19th INTERNATIONAL CONGRESS ON ACOUSTICS
MADRID, 2-7 SEPTEMBER 2007

CONCERT HALL ACOUSTICS: SCIENCE VERSUS REALITY

PACS: 43.55.Fw

Commins, Daniel
commins acoustics workshop, 15 rue Laurence Savart, F-75020 Paris, France
d.commins@comminsacoustics.com

ABSTRACT
Over the last decades, concert hall design tools have improved. Today, the design process and construction technologies are changing rapidly. Some construction technologies are replaced by new ones without a genuine evaluation of the acoustical consequences.

Reliable results are not always available. Often, professionals have no access to data and construction details. Objective and subjective evaluations are often nonexistent or unpublished. As a result, the practitioner may not always be able to take advantage of up-to-date know-how to improve the chances of designing a good or an exceptional concert hall.

A new approach to the design of concert halls seems to be in order at this point in time. Some essential questions should be investigated jointly by academics and practicing engineers. They could include the following topics: subjective and objective information on old and exceptional halls, acoustically correct construction techniques, acoustical response of concert hall components, effects of safety regulations.

Considering that acoustical engineers have the responsibility to reach high standards and that the failure to do so may result into expensive lawsuits, it seems necessary to fill the gap between theoretical work and contemporary design constraints and to develop pragmatic criteria that would guarantee acoustical quality.

THE CONCERT HALL DESIGN PROCESS IN PRACTICE

Initial steps
Budgets assigned today for the design and construction of concert halls dedicated mainly to “classical music” vary from 10 to 400 million euros. The planning, design and construction phases can last several years in the best case and fifteen years in the worst case.

In spite of the colossal amounts of money and of the length of the process, concert hall designers do not have reliable criteria and methodologies that would lead to a guaranteed quality, unlike for example structural or air-conditioning engineers.

The key parameters, which may have an important effect on the acoustical outcome, are influenced by numerous factors: the requirement to fulfil the needs of most of the community that the building will serve, the requests of sponsors, orchestras, and musicians, the need to fit all types of artistic activities, some of which may be acoustically contradictory, the necessity to integrate into the urban landscape, the requirement to match political and cultural ambitions, the obligation to master construction and running costs. Reality is often hidden behind political or financial considerations.

Often, at the onset, the input of acoustical experts is overshadowed by multiple factors. To increase their credibility and to be able to describe the weight of each essential parameter, the acoustical consultant should be able to rely on uncontested goals and arguments.

What is in a brief?
When consulting the briefs of recent concert hall competitions or requests for proposals, one finds many words insisting on the “quality” of the concert hall and providing values for some

criteria. Very often reference is made to four “extraordinary” concert halls: three traditional halls, the Vienna Musikverein, the Amsterdam Concertgebouw and Boston’s Symphony Hall and to one “modern” hall, the Berlin Philharmonie. These statements are not illustrated by data that the design engineer could rely upon. Since these concert halls have very different acoustical qualities, responses and geometries, the information given is not useful.

One often reads in a brief that the goal is to build an “international class concert hall”, an undefined concept.

The briefs generally quote values for simple parameters such as reverberation time at mid and low frequencies. Sometimes, the “client” provides values for more advanced parameters. A typical example follows:

“*Time of reverberation with audience and normal orchestra staging shall be >2.1 sec. for middle frequencies with an increase in the bass:* T_{125Hz} *= ca 1,3 x* $T_{500\text{-}1000Hz}$.

To ensure clarity in the soundtrack with such a long time of reverberation, it is important to save early reflections, especially laterally (sideways).

To make sure that the acoustic change between full/empty halls shall be as little as possible, all chairs shall be padded on all surfaces which are not covered by the audience.

All other surfaces shall, normally, reflect sound.

For acoustic chamber music etc, it shall be possible to reduce the reverberation time to approx. 1.4 sec (in the middle frequency area) by reducing the height of the ceiling.

For reduction of reverberation time for ”light music”, simple devices such as carpets/curtains or reversible elements shall be ordained.

Detailed acoustic parameters, as G, C50, C80 and L_{EF} *will be clarified in collaboration with the chosen acoustical consultant, the user and the Contractor’s acoustics consultant.”*

Today’s concert hall briefs require, with few exceptions, that the design accommodates all types of music: recitals and chamber music, symphonic music, jazz, pop, rock and the like.

Writing the acoustical specifications of the brief of a future concert hall is no simple affair. Many words can be used to describe the acoustical “climate” or “quality” that is sought but their interpretation is highly subjective.

The design phase

Objective criteria, goals and guarantees

The acoustical goals must be sustained by objective measurable criteria. Unlike noise and vibration criteria that can be compared to computed and measured quantities, room acoustics criteria often remain vague. The ISO 3382 standard needs to evolve towards more complete criteria [1].

The observation of the design and construction process of recent concert halls and an evaluation of the results demonstrate that existing criteria are not sufficient. Criteria that guarantee the outcome are needed. Reverberation time values are useful but do not reflect significantly the acoustical quality of a room.

Different criteria should be defined to take into account various types of music: baroque, “classical”, jazz, pop, rock, amplified and overamplified sound. For commercial reasons, today’s concert halls must accommodate all musical genres; after the recent renovation, Paris Salle Pleyel is recognised as a “music hall” or a variety theatre. The future “Philharmonie de Paris, if built, will be a multipurpose hall suitable for amplified sound such as jazz and world music.

This trend implies the integration of variable acoustics devices capable of transforming radically the acoustics of the room without any loss in quality. Recent attempts, including the cases of coupled resonating or absorptive volumes, show that the solutions to this problem need to be investigated seriously, and if validated, improved technically and economically.

The present situation demonstrates that the community of acoustical consultants must define criteria that will guarantee the results, reflect the different needs of the audience and of the musicians, define diffusion requirements, refine strength criteria, take into consideration orchestra platform and conductor platform conditions, include ensemble conditions and rehearsal conditions. Future criteria may vary with room size and room shape and include four-dimensional criteria.

The acoustical consultant must guarantee acoustical quality with musicians on stage and with an audience in the hall. In practice, with few exceptions, criteria are derived from data acquired in empty halls. It remains important to develop in the near future methods which include real concert conditions and to use “in concert” measurement techniques of all relevant quantities.

Objective concert hall engineering

Generally, the major steps of concert hall design and construction are the same: planning, cost evaluation, sketch, preliminary design, detailed design, executive project, construction, commissioning. The methods may vary slightly from case to case or from country to country but skipping a phase, whether formalized or nor, may have costly consequences.

The parameters and components that are actually used in the sketch and preliminary design phases are the main dimensions, the volume, the acoustical height, the acoustical width, the seating width, the row-to-row distance, the size and nature of reflective surfaces and of diffusive and absorptive elements, the nature of the materials. The tools at hand are preliminary plans, cross-sections, hand calculations, simplified computer simulations. In fact, the essential acoustical conditions, that will actually have a great deal of influence on the final outcome, are defined at a very early stage.

In the detailed design phases, more precise studies are in order using more detailed computer models or large scale models. The information and the tools available in the detailed design phases are more complete and powerful: physical data on materials, construction details, detailed calculations, computer and scale models, calculated and graphical outputs, auralisations. Hopefully, the results should confirm early expectations. The resulting decisions should be limited to details because, at that stage, it is generally too late to introduce major modifications.

During the construction phase, the acoustical engineer, through visual inspection of construction details and sometimes with the help of physical tests of the acoustical behaviour of components, may identify errors or propose technical substitutions and adjustments.

Finally, when the building is very close to completion, various tests can take place. Musical tests and acoustical measurements can lead to useful results provided the building is close to completion and provided all the components are actually in place.

The dangers of the construction phase

Usually, during construction, critical conditions such as programme changes, budget ceilings, deadline problems, material supply difficulties may interfere. They may result in major project modifications. Elements that play an essential acoustical function may be abruptly modified or removed. The acoustical engineer, at that point, needs to bring up well-documented arguments to prevent hasty decisions that may affect significantly acoustical quality.

WHAT DO WE KNOW? WHAT IS BEING TAUGHT?

What do practicing acousticians actually know about acoustics of concert halls? Setting aside purely subjective evaluations, one observes that decision makers are mainly influenced by what they read or what they are told about concert halls rather than by rational reliable statements.

One must ask also what kind of education future specialists actually receive, what kind of information they have and how they use it.

The literature on concert hall acoustics has been enriched over the last half century by remarkable work performed by talented acousticians. More information is available on the characteristics of concert halls than ever before.

Nevertheless, a gap remains between academics and practitioners. A recent informal survey on the knowledge of important acoustical details by teachers has demonstrated that a number of important constructive details are ignored by academics. Our rich technical literature includes a large amount of data but ignores contemporary technologies and construction techniques. It provides little information on genuine acoustical failures or on simple shortcomings.

Trends in concert hall design

The earliest concert halls do not have much in common with the contemporary concert hall. Can one really compare the 1744-seat Musikverein in Vienna to the 1700-seat Sage Gateshead? Today's concert hall answers different needs.

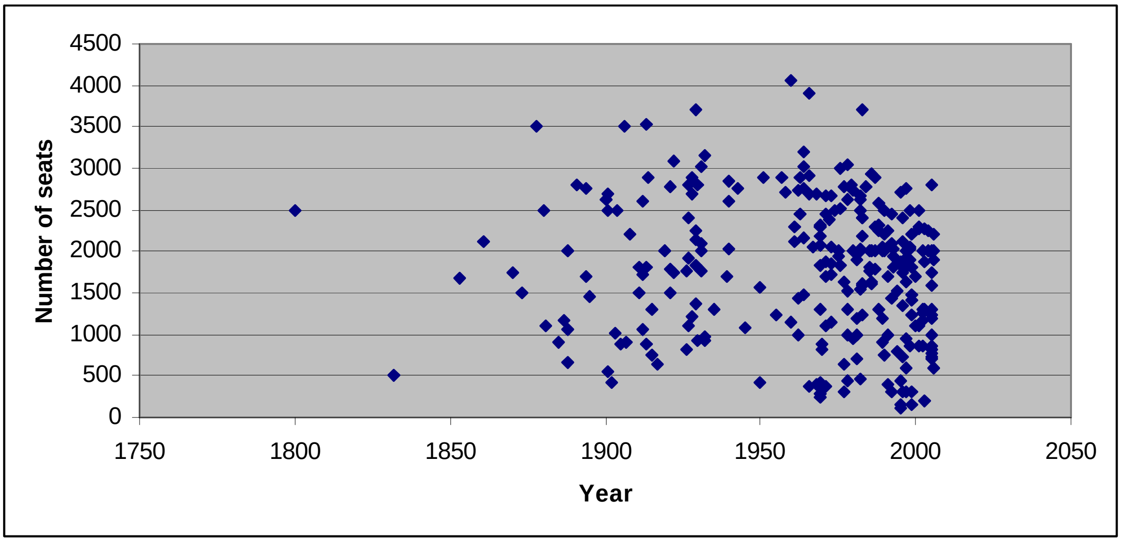

Figure 1. - Number of seats vs. year of construction for 280 existing concert halls

The small concert halls are easier to design for multiple uses than the large ones. The larger halls are the real challenge since today, in most cases; they tend to be used for all types of music from recitals to overamplified "rock".

Concerning the larger concert halls built before 2000, recent investigations have identified trends [3]: the average capacity has decreased slightly but the volume per seat has increased. I the 21st century, there is a chance that seat capacity will increase, as data on recently built halls and on halls under construction show, that the volume per seat will also increase making the use of sound systems unavoidable even for romantic and classical music.

The increase in capacity results from economic considerations: costs as are increasing and sales have to follow. The increase in volume per seat, which contributes to higher construction costs and as recent halls show may not lead to acoustical excellence, has not yet been justified rationally. This deserves attention on the part of the acoustical community.

The same requirement applies to other parameters and indices. Moreover, the role of important components often remains poorly documented.

One may ask what limits should be set for the size and the volumes of genuine symphony halls. One may wonder whether all types of music can flourish in the same hall and whether the devices that are developed to minimize incompatibilities such as coupled volumes, variable acoustical devices and the like do not contribute to a devaluation of acoustical quality.

It is necessary to explain why the acoustics of recent concert halls never match that of ancient halls built with now obsolete technologies.

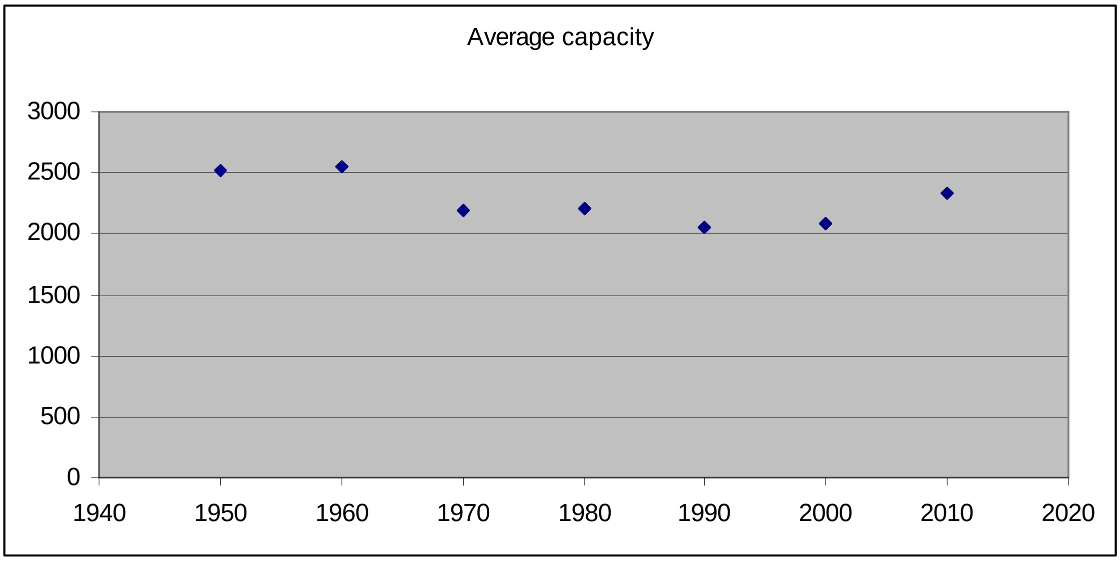

Figure 2. - Average capacity of 123 concert halls with more than 1500-seats

Details which deserve more attention

Quite a few details which actually affect what you hear in a concert hall. These details should be carefully specified by the acoustical designer who needs better documentation. Some consultants actually own some proprietary data but accurate information is needed in particular by teachers, students and by the future concert hall designers.

An investigation of existing and planned concert halls has identified some topics, in various disciplines, which deserve answers:

Geometry and design

- Is there a maximum capacity for a symphony hall? What are the optimum values of the volume per seat?
- Should the volume of a hall actually be modified according to the type of music? Does romantic music deserve a larger volume than classical music? Can movable walls and ceilings be avoided altogether and how? What does a volume change do to acoustical quality?
- Is there an optimum size for reflecting surfaces or diffusive surfaces as a function of frequency and direction and as a function of the listener's distance?
- What is the effect of damped and undamped coupled volumes on acoustical quality?
- What is the effect on the acoustical response of seat dimensions, materials, construction?
- What is actually the effect of row-to-row distance? What is the effect of the slope of the stalls or balconies?
- What is the effect of ceiling diffusion on strength?
- What are the effects of suspended dishes? How can the effect on bass be compensated?
- What is the effect of the air volume under the stage?
- Is absorption around the orchestra actually needed?

New technologies

- What is the effect of the technical improvement and of the increasing power of music instruments?
- What is the effect of mechanized platforms and risers on the acoustical response of the stage?
- Should halls be fixed or variable? Should volumes vary according to the type of performance?
- Is amplified classical music acceptable? Is it the only way for the future?
- Should electroacoustics be a substitute for architecture?
- What are the effects of mechanized movable platforms? Can negative consequences be compensated?
- How does auralisation compare with real sound? Can it be improved?
- What is the future of scale and computer models? Can 1/50 scale model techniques be improved?

Materials and construction

- What are the acoustical effects of construction details, for example on walls or floors behaviour?

- What is the effect of the nature of materials (for example acoustical behaviour of various types of wood)? Can oriented strand board (OSB), Medium Density Fibreboard (MDF) or plywood replace genuine wood?
- What is the effect on the acoustical response of concrete and wooden floors on sleepers? How do various floor constructions actually behave at low frequencies?
- What are the effects of thickness, rigidity and damping on the behaviour of a material or component?
- Can stucco be replaced by plasterboard? Under what conditions?
- What is the effect on the acoustical response of ventilation and smoke-exhaust grills and openings, of lighting and electromechanical equipment, of metal riggings?
- What are the effects of components close to the orchestra on ensemble?
- Can we improve knowledge of seat acoustics: absorption, diffusion and diffraction?
- Can design details be used to simulate with thin wood components the behaviour of thick wood elements?

Measurement and evaluation techniques

- Can we define acoustical quality, according to the type of music?
- Can we extrapolate acoustic tests in empty halls to the fully occupied hall?
- Can we define practical "in concert" measurement techniques?
- What is the effect of public relation efforts on the listener's opinion?
- Can we compare educated comments to public relation induced comments?
- Can we develop survey techniques that would lead to a genuine evaluation of acoustical quality?
- Can we improve musician's surveys?
- How does the taste of musicians and listeners change over time under the influence of new sound technologies (digital sound, MP3 sound)?
- What does tuning a hall actually mean? How do musicians adapt to a new hall? What details can be adjusted after completion of a building? Can extensive modifications be considered?
- Can we encourage the diffusion of subjective data and of measurement data? Is there a way to relax confidentiality and to screen biased information?
- Can we improve cost effectiveness studies? What should a large concert hall cost?

THE EVOLUTION OF OPERATIONAL CRITERIA AND THE INSURANCE PROBLEM

In the course of a project, the criteria may evolve and an agreement may be reached on values. Criteria such as RT, G, C50, C80, D, LEF, etc. may not actually guarantee acoustical quality.

The requirement to allow, in the same concert hall, acoustically incompatible genres unavoidably leads to the design of flexible acoustic systems that, almost always, result in a loss of acoustical quality for "classical" music.

In many industrialised countries, acoustical engineers are required to be covered by professional insurance and to guarantee the result. The clients and users are now liable to go to court if the building is inadequate for the planned functions. Such a lawsuit is being prepared for a recently built symphony hall which did not match expectations. The very high construction costs may lead to damages in the tens of millions of dollars.

It is therefore important to determine objectively acoustical quality and, in case of failure, to measure how far the result is from the goals. It would be unreasonable to rely only on values of reverberation time to evaluate the situation.

CONCLUSION

At this point in time, the credibility of the profession of acoustical consultant is at stake. A dogmatic or an instinctive approach to concert hall acoustics is no longer acceptable.

The progress made in room acoustics over the last decades needs to be translated into reliable engineering methods that will lead to excellence. The need for an independent and impartial organisation, which would not be influenced by unscientific arguments, is needed to gather unbiased subjective and objective data on concert hall acoustics, to define acoustical quality, to identify incompatibilities between various types of music, to validate or invalidate techniques, to develop reliable design tools, to provide education guidelines.

The acoustician of the future deserves to receive a good education in concert hall acoustics and must be given the tools that will lead consistently to good results.

References: [1] R.J. Orlowski: The relevance of ISO 3382 in auditorium design and measurement. International Symposium on Room Acoustics, ICA 2004 Kyoto

[2] Y.Kwon and G.W. Siebein : Chronological analysis of music halls. Journal of the Acoustical Society of America **121** (2007) 2691-2699