ACOUSTIC DESIGN CRITERIA AS A RELEVANT FACTOR FOR ARCHITECTURAL PROJECTS

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ABSTRACT

The goal of this paper is try to offer new perspectives for acoustic conditioning of rooms and other spaces with a concept different of classical sound isolation but with the idea of increasing the communication level. Communication is basically about hearing and being heard. Attractive interior design and comfort are both required for well-being in multi-purpose halls, restaurants, auditoriums, rooms, etc. Current architectural trends, which favour strongly reflecting materials like concrete or glass, do not aid acoustic requirements in such spaces. In order to achieve acoustic comfort, a room must exhibit an adequate reverberation time down to low frequencies. Furthermore, depending on the main use other quantities such as clarity etc. may also become important. It is a requirement that acoustic comfort and attractive design can harmonize, taking into account other ***relevant*** factors like light efficiency, accessibility, fire safety, cleaning resistance, Environmental impact and Indoor climate and so on.

It seems clear that a window market for steel based panels will exist according to incoming harmonized acoustic regulations in order to fit the objective tonal curve for room uses. From here, and as far as these panels must be produced as new product, a research effort is required in order to provide panels useful for absorption at high frequencies at low frequencies, band absorbers, and resonators.

KEYWORDS: Acoustic design, tonal curve, construction projects, acoustic criteria

LÍNEA TEMÁTICA: Ingeniería de Producto y de los Procesos.

INTRODUCTION

Steel is a classical construction material having been more and more replaced by concrete elements. On the other hand in regard of the relation span/weight steel remains the number one for modern construction. Nevertheless due to its Young modulus steel conducts sound and impact noise very well. So it may be a less loved material in domestic housing also in regard of this property.

Steel may not be considered only from the point of view of new buildings. Especially old houses, which need a replacement of the ceilings or are to be raised by a storey, often meet a problem of unfavourable static. In this case the ratio of stiffness to weight of steel elements is unsurpassed up to now.

In order to get desired tonal curve two main difficulties must be addressed:

Management of medium and high frequencies. They can be absorbed by open pore materials, like mineral fibbers and polyurethanes and this is the easy part of the problem.

Management of low and very low frequencies. They can be absorbed by materials with high degree of deformability, which allow them to show a broad band of absorption at low frequencies.

Also it is possible to use resonators, membranes or panels with a very thin band of frequencies. The usual strategy found when we try to apply these materials is:

When porous are used and as far as they are soft, they must be covered by cloths or similar

When high deformability materials are used, and in order to avoid undesired displacements some coatings of Teflon are used.

The panels and membranes are usually built in wood or gypsum.

Normally the most relevant problem with previous strategy is the impossibility of use the same element showing the desired acoustic properties and the problem with the design aspects in coating rooms, as far as the acoustic design must be compatible with aesthetics and design criteria.

This can be seen as a market opportunity for steel panels and mixed but steel based panels, in such a way that becomes a new product, i.e. for acoustic absorption and acoustic conditioning.

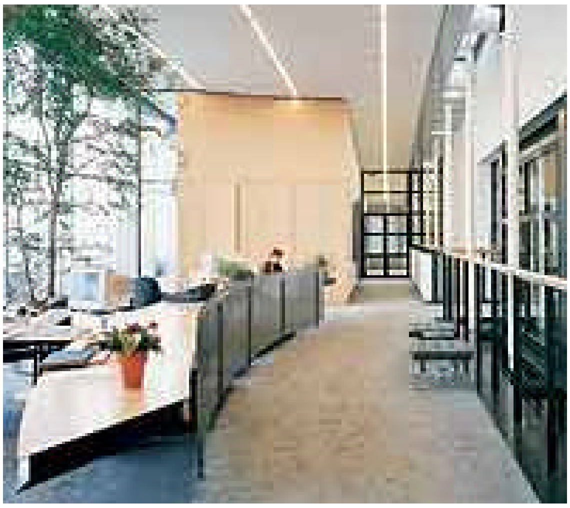
The required research looking to overcome difficulties and to obtain right designs is the focus of this proposal.

The first thing to be clarified is why, and the answer for this could be the new regulation promoted by the European Commission [1].

The European Standardisation Organisation CEN received mandates from the European Commission to facilitate trade within the European Single Market by harmonised European standards which must be published by each of the National Standards Bodies as identical national standards.

Most of these anticipated harmonised European standards are already available at least in a stage of advanced drafts. They cover the areas determination of material properties, **absorption and reverberation time (RT) measurements**, measurement and rating of sound insulation as well as testing of sound emission from water installations and from service equipment in buildings, on measurement of flanking transmission and also on the estimation of acoustic performance of buildings from the performance of products. The measurement of sound intensity in building acoustics and also standards on new techniques as MLS will supplement later harmonised European standards which shall form a comprehensive tool to avoid trade barriers between countries.

Regarding sound problems, the basic idea is not only “noise reduction” (classical) and “noise emission reduction” (environmental) but also (and mainly) **acoustic conditioning**. So, new elements must be offered to the market in order to improve this approach.



A modern office is a complex unit, comprising many different areas, each with its own requirements and acoustic conditions. Whatever the area’s intended activity, the challenge is to ensure that this does not cause disturbance.

Research shows that staffs divide their time evenly between communication, concentration and administration, meaning that all tasks of various natures are carried out between periods of communication and concentration.

The well-planned office offers areas for both these activities in equally carefully designed environments.

Communication is basically about hearing and being heard. Good speech intelligibility is fundamental, be it informal conversations at your desk, or formal meetings with several people in a conference room. Speech should not be masked by background noises, such as ventilation systems or other peoples' conversations.

Low noise levels and low sound propagation is achieved by ensuring short reverberation times, which requires optimum sound absorption in the room.

While all occupants of multi-family buildings may insist on the right to live peacefully at home without having to worry about bothering or being bothered by the neighbours, few of them can objectively describe the acoustic privacy of their dwelling. To most people, acoustic comfort is a vague concept that becomes clear only when they are dissatisfied. The vocabulary that builders use to describe the acoustic comfort from which future tenants will benefit is just as inadequate; they often refer to “superior” soundproofing, which is very difficult to define in a legal context when occupants are not satisfied and turn to the courts to exercise their rights.

Attractive interior design and comfort are both required for well-being in multi-purpose halls, restaurants, auditoriums, rooms, etc. Current architectural trends, which favour strongly reflecting materials like concrete or glass, do not aid acoustic requirements in such spaces. In order to achieve acoustic comfort, a room must exhibit an adequate reverberation time down to low frequencies.

Furthermore, depending on the main use other quantities such as clarity etc. may also become important. It is a requirement that acoustic comfort and attractive design can harmonize, taking into account other ***relevant*** factors like:

> **Light efficiency** .From a lighting point of view, an acoustic ceiling should provide good light reflectance and diffusion. The effect of indirect lighting is highly dependent on the way the ceiling is able to reflect and diffuse light. For good light efficiency the reflectance factor should be above 80% and the diffusion factor as high as possible.

Accessibility. The requirement for ease of demounting is determined by the user's need for access inside the acoustic ceiling or wall. It may be a case of servicing the ventilation system or adding new cables. The need for access may be local, for example, in a passage or an open plan office, or more general, such as a whole corridor.

Clearing. In order for an acoustic ceiling to last a long time, the visible surface should be dirt and dust repellent and easy to clean.

Fire safety. The category of an area determines the basic requirement for ceilings and walls in respect of surface layer fire classifications. Relevant test methods and standards to consider this are, for example, BS 476 part 6 and 7, ASTM E 1264, DIN 4102 together with requirements for non-flammable coverings along evacuation routes.

Environmental impact and Indoor climate.

After this introduction it seems clear that a window market for steel based panels will exist according to incoming harmonized acoustic regulations in order to fit the objective tonal curve for room uses.

From here, and as far as these panels must be produced as new product, a research effort is required in order to provide panels useful for absorption at high frequencies at low frequencies, band absorbers, and resonators:

For high frequency absorption, some holes must be carried out over 30% of surface in order to leave operate to porous material.

For low frequency absorption, high deformation members are adequate, so geometry of panels must be selected adequately in order to produce adequate diffusion.

Using steel panels could be possible to produce serial resonators operating to low frequencies.

The wearied steel wire could help to wear absorbent material offering a support frame helping to acquire required shape.

STATE OF THE ART

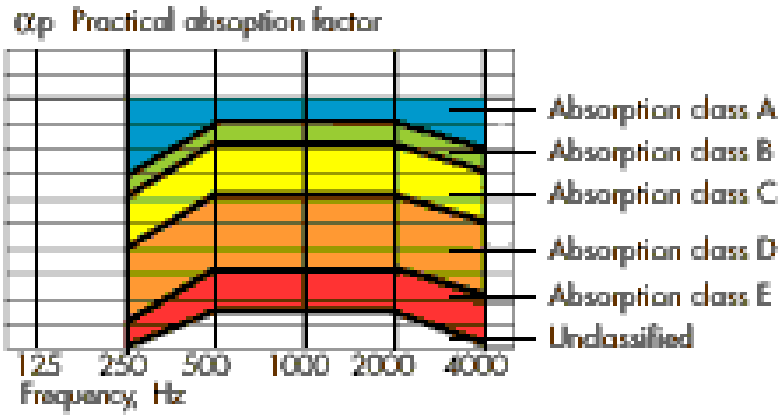
There are two basic environments in which one makes measurements of sound and noise: outdoors and indoors. An outdoor acoustic environment may be quite often referred to as a free field. A sound field is said to be a free field if it is uniform, free from boundaries, and undisturbed by other sources of sound. Anechoic chambers and well-above-the-ground outdoors are free fields. Sound radiated by a source in a free field propagates away from the source and is never reflected back [2,3].

The indoors acoustic environment introduces boundaries which reflect sound. If the boundaries completely reflect all incident sound without any absorption then the resulting sound field is termed diffuse or reverberant. In a diffuse sound field the time average of the mean square sound pressure is the same everywhere through the enclosure. The flow of energy is equally probable in all directions. If the boundaries absorb some of the incident sound and reflect the rest, then the sound field is called semi reverberant. Energy flows in more than one direction. Much of the energy is truly diffuse, though there are regions of the sound field that have a definable direction of propagation from the noise source. Semi reverberant fields are the most widely encountered in the majority of architectural acoustic environments [2,3].

Traditionally indoor sound problems were addressed firstly based on isolation idea. Currently the simplest method is to fill the floor with a thick layer of concrete producing a passive sound absorption. That's all.

Special cases were convention rooms, theatres, church and other special spaces, where hearing problems are much more specialized.

In our days the standards are evolving to a much more scientific approach taking into account not only average values but frequency dependent parameters, so the international standard called EN ISO 354, by which sound absorbers are classified in absorption classes from A to E, where class A has the highest level of sound absorption. Higher absorption class produces shorter reverberation time in the room [13].

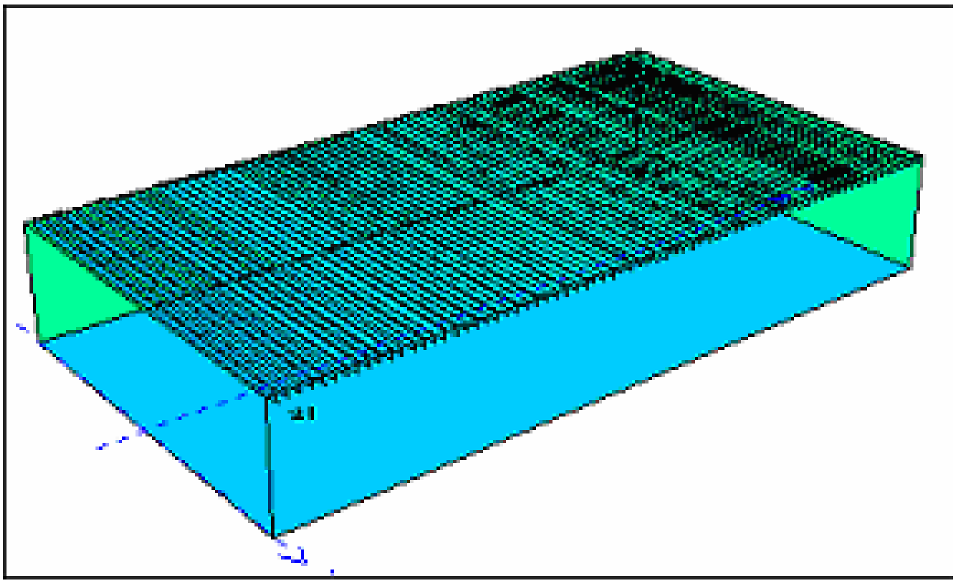


Also procedure tests have been defined for carry out these measurements, like EN ISO 3741 [14, 15, 16, 17, 31]. *Our idea is to use these tests for study parameter influence in designs being designed.*

Even when measurement procedures for sample testing are defined, the room conditioning needs additional analyses and simulations as far as physical test is not possible before its conditioning. The non linearity of its comportment has attract specific research [18, 19, 20 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 32, 33].

Apart of problems show in introduction part regarding the differences in sound diffusion as the number of reflections are different in horizontal and vertical sound propagation, there are several factors producing reverberation times quite different of those proposed by classical formulations such as those proposed by Wallace C. Sabine and published in 1898, known as Sabine method [2].

In several practical cases it can be seen that the most sensitive case is a non-mixing shape with uneven absorption where the actual measured T-30 sometimes may be 2-3 times longer than that predicted by Sabine.

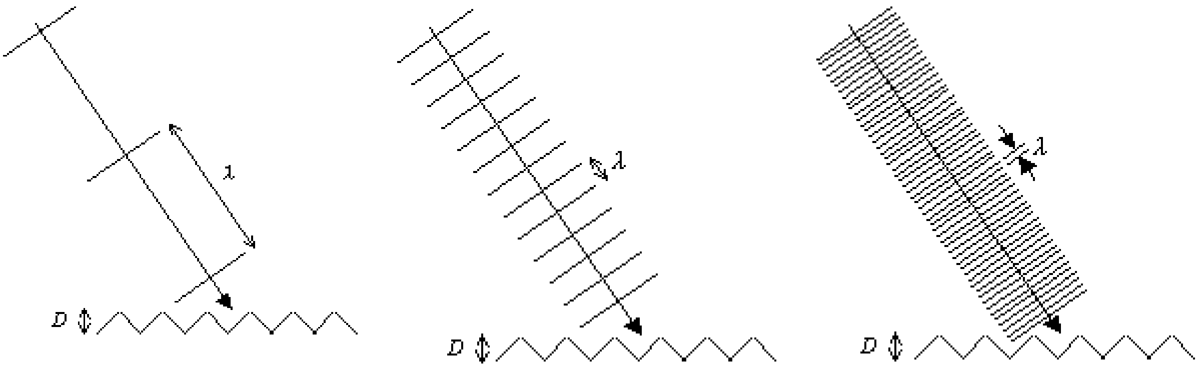


Sports hall 43m x 23m x 7m. RT @ 1 kHz according to Sabine was 1.9 sec while the actually measured T-30 was 5.7 sec

Several researchers [34, 35, 36, 37] show that the actual RT can be well predicted by selecting proper scattering coefficients, as was also done by the consultant. Note that this case is also affected by uncertainties regarding absorption coefficient values but any such uncertainties would result in a much smaller error than that caused by using the Sabine formula.

Also several researchers make efforts for promoting new methods for RT estimation, as far as it is necessary to offer techniques for right estimation [38, 39, 40, 41, 42, 43].

Diffusion is strongly related to the ratio between surface roughness/size as we can see a schematic illustration of how the ratio affects diffusion.

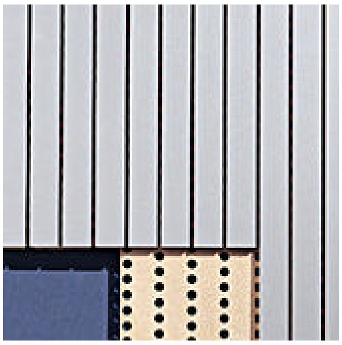
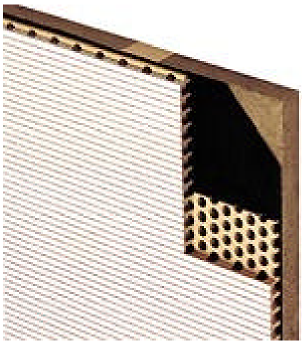


wavelength >> *D* low diffusion

wavelength = D : high diffusion, complex actual behaviour

wavelength << D : geometrical mixing(effectively acts as diffusion)

Obviously, currently there are materials for acoustic conditioning of rooms, as we can see:

But it is clear, from the market that for address acoustic conditioning there is not a unique material bringing a uniform aspect compatible with high mechanical resistance and well behaviour against cleaning and environmental agents. In effect:

- ? Absorption of medium and high frequencies. They can be absorbed by open pore materials, like mineral fibbers and polyurethanes and this is the easy part of the problem.
- ? Absorption of low and very low frequencies. They can be absorbed by materials with high degree of deformability, which allow them to show a broad band of absorption at low frequencies.

When porous are used and as far as they are soft, they must be covered by cloths or similar, bringing stiffness.

When high deformability materials are used, and in order to avoid undesired displacements some coatings of Teflon must be used.

The panels and membranes are usually built in wood or gypsum.

This problem and the improvement of homogeneous regulation and standards make possible try to solve it and fostering the use of steel and mixed panels and wires as a new market for them

OPPORTUNITIES FOR PROJECT MANAGEMENT

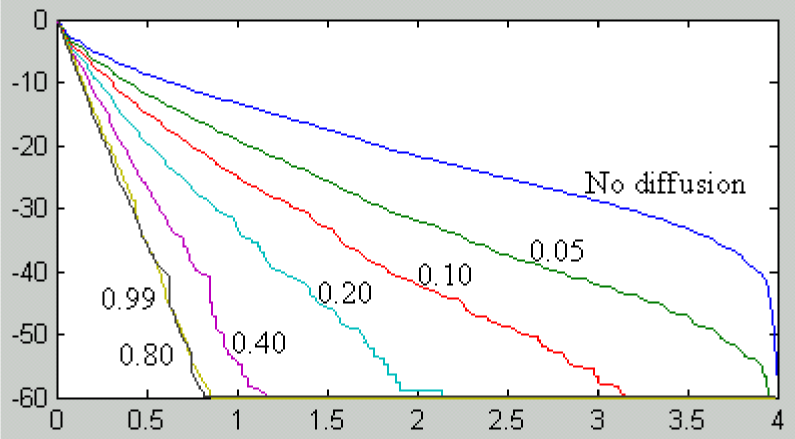
As we said before, acoustic characterization is the goal but other criteria must be addressed to like mechanical resistance, corrosion and so on.

When designs of steel and mixed –steel based- panels become proposed still a tool for product characteristics generation is required.

Also some help must be provided to the technical people, consultants and potential client regarding the acoustic design of spaces.

When a sound source is enclosed the radiated sound energy is retained within the enclosure. If the boundaries are perfectly reflective then the sound energy inside the enclosure could theoretically grow until a pressure is reached that would be explosive [2,3].

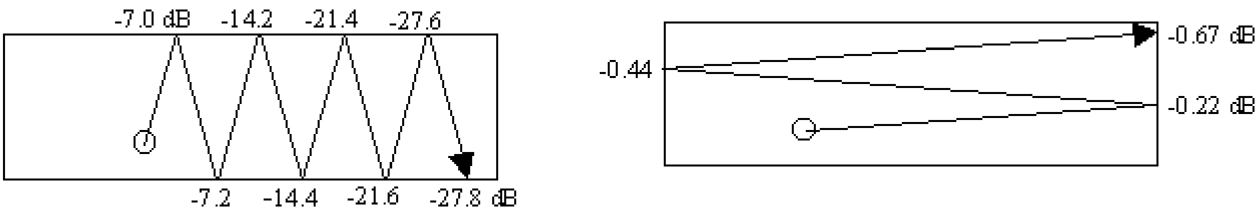
Fortunately, most realistic boundaries are at least partly absorbing (air also absorbs sound) and the kinds of sound sources usually encountered in a room (eg., human speech) are not extremely powerful. For example the sound power produced by human speech is very small. In his book Speech and Hearing in Communication Harvey Fletcher states that it would take " . . . 500 people talking continuously for one year to produce enough energy to heat a cup of tea." Typical male and female speakers generate 34 µW and 18 µW, respectively, at a distance of 1m [4,5,7].



Decay curves using various wall scattering coefficients.

By redirecting the reflected sound in many directions, diffuse reflection will let room surfaces be hit by sound in a more uniform manner and absorbing surfaces will be better utilized. It thus prevents cases where the sound field e.g. becomes predominantly horizontal such as with hard parallel walls where a ceiling absorber does not have any major effect on the late decay.

This non-linearity is created because the sound in some direction (often the vertical) is quickly absorbed giving a fast initial decay (both due to the higher average absorption in the vertical direction and because vertical reflections occur more frequently - the height is often the smallest dimension). In contrast, the horizontal sound lingers since it is reflected between hard surfaces [6,8,9].



This is of course a simplification but it illustrates the necessity to handle diffusion with frequency dependence and the relevance to provide additional services to consultants and clients.

Globally there is a close gearing between the work packages of the partners to ensure mutual profit from the experience and results gained, but taking into account efficiency and cost limitation.

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