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# Improving Building Floor Acoustics with Innovative Inorganic Sound Insulation Coating

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**Abstract:** Floor impact sound insulation is essential for improving living environments and has become a mandatory requirement for green buildings in Southern China. This study introduces an innovative inorganic sound insulation coating technology for enhancing building floor acoustic performance. Through comprehensive laboratory experiments and field tests, we evaluated inorganic coatings of 3 mm and 5 mm thickness, comparing their performance against traditional methods, including organic coatings and soundproof mortar. Standardized impact sound pressure level measurements, conducted in accordance with the China GB/T 50121 standard, demonstrated significant acoustic improvements. Laboratory testing revealed impact sound reductions of 6–7 dB and 9–10 dB for the 3 mm and 5 mm inorganic coatings, respectively, while field applications of the 3 mm coating achieved an average reduction of 14.3 dB. The inorganic coating exhibited superior performance characteristics compared to both organic coatings and soundproof mortar in terms of sound insulation efficiency, fire resistance, and application feasibility, demonstrating particularly effective attenuation in the mid- to high-frequency range. This investigation presents an innovative, cost-effective, and environmentally sustainable solution for improving floor sound insulation in green buildings.

**Keywords:** floor sound insulation; green building; inorganic sound insulation coating; sound insulation floating floor; standardized impact sound pressure level

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## 1. Introduction

Floor impact sound insulation has become a critical concern in modern urban environments. As population density increases and living spaces become more compact, the need for effective noise reduction strategies has grown significantly [1,2]. This urgency is reflected in the latest environmental statistics of China, which show that noise-related complaints reached 5.706 million cases in 2023, an increase of 1.203 million cases from the previous year [3]. Floor impact sound, resulting from footsteps, dropped objects, or furniture movement, can be particularly disruptive to occupants in multi-story buildings [4,5]. As cities grow and living spaces become more compact, the need for effective noise reduction strategies has intensified, making this topic crucial for improving quality of life and meeting increasingly stringent building standards [6,7].

Impact sound in buildings results from actions exerted on the floor, propagating through various materials and structural elements connected to the floor system. This phenomenon diffuses sound energy across a wide frequency spectrum, generated by localized vibratory motions [8,9]. The propagation becomes more complex in heterogeneous floor systems, such as ribbed or hollow slabs, due to their orthotropic characteristics [10].

Acoustic performance in floor systems is determined by compositional characteristics, thickness parameters, and construction typology. Total thickness, rigid structural layers, and non-uniform transmission patterns from unidirectionally arranged concrete beams

can all affect these factors [11,12]. The principle of energy propagation suggests that higher-quality floors are less prone to transmitting sound through vibration. This can be interpreted as improved rigidity and continuity in the structure and construction layers leading to reduced sound energy transmission [13,14].

Interestingly, while the mass of a component plays a crucial role in airborne sound attenuation, it has a less significant impact on sound insulation. This is because the vibration energy in impact scenarios is greater and applied directly to the building structure, resulting in minimal energy loss during transmission [15,16]. This distinction underscores the unique challenges posed by the impact of sound insulation in building acoustics.

In response to these challenges, many countries have implemented stringent building acoustics standards, with floor impact sound insulation being a key component [17,18]. Table 1 illustrates the diverse requirements across different countries, highlighting the global significance of this issue.

**Table 1.** Foreign countries' floor sound insulation limit requirements.

| Country | Air Sound Insulation | Value | Impact Sound Insulation | Value | Standard |
|---|---|---|---|---|---|
| Italy | $R'_w$ | 50 | $L'_{n,w}$ | 63 | DPCM 5/12/97 [19] |
| Denmark | $R'_w + C_{50\sim3150}$ | 55 | $L'_{n,w}$ | 53 | DS 490 [20] |
| Finland | $R'_w$ | 55 | $L'_{n,w}$ | 53 | SFS 5907 [21] |
| Norway | $R'_w + C_{50\sim5000}$ | 55 | $L'_{n,w}$ | 53 | NS 8175 [22] |
| Germany | $R'_w$ | 53 | $L'_{n,w}$ | 53 | VDI 4109 [23] |
| Sweden | $D_{nT,w} + C_{50\sim3150}$ | 52 | $L'_{nT,w} + C_{I,50\sim2500}$ | 56 | SS 25267 [24] |
| Australia | $D_{nT,w}$ | 45 | $L'_{n,w}$ | 62 | ABCB Sound Handbook [25] |
| England | $D_{nT,w} + C_{tr}$ | 45 | $L'_{n,w}$ | 62 | ADE [26] |
| France | $D_{nT,A}$ | 53 | $L'_{nT,w}$ | 58 | Arrêté du 30 juin 1999 [27] |
| Switzerland | $D_{nT,w} + C_{tr}$ | 58~52 | $L'_{n,w}$ | 47~53 | SIA 181 [28] |
| Spain | $D_{nT,A}$ | 50 | $L'_{nT,w}$ | 65 | DB HR [29] |
| China | $R_w + C$ | 50 | $L_{n,w}$, $L'_{nT,w}$ | 65~75 | GB 50118 [30] |

Note: $R'_w$ denotes the weighted apparent sound reduction index, utilized for quantifying airborne sound insulation performance in field conditions, while $R_w$ represents the weighted sound reduction index measured under laboratory conditions, excluding flanking transmission. $L'_{n,w}$, $L'_{nT,w}$, and $L_{n,w}$ are all related to impact sound transmission, albeit with subtle distinctions: $L'_{n,w}$ represents the weighted standardized impact sound pressure level; $L'_{nT,w}$ signifies the weighted standardized field impact sound pressure level, which incorporates flanking transmission and is applicable to in situ building environments; and $L_{n,w}$ is the weighted normalized impact sound pressure level, applicable to laboratory conditions and excluding flanking transmission. $D_{nT,A}$ represents the weighted standardized level difference for airborne sound insulation using A-weighting, while $D_{nT,w}$ represents the weighted standardized level difference using ISO 717-1 reference curve. $C_{tr}$, $C_{50–3150}$, and $C_{100–5000}$, among others, are spectral adaptation terms employed to adjust acoustic performance within specific frequency ranges. Particularly, $C_{100–5000}$ is optimized for residential environments, considering sound sources typical in homes within the 100 Hz to 5000 Hz range. In general, lower values for impact sound parameters or higher values for airborne sound parameters indicate superior sound insulation performance. Due to differences in the specific provisions and frequency ranges used in national provisions, it is difficult to compare these requirements; only the relevant limits are listed.

In the context of green building development, especially in regions like China, floor impact sound insulation has transitioned from a desirable feature to a mandatory requirement [1,31]. This shift presents unique challenges for the construction industry, necessitating solutions that are not only acoustically effective but also environmentally friendly, cost-efficient, and easily implementable [32].

Traditional approaches to floor sound insulation have primarily included floating floors, resilient underlays, and damping compounds or acoustic mortars [33–36]. A floating floor system can be conceptualized as a simplified mass–spring–damper model, where the mass is defined by the surface density of the floor covering, the spring is represented by the dynamic stiffness of the elastic underlayer, and the system damping is equivalent to the internal friction of the insulating material [37]. This configuration effectively decouples the floor surface from the structural slab, reducing impact sound transmission. Resilient underlays, typically made of materials such as rubber, cork, or specialized foams, function by absorbing impact energy and reducing its transmission to the structure [38]. Damping

compounds and acoustic mortars, on the other hand, function through mass enhancement and internal damping mechanisms, thus attenuating sound vibrations [39]. While these methods have demonstrated varying degrees of effectiveness, they often present challenges such as increased floor thickness, higher material and installation costs, or complex implementation processes [40]. These drawbacks can be particularly problematic in retrofit applications or projects with strict height limitations.

Recent research has explored alternative solutions, focusing on sustainable and cost-effective options. These include the use of recycled materials, composite structures, and advanced engineered products [41–43]. For instance, studies have investigated the acoustic performance of extruded polystyrene (XPS) insulation boards, composite foamed cement boards, and high-performance sound insulation mortars [44–46]. These innovations aim to provide effective sound insulation while addressing some of the limitations of traditional methods.

Despite these advancements, there remains a significant gap in the field. Current solutions often struggle to balance optimal acoustic performance with practical considerations such as ease of installation, cost-effectiveness, and compatibility with existing construction practices. Moreover, the growing emphasis on sustainable building practices necessitates solutions that not only meet stringent acoustic requirements but also align with green building standards [47,48].

Inorganic sound insulation coatings have emerged as a promising technology in this field [49]. These coatings offer potential advantages over organic counterparts, including better fire resistance, improved durability, and lower environmental impact. This study extends the current understanding of inorganic coatings by conducting a systematic investigation of their performance in floor impact sound insulation, with detailed comparisons to established methods.

The purpose of this study is to comprehensively evaluate a new inorganic sound insulation coating technology for improving floor impact sound insulation. We hypothesize that this inorganic coating will provide superior sound insulation performance compared to traditional methods while offering additional benefits in terms of fire resistance, ease of application, and environmental impact.

Specifically, this study aims to:

1. Evaluate the sound insulation performance of inorganic coatings of different thicknesses (3 mm and 5 mm) through laboratory experiments and field tests.
2. Compare the performance of inorganic coatings with traditional methods such as organic coatings and soundproof mortar.
3. Analyze the frequency-dependent performance of inorganic coatings in attenuating floor impact sound.
4. Assess additional properties of inorganic coatings relevant to their practical implementation.

By addressing these objectives, this study aims to provide valuable insights into the potential of inorganic sound insulation coatings as a solution for meeting the acoustic and sustainability requirements of modern building construction, particularly in the context of green building development in Southern China.

## 2. Theoretical Background and Materials

### *2.1. Regulatory Framework and Theoretical Foundations*

Before delving into the specifics of our study, it is crucial to understand the regulatory context and theoretical basis of floor impact sound insulation.

The impact of construction noise, particularly floor impact sound, has become increasingly prominent in civil buildings. To address this issue and ensure a satisfactory acoustic environment, several national standards in China have established relevant requirements for floor sound insulation in buildings.

The “Code for Sound Insulation Design of Civil Buildings” (GB 50118-2010), the “Unified Standard for Design of Civil Buildings” (GB 50352-2019), and the “Code for

Residential Building" (GB 50368-2005) all specify criteria for floor sound insulation performance. Furthermore, with the implementation of the "Green Building Evaluation Standard" (GB 50378-2019), many regions have fully adopted green building standards, which impose more stringent requirements on floor impact sound insulation.

The theoretical basis for evaluating floor impact sound insulation is primarily founded on the concept of impact sound pressure level ($L'_{n,w}$). This parameter can be calculated using the following equation:

$$L'_{n,w} = L'_{nw,eq} + \triangle Lw + K$$

where $L'_{nw,eq}$ is the impact sound pressure level of the structural floor;$\triangle$Lw is the impact improvement value of the sound insulation material, obtained based on EN ISO 10140; K is the correction factor for lateral sound transmission.

The impact sound pressure level of the structural floor ($L'_{nw,eq}$) can be further estimated using the following:

$$L'_{nw,eq} = 164 - 35\log(m_{floor}/m_0) \text{ (applicable for } 100\ kg/m^2 \leq m_{floor} \leq 600\ kg/m^2)$$

where $m_{floor}$ is the surface density of the structural floor; $m_0$ is the unit of fundamental density, equal to 1 $kg/m^2$.

This theoretical framework allows for the prediction and evaluation of floor impact sound insulation performance. It considers the mass of the floor structure, the effectiveness of the sound insulation materials, and the influence of flanking transmission. Figure 1 illustrates the prediction principle of sound insulation on the impact of sound insulation floor, visualizing how these factors interact in the overall system.

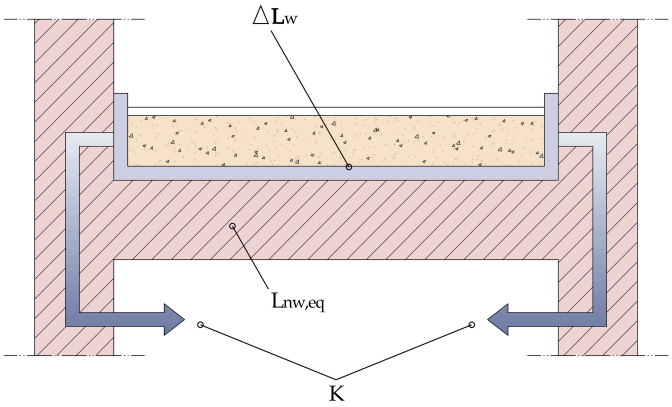



**Figure 1.** The prediction principle of sound insulation on the impact of sound insulation floor.

As illustrated in Figure 1, comprehensive sound insulation performance derives from the combined influence of structural mass distribution, supplementary insulation layer properties, and potential flanking transmission mechanisms. This comprehensive approach ensures a more accurate prediction of the actual performance in real-world applications.

Research findings [50] and our field measurements indicate that typical reinforced concrete floors (100–140 mm thick) with a 40 mm mortar surface layer generally exhibit a weighted standardized impact sound insulation of about 80 dB or higher. However, this performance falls short of the more stringent requirements for high-quality living spaces in China, which stipulate that impact sound insulation for bedroom and living room floors should not exceed 65 dB. This significant gap underscores the necessity for additional structural measures to enhance floor impact sound insulation performance, particularly in the context of increasingly demanding green building standards. The prediction principle illustrated in Figure 1 aligns with this need, demonstrating how the addition of sound insulation materials can substantially improve overall acoustic performance and help bridge this 15 dB or greater performance gap.

These regulatory requirements and theoretical principles form the foundation of our study. They guide our experimental design and provide context for evaluating the performance of the inorganic sound insulation coating developed in this research. Understanding these regulatory requirements and theoretical principles is crucial for developing effective strategies to enhance floor impact sound insulation in civil buildings. It provides the foundation for evaluating current practices and innovating new solutions to meet the increasing demands for acoustic comfort in modern constructions.

### *2.2. Materials*

Inorganic coatings can be classified into three main categories based on their film-forming materials: alkali metal silicate coatings, silica sol coatings, and phosphate coatings. In the construction industry, inorganic coatings commonly utilize alkali metal silicate aqueous solutions or silica water dispersions as film-forming materials. These are combined with pigments, fillers, and various additives, then mixed and ground to achieve the desired dispersion.

This study focuses on a specific type of inorganic sound insulation coating, which primarily uses silicate as the main film-forming material. Compared to organic sound insulation coatings, inorganic variants offer greater convenience in production, transportation, and application processes. The inorganic sound insulation coating examined in this research comprises inorganic damping materials enhanced with additives for water retention, waterproofing, bonding, and early strength development. This formulation results in a coating with multiple beneficial properties, including longevity, fire resistance, thermal insulation, and sound attenuation.

The coating formulation consists of precisely controlled component proportions: Portland cement (P.O. 42.5, 32 parts), mineral fiber (20 parts), mica sheet (40 parts), hollow ceramic beads (3 parts), and specialized additives (5 parts). The binding system utilizes silicone-modified acrylic emulsion to enhance adhesion properties. This formulation creates a nano-multilayer structure where inorganic damping fillers are uniformly distributed within the polymer matrix.

The strong bond strength with concrete substrates is achieved through two mechanisms: (1) the silicone-modified acrylic emulsion provides chemical bonding with the concrete surface, and (2) the fine particle distribution of inorganic components enables mechanical interlocking within concrete pores. The uniform distribution of damping particles throughout the coating matrix, combined with its micro-structural stability, enhances both acoustic performance and substrate adhesion.

Laboratory testing was conducted on this inorganic sound insulation coating and its raw materials (Figure 2). To ensure compliance with building material standards, the raw materials were subjected to testing by relevant national testing institutions. The test results meet the requirements of both Chinese standards and international mutual recognition testing (CNAS L0230), demonstrating stable performance across various parameters.

As shown in Table 2, the test data of the inorganic sound insulation coating reveal several key properties. The coating achieves a B1 level for combustion property, indicating good fire resistance. It demonstrates excellent water tolerance, showing no abnormalities after 72 h of exposure. The weighted impact sound pressure improvement is significant, with an 8 dB improvement for a 3 mm thickness and a 12 dB improvement for a 5 mm thickness. The heat conductivity of the coating is 0.124 W/(m K), contributing to its thermal insulation properties. Adhesive strength of the coating exhibits temporal enhancement, with a mean value of 0.27 MPa after 7 days and 0.38 MPa after 28 days.

These results indicate that the inorganic sound insulation coating meets the necessary performance requirements for use as an elastic material in floor structures, offering a combination of sound insulation, fire resistance, and durability. The comprehensive performance of this coating makes it a promising solution for improving acoustic comfort in buildings while maintaining other essential structural and safety properties.



**Figure 2.** Inorganic sound insulation coatings.

**Table 2.** Test data of inorganic sound insulation coatings.

| Property | Value |
|---|---|
| Combustion | B1 Level |
| Water tolerance | 72 h no abnormalities |
| Weight impact sound pressure improvement | The improvement of 3 mm thickness is 8 dB<br>The improvement of 5 mm thickness is 12 dB |
| Heat conductivity (W/(m K)) | 0.124 |
| Adhesive strength (MPa) | 7 d: 0.27 (mean)<br>28 d: 0.38 (mean) |

## 3. Experimental Methods and Procedures

### *3.1. Acoustic Performance Testing*

The acoustic performance of the inorganic sound insulation coating was evaluated using a comprehensive laboratory setup designed to simulate real-world conditions. The experimental environment consisted of a two-story structure featuring a 100 mm thick concrete floor and a 95 $m^3$ test room (Figure 3), utilizing certified acoustic chambers that conform to ISO 10140 standards. Testing was conducted under controlled temperature ($23 \pm 2$ °C) and humidity ($50 \pm 5\%$) conditions, with concrete floor specimens mounted using standard construction practices and perimeter sealing methods identical to field applications. Measurement reliability was ensured through multiple position sampling protocols conforming to ISO standards, with triplicate measurements at each test point using calibrated instrumentation, thereby enabling systematic evaluation of coating effectiveness in attenuating inter-floor impact sound transmission.



**Figure 3.** Inorganic sound insulation coating experimental building.

(1) Sample preparation

The experimental procedure involved a systematic approach to sample preparation and application. Initially, the base floor surface was thoroughly cleaned and prepared. An interface agent was then applied to ensure proper adhesion. The inorganic sound insulation coating was mixed with a fixed water-cement ratio of 1.2:1. Two sample thicknesses were prepared—3 mm and 5 mm—and applied uniformly via spraying. The coated surfaces underwent spray curing twice within three days after the surface had dried. Finally, bricks were laid on the coated surface and allowed to cure to the specified age for testing. The resulting floor structure configuration is illustrated in Figure 4.

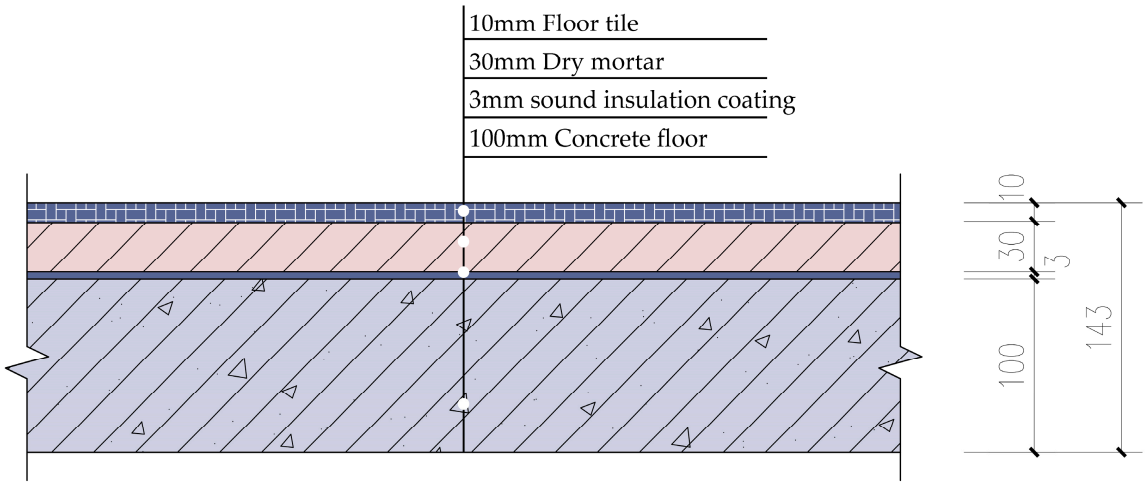



**Figure 4.** Floor insulation structure drawing.

(2) Testing procedure

Acoustic measurements were conducted using wireless building acoustics measurement equipment. We tested both 3 mm and 5 mm thick samples at two time points: 7 days and 14 days post-application. The methodology adhered to GB/T 50121-2005 "Rating standard of sound insulation in buildings—Part 7: Field measurement of impact sound insulation", which corresponds to ISO 16283-2:2020, Acoustics—Field measurement of sound insulation in buildings and of building elements—Part 2: Impact sound insulation, MOD.

The experimental setup positioned the sound source room upstairs and the receiving room downstairs. An AWA6290L multi-channel signal analyzer was employed for data acquisition. Three conditions were tested: bare floor (control), floor with a 3 mm coating layer, and floor with 5 mm coating layer. Measurement points were strategically arranged, as depicted in Figure 5, to ensure comprehensive data collection and adherence to signal-to-noise ratio standards.

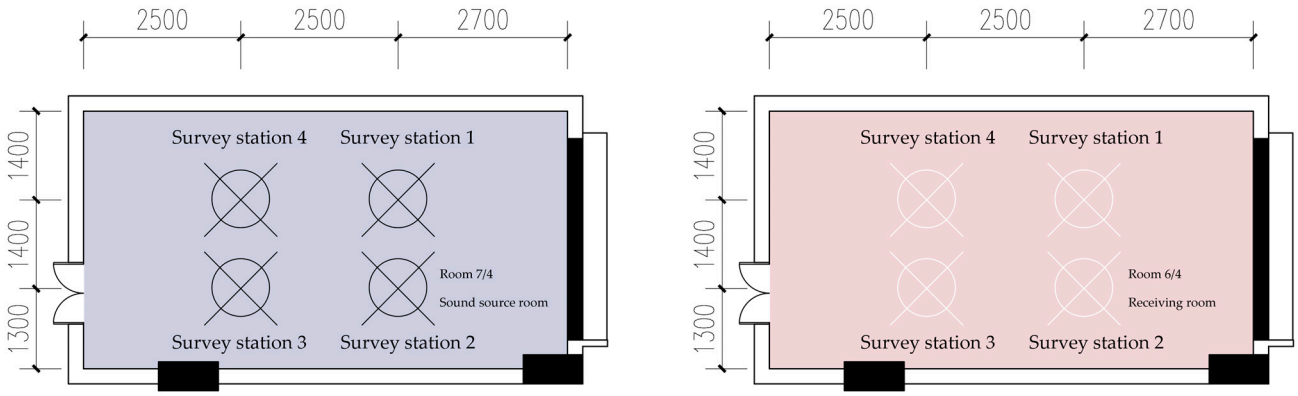



**Figure 5.** Schematic diagram of experimental measuring points.

(3) Data collection

For each condition, the weighted $L'_{nT,w}$ was determined after applying reverberation time corrections. Multiple measurements were taken at each point, and average values were calculated to ensure reliability.

We also conducted a detailed frequency analysis on the 14-day samples. Spectral analysis was conducted across frequencies ranging from 100 Hz to 3150 Hz, enabling comprehensive evaluation of acoustic attenuation characteristics throughout the frequency domain.

Through this rigorous testing procedure, we were able to quantify the acoustic performance of the inorganic sound insulation coating at different thicknesses and curing times, as well as its effectiveness across various frequencies. This systematic methodology facilitates a comprehensive assessment of acoustic insulation enhancement capabilities in building construction applications.

### *3.2. Data Analysis Techniques and Results Evaluation*

The acoustic performance data collected from the experiments were subjected to rigorous analysis to evaluate the efficacy of the inorganic sound insulation coating. The following analytical techniques were employed, along with their respective evaluations:

(1) Acoustic performance metrics

The primary acoustic performance indicator utilized was the $L'_{nT,w}$. This metric was calculated in accordance with GB/T 19889.7-2022, Acoustics—Measurement of sound insulation in buildings and of building elements—Part 7: Field measurement of impact sound insulation," which corresponds to ISO 16283-2:2020. Table 3 presents the $L'_{nT,w}$ values for different experimental conditions.

**Table 3.** Weighted standardized impact sound pressure level ($L'_{nT,w}$) for different floor conditions.

| Floor Condition | $L'_{nT,w}$ (dB) | Improvement (dB) |
|---|---|---|
| Bare floor | 80.0 | -- |
| 3 mm thick coating, 7 days | 73.0 | 7 |
| 3 mm thick coating, 14 days | 74.0 | 6 |
| 5 mm thick coating, 7 days | 70.0 | 10 |
| 5 mm thick coating, 14 days | 71.0 | 9 |

Note: improvement values are calculated relative to the $L'_{nT,w}$ of the bare floor.

Analysis of the $L'_{nT,w}$ values reveals significant improvements in floor impact sound insulation with the application of the inorganic sound insulation coating. The 3 mm thick coating showed an improvement of 7–6 dB, while the 5 mm thick coating demonstrated an improvement of 10–9 dB. These results indicate that both coating thicknesses meet the requirements of current relevant specifications, with the 5 mm coating providing superior sound insulation performance.

(2) Frequency response analysis

We analyzed the impact sound pressure levels ($L'_{nT}$) across the frequency range from 100 Hz to 3150 Hz, as presented in Table 4 and visualized in Figure 6.

The frequency analysis reveals that the inorganic sound insulation coating exhibits a relatively stable improvement in floor impact sound across the frequency spectrum. The 5 mm thick coating shows better performance, particularly in the middle and high-frequency ranges. Notably, the thicker coating demonstrates enhanced attenuation of high-frequency impact sounds.

Characteristic patterns in $L'_{nT}$ frequency trends can be explained through fundamental acoustic mechanisms. Within the low-frequency range (100–315 Hz), significant $L'_{nT}$ variations (37.7 to 72.1 dB for bare floor specimens) are primarily governed by modal behavior and structural resonance phenomena. At these frequencies, vibration mode characteristics dominate the acoustic response, resulting in pronounced peaks and dips in transmission curves.

The mid-frequency range (400–1000 Hz) exhibits notably stable performance, with $L'_{nT}$ values maintaining between 71 and 74 dB for bare floor specimens. This stability predominantly derives from mass-law behavior in concrete floor structures. Within this frequency range, wavelength dimensions become comparable to floor thickness parameters, wherein transmission mechanisms are primarily controlled by mass distribution rather than stiffness or modal characteristics. Furthermore, the equilibrium between material stiffness and damping properties contributes to sustained performance stability.

**Table 4.** Frequency-dependent acoustic parameters for different floor conditions.

| Frequency (Hz) | T(30) (s) | $L'_{nT}$ (dB) | | |
|---|---|---|---|---|
| | | Bare Floor | 3 mm Coating | 5 mm Coating |
| 100 | 5.5 | 37.7 | 33.8 | 36 |
| 125 | 3.2 | 60.5 | 59.6 | 54.2 |
| 160 | 3.9 | 66.5 | 64.4 | 65.6 |
| 200 | 3.8 | 69.1 | 66.7 | 66.8 |
| 250 | 3.5 | 71.4 | 69.8 | 68.4 |
| 315 | 2.6 | 72.1 | 72.3 | 70.8 |
| 400 | 2.7 | 71.6 | 70.4 | 70.1 |
| 500 | 2.6 | 72.4 | 71.2 | 69.7 |
| 630 | 2.6 | 73.5 | 71.4 | 71.4 |
| 800 | 2.3 | 73.4 | 71.9 | 71.7 |
| 1000 | 2.3 | 74.6 | 73.2 | 69.9 |
| 1250 | 1.9 | 74.6 | 70.9 | 69.9 |
| 1600 | 1.8 | 74.7 | 70.6 | 67.6 |
| 2000 | 1.7 | 74.4 | 71.5 | 65.5 |
| 2500 | 1.5 | 73.2 | 70 | 60.9 |
| 3150 | 1.4 | 71.2 | 68.2 | 55.5 |

Note: T(30) represents the reverberation time. $L'_{nT}$ represents the standardized impact sound pressure level. All measurements were taken after 14 days of coating application.

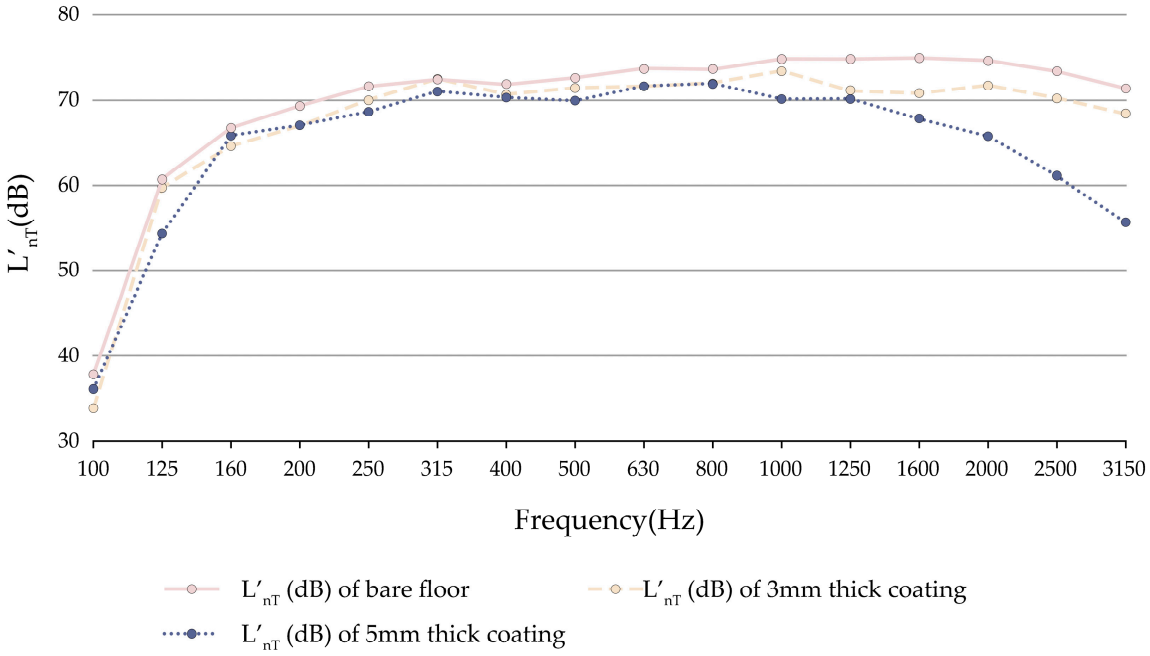



**Figure 6.** The frequency trend of $L'_{nT}$ drawing.

At higher frequencies (1250–3150 Hz), the gradual decrease in $L'_{nT}$ values is observed due to increased material damping effectiveness. As wavelengths become shorter, energy dissipation through internal friction becomes more efficient. This phenomenon is further enhanced when damping treatments (coatings) are applied, as evidenced by the more

pronounced reductions in $L'_{nT}$ values for coated floors in this range. The enhanced performance at higher frequencies also relates to better impedance matching between the coating and floor structure, allowing for more effective energy transfer and dissipation.

(3) Comparative analysis

Analysis of the experimental data reveals a consistent performance difference between the 3 mm and 5 mm coatings. At both 7 and 14 days after application, the 5 mm coating demonstrated a 3.0 dB lower $L'_{nT,w}$ value compared to the 3 mm coating. This consistent difference suggests a clear thickness-dependent effect on sound insulation performance. In building acoustics, a 3 dB change is generally considered the minimum difference perceptible to the human ear [51], indicating that the thicker coating provides a noticeable enhancement in impact sound insulation.

Examination of the frequency-dependent data (Table 4) provides further insights into the coatings' performance. The 5 mm coating shows superior sound insulation properties across the frequency spectrum, with particularly notable improvements in the mid to high-frequency range (1000–3150 Hz). This enhancement is crucial, as it corresponds to the frequency range most relevant to common impact noises in residential settings, such as footsteps and dropped objects [52].

The practical implications of these findings are substantial for the construction industry. Both coatings significantly improve impact sound insulation compared to the bare floor (80.0 dB), with the 3 mm coating ($L'_{nT,w}$ 73.0–74.0 dB) providing a 6–7 dB reduction, suitable for moderate improvements in renovations, and the 5 mm coating ($L'_{nT,w}$ 70.0–71.0 dB) offering a 9–10 dB reduction, making it ideal for new constructions or premium renovations in noise-sensitive areas. Notably, a 10 dB reduction is generally perceived as halving the loudness, underscoring the significant acoustic enhancement provided by these coatings.

### *3.3. Additional Property Tests*

In addition to acoustic performance, several other properties of the inorganic sound insulation coating were evaluated to assess its overall suitability for construction applications. Experimental evaluation focused on three critical performance parameters: tensile bond strength, fire resistance, and water resistance, which collectively determine material durability, safety characteristics, and implementation feasibility.

(1) Tensile bond strength test

The tensile bond strength of the inorganic sound insulation coating was evaluated to ensure its adherence to the substrate over time. Tests were conducted on both 3 mm and 5 mm thick coating layers, with measurements taken 7 days after application. For each thickness, three measuring points were selected to obtain a representative average value.

The test procedure involved attaching a metal disk to the coating surface using an epoxy adhesive. After the adhesive was cured, a pull-off tester was used to measure the force required to separate the coating from the substrate. The force at failure was recorded and divided by the area of the disk to calculate the bond strength in MPa.

The results of the tensile bond strength tests are presented in Table 5. The seven-day bonding strength of the 3 mm thick coating averaged 0.34 MPa, while the 5 mm thick coating averaged 0.33 MPa. The lower tensile bond strength observed in the 5 mm coating compared to the 3 mm coating can be attributed to several thickness-dependent mechanisms during the curing process. In thicker coatings, the increased material volume leads to greater internal stress development due to differential shrinkage between surface and deeper layers. This non-uniform curing process occurs because the surface layers cure faster than the interior, creating residual stresses that can potentially weaken the bond interface. Additionally, moisture gradient effects are more pronounced in thicker coatings, where water migration from deeper layers to the surface can create microscopic channels that might slightly compromise the coating-substrate bond integrity. Despite these mechanisms, the difference in bond strength is minimal (0.01 MPa), and both thicknesses exceed the minimum requirements for floor applications. Analysis indicates that although

thickness-dependent curing dynamics influence adhesion characteristics, the observed variations remain within acceptable performance thresholds for practical applications.

**Table 5.** Tensile bond strength test results of inorganic sound insulation coating after 7 days.

| Test Point | 3 mm Thick Coating (MPa) | 5 mm Thick Coating (MPa) |
|---|---|---|
| 1 | 0.41 | 0.34 |
| 2 | 0.25 | 0.34 |
| 3 | 0.37 | 0.30 |
| Average | 0.34 | 0.33 |

(2) Fire resistance test

The fire resistance of the inorganic sound insulation coating was evaluated through localized high-temperature exposure using a propane torch (Figure 7). Samples were subjected to direct flame contact at approximately 500 °C. Post-heating inspection revealed minor surface discoloration and localized color variations in the flame-exposed area, which are typical thermal responses of inorganic materials due to dehydration and phase changes rather than combustion. Despite the intense local heat exposure, no charring, melting, or structural deterioration was observed. The coating maintained its structural integrity throughout the test, demonstrating that while direct flame exposure may cause superficial appearance changes, the material retains its non-combustible nature, which is essential for building safety applications.

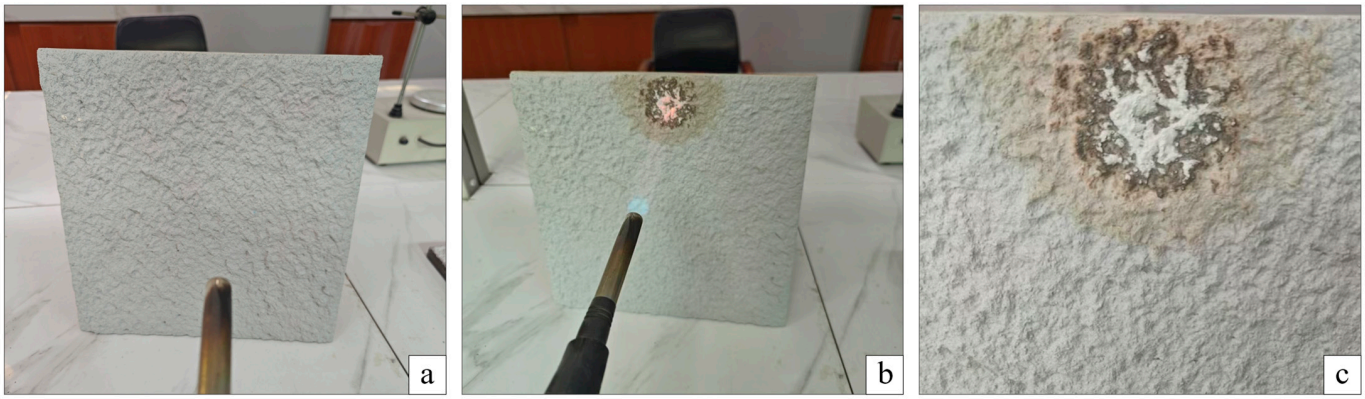



**Figure 7.** Fire resistance test of the inorganic sound insulation coating: (**a**) sample before testing, (**b**) direct flame exposure using propane torch, and (**c**) surface appearance after 500 °C flame exposure showing localized thermal discoloration without structural damage.

(3) Water resistance test

Water resistance evaluation consisted of two distinct experimental phases: immersion testing and bond strength assessment.

In the first phase, coated specimens underwent 96 h water immersion to simulate long-term moisture exposure in building applications. As shown in Figure 8, visual inspection revealed no signs of material degradation, such as surface softening, swelling, or delamination, indicating robust water resistance characteristics.

The second experimental phase involved pull-off adhesion testing of 5 mm coating specimens following a 15-day curing duration, conducted with an HG-6000C testing apparatus. Extended curing duration enhanced adhesion characteristics, with measured values exceeding those observed in 7-day specimens by approximately 20%. Comparative analysis between standard and water-exposed specimens demonstrated sustained adhesion performance (Figure 9). Bond strength measurements achieved 0.41 to 0.50 MPa for standard specimens and 0.32 to 0.38 MPa for water-exposed specimens. The moderate strength reduction (less than 25%) under moisture exposure conditions indicates robust material durability.

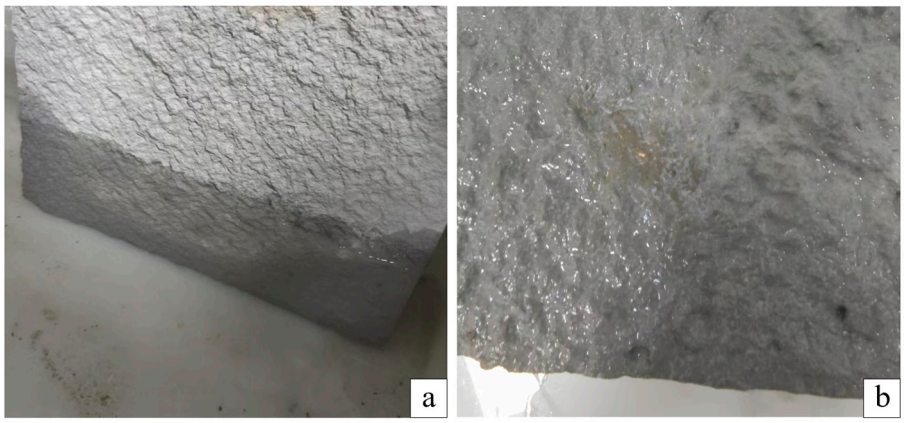



**Figure 8.** Water resistance evaluation of coating specimens: (**a**) experimental setup during 96 h water immersion testing; (**b**) post-immersion surface morphological examination showing preserved material integrity.

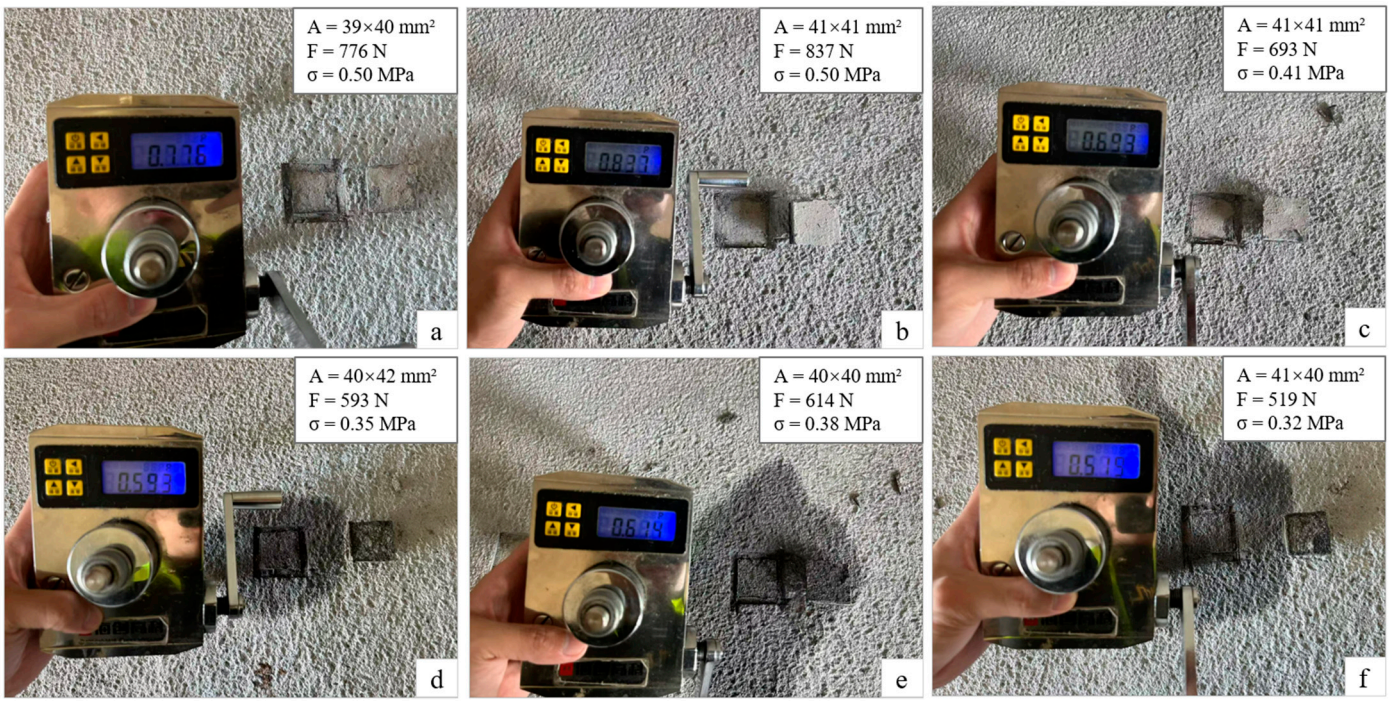



**Figure 9.** Pull-off adhesion test results showing measured parameters (A: cross-sectional area in $mm^2$; F: pull-off force in N; σ: bond strength in MPa) for (**a**–**c**) standard specimens and (**d**–**f**) water-immersed specimens.

These experimental results demonstrate substantial water resistance properties, suggesting high potential for long-term durability in building applications.

## 4. Inorganic Sound Insulation Coating: On-Site Performance Study

### *4.1. Project Overview*

To evaluate and compare the sound insulation performance of various floor sound insulation technologies in Zhuhai, China, a comprehensive engineering case study was conducted. The project aimed to ensure comparability by implementing unified requirements for engineering conditions across selected construction projects. The entire process, from material application to performance testing, was carefully controlled to maintain consistency in measured working conditions.

This study compared three sound insulation methods: 3 mm thick organic sound insulation coating, 3 mm inorganic sound insulation coating, and 30 mm thick sound insulation mortar. Floor impact sound insulation measurements were carried out 21 days after the application of these materials. Four measuring points were tested for each method in rooms with a 2.9 m net height and untiled floor surfaces. The floor structure diagrams for the 3 mm sound insulation coatings and 30 mm sound insulation mortar are illustrated in Figures 10 and 11, respectively.

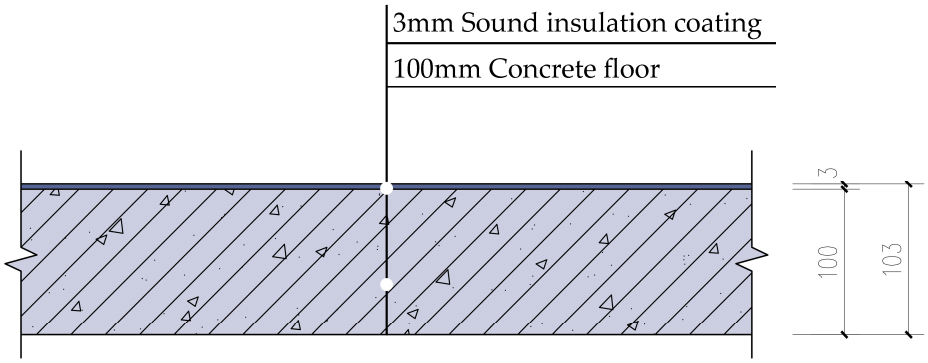



**Figure 10.** Structure drawing of 3 mm sound insulation coating.

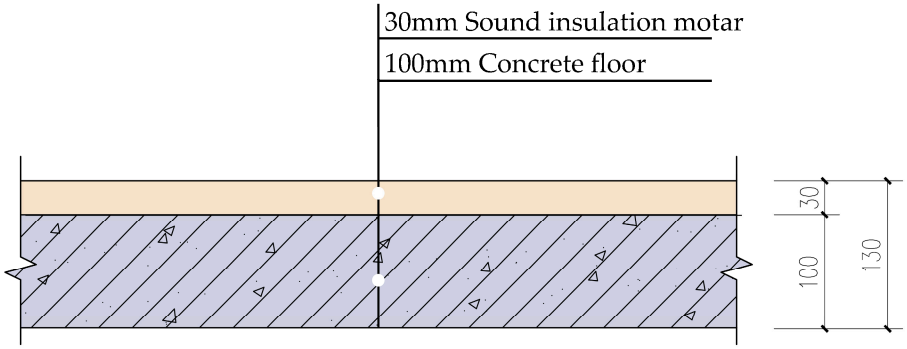



**Figure 11.** Structure drawing of 30 mm sound insulation mortar.

While laboratory tests demonstrated superior acoustic performance for the 5 mm coating, particularly in higher frequencies, the selection of 3 mm thickness for field implementation emerged from a comprehensive evaluation of technical and practical factors. From a cost-performance perspective, the 3 mm coating achieves a 14.3 dB improvement in field conditions, adequately meeting building acoustic requirements while optimizing material usage. This thickness also demonstrates better workability and more consistent curing behavior and allows faster project completion. These factors, combined with their proven acoustic performance, made the 3 mm coating the optimal choice for practical implementation.

### *4.2. Construction Methodology*

Using the MDO-360 brand inorganic sound insulation coating as a representative example, this section elucidates the key construction methodologies. It is noteworthy that the application processes for organic sound insulation coatings and sound insulation mortar share similar principles, all aimed at enhancing the elastic sound insulation properties of the structural layer.

(1) Substrate preparation

The initial phase involves meticulous preparation of the floor base. The surface must exhibit structural integrity, free from loose particulates, agglomerations, or oil residues. In instances where loose material or agglomerations are present, mechanical planing to the

structural layer is requisite. Surface cleansing is achieved through the application of compressed air or high-pressure water, ensuring a dust-free substrate devoid of standing water. Horizontal reference points are established using infrared technology, with positioning typically concentrated at 2–3 points within the shaded corners of each wall, accounting for site elevation and intended construction thickness.

(2) Coating application

The coating application follows a standardized protocol to ensure optimal thickness control and performance. Surface preparation requires thorough cleaning and inspection of the concrete substrate, with any damage or cracks repaired prior to application. The material is prepared at a specific water-cement ratio of 1.2:1 using a dual-speed mixing protocol. Application proceeds using a calibrated airless spray system, maintaining a working distance of 30–40 cm at controlled pressure settings. The coating is deliberately applied in two successive layers, with each pass depositing approximately 1.5–1.8 mm, achieving a final thickness of 3–3.5 mm. This dual-layer approach helps compensate for minor surface variations while ensuring consistent acoustic performance. The process is conducted under controlled environmental conditions (15–30 °C, relative humidity < 75%), with a minimum curing period of 72 h before subsequent construction activities. The construction sequence is visually represented in Figure 12.



**Figure 12.** Inorganic sound insulation coating construction process.

(3) Post-Application Care

Following the application of the inorganic sound insulation coating, specific maintenance protocols for the material layer are not mandated. However, implementation of appropriate protective measures for the finished surface is crucial. A 14-day period of restricted foot traffic is enforced, during which the use of wheeled equipment and the placement of materials or objects on the coated surface are strictly prohibited. It is advisable to defer any subsequent surface layer construction until after a minimum 21-day period, ensuring complete hardening of the coating.

### *4.3. Results*

The performance of different floor sound insulation treatments was evaluated using an AWA6290L multi-channel signal analyzer, following the GB/T 19889.7-2022 standard. The $L'_{nT,w}$ was measured for each method. Table 6 presents the comprehensive results of this analysis.

All measurements were conducted 21 days after application in rooms with a net height of 2.9 m and untiled floor surfaces.

**Table 6.** Comparison of weighted standardized impact sound pressure levels ($L'_{nT,w}$) for different floor treatments.

| Treatment | Number of Measurements | Mean $L'_{nT,w}$ (dB) | Standard Deviation | Range (dB) | Improvement (dB) |
|---|---|---|---|---|---|
| Bare floor | 4 | 80.3 | 0.5 | 80.0–81.0 | -- |
| 3 mm Inorganic Coating | 4 | 66.0 | 2.4 | 63.0–69.0 | 14.3 |
| 3 mm Organic Coating | 4 | 67.5 | 1.3 | 66.0–69.0 | 12.8 |
| 30 mm Sound Insulation Mortar | 4 | 68.3 | 0.5 | 68.0–69.0 | 12.0 |

Quantitative analysis of measured data demonstrates statistically significant improvements in acoustic attenuation characteristics through the implementation of inorganic coating systems, indicating superior performance in floor acoustical enhancement. With an average improvement of 14.3 dB over the bare floor condition, the inorganic coating significantly outperforms both the organic coating and the sound insulation mortar.

The exceptional performance of the inorganic coating (mean $L'_{nT,w}$ = 66.0 dB, SD = 2.4) is particularly noteworthy, especially considering its thin application layer of only 3 mm. This remarkable effectiveness can be attributed to its function as an elastic layer adhered to the structural surface, efficiently impeding the propagation of impact sound. These findings strongly corroborate the material performance analysis presented in Section 3, which indicated superior binding properties and overall performance of the inorganic coating with the floor structural layer.

The variability in the performance of the inorganic coating, as indicated by its standard deviation (SD = 2.4), suggests potential for even greater improvements through optimization of application techniques. This variability might be due to factors such as application consistency or local variations in floor structure and presents an opportunity for further refinement of the product and its application process.

The analysis of acoustic performance across multiple sound insulation methodologies revealed distinct efficacy differentials. The comparative evaluation demonstrated that organic coating systems and sound insulation mortar achieved measurable but limited acoustic improvements. Performance analysis of equivalent-thickness coating formulations indicated a 1.5 dB attenuation differential, with organic systems demonstrating lower effectiveness compared to inorganic counterparts. Notably, sound insulation mortar applications, even at increased thickness parameters (30 mm), exhibited minimal acoustic enhancement, underscoring the superior acoustic attenuation efficiency achieved through inorganic coating implementation.

## 5. Discussion

The results of this study demonstrate the significant potential of inorganic sound insulation coatings in improving floor impact sound insulation. The coating achieved substantial sound reduction with minimal thickness (3 mm), showing impact sound improvement of 6–7 dB in laboratory conditions and up to 14.3 dB in field applications, representing a significant advancement in building acoustics technology.

### *5.1. Comparison with the Existing Literature*

Our findings align with recent studies on innovative acoustic materials. For instance, Wang et al. [50] reported a 5–7 dB improvement in impact sound insulation using a polyurethane foam board of 10 mm thickness. However, our inorganic coating achieved comparable performance (6–7 dB) with just a 3 mm layer and demonstrated superior field performance up to 14.3 dB, particularly in the critical frequency range of 500–1000 Hz, where it averaged 8.2 dB reduction. This superior performance can be attributed to the unique composition of our inorganic coating, which combines strong adhesion (up to 0.50 MPa) with excellent damping properties.

The frequency-dependent performance of our coating, particularly its effectiveness in mid to high frequencies, is consistent with the findings of Branco et al. [36], who noted that thin-layer solutions tend to be more effective at higher frequencies. However, our coating showed a better low-frequency performance compared to their results, possibly due to its higher mass per unit area.

### *5.2. Economic and Environmental Implications*

The development of this inorganic coating has significant implications for both economic efficiency and green building practices, especially in rapidly urbanizing areas like Southern China. From an economic perspective, the coating system offers notable advantages through its simplified application process. As a single-component water-based coating that can be spray-applied in one continuous operation, it significantly reduces labor costs and installation time compared to conventional multi-layer acoustic systems. The direct application to concrete surfaces, without requiring additional protective layers, results in a more streamlined installation process that provides both time and cost benefits.

Economic feasibility analysis indicates significant cost advantages, complementing the environmental sustainability metrics of this coating methodology. As noted by Alassaf [53], the integration of eco-friendly, high-performance materials is crucial for meeting increasingly stringent green building standards. Our inorganic coating, with its excellent acoustic properties achieving up to 14.3 dB sound reduction and minimal thickness requirement of 3 mm, addresses this need effectively. Enhanced fire resistance characteristics coupled with optimized application methodology demonstrate significant implementation advantages for large-scale deployment across both new construction developments and structural rehabilitation projects. This aligns with the growing trend toward sustainable urban development, as highlighted by Kolya et al. [54] in their discussion of new building materials for more sustainable and livable cities.

### *5.3. Potential Applications and Future Directions*

The versatility of this inorganic coating extends its potential applications well beyond residential buildings, offering promising solutions across various sectors. In commercial spaces, such as office buildings, the coating could significantly reduce inter-floor noise transmission, potentially enhancing workplace productivity. Educational institutions, including schools and universities, could benefit from improved acoustic environments, potentially leading to enhanced learning outcomes. In healthcare settings, hospitals and clinics could utilize this coating to create quieter environments, potentially contributing to improved patient recovery and staff well-being. Prospective research trajectories encompass several critical domains. Primary investigation priorities include systematic evaluation of long-term performance stability under varied environmental parameters and synergistic effects with complementary acoustic attenuation methodologies. Furthermore, a comprehensive lifecycle assessment focusing on environmental impact metrics would strengthen sustainability credentials, potentially catalyzing broader implementation within sustainable construction frameworks.

### *5.4. Limitations and Challenges*

Despite the promising results, several limitations of this study should be acknowledged. While our results are statistically significant, a larger-scale study across more diverse building types would further validate these findings, addressing the current sample size limitations. Current experimental protocols, while establishing baseline performance parameters, necessitate complementary longitudinal investigations to comprehensively evaluate the temporal stability of acoustic attenuation properties and assess long-term material integrity under operational conditions. From an economic perspective, although the coating demonstrates excellent performance, a comprehensive cost-benefit analysis comparing it with traditional methods is crucial to fully evaluate its economic viability in real-world applications.

Resolution of current research limitations through systematic investigation will establish comprehensive validation protocols for temporal performance stability, economic viability, and environmental sustainability parameters. Such enhanced understanding will provide an essential empirical foundation for broad-scale implementation within construction industry frameworks. Such in-depth investigations will not only strengthen the credibility of this innovative solution but also pave the way for its integration into mainstream construction practices, potentially revolutionizing acoustic insulation in various building types.

## 6. Conclusions

This study has provided valuable insights into the performance of inorganic sound insulation coatings in addressing construction acoustic challenges. Through laboratory testing and field applications, we have demonstrated the effectiveness of these coatings in mitigating impact sound transmission.

Our research revealed that inorganic sound insulation coatings exhibit significant sound absorption characteristics, particularly in the frequency range critical for residential settings. In practical field applications, the inorganic coating demonstrated superior performance, achieving an average improvement of 14.3 dB in $L'_{nT,w}$ values over bare floors with just a 3 mm application thickness. This outperformed both organic coatings and traditional sound insulation mortar, highlighting its efficiency in noise reduction.

Optimized acoustic attenuation characteristics achieved through minimal material thickness requirements demonstrate significant implementation advantages in spatially restricted construction environments, offering enhanced design flexibility in architectural applications. Its performance stability over the testing period indicates potential for long-term effectiveness.

These findings have implications for the construction industry, particularly in urban environments where noise management is increasingly important. The inorganic sound insulation coating presents a potential solution for both new construction and renovation projects, contributing to the field of building acoustics.

Future research opportunities include studying long-term performance under various conditions, refining application techniques, and exploring combinations with other sound insulation methods. Further investigations into environmental impact and broader applications could also be beneficial.

In conclusion, inorganic sound insulation coatings show promise in the field of building acoustics. Their quantifiably superior performance and practical application advantages suggest they could be a useful tool in addressing urban acoustic challenges. As cities continue to develop, such sound insulation technologies may contribute to improving the acoustic quality of built environments.

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