

## Building Acoustics

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Expand All Collapse All

- **Measuring The Impact Sound Reduction at a Compact Measurement Setup - Design, Results and Uncertainties**

- **Abstract:** A method to measure the impact sound reduction at a compact measurement setup (COMET) is developed at the Physikalisch-Technische Bundesanstalt. This paper presents the setup and the test procedure with respect to a physical model of impact sound reduction for locally reacting floor coverings. The impact sound reductions of many floor coverings obtained at different test facilities according to ISO 10140 and obtained at different COMETs are compared. Under consideration of the standard uncertainties, an alternative procedure to calculate the impact sound reduction at the COMET is proposed which is different to the procedure in the current version of the standard describing the COMET (ISO/DIS 16251-1).

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Category Research Article

Pages 107-140

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- **3D Impulse Response Measurements of Spaces using an Inexpensive Microphone Array**

- **Abstract:** The acoustical characteristics of a room are traditionally determined using omnidirectional impulse response measurements, yielding information about sound reflections in terms of magnitude and time, but not direction. However, the direction of reflections is often important, and thus the need for a practical, low cost measurement system for determining this. In this paper we present the performance of a low cost measurement system utilising an inexpensive microphone array, namely the Core Sound TetraMic, for the determination of 3D room impulse responses. These can then be visualised, for example, as a "hedgehog pattern". Experiments undertaken in an anechoic chamber indicate that the accuracy of directional estimation of this system is in the region of  $\pm 7.5^\circ$ .

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Pages 141-156

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- **The Influence of the Wall Cavity on the Transmission Loss of Wall Systems - Experimental Trends**

- **Abstract:** Numerous experimental investigations have been conducted into the sound transmission loss of double leaf wall systems. From these investigations, it has been observed that the properties of the wall panels, material placed within the wall cavity as well as the type of wall connections used, greatly influence the sound transmission through the wall system. In all of these cases the wall cavity greatly affects the extent of this influence and in some cases it can even nullify their effect when changes are made. In this paper the influence of the wall cavity based on experimental trends is investigated. The investigation revealed that a wide variety of conclusions were obtained by different researchers concerning the role of the cavity and the properties of any associated sound absorption material on the sound transmission loss through double leaf wall systems. Consequently recommendations about the ways in which sound transmission through cavity systems can be improved should always be qualified with regard to the specific frequency range of interest, type of

sound absorption material, wall panel and stud characteristics.

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- **A History of the Use of Time Intervals After the Direct Sound in Concert Hall Design Before the Reverberation Formula of Sabine Became Generally Accepted**
  - **Abstract:** With the proposal of the D50 and the C80 two room acoustic parameters were introduced in which the time interval after the direct sound was taken into account. It is not widely known that comparable applications have a history which date back into the 17th century. Already B.C. Vitruvius had noticed that echoes occurred in theatres and that these were unwanted to create good hearing conditions. During the 17th and 18th century a theory on echoes arose in books about general physics and sound. This theory influenced the books about architectural acoustics written during the end of the 18th and the 19th century and consequently concert hall design at the end of the 19th century. Examples where the theory on echoes was used in the design are the Palais du Trocadero in Paris, the Neue Gewandhaus in Leipzig and the Salle Pleyel in Paris.

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- **Roof Configurations, Room Quality Parameters and Musical Performances: An Analysis of the São Paulo Hall**

- **Abstract:** The São Paulo Hall (SPH) is recognized by musicians and musical critics in general by its good acoustical quality. Having geometric dimensions similar to the ones of some famous concert halls, it has as an important feature a variable acoustics due to its movable roof, which is employed by musicians to tune the room according to the musical style, in an ad hoc procedure. This work addresses the acoustical quality of the São Paulo Hall and the dependence of its acoustics on the roof configuration. Impulse responses for one source, eight microphone and two dummy head positions, using the sweep-sine technique with pre-emphasis, were obtained for seven distinct roof configurations. Several details of the measurement procedures to ensure good accuracy and repetitiveness are widely discussed. The measurement results were then used to compute the main room acoustical quality parameters, for each octave band between 63 Hz and 8 kHz. The spatial average and deviation of these data are presented as a function of the frequency band. The influence of the roof configurations on the obtained acoustical parameters is then presented and discussed. Furthermore, comparative plots among some acoustical parameters presented by São Paulo Hall at the chosen roof configurations and two famous and representative halls from the classical and romantic periods are reported. It is concluded that the movable roof is very effective in modifying the room acoustics and that the musician's ad hoc choices seems to be quite good.

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- **The Conventional RT is Not Applicable for Testing the Acoustical Quality of Unroofed Theatres**

- **Abstract:** The use of reverberation parameters (reverberation time and early decay time) was a question for reverberance evaluation of unroofed spaces such as traditional Chinese courtyard theatres or Greek/Roman amphitheatres, with the absence of large amount reflections from the top. Subjective reverberance comparison tests of synthetic listening signals in an unroofed space and an enclosed space which have approximately the same exponential decay rate were conducted in our laboratory. It demonstrated the perceived reverberance is also affected by their spatial aspects, which is noticeable in an unroofed space. Therefore, conventional reverberation parameters RT and EDT based on monophonic recording are not adequate for describing the acoustical quality in unroofed spaces as we usually do for enclosed spaces, and the factor of spatial information of the reflections should not be neglected for reverberance criteria.

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- **The Interrelationship Between Room Acoustics Parameters as Measured in University Classrooms Using Four Source Configurations**

- **Abstract:** This paper investigates the interrelation of room acoustics parameters as measured in lecture theatres/classrooms using four sound source configurations. Ten typical rooms were selected as representative of university premises and measured to ISO 3382 standards. The study focuses initially on the type of sound source used, to establish the suitability of multi source based measurements in assessing the acoustics of classrooms. Acoustic performance is then discussed in the context of the relationship between room acoustics parameters with and without significant background noise, with a particular focus on speech intelligibility. To facilitate a more efficient discernment of results, EDT, T30, Clarity indices and MTI were considered, as they are commonly included in general room acoustics assessments. Either of the source configurations

was found to be suitable for performing general purpose measurements in (small) rooms. Clarity and EDT were found to be linearly related to the modulation transfer index in noiseless conditions, in line with earlier findings, thus an excellent predictor of STI. Background noise could be ascertained as of primary importance in the case of a non linear relation.

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- **Elastic Layers to Reduce Sound Transmission in Lightweight Buildings**

- **Abstract:** To obtain satisfactory sound insulation is a challenging task when designing lightweight buildings. Poor performance at low frequencies as well as severe flanking transmission has traditionally often been more pronounced compared to heavier constructions. In the present casestudy based paper, various aspects of using elastic layers to improve sound insulation in lightweight buildings are considered. The effect on impact and airborne sound insulation by using two different kinds of vibration insulators between floor plans was examined together with the effect of using glues of various degree of elasticity in the construction. In situ measurements were performed inside a four-storey wooden frame based residential building and statistically significant variations in sound insulation were found. The efficiency of the two vibration insulators was further evaluated by vibration reduction measurements over the junctions. The difference in vibration reduction was found to be nearly constant in the frequency range 50-1000 Hz while the improvement of impact sound insulation increased by frequency. Along term test of elastic glues was also conducted, during three years, for stability over time. The best glues preserved a significantly higher damping ratio over time compared to the main part of the glues.

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- **Noise Abatement in a Reverberant Sound Field Using the Particle Swarm Method**

- **Abstract:** Noise control is essential in an enclosed machine room where the noise level is regulated by the occupational safety and health act. In order to overcome noise hybridized by a direct and reverberant sound wave, a sound absorber in conjunction with an acoustical enclosure has been used. However, the traditional method for designing a sound absorber and an acoustical enclosure has proven to be time-consuming. In order to efficiently control the noise level specified by the Environmental Protection Agency, interest in shape optimization of a sound absorber as well as acoustical enclosure is coming to the forefront. In this paper, the numerical technique of particle swarm optimization (PSO) in conjunction with the theoretical sound propagation model and the method of minimized variation square are applied in the following numerical optimizations. Before noise abatement is carried out, the accuracy of the mathematical model in a single-noise enclosed system will be checked by SoundPlan (a professional simulation package). Moreover, the noise abatement of five kinds of multi-equipment machine rooms using the PSO method has been exemplified and fully explored. The results reveal that both the acoustical panel and the acoustical enclosure can be precisely designed. Consequently, this paper may provide an efficient and rapid way of depressing both the direct and reflected sound wave by using a well-designed acoustical panel and acoustical enclosure in a complicated sound field.

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- **A Comparison of Measurement Standard Methods for the Sound Insulation of Building Façades**

- **Abstract:** This paper focuses on the limits of measurement of the sound insulation of building façades at low frequencies. Three standard methods are compared mainly for the position of the equipment. In particular, the positions proposed by the international standard ISO 140-5 and the national standards ASTM E 966 (USA) and JIS A1430 (Japan) are considered. The limits of measurement of the sound pressure level in front of the façade are investigated. Different placements of the external source and receiver are considered. Moreover, different placements of the receiver inside small rooms are compared by focusing on corner vs. center room positions. The uncertainties of room averaged sound pressure levels measured according to different standards are discussed. The problems of measurement of the reverberation time in small rooms and of sound insulation in irregular shaped rooms are introduced because these measurements present several critical challenges. Finally, suggestions to improve the future version of the ISO 140-5 are reported.

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Pages 267-282

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- **A Review of Sustainable Materials for Acoustic Applications**

- **Abstract:** Acoustical sustainable materials, either natural or made from recycled materials, are quite often a valid alternative to traditional synthetic materials. The production of these materials generally has a lower environmental impact than conventional ones, though a proper analysis of their sustainability, through Life Cycle Assessment procedures, has to be carried out. Airborne sound insulation of natural materials such as flax or of recycled cellulose fibres is similar to the one of rock or glass wool. Many natural materials (bamboo, kenaf, coco fibres) show good sound absorbing performances; cork or recycled rubber layers can be very effective for



impact sound insulation. These materials also show good thermal insulation properties, are often light and they are not harmful for human health. Furthermore, many of these materials are currently available on the market at competitive prices. There is however a need to complete their characterization, both from an experimental and a theoretical point of view, and especially to propose a standard and unique procedure to evaluate their sustainability. The paper presents an updated survey on the acoustical properties of sustainable materials, both natural and from recycled materials, including mixed and composite materials and systems such as green roofs and green walls, and is completed by a wide selection of recent related bibliography.

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Pages 283-312

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- **Factors Affecting Ventilation and Acoustical Quality in a Sustainably-Designed and in Conventional Buildings - A Pilot Study**
  - **Abstract:** This paper discusses a pilot study involving direct monitoring of airflow and acoustical quality in a sustainably-designed and in conventional buildings. The objectives were to measure these environmental aspects, determine the factors affecting them and the relationships between them and key building-design concepts, and consider the implications of the results for ventilation-system design. Selected rooms in buildings with natural and mechanical ventilation, without and with acoustical treatment, were monitored. Measurements were made of airflow rates and acoustical quality. Correlations between these environmental aspects, the types of building and ventilation system, and the building window status were investigated. In rooms with natural ventilation, noise levels were lower; however, the rooms had lower airflow rates. Rooms with mechanical ventilation had higher airflow rates, but noise levels were higher; HVAC noise was a problem if the system was not well

designed. In naturally-ventilated buildings, airflow rates and noise levels were low with windows closed, but opening the windows to increase the airflow rate resulted in higher noise levels. The results of the study suggest that the acceptability of indoor environments in buildings depends on the degree of compliance of the design and its implementation with standards and design guidelines, whether the original design is 'sustainable' or not.

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Pages 313-326

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- **A Symphony Hall: L'Auditori Barcelona**

- **Abstract:** This paper describes the design of the Concert Hall of Barcelona, called "L'Auditori". The acoustical design of the project was finished in 1990 but it was built later and finally opened on 22nd March 1999. The acoustics of the concert hall have been very well received by audiences. In this manuscript, we outline several acoustic features which had to be designed using old methods because the more modern systems had not yet been developed. However, construction was delayed nine years, which meant that new computer tools were available when work was coming to an end in 1990, it allowed us to carry out an overall review of many aspects of the design, A very important issue that required years of research before we discovered the cause of the problem was that musicians could not hear themselves on stage, yet Gade's measurements of ST1 made in 2001 were comparable with those found in the best reference halls. In this paper we discuss this issue, and conclude that the musicians were correct.

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- **A Consolidated Theory for Predicting Rain Noise**

- **Abstract:** This paper presents a theory for rain noise prediction, consolidating discussions of drop impact on a plate and resulting work on rain noise predictions that is found in the literature. An objective of the consolidated theory is a robust engineering model which does not rely on complex computational techniques or lengthy computer simulation. The model described is compared to measured data to establish accuracy and reliability.

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- **Separability of Distortion Products in Room Impulse Response Measurements with Maximum Length Sequences**

- **Abstract:** In the room impulse response measurements, one of the common disturbances affecting the measured results is nonlinearity. When maximum length sequences are applied for the measurements, the distortion products are distributed along the estimated impulse response. While this property of maximum length sequences has been widely used in the auditory system applications for characterization of a nonlinear system, it has not been exploited in room acoustics. Due to this reason, the possibility of separating the distortion products in the measurements of the room impulse responses with maximum length sequences is analyzed in this paper. The results show that this measurement method is sensitive to

nonlinearities, but the separability of the distortion products could reduce the nonlinearity effects.

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Pages 173-184

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- **Sound Pressure Levels in Rooms: A Study of Steady State Intensity, Total Sound Level, Reverberation Distance, a New Discussion of Steady State Intensity and Other Experimental Formulae**

- **Abstract:** In this publication we include all, or almost all, the valid formulas of sound levels in different types of rooms. We will explain all the theoretical basis of each of them, starting with reflected intensity, both classical and revised theories, the total sound level and its uses in concert venues. We will also deal with empirical formulas mainly for classrooms, churches and religious buildings and industrial use. However, the main significance of this work is not only the wide range of formulas exposed but also that we have found the explanation of why the reverberation radius, or distance radius, cannot exist in the revised theory. This finding can help that the revised theory of M. Barron be slightly modified to apply it to any room for several uses, other than concerts.

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- **The Refurbishment of Tonhalle St. Gallen**

- **Abstract:** In this paper we describe one case of acoustic of refurbishment design. It is the refurbishment of Concert Hall of "Tonhalle St. Gallen. The centennial St. Gallen Concert Hall in Switzerland was a hall with many issues relating to the stage. High levels of sound, focusing, flutter echoes, and so on; the problem was never solved. The Director of the Orchestra and his musicians were generally very unhappy with this hall. In the last paper we analyse the St. Gallen Concert hall before refurbishment. In the Tonhalle St. Gallen the diffuser occupies only of stage area, but RT, EDT and G all are increased in audience zone, but in stage the G is decreased 3dB. The response by musicians, audience, and critics has been overwhelmingly favorable. Further research is needed to elucidate the mechanisms by which the labyrinth achieves these improvements, but the results in these venues suggest that this type of structure has an important role to play in acoustic design, particularly in smaller venues.

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- **The Uncertainty of the Proposed Single Number Ratings for Airborne Sound Insulation**

- **Abstract:** A replacement of the ISO 717-1 standard for the calculation of the single number ratings for airborne sound insulation has been

proposed. The proposed replacement, ISO 16717-1 introduces new single number ratings for airborne sound insulation. The weighted sound reduction index which has traditionally been calculated from the sound reduction index measured in the 1/3 octave bands from 100 Hz to 3150 Hz will be replaced by a new single number rating  $R_{living}$  which is calculated from the 1/3 octave bands between 50 Hz and 5000 Hz. The uncertainty of the proposed single number ratings has been estimated using the ISO Guide to the Expression of Uncertainty in Measurement (GUM) and validated using Monte Carlo simulations. The uncertainty of the single number ratings of 200 building elements was evaluated. It was found that the uncertainty of the single number ratings is highly dependent on the shape of the sound reduction index curve. The uncertainty of the new single number rating  $R_{living}$  was found to be greater than the uncertainty of the traditional weighted sound reduction index for 98% of the 200 lightweight building elements included in the evaluation. It is recommended that the current weighted sound reduction index be maintained in the replacement standard until the uncertainty of the calculation of the sound reduction index at the low frequencies can be reduced through a redefinition of the measurand.

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- **Comments on "Empirical Prediction of Speech Levels and Reverberation in Classrooms" [Build Acoust, 8(1), 1-14, 2001]**
  - **Abstract:** The goal of this letter is to comments on the article "Empirical Prediction of Speech Levels and Reverberation in Classrooms" by Hodgson (2001). Hodgson proposed an empirical equation for prediction of classroom early decay time. Hodgson EDT equation with regard to the classroom ceiling height was theoretically discussed and it was concluded that when a classroom ceiling height is decreased or increased, it is not

reasonable to judge about the acoustical condition of the new space based on the Hodgson EDT equation if the average absorption coefficient of the additional walls is equal to the average absorption coefficient of the original space.

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- **Effects of Non-Traditional Forms on Masjids Acoustics**

- **Abstract:** This work assesses effects of the modern pyramidal forms versus the traditional forms on the acoustical qualities inside the Masjids (Mosques). For this purpose; three rooms were acoustically compared utilizing ODEON ver. 4.2. They are: a pyramidal room (MRM), the reference room (RR) and a right rectangular prismatic room (CUB). Results showed that MRM exhibits the shortest T in comparison with CUB and RR. In case of MRM, if its internal space was left free from any obstruction (columns or slabs like mezzanine); it has the highest values for speech indicators among the others (D50 0.41 (SI 90 %) and STI 0.24). CUB has the next shortest T whereas RR has the longest T. Results also showed that CUB and RR together have very close values for speech indicators (D50 0.36, and 0.375, (SI 86 %) respectively, and STI 0.24 for both).

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