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The Characteristics of Concrete for Controlling Building Noise Reduction

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Amy Nursarah Ahmad Zahidi[1], Norsafiah Norazman[*,1]

[1] Building Surveying Programme, School of Housing Building and Planning, Universiti Sains Malaysia, 11700 Gelugor, Pulau Pinang, Malaysia

[*] **Correspondence email:** safiahazman@usm.my

Abstract

Improving building acoustics is increasingly crucial due to urban growth and the impacts of noise pollution on the health and productivity of human beings. Concrete is a common building material often facing sound absorption and noise transmission challenges. Research shows that noise pollution, particularly in urban settings, can have adverse physical and psychological effects, making the need for enhanced acoustic design in buildings more urgent. Studies indicate that the degree of sound reflection in such modified concretes depends largely on specific aggregate types, pore size and distribution, and other changes in mix composition. This research investigates how properties like density and porosity of concrete influence acoustic performance, focusing on lightweight, high-density, and porous concrete types. Therefore, this research aims to identify the most effective type of concrete for enhancing acoustic performance in buildings. This research will offer practical recommendations for concrete selection based on acoustic needs by examining various concrete formulations and how their properties influence sound behaviour.

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1. Introduction

Noise pollution, as stated by Hannan et al. [1], produces a significant environmental issue, with negative effects on human health, including physical and psychological impacts. There is growing interest in building materials that control indoor noise, particularly sound-absorptive materials that minimise reflected sound waves, creating acoustically comfortable environments. As a construction material, concrete is valued for its sound-blocking properties due to its dense composition, effectively reflecting external noise. However, Tie et al. [2] mentioned that its limited sound absorption can increase issues like echo in restricted spaces. High-density concrete reflects up to 99% of sound energy, making it an effective block against external noise in urban areas. Despite this advantage, its inability to absorb sound makes it less effective for controlling internal noise, according to research by Amran et al. [3]. Recent research by Kim and Lee [4] have aimed to overcome these limitations by modifying concrete with lightweight or porous materials to improve sound absorption while retaining structural durability. Holmes et al. [5] identified adjustable factors, including cement flow and aggregate type, which have demonstrated potential to enhance acoustic performance by optimising the balance between sound reflection and absorption.

This research investigates the acoustic properties of various concrete types, focusing on their ability to reduce noise transmission and improve sound absorption. The research seeks to contribute to building materials and designs that enhance indoor acoustics and produce more comfortable environments by identifying key material properties and exploring optimised concrete mixes.

This study identifies the best concrete types for boosting acoustic performance in buildings by analysing previous research and secondary data on concrete characteristics. It focuses on key properties like density, porosity, and aggregate composition to optimise concrete use for better sound absorption and noise reduction. By reviewing existing studies, reports, and standards, the study recommends concrete options that enhance sound absorption and decrease noise transmission in structures.

1.1. Literature Review

1.1.1. Building Acoustic

Acoustics is the scientific study of how sound behaves in different environments. It encompasses essential concepts such as sound waves, frequency, and amplitude, which Erbe et al. [6] explained as how sound travels through various materials and media. Effective acoustics reduce unwanted noise while improving the clarity of how people speak. Lowering background noise improves focus and reduces distractions.

1.1.2. Factors Affecting Acoustic Performance

Acoustic comfort is the study of different aspects that affect acoustic comfort and decrease discomfort, not something that gives the occupant a comfortable indoor environment. In addition to the factors affecting acoustic performance, acoustic insulation, absorption, and echo time also affect the acoustic comfort of an occupant, as mentioned by Ganesh et al. [7]. Different thicknesses of porous concrete have different sound absorption effects and different numbers of high-frequency sound absorptions. Hence, Amran et al. [3] emphasised that the sound wave energy absorbed and reflected during the propagation of porous concrete of different thicknesses varies, which will cause different absorption effects of the sound.

1.1.3. Impact of Noise Pollution on Buildings

According to Adekunle et al. [8], noise is an undesirable sound, while vibrating objects create sound and arrive at the listener's ears as waves in the air or other media. Researchers have recently found that noise pollution in the environment negatively affects the health, social, and professional efficiency of those affected. According to the International Standard Organisation's guidelines for hearing limitations, those who are exposed to the highest sound pressures and intensities are more likely to experience long-term health problems like headaches, muscle tension, anxiety, insomnia, exhaustion, resentment, distraction, hearing impairment, communication problems, drug use, relaxation problems, and temporary threshold changes. All of these noise sources have the potential to cause vibrations that could disrupt the comfort and activities of those who live in the built environment.

1.1.4. Characteristics of Concrete

Different types of concrete showcase varying acoustic properties, which can influence its application in construction. Concrete has some characteristics that significantly influence its noise reduction ability, including density, porosity and aggregate composition. These factors determine whether concrete primarily absorbs, transmits or reflects the sound waves.

Research shows that high-density concrete offers better sound insulation than traditional concrete, especially for low-frequency sounds. This is because heavier materials are better at blocking sound waves, which makes high-density concrete good for soundproofing. Research by Amran et al. [3] mentions that the dense composition of this type of concrete makes it very effective at blocking noise from external sources, such as traffic or industrial activities, which are common issues in cities.

On the other hand, porous concrete is known for its ability to absorb sound due to its interconnected voids, which allow sound waves to penetrate and dissipate within the material. Shtrepi et al. [9] emphasise that the efficiency of sound absorption in porous concrete depends on factors such as pore size, thickness, and composition distribution, which influence its acoustic performance across different sound frequencies.

The aggregate composition also plays an important role in determining the acoustic properties of concrete. Amran et al. [3] found that lightweight aggregates like expanded clay and rubberised concrete improve sound absorption, making them suitable for noise reduction. The lower density of lightweight concrete results from the air-filled voids created by these aggregates. These voids make the concrete lighter and give it better sound absorption capabilities than traditional or high-density concrete. Fediuk et al. [10] explained that the cellular structure of lightweight concrete captures sound waves within its voids, significantly lowering noise levels inside buildings. This makes it highly effective in environments where quietness and noise reduction are essential.

1.1.5. Acoustic Properties of Concrete

Acoustic properties of concrete are essential in construction, influencing how buildings adapt sound transmission and absorption. High-density concrete efficiently reflects sound due to its mass, producing substantial sound insulation. Research by Fediuk et al. [10] studied that while this reflection nature can increase reverberation time within enclosed rooms/ spaces, it may cause acoustic discomfort. Porous concrete, characterised by its interconnected voids, allows sound waves to penetrate and dissipate within its component, where it may reduce noise levels. Sound absorption efficiency for porous concrete differs with its thickness and pore structure, affecting its performance across various sound frequencies as stated by Shtrepi et al. [9].

2. Secondary Data

To provide a comprehensive understanding of the variables affecting building acoustics and the effect of different concrete types on noise reduction, this research used a qualitative approach based on secondary data analysis to review the characteristics of concrete for noise reduction. The research relies on existing studies, literature reviews, academic reports, and thematic analysis to study the knowledge of the acoustic properties of concrete. This approach ensures that the research remains connected to theoretical and real-world contexts while improving the validity and dependability of the results by using several types of data sources.

2.1. Literature Review

Literature review is the basis of this research, which systematically collects and reviews related academic and industry research. The research studies include sources such as academic and professional journal articles, books and web-based resources. It provides an in-depth research and investigation of key terms and ideas connected to acoustics, including the properties of sound in construction environments, the factors that influence sound transmission and absorption, plus the methods that apply to assess acoustic properties.

2.2. Academic Report Analysis

In addition to the literature review, this research relies on report analysis, which examines case studies, technical reports, experimental findings from previous studies, and industry assessments. It works as a key part of presenting and discussing research findings. From this, the references of standards and guidelines such as ISO (International Organisation for Standardisation) and ASTM (American Society for Testing and Materials) for measuring the acoustic properties of concrete materials can be achieved (see Table 1).

Table 1: Standards for determining acoustic characteristics in materials.

Ref	Standard	Measured Characteristic
[3]	ISO 10534-2:1998	Sound absorption coefficient α
[11]	ISO 10534-2, ASTM E1050 – 12	Sound Transmission Loss (STL)
[12]	ISO 10534-2, ASTM E1050	Sound absorption coefficient α

2.2.1. Sound Absorption Results

Identifying which concrete absorbs the most sound within specific frequency ranges is important. Porous concrete might perform better at high frequencies, whereas lightweight concrete could be effective over a broader spectrum.

2.2.2. Sound Transmission Results

The analysis involves the Sound Transmission Class (STC) results to determine which concrete type offers better sound insulation, especially against low-frequency sounds. High-density concrete is expected to provide superior sound insulation, while lightweight and porous concrete may have lower STC ratings due to the lower mass.

By integrating qualitative insights with quantitative measurements, the research thoroughly analysed the acoustic performance of the selected concrete types. These different methods ensured that the research findings were based on expert knowledge and supported by the report evidence.

2.3. Thematic Analysis

Thematic analysis is a method of analysing qualitative data. According to Caulfield [13], the researcher closely examines the data to identify common themes, which include topics, ideas and patterns of meaning that come up repeatedly from respondents. Thematic coding was used to extract insights related to significant components influencing the acoustic performance of concrete, such as density, porosity, and structural composition. These themes helped frame the study’s discussion and provided a deeper understanding of the expert perspectives on improving sound absorption and noise control in buildings. This analysis also highlighted professional opinions on the practical applications and challenges of using different types of concrete in real-world construction.

3. Results and Discussion

Secondary data complements the primary data by providing theoretical information and context for the research. This data is sourced from academic research, industry reports, and guidelines from organisations like the World Health Organisation (WHO) and laboratory standards. By reviewing existing studies on advanced materials of concretes, the research can identify gaps in knowledge and ensure the importance of investigating the specific concrete types selected for this research.

3.1. Sound-Absorbing Concrete Structure

The main sound-absorbing mechanism of porous media is that sound wave energy can change its form to thermal energy through internal pore friction. Therefore, the following considerations for properly designing sound-absorbing materials must be adequately monitored: voidness coefficient, pore size, porosity opening size, and pore layer thickness. Using porous media is one of the most effective ways to reduce noise, and numerous studies have already been conducted to clarify the noise control mechanism in porous surfaces [3].

According to the review, there are practical ways to enhance the acoustic absorption capacity of concrete, including adding voids to create pervious concrete and altering the concrete with lightweight aggregate. This is mostly because more voids are made in the concrete, which produces pores and better sound absorption capabilities. Certain factors need to be considered for these concretes to ensure effective sound absorption. Pervious concrete should ideally have a mix design with a larger void content to provide good sound absorption performance. Using lightweight particles instead of regular aggregates will further enhance sound absorption. In the case of concrete with lightweight aggregates, selecting suitable aggregates is as important as increasing the content of the lightweight aggregate to lower the density and improve the sound absorption of the concrete [2].

3.2. Comparative Analysis of Concrete Types for Noise Reduction

Due to the literature review's thematic analysis, various concrete types presented differ in their level of noise reduction effectiveness. The summary of the literature review can be shown in Table 2.

These findings highlight the importance of material selection in building acoustics and noise reduction. The choice of concrete types should align with acoustic requirements, balancing sound insulation and absorption depending on the building application.

This study evaluates the effectiveness of different types of concrete in reducing noise transmission and compiles research on the elements affecting a building's acoustic performance. Material density, porosity, aggregate composition, and structural design are important factors that affect acoustic performance. Certain types of concrete with particular density and porosity forms have been discovered to minimise noise while maintaining structural integrity. The potential of these materials in various applications has been highlighted by the additional assessment of their acoustic performance through modern testing techniques and simulations. The results support the aim and objectives by suggesting that concrete be chosen with consideration for mechanical performance, sustainability, and acoustic properties.

Table 2: Summary of Literature Review.

Author [Ref]	Title	Aim & Objectives	Methods	Findings
Mugahed Amran, Roman Fediuk, Gunasekaran Murali, Nikolai Vatin, and Amin Al-Fakih [3]	Sound-Absorbing Acoustic Concretes: A Review	This research aims to comprehensively review sound-absorbing acoustic concretes, focusing on measurement techniques, building materials' insulation properties, and construction materials' sound absorption characteristics.	Acoustic Testing and Field Testing Observations	The review highlights that sound-absorbing acoustic concretes mitigate noise pollution using porous aggregates or foam agents, enhancing absorption and sustainability. Performance depends on aggregate type, pore size, and mix design.
Roman Fediuk, Mugahed Amran, Nikolai Vatin, Yuriy Vasilev, Valery Lesovik and Togay Ozbakkaloglu [10]	Acoustic Properties of Innovative Concretes: A Review	This article reviews the noise and sound transmission in buildings, types of acoustic insulating materials, and the acoustic properties.	Acoustic testing of materials	The review shows that lightweight, porous concretes absorb sound better than dense ones, and their performance is influenced by aggregates and pore structure.
Tzer Sheng Tie, Kim Hung Mo, Azma Putra, Siaw Chuing Loo, U. Johnson Alengaram [2]	Sound absorption performance of modified concrete: A review	This article aims to review the published works of various types of concrete, discussing the modifications done to improve the sound absorption performance of the materials.	Lab Testing	The design of these modified mixes must account for the aggregate size, type of aggregate, and amount of foaming admixture to optimise the formation of porosity in the materials and improve the sound absorption performance.
Anu Bala and Supratic Gupta [14]	Thermal resistivity, sound absorption and vibration damping of concrete composite doped with waste tire Rubber: A review	This research aims to review and compile the findings on the thermal resistivity, sound absorption, and vibration-damping properties of rubberised concrete (RC), focusing on the impact of recycled rubber substitution on concrete behaviour in terms of performance, sustainability, and environmental benefits.	Interview and Lab Testing	Rubberised concrete has higher porosity, which increases sound wave scattering, resulting in a significant reduction in the amplitude of the transmitted sound wave.
Louena Shtrepi, Arianna Astolfi, Elena Badino, Giovanni Volpatti, and Davide Zampini [8]	More Than Just Concrete: Acoustically Efficient Porous Concrete with Different Aggregate Shape and Gradation	This research aims to increase awareness of porous concrete properties among professionals such as architects, designers, acousticians, policymakers, etc., who deal with noise control strategies in outdoor and indoor environments.	Lab Testing	The research shows that the acoustic performance of porous concrete depends on aggregate shape, gradation, panel thickness, and the addition of materials like rock wool.

4. Conclusions

Optimising concrete properties performs a sustainable and cost-effective approach to enhancing building acoustic performance and addressing noise reduction challenges in construction. The research aims to close the gap between structural and acoustic efficiency by evaluating high-density, lightweight, and porous concrete. The findings are expected to provide practical perspectives for developing multifunctional materials that tackle urban noise issues, support sustainability, and minimize reliance on additional soundproofing components.

Declaration of Conflict of Interest

The authors declared no conflict of interest with any other party on the publication of the current work.

ORCID

Norsafiah Norazman https://orcid.org/0000-0002-8496-723X

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