility to mount acoustical panels around existing objects. In addition to reducing echo and reverberation, these acoustical panels are used to create unique designs and patterns. The glass fiber

core is faced with a paintable covering, allowing for matching or complementing existing wall colors. Fabric wrapped panels are also available and utilize 6-7 PCF glass fiber material for maximum absorption. These materials are available as wall panels, ceiling tiles, hanging baffles, acoustical clouds, and bass



traps, with more than 50 standard colors to choose from.

Acoustical wall fabric is another option for acoustic treatment. It is a dimensional fabric that offers excellent acoustical properties, unmatched fade resistance, and a fire/smoke retardant class A rating. Produced with no VOCs, ODSs, heavy metals, or formaldehyde, it is the perfect acoustic fabric for offices, classrooms, conference centers, or any area where speech intelligibility is a critical factor. This material is not factory trimmed and must be cut to a straight vertical edge following the ribbed pattern, with all edges butt joined. The wall carpet should be hung straight up without alternately reversing strips. A premixed heavy-duty adhesive should be applied directly to the wall, allowing it to dry to its maximum tackability without it being overly dry. The adhesive should not be applied to the back of the wall covering. Sound diffusers are devices that reduce the intensity of sound by scattering it over an expanded area, rather than eliminating the sound reflections as an absorber would. Traditional spatial diffusers, such as the polycylindrical (barrel) shapes, also double as low-frequency traps. Temporal diffusers, such as binary arrays and quadratics, scatter sound in a manner similar to diffraction of light, where the timing of reflections from an uneven surface of varying depths causes interference which spreads the sound.

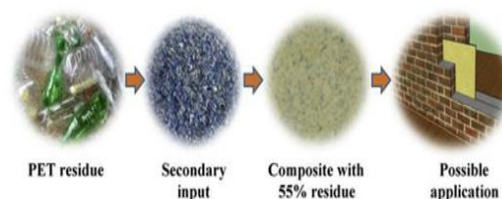
Finally, sound barrier materials, such as the BlockAid® series of products (mass loaded vinyl), are used to reduce the transmission of airborne sound. The series includes the standard one pound per square foot non-reinforced barrier, transparent material when obstructing views is not desired.

#### 4. Acoustic Recycled Material

There is a growing emphasis on sustainability in the development and use of advanced acoustic materials. Here are some examples of sustainable advanced acoustic materials commonly used nowadays:

**4.1.1. Recycled PET (Polyethylene Terephthalate) Panels:** These panels are made from recycled plastic bottles and offer excellent sound absorption properties. They provide an eco-friendly alternative to traditional acoustic materials and help reduce plastic waste.

#### PET recycle process



**4.1.2. Recycled Cotton Panels:** Panels made from recycled cotton fibers, often sourced from textile waste, are another sustainable option for acoustic treatment. They offer good sound absorption and are biodegradable at the end of their lifecycle.

#### Recycled cotton fiber

**4.1.3. Natural fiber panels:** Panels made from renewable natural fibers, such as hemp, jute, or coconut coir, are increasingly used for acoustic applications. These materials are sustainable, biodegradable, and offer excellent sound absorption properties.



Natural fiber material

**4.1.4. Wood Wool Panels:** Wood wool panels are made from wood fibers, often sourced from sustainably managed forests, and a small amount of cement or mineral binders. They provide good sound absorption and are biodegradable and recyclable.



Wood fiber

**4.1.5. Bio-based Foam Panels:** Some companies are developing foam panels made





from bio-based materials, such as soybean oil or corn starch, as alternatives to traditional petroleum-based foams. These bio-based foams offer similar acoustic properties while being more environmentally friendly.

Applying layer of Bio-based foam

**4.1.6. Acoustic Fabrics:** Fabrics made from recycled fibers or organic materials are used to cover acoustic panels and baffles. These fabrics offer both acoustic performance and sustainability, contributing to a healthier indoor environment.

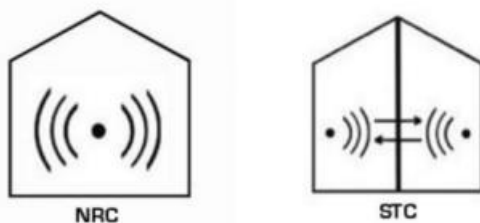
Fibre board used in lobby

**4.1.7. Plant-based Resins:** Some acoustic panels are manufactured using plant-based resins as binders instead of traditional synthetic resins. These plant-based resins reduce the environmental impact of the panels and help promote sustainability.

**4.1.8. Modular and recyclable Systems:** Modular acoustic systems made from recyclable materials allow for easy disassembly and reuse, minimizing waste and extending the lifecycle of the materials.

## 5. Measuring Sound Insulation

To compare the amount of sound insulation which is to be delivered from different materials, the study of measuring sound insulation is important. There are various ratings which are used to measure the sound insulation such as Noise Reduction Coefficient (NRC) and Sound Transmission Class (STC). While one measures the build-up of noise within a space, the other measures the sound transmission between spaces. It is important to understand these two ratings. The Noise Reduction Coefficient (NRC) is a measure of how much noise accumulates within a space. It's a single number index rating that's used to assess the sound-absorbing capacity of a material. The NRC rating of insulation products ranges from .75 to .82, depending on factors like wall design, materials, and density of the product. This means that insulation



products can absorb up to 82% of the sound that comes in contact with them and reflect back only 18% to 25% of it. However, NRC doesn't take into account a material's barrier effect, and it doesn't provide information on how well a material absorbs sound at low and high frequencies. NRC is simply an average of the mid-frequency sound absorption coefficients (250, 500, 1000 and 2,000 hertz), rounded to the nearest 5%.

## Measuring sound insulation

The Sound Transmission Class (STC) measures the sound transmission between spaces. It is single number rating which is used to measure the assembly's barrier effect. A higher STC rating blocks more noise from transmitting through a partition. Loud speech can be understood through an STC 30 wall but should not be audible through an STC 60 wall. Insulation products have an STC rating of 44 to 68 depending on the wall construction. STC ratings do not measure the low-frequency sound transfer. It depends on the performance with frequencies from



125 to 4,000 hertz (speech frequencies). The STC rating is a lab test that does not take into consideration weak points, perceptions, or flanking paths. NRC and STC are completely mutually exclusive. A material with a high NRC will help to absorb sound, stopping it from reflecting back into the room. The same material having a low STC will allow a large amount of sound to pass through it and into an adjacent room. Acoustic wall treatment with a high NRC can stop sound from reflecting back into space, possibly lowering the noise level within a space, while in STC it will not stop sound from passing through and into an adjacent space, therefore they do not improve STC.

## II. RESULT AND DISCUSSIONS

The article highlights the crucial role of architectural acoustics in shaping our acoustic experiences and how it impacts our daily lives. However, traditional approaches to acoustic design often neglect environmental sustainability, prioritizing performance instead. But, there's a growing need for sustainable solutions in architectural acoustics, in line with the broader trend towards green building practices and sustainable design principles. The text also provides a brief overview of key acoustic materials used in the past, including stone, earth, acoustic foam panels, and mineral wool. The research paper aims to explore innovations in sustainable acoustic building materials and technologies. It also showcases how sustainable acoustic solutions can revolutionize the way we design and construct buildings with sound in mind.

Different types of materials utilized in acoustic treatments, such as sound absorbers, sound diffusers, noise barriers, and sound reflectors. Acoustic foam panels, anechoic wedges, and white paintable panels are the most commonly employed materials for acoustic treatment, while bass traps, acoustic panels/tiles, and acoustic foam sheeting are typically necessary. The passage also covers new and sustainable advanced acoustic materials, such as

recycled PET panels, recycled cotton panels, natural fiber panels, and wood wool panels.

The significance of measuring sound insulation and compares two ratings utilized in this process - the Noise Reduction Coefficient (NRC) and Sound Transmission Class (STC). The NRC measures the amount of noise accumulated within a space and is utilized to evaluate the sound-absorbing capacity of a material. In contrast, the STC measures the sound transmission between spaces and gauges an assembly's barrier effect. The insulation products have an NRC rating of .75 to .82 and an STC rating of 44 to 68, depending on factors such as wall construction. However, it is important to note that the NRC does not take into account a material's barrier effect, whereas the STC does not measure low-frequency sound transfer. NRC and STC are mutually exclusive, and a high NRC can lower the noise level within a space, while it will not improve STC.

### III. CONCLUSION

The text provides an in-depth analysis of the field of architectural acoustics and its impact on our daily lives. It points out that the built environment is a critical factor in influencing everything from our productivity to our overall well-being. Within this context, acoustic design plays a crucial role in shaping our acoustic experiences and how we perceive and interact with the spaces around us. Traditional approaches to acoustic design often prioritize performance over environmental sustainability. They rely on materials and technologies that have significant negative impacts on the planet, such as non-renewable resources, high energy consumption, and generation of waste. However, in recent years, there has been a growing recognition of the need for more sustainable solutions in architectural acoustics. This shift towards sustainability in acoustic design reflects a broader trend towards green building practices and sustainable design principles. Urgent need for more sustainable alternatives that can help mitigate the environmental impact of building construction and operation. It underlines the significance of integrating sustainability into acoustic design practices, not only to reduce environmental harm but also to create healthier and more comfortable indoor environments for occupants. By prioritizing sustainability in acoustic design, we can contribute to the broader goals of reducing carbon emissions, conserving natural resources, and promoting human well-being.

Furthermore, the introduction provides a roadmap for the subsequent sections, which explore emerging

materials and technologies, case studies, and real-world examples. The paper aims to showcase the potential of sustainable acoustic solutions to transform the way we design and construct buildings with sound in mind. It advocates for a more comprehensive approach to acoustic design that takes into account the environmental impact of building materials and technologies.

The text also provides a historical overview of acoustic materials, from thick stone walls and earthen structures used in ancient civilizations to engineered wood products developed in the present day. It highlights the evolution of acoustic design over time and the different materials and technologies that have been used to shape our acoustic experiences in various architectural contexts.

### IV. ACKNOWLEDGEMENT

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### V. REFERENCES

- Arenas, Jorge & Sakagami, Kimihiro. (2020). Sustainable Acoustic Materials. Sustainability. 12. 6540. 10.3390/su12166540.
- Soha, S & Ibrahim, Ebtelhal. (2022). IMPROVING THE ACOUSTIC PERFORMANCE USING SUSTAINABLE MATERIALS CASE STUDY: LECTURE ROOMS.
- [Green Acoustics: Sustainable Materials and Practices in Sound Design. - Aural-Aid \(auralaid.com\)](https://auralaid.com)