

DEVELOPING A NEW STANDARD:

Examining in-room impact noise reduction of varying flooring materials

Introduction

In the healthcare environment, increased noise levels can result in higher rates of sleep disturbance and extended length of hospital stays, among other negative health effects [1]. Additionally, hospitals in the United States are increasingly relying on HCAHPS (the Hospital Consumer Assessment of Healthcare Providers and Systems) surveys to gather patient feedback. Because HCAHPS scores are reported publicly, poor scores can impact a hospital's reputation. Nation-wide, "Quietness of Hospital Environment" has consistently been either the lowest or the second lowest scoring category of the ten HCAHPS evaluation categories in the last several years [2].

In an educational setting, another basic but often unmet requirement in the learning environment is the ability of everyone to hear and be heard clearly. Noise can distract from the focus of learning and lower speech intelligibility, which can have a significant effect on reading comprehension [3]. A growing body of research links acoustics to student learning and achievement [4]. The Acoustical Society of America estimates that many classrooms have a speech intelligibility rating of 75 percent or less, with normal hearing, they recommend a 95 percent recognition level [5].

Background

Over the last several decades, there has been an increased awareness of the detrimental effects of noise in the built-environment. Design guidelines and standards have been developed to effectively address some of the root causes of excessive noise inside buildings. These guideline documents typically provide design targets for reverberation time (or how lively a space can be) minimum noise isolation between rooms, maximum background noise from HVAC equipment, and impact noise transmitted to adjacent rooms. However, none of these guidelines address noise from floor impacts in the same room as the listener, such as from people walking in hard heeled shoes or objects falling to the floor. The lack of specific design guidelines related to the various floor impact noises within a room is due to both a lack of research in this area and the

absence of a comprehensive testing standard. As part of a larger research initiative, nora systems, Inc. sought to expand current evidence and support the development of a new testing standard for floor impacts within a room.

To provide context, there are two types of sound transmission:

1. Sound that travels through the air (airborne) and
2. Sound that travels through the structure of a building (structure-borne)

Most acoustical testing standards related to flooring focus on evaluating the structure-borne noise that travels through a floor/ceiling assembly due to impacts on the floor. These tests call for the use of a standardized tapping machine in the "source" room while measuring the sound levels in the "receiver" room, as shown in Figure 1. They provide information about the impact

noise traveling to adjacent spaces, but do not provide any information about the noise produced in the same room where the impact occurs, as shown in Figure 2.

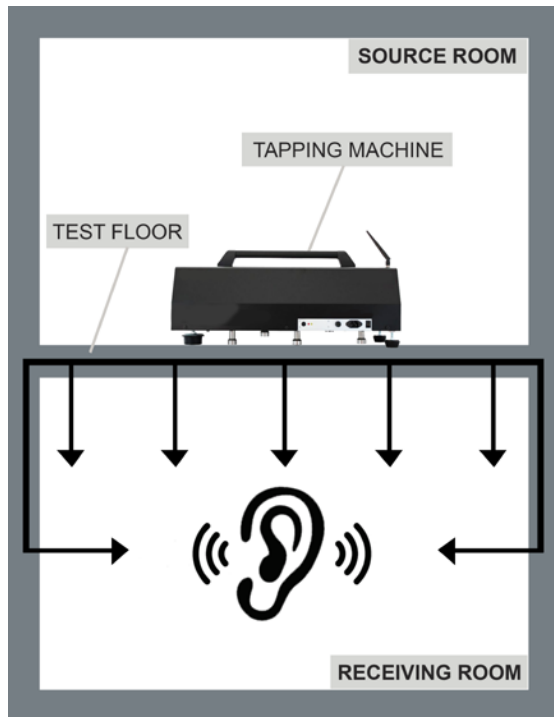


Figure 1: Typical Tapping Test



Figure 2: "In-Room" Impact Noise

The 2013 European standard EN 16205 aims to address the issue of rating "in-room" impact noise reduction using the standardized tapping machine or tapper. However, the standard does not account for the noise of the tapper itself. ASTM E3313, recently released in 2018, is a similar standard that also uses the tapper as the "in-room" impact source, but it includes

methodology to subtract out the noise of the tapper, isolating the noise reduction provided by the flooring. Using the tapper as the noise source, both standards focus on "in-room" noise primarily due to footfall or a person walking.

While the ASTM E3313 standard was still in the development stage, nora[®] saw a need to broaden the body of knowledge on "in-room" impact noise beyond just footfall. nora commissioned the University of Salford, Manchester in the UK to conduct a third-party research study on "in-room" noise using a wide range of impactors, as well as a rolling wheel, as the noise sources instead of the tapper [6]. This approach allows for deeper understanding of how different flooring materials affect "in-room" impact noise and provides a new methodology for the development of a more robust testing standard.

Objective

The focus of this paper is to highlight the repeatable testing methodologies that showed the most promise for further development of a testing standard, and to present a summary of select testing results showing how flooring can affect the "in-room" impact noise.

Terminology

Several acoustical terms are used to describe the test methods and results from the "in-room" floor impact noise research. These terms are briefly described below.

Decibel (dB) - The logarithmic unit of measurement used to quantify sound. Because there is such a large range between the quietest and loudest sounds humans can hear, it is convenient to express sound levels using a logarithmic scale.

A-weighting - The human ear does not respond with equal sensitivity at all frequencies or all loudness levels. A-weighting reduces the relative influence of low frequency and high frequency sound to approximate the response of the human ear at quiet to moderately loud sound levels.

Decibel (dBA) - When sound levels are A-weighted, the unit is expressed as dBA. A-weighting is used for the vast majority of noise standards, and is the most common metric of how humans perceive sound. Table 1 describes the subjective evaluation of how humans perceive a change in sound level.

Table 1: Subjective Effects of Changes in Sound Levels

(Reynolds, 1981) (Long, 2006)

Change in Sound Level	Change in Apparent Loudness
3 dBA	Perceptible
5 dBA	Clearly noticeable
10 dBA	Twice or half as loud
20 dBA	Four times louder or quieter

Insertion loss - In the case of floor impact noise, insertion loss is the amount of noise reduction calculated by comparing the impact noise on the base floor with a flooring material versus the impact noise on the base floor with no flooring material.

Table 2: Flooring Reference as Tested by Type

Sample Reference	Flooring Type	Thickness
A	Premium Rubber Acoustic	4 mm
B	Premium Rubber	3 mm
C	Premium Rubber	2 mm
D	Premium Rubber	3.5 mm
E	PVC-Free Sheet Vinyl with PUR Coating	2 mm
F	Linoleum	2.5 mm
G	PVC Sheet Vinyl	2 mm
H	VCT (Vinyl Composition Tile)	3.2 mm
I	Commercial Carpet Tile	6.5 mm
J	LVT (Luxury Vinyl Tile)	2 mm

Research Study Experiments

The research study investigated “in-room” sound level reduction provided by 10 flooring types as shown in Table 2, using various impactors as noise sources including:

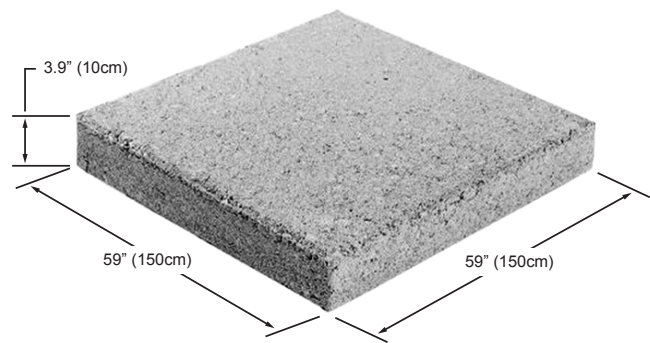
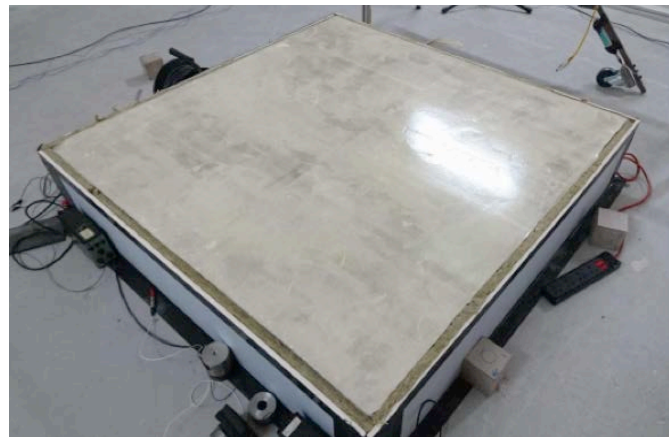
1. Small and large impactors on a large concrete slab
2. Different wheel types on a large concrete slab
3. A book dropping on a small concrete block
4. A metal chair leg impacting on a small concrete block
5. A hollow metal sphere impacting on a small concrete block

In each case, the floor covering was applied to a hard-concrete floor or block and the sound level reduction was measured relative to the “in-room” impact noise on the bare concrete floor

surface. The methodologies that were repeatable and showed the most promise for further development of a testing standard were 1, 2, & 3 listed above.

Impacts on Concrete Test Slab

The testing methodologies that were most promising were conducted on a large concrete test slab Figure 3 and Figure 4.


Figure 3: Concrete Test Floor Size

Figure 4: Concrete Test Slab

Each flooring type was glued to the concrete test slab according to manufacturers recommendation without any additional pad or resilient underlayment. Small and large cylindrical masses that could be fitted with interchangeable tips (steel, hard plastic, and soft plastic) were used as the impacting objects as shown in Figure 5.

The different impactors were used to assess how the mass and the hardness of an impacting object affect the “in-room” noise

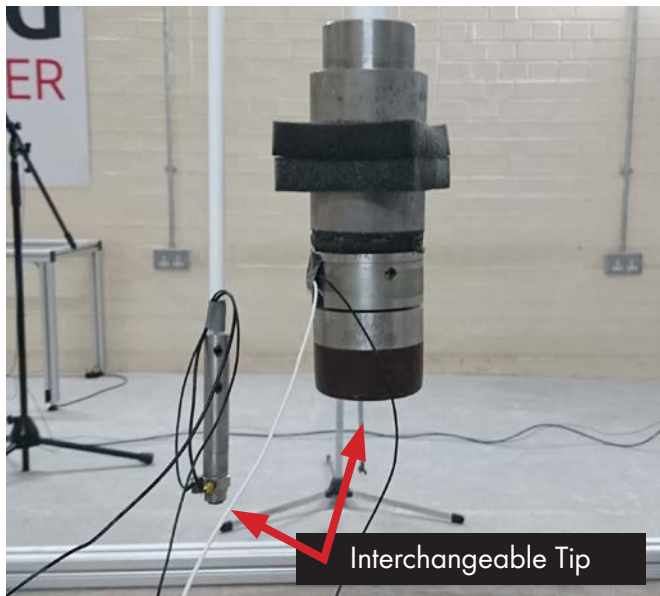


Figure 5: Small Impactor (left), Large Impactor (right)

with different flooring types. The lighter object (Figure 5- left) was used to mimic smaller falling objects, such as a water bottle, or a cell phone. The heavier object (Figure 5 - right) was used to mimic larger impacts, such as a person walking.

For each flooring type, both impactors were used with all three tip materials (steel, plastic, and rubber). The overall sound level of each impact was compared to the sound level of the same type of impact on bare concrete. The difference between these two measurements was determined to be the noise level

reduction due to the flooring type or insertion loss. Figure 6 shows the assembly set up.



Figure 6: Drop test assembly on the bare concrete floor in the reverberation chamber

Results

All flooring types provided a less significant reduction in sound level with the soft rubber tip compared to the hard plastic and steel tip impactors. Conceptually, this is similar to the difference between a marble and rubber ball hitting a floor. The rubber ball is softer and more flexible, so it will not make as much noise on impact compared to the hard marble. For this reason, only the results with the steel tipped impactor are described below.

Figure 7 compares the impact sound level reduction for different types of flooring with the steel tip on the small and large impactor. With the small impactor, the 4 mm premium rubber acoustic flooring provided the highest sound level reduction of 14 dBA, which cut the impact sound in half. However, the carpet provided the highest sound level reduction with the larger impactor at 16 dBA. Four of the flooring types tested at <1 dBA for “in-room” impact sound reduction with the large steel impactor (Figure 7).

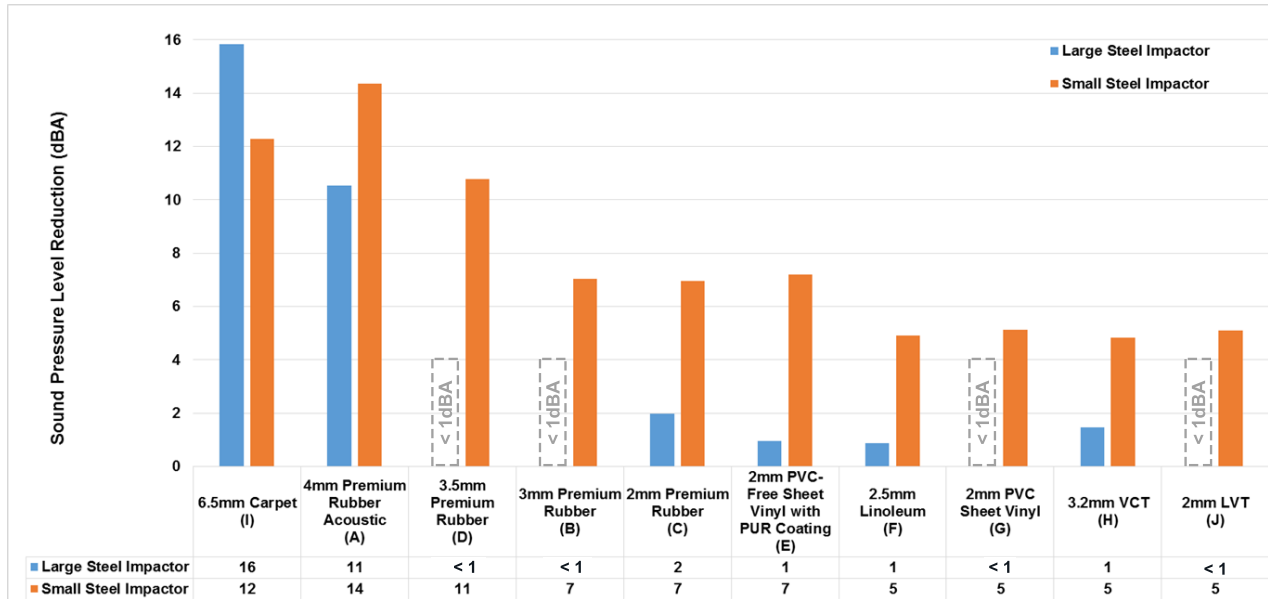


Figure 7: “In-Room” Impact Sound Reduction Compared to Bare Concrete for Large and Small Impactors with Steel Tip (10 cm / 4 in Drop Height)

Figure 8 shows the same comparison for the small impactor with steel tip but adds the impact sound level reduction for different drop heights, as well. The 4 mm premium rubber acoustic provided the best level of sound reduction at all three heights tested. In general, the largest sound reduction is observed with the thickest, softest flooring types. This aligns with the common experience of dropping something on a carpet as opposed to hard flooring. We would expect an impact on softer flooring to be quieter

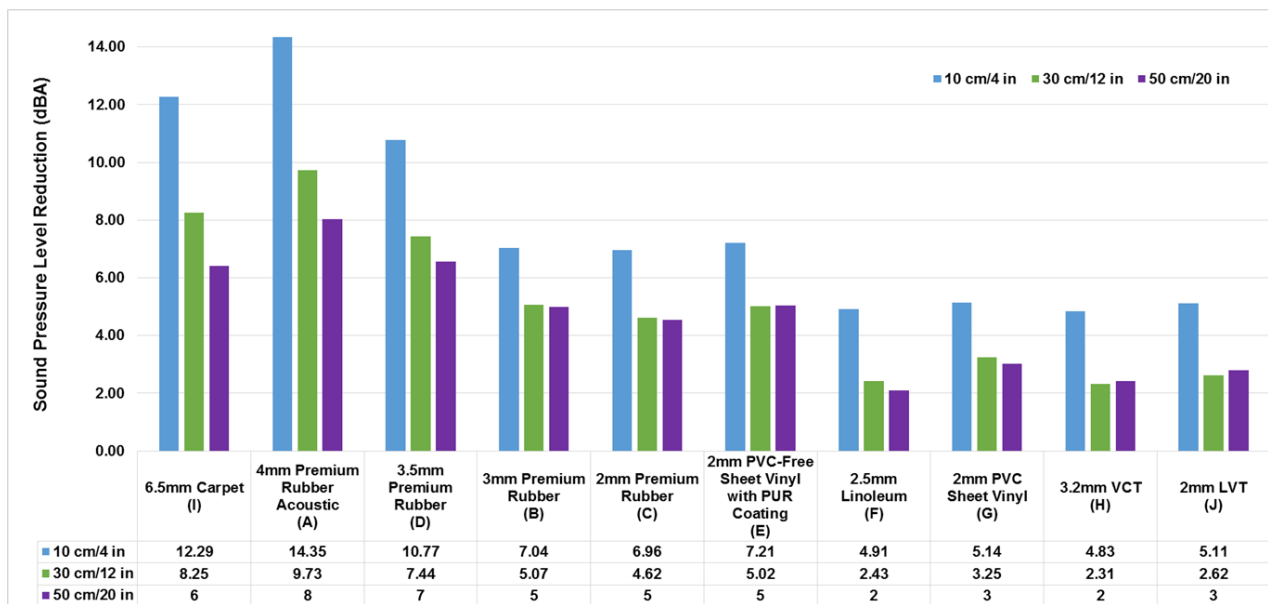


Figure 8: “In-Room” Impact Sound Reduction Compared to Bare Concrete for Small Impactor with Steel Tip Dropped from Three Heights

Overall, there is more reduction in sound level on all flooring types with the small impactor than the large impactor. Interestingly the results show that with the large, heavy impactor, only the 4 mm premium rubber acoustic flooring and carpet provide a significant reduction in sound level.

With regard to how the drop height affected the sound level reduction, different flooring types showed a larger difference in performance at smaller drop heights than they did at larger drop heights. For thinner floors, the impact sound reduction leveled off with increasing drop heights. Regardless of drop height, the 4 mm premium rubber acoustic flooring provided more sound level reduction than carpet with the smaller impactor.

In addition to impact noise, testing was also done with a wheel rolling on the large concrete slab. Rolling noise is a common noise source, especially in healthcare settings. Two different wheel types (steel and polyurethane) were used, both with a defect in the wheel (Figure 9). The performance ranking of each flooring material followed a similar pattern as with the impactors;

the carpet provided the most reduction at 26 dBA, followed by the 4 mm premium rubber acoustic at 8 dBA, and the 2 mm and 3.5 mm premium rubber at 5.2 and 4.6 dBA respectively (Figure 10). Although, the carpet provided the best attenuation for a rolling noise source, it has the disadvantage of increased rolling resistance. Further research in this area, could help identify flooring that reduces sound without increasing rolling resistance.



Figure 9: Steel and Polyurethane

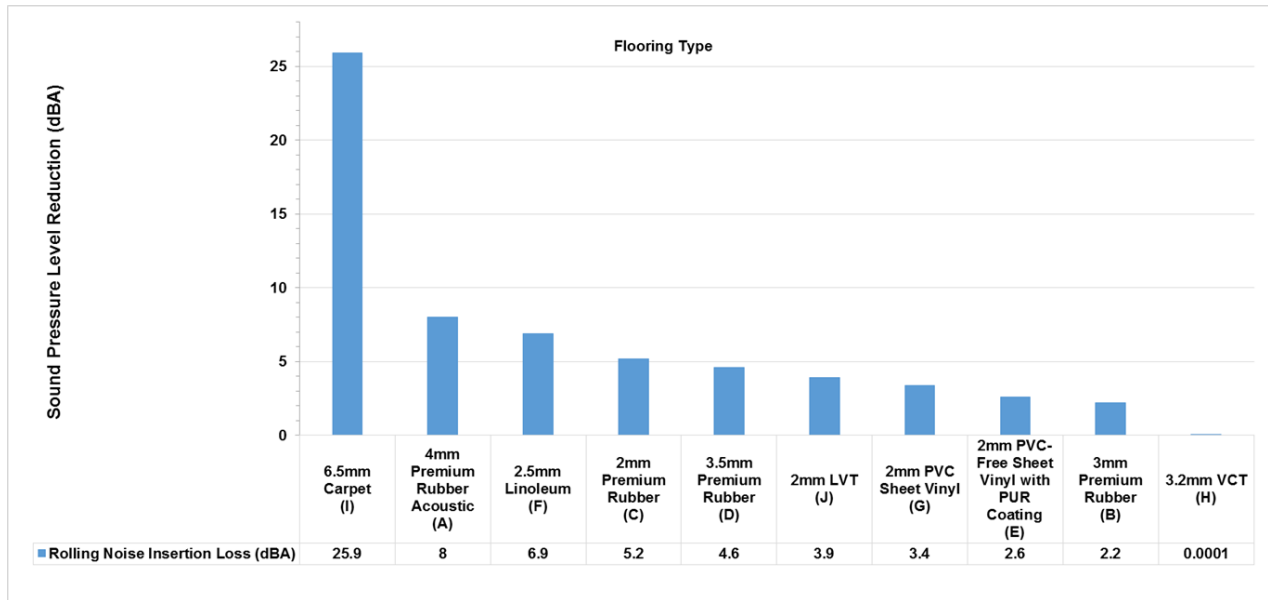


Figure 10: Rolling Noise Sound Reduction Compared to Bare Concrete for Steel Wheel with Defect

Discussion

Numerous entities contribute to the acoustic environment, or soundscape of a space, from the drone of air conditioning, to the type of ceiling tile, to the rolling of a cart on the floor. We have the standards and tools to address much of these sounds, but there has been limited research to understand how flooring can help reduce unwanted “in-room” impact noise. The study defines tangible results to develop a more accurate representation of flooring and its contribution to acoustics. The results from the University of Salford study filled some of that gap in knowledge, by quantifying how different flooring materials can affect the acoustic environment. Findings from this study provide evidence that the type of flooring can greatly affect the amount of “in-room” impact noise. This research also provides a repeatable testing methodology that can be used to compare the amount of “in-room” impact sound reduction provided by different types of flooring. Having comprehensive standards and design guidelines that address “in-room” impact noise can support end users, consultants, designers and specifiers with comprehensive tools to help further improve the acoustic environment in any space, from hospitals, to hotel lobbies and offices space, to classrooms.

Practical Implications

- 4 mm premium rubber acoustic can provide greater or equitable “in-room” noise reductions as compared to carpet.
- 4 mm premium rubber acoustic provides the best reduction in impact noise from small falling objects followed by carpet.
- 4 mm premium rubber acoustic can help reduce unwanted “in-room” impact noise by up to four times as compared to VCT.
- 3.5 mm premium rubber can be up to two times quieter than VCT and 2 mm premium rubber provides for a very noticeable sound difference.
- While carpet was found to exhibit the greatest potential for reducing rolling noise from a steel wheel, it is essential to also consider rolling resistance when designing environments that

require frequent movement of equipment and supplies, such as healthcare and educational environments.

- Impact sound transmission is affected by more than just the floor covering. Other factors include the underlayment, subfloor and adhesive used during installation.
- The inherent performance characteristics of premium rubber provides for sound, like an echo, to reflect less when sound waves strike a surface and are reflected back into the space (reverberation).
- Acoustics is an important consideration when specifying flooring and should be evaluated based on the unique demands of the intended environment.

Acknowledgements

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References

- [1] T. Hsu, E. Ryherd, K. P. Wayne and J. Ackerman, “Noise Pollution in Hospitals: Impact on Patients,” *Journal of Clinical Outcomes Management*, pp. 301-309, July 2012.
- [2] Hospital Consumer Assessment of Healthcare Providers and Systems, “CAHPS Hospital Survey,” July 2018. [Online]. Available: http://www.hcahpsonline.org/globalassets/hcahps/summary-analyses/results/2018-07_summary-analyses_states-results.pdf.
- [3] National Research Council of the National Academies, Review and Assessment of the Health and Productivity Benefits of Green Schools: An Interim Report, Washington, D.C.: The National Academies Press, 2006.
- [4] “National Survey of Public School Teachers.” Beth Schapiro & Associates. March 2001.
- [5] “Classroom Acoustics”. Acoustical Society of America. http://acousticalsociety.org/about_acoustics/acoustics_of_classrooms
- [6] A. Elliott, “Measurement of In-Room Impact Noise Reduction,” *Journal of Applied Acoustics*, 2018.
- [7] D. D. Reynolds, *Engineering Principles of Acoustics: Noise and Vibration Control*, Boston: Allyn and Bacon, Inc., 1981.
- [8] M. Long, *Architectural Acoustics*, Burlington: Elsevier Academic Press, 2006

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This manuscript for this research study from University of Salford, Manchester, UK has undergone a peer-review process and has been published in the *Journal of Applied Acoustics*.

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