THE ACOUSTICS OF ACCORHOTELS ARENA AND OTHER LARGE SCALE INDOOR POP VENUES

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ABSTRACT

Since the 70-ties, pop music has moved from outdoor to indoor venues. Especially sport arenas were converted or just used as venue for large scale pop concerts. Also new halls, sometimes dedicated to music were built. Especially the pour sound insulation of existing sport venues let to the building of new halls. For both new and existing halls the main issue, not always well understood, is the room acoustics of these venues. The large size of these venues results in significant delay of reflections. Every reflection that carries enough energy is disturbing in the sense that it is audible as echo, it colors or it blurs the sound. So the effort focuses on the removal of reflections, as thorough as possible. In new halls there are more possibilities than in existing halls, however also in existing halls significant improvements can be obtained. One example of an existing hall that was improved is the AccorHotels Arena (formerly Palais Omnisports de Paris-Bercy or POPB). Others are for example Ahoy Rotterdam and Johan Cruijf Arena Amsterdam. New large venues, that were built with optimized acoustics are AfasLive! (formerly Heineken Music hall), Ziggo dome Amsterdam and Volkswagen Arena Istanbul.

Though it is not the reverberation time itself that should be used as a criterion, reflections do generate reverberance, so a relation can be derived between volume and reverberation time for the optimal situation with sufficient suppression of early and late reflections.

With the renovation of the AccorHotels Arena as an example, the approach and potential for improvement of existing sport venues, compared to new venues, is explained.

1. INTRODUCTION

Many sport arenas are used to host various shows such as amplified music concerts since they provide very large seating capacity. In existing arenas, originally designed to host sport events, it is common to find acoustic defaults making those venues not suited for the diffusion of live music through loudspeakers (line arrays and subwoofers) producing high noise levels. Most of the time reflective surfaces cause multiple reflections, in particular at low frequencies at octave bands 125 Hz and below. The sound strength of amplified music (especially music types like electronic music) is significant at low frequencies and has increased in the last 20 years due to improved equipment. Because of the size of the venues, these reflections come in late which leads to a lack of intelligibility and clarity which cannot always be corrected with a fine tuning of the sound system. Especially the bass sound should have a temporal clarity; the rhythm should not be blurred by individual or multiple reflections, often experienced as reverberance.

So, one needs to avoid any strong (or high energy) late reflections at any receiver or seating location, taking into account the directivity of the loudspeaker system.

In newly constructed arenas the architectural brief now usually ask for the possibility of hosting concerts, making the venue a tool to host all type of shows, from sports to music shows. There, the acoustic quality shall be taken into account from the first conception stage to make venues fit to their purpose.

2. ACOUSTIC IMPROVEMENTS IN EXISTING ARENAS

Removing reflections by aplication of sound absorptive materials will lead to reduction of reverberation time. So as a derivative, it is possible to have a first evaluation of the acoustics by means of the reverberation time instead of the reflection strength of individual reflections.

As a first step, it is possible in large venues for amplified music, to determine the optimal reverberation time in relation to its volume with Eq. 1 [1], assuming that the first reflections be at least 6 to 10 dB below the direct sound.

$$T_{60} = 0.038 \cdot V^{0.325} \qquad (1)$$

Since the audience, classic upholstered seats and usual absorptive materials have lower absorption at low frequencies relative to mid- and high frequencies, high values of RT in low frequencies can be expected, especially in the 63 and 125 Hz octave bands. It is therfore needed the provide a large quantity of effective low frequency absorbing material in the hall. This can be achieved with thick porous materials or assembling several porous and non pourous materials in a sandwich material to get broadband absorption [2].

As a second step, the individual reflections can be evaluated. Especially walls in or adjacent to the audience areas are critical while the sound energy is directed to these audience areas. In any case, the achivement of excellent acoustics in a large volume such as an arena can only be obtained if audible echoes are avoided at any receiver location. This issue has to be looked thoughtfully since sport arenas are made of surfaces very distant from each other, and sometimes very reflective or even with particular shapes like curved surfaces. This effect is even more audible when the overall reverberation is low.

However, having a short reverberation time might also have two drawbacks:

- The liveliness of the hall will be less. Reaction of the audience such as applause is less audible in the audience. This argues not to reduce reverberance too much. Reflective surfaces might be possible to some extent, provided they are not in the radiated field of the loudspeaker system (like the roof for the mid- and high frequencies.)
- Related to the previous issue: the feedback of the sound from the audience to the musicians is low. This needs to be covered by the sound engineer, using audience mics and feeding it into the monitor signal.

3. ACCORDHOTELS ARENA BEFORE REFURBISHEMENT (POPB) : SOME ACOUSTIC DEFAULTS

AccorHotels Arena located in Paris (formerly known as Palais Omnisport de Paris-Bercy or POPB), one of Europe's major indoor stadiums with a capacity of about 17.000 seats, was hosting concerts in fairly bad conditions, especially at the sound engineers location were some of them indicated *"difficulty to get tight bass"* and *"to much return from the hall"* [3]. The venue has been globally refurbished and reopened in 2015. One of the main objectives, among other things, was to provide excellent acoustic conditions for amplified music concerts, since the main hall was suffering from poor acoustic conditions.

3.1 Reverberation time

As stated before, the reverberation time is the starting point in order to get very good room acoustic quality.

The POPB hall was fitted with consequent absorptive surfaces: perforated metal ceiling hiding thick mineral wool, acoustic baffles in the technical grill, and additional absorbing, tilted surfaces on top of sourrounding wall. Although this induced a globally acceptable reverberation time for a volume of this size, ca. 245 000 m^3, with $RT_{30} = 2.7$ s in the octave bands 125 to 2000 Hz (see Fig. 6), the optimal RT value should be around 2.1 s in this frequency range according to Eq. (1).

While the RT at 125 Hz does not deviate from the mean value, the RT value at 63 Hz turns out to rise to 3,3 s in average with some greater variability according to the location in the hall, giving blurry bass sounds.

3.2 Individual (late) reflections

Acoustic measurements carried out in the existing hall showed that strong audible echoes were detrimental to the room acoustics of the venue [3].

Fig. 1 illustrates identified echoes (measured with quasi-impulse room response excitation signal) for different receiver point with the source at the position of one line array speaker for the stage located at one and of the ground floor.

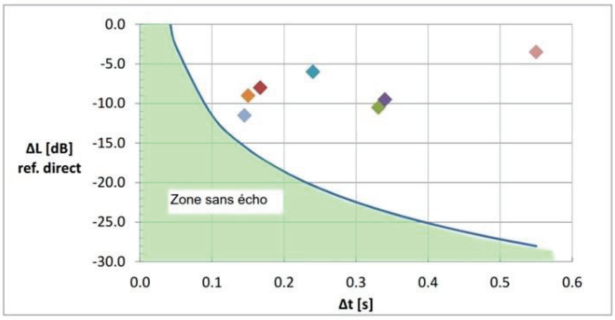

Figure 1. Identification of echoes before refurbishment

Yamamoto's method [4] on the smoothed ETCs (Energy Time Curve) and the echo-criterion EK(τ) by Dietsch [5] has been used to determine audible echoes. For example, at the sound engineer's location, echoes with time delays of more than 160 ms were found. These methods also lead to the identification of reflecting surfaces involved in the process. Those disturbing flat, reflecting surfaces are shown in Fig. 2. Four of the largest are located around the two concrete piles at each end of the hall.

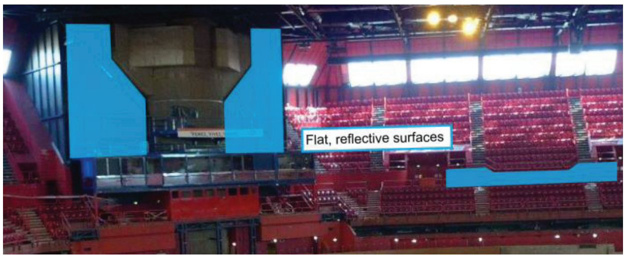

Figure 2. Reflecting surfaces causing adverse echoes

4. CORRECTIVE SOLUTIONS

4.1 Reverberation time

An important aspect of the hall refurbishment was the complete replacement of all tiered seats, with modified slope for better visibility and an increased seating capacity of up to 20.300 persons. Since seats play a major role in reverbeation control, special care was taken for the selection of new ones to slightly lower reverberation times in desired octave bands to reach the above criterion.

Previous seats were lightly uphosltered with 1 cm thick foam coated with a slick, airtight fabric. They have been tested in acoutic laboratory and showed absorption coefficients as little as 0,1 to 0,2 depending on frequencies. Therefore, the new seats have been carefully selected with thicker foam (5 cm for the seat, 2,5 cm for the back) given more absorption, in particular at low frequencies, thus lowering reverberation in desired octave bands.

Low frequency absorbers were also installed in the attic in front of existing windows and shadow boxes (see Fig. 3) in order to decrease low frequency RT further, but also to improve thermal comfort with more insulation to the outdoor.

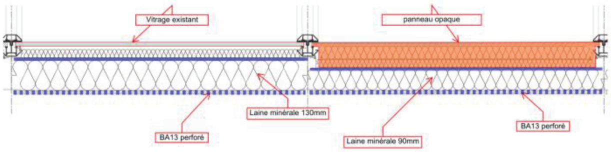

Figure 3. Low frequency absorbers on attic level

4.2 Elimination of adverse echoes

To avoid individual reflections with large delays, the identified flat surfaces have been treated in two ways. The first was to cover the largest surfaces (around the concrete piles) with absorptive material, as shown in red in Fig 4. After this absorption was introduced, the total quantity of sound absorption in the hall was almost reached to keep a good balance of reverberation, not to get too short reverberation as discussed in Chapter 2. Therefore, the second type of treatment for echoes elimination was done by partly scattering the reflections (redirecting them in all directions) with angled mircoperforated timber also allowing for little absorption. The creation of new balconies in front of the concrete piles gave more scattering as well as absorption from the seats.

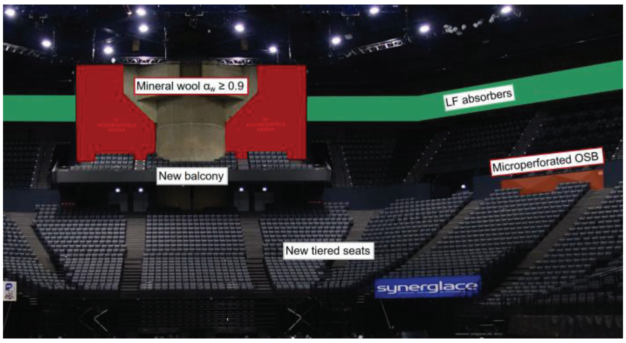

Figure 4. Treatment solutions to avoid audible, strong echoes

Thus, the room acoustics has been improved by reducing the reflecting surfaces, adding absorptive/ diffusing surfaces to absorb/ scatter unwanted reflections (see Fig. 4) while keeping a good balance of absorption / reverberation in the venue.

5. ACCORDHOTELS ARENA: IMPROVED ROOM ACOUSTICS QUALITY

Eventually after completion, thanks to the major modifications described above and to some others, the measured RT_{30} was 2.2 s on average from 125 to 2000 Hz, compared to 2.7 s before refurbishment, see Fig. 6. The overall value meets the desired criterion, and an even reduction of RT (by around 0.5s) was achieved for every octave bands. Moreover, a 0.8 s reduction of RT in the 63 Hz octave band ensures a very well balanced reverberation, suited for amplified music. This low frequency reverberation needs to be controlled in every hall for amplified music, especially since more and more bass frequencies content are part of current performed music styles.

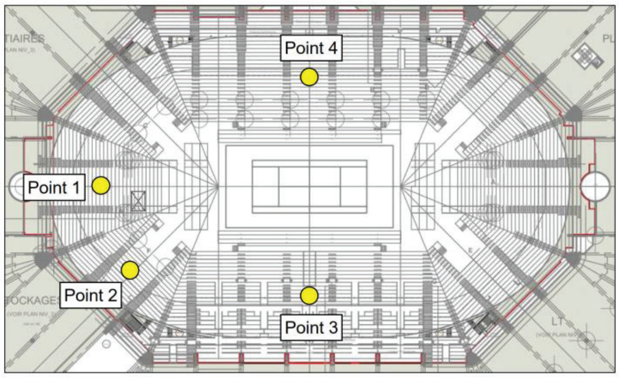

Figure 5. RT_{30} measurement locations after completion

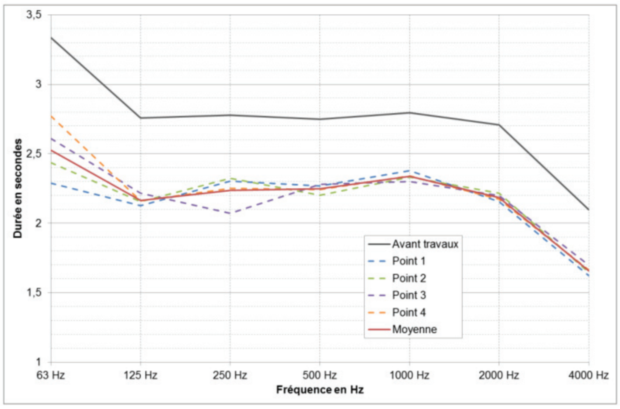

Figure 6. Measured RT_{30} in unseated, concert set-up before (black line) and after (red line, average) refurbishment

After completion, the presence of audible echoes has been checked with the same technique as per initial measurements : a impulsive, mobile sound source was used to listen to possible strong echoes. The perceptive tests showed that echos can no longer be audible in the main hall.

A relevent evaluation has also came from sound engineers working on the first shows hosted in the AccordHotels Arena : many of them found that the acoustics of the new hall has improved and allow an easier tuning of sound systems.

6. ACOUSTIC IMPROVEMENT SOLUTIONS AND RESULTS IN OTHER SPORT ARENAS

6.1 Ahoy in Rotterdam, The Netherlands

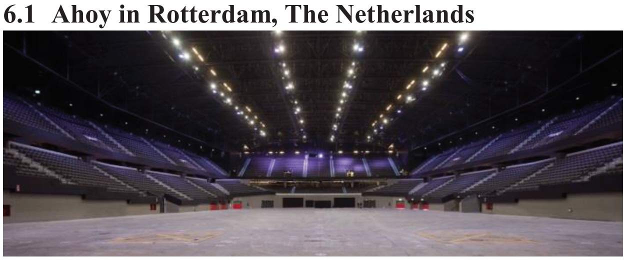

Figure 7. Ahoy arena, Rotterdam

Ahoy Arena has been expanded and modernized after forty years. The roof is raised and at the west side an extension of the gallery is realized. The audience area is increased from 10.500 to 15.500 people. The volume was raised from 120.000 to 165.000 m^3. The existing arena was suffering from some strong, late (annoying) reflections (Fig.8 left) in combination with a too long reverberation time (Fig.8 right).

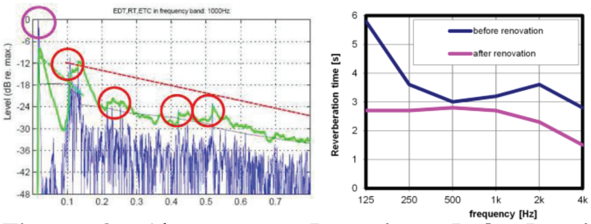

Figure 8. Ahoy arena, Rotterdam, Left: Impulse response before renovation. Purple circle is direct sound, red circles indicate too strong reflections. Right: reverberation times before and after renovation.

To prevent late reflections and shorten the reverberation time in this enlarged space with stronger curved roof, broadband sound absorbing material is integrated in the ceiling and walls of the arena. The broadband absorption consists of 5 cm mineral wool, a heavy foil, 10 cm mineral wool and an air gap (5 cm at the roof). The absorption of the roof was optimised using laboratory measurements. Also at the bottom of the stands absorbing materials have been applied. Due to practical considerations the seats are not absorptive, enlarging the difference in acoustics between the empty and occupied hall. In case the 2nd tier is not used, a curtain can be hung in front of the seats, compensating the difference in absorption for that area. The impulse reponses do not show disturbing reflections any more and the reverberation time was reduced from 3,5 to 2,7 s in the empty hall, despite the 37% volume enlargement. The frequency plot (Fig. 8 right) shows the improvement at 125 Hz. Though the RT in the empty hall is longer than indicated by Eq. (1), with full audience the arena has a much tighter acoustics, where the amplified sound can be properly heard and that is pleasant to perform in.

6.2 Johan Cruijff Arena in Amsterdam, The Netherlands

The Johan Cruijff Arena in Amsterdam, built in 1996, is basically a football stadium with a partly transparent roof, that can be opened and closed. Though not intended for concerts, the ability to close the roof makes the venue very suitable for large performances and shows. The volume is about $1.25{\cdot}10^6$ m^3 and the audience capacity 70.000 for soccer and about 50.000 for concerts. Although in the original design a considerable amount of sound absorbing material was applied, the reverberation time was considerable: 10 s, in the empty stadium.

Figure 9. Johann Cruijff Arena, Amsterdam in concert

A special acoustic baffle construction was developed to reduce reverberation, especially in the low frequencies. The construction had to be very light, the middle parts only consist of 2 fabric layers with an air gap in between. This 3000 m^2 baffle construction is only present during shows and can be removed in a relatively simple way to allow maximum daylight for the benefit of the grass soccer field. The RT was reduced to 6,5 s (empty) and from 5.9 to 4.3 s. with full audience. A significant improvement, but still not easy to amplify this hall.

7. ACOUSTIC CONCEPTS AND RESULTS IN OTHER ARENAS

7.1 Heineken Music Hall in Amsterdam, The Netherlands

Heineken Music Hall (HMH), now called AfasLive!, was built for the single purpose of hosting pop concerts of the highest acoustic quality. It is built as a black box for 5.500 people (standing audience), with a large flat floor; basically a work area where a stage and associated decor are put in place according to the requirements of each event.

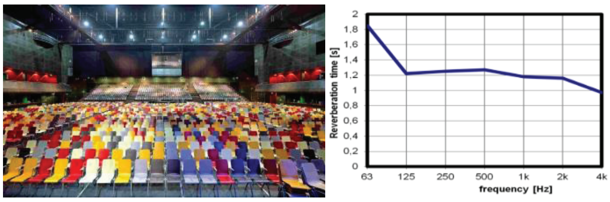

Figure 10. Heineken Music Hall Amsterdam: Left picture of interior for a seated concert, right: RT in empty hall.

The aim was to achieve outdoor acoustics, so reverberation has been minimised to the greatest technically achievable extent, also in the lowest frequencies. All walls and the ceiling consist of broadband sound absorbing materials of about 30 cm thickness in three different setups and are covered with perforated steel. There are no disturbing reflections and with a volume of 48.000 m^3 a reverberation time of 1,2 s. with a rather flat frequency response was achieved, only longer at 63 Hz , but still below 2 s. (see Fig. 10). The HMH has become the standard for amplified halls with excellent acoustics.

7.2 Ziggo Dome in Amsterdam, The Netherlands

Figure 11. Ziggo Dome, Amsterdam

Like HMH, Ziggo Dome Amsterdam was built for a single purpose: a venue for popmusic of the highest acoustical quality. The Ziggo dome has a rectangular ground plan with two levels of tribunes. It has a volume of about 145.000 m3 and can accomodate an audience of 17.000 people. All walls and ceiling are covered with broadband absorption of about 30 cm in thickness. The tribunes have been made absorptive by openings in between the seating platforms (T-beams), see Fig. 12 left. The gallery (VIP area) between 1st and 2nd tier is weakly coupled to the main volume and is more lively. There are no disturbing echos and the RT is close to Eq. (1).

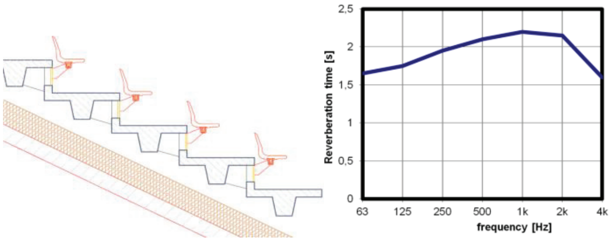

Figure 12. Ziggo Dome,left; Tribune construction with Helmholtz resonator, Right: RT in empty hall.

7.1 Volkswagen Arena Istanbul, Turkey

Figure 13. Volkswagen arena, Istanbul

The Volkswagen arena is built in the new financial district in Istanbul. The volume is 56.000 m^3 and the capacity 5.800 audience. Based on Eq. (1), the aim is RT = 1,45 s. Walls and ceiling are covered with broad band absorption (mineral wool/foil/mineral wool) with different compositions, covered with a woodwool cement board. The fixed tribunes have highly effective low frequency resonator slits with mineral wool in the cavity. The seats are upholstered, though the surface is plastic. For practical reasons the woodwool cement board was not painted black in factory but on site. This accounts for a slightly longer reverberation time at higher frequencies, see Fig. 14 right. This is audible in the empty hall during sound checks, but not with audience. As can be seen in Fig. 14 left, the impulse response is without echos.

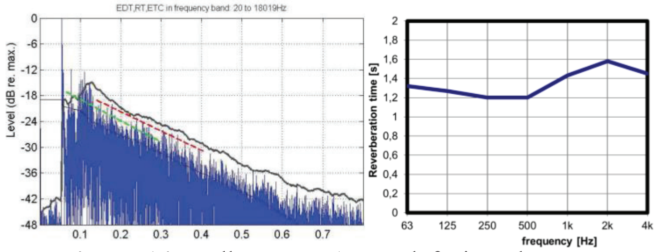

Figure 14. Volkswagen Arena, left: impulse response to receiver halfway the floor, right: RT in empty hall

8. OVERVIEW

The average RT of the halls presented in this paper (not including Johann Cruijff Arena) are given in Fig. 15 and related to Eq. (1).

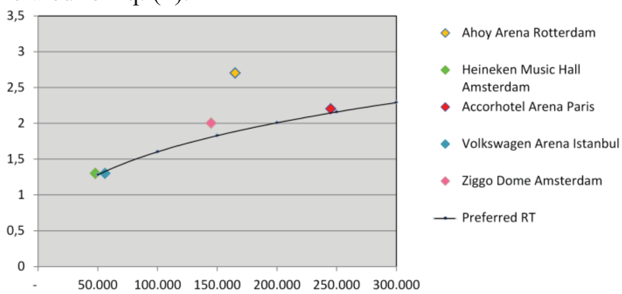

Figure 15. Average RT in empty hall as function of volume for the halls presented in this paper. The preferred RT refers to Eq. (1).

It shows that the acoustic quality of Accorhotel Arena after renovation can meet up with high quality halls HMH and Ziggo Dome in Amsterdam. Though RT in itself is less important than the absence of disturbing reflections, the approach using Eq. (1) gives a first impression of the acoustical quality that can be obtained.

9. OTHER ACOUSTIC ISSUES NOT TO BE FORGOTTEN

This paper only focuses on room acoustics for amplified events in arenas, but in this kind of buildings other topics also play a major role in their success to host concerts and other cultural performances.

A separate, permanent, electroacoustical system is needed as public adress for the audience, also for evacuation purposes. Reduction of reverberance and overall reduction of loudness helps in achieving or approximation of speech intelligibility requirements.

The sound insulation from and to the exterior environment is of high importance in order not to be disturbed by unwanted noise (or vibration) from the surrounding environment and, maybe more importantly, not to bother the neighborhood with noisy shows. In the case of concerts producing loud sound levels, including at low frequencies, the later issue is commonly driving the design of the building shell with highly insulating materials, requiring commonly sound attenuation of more than R_w+C_{tr} 65 dB when sensitive receivers are closeby.

Finally, HVAC and mechanical services noise must be carefully controlled to be kept at their minimum during any part of a concert, even if it is highly amplified ; otherwise the sound dynamics would be altered and a silent part of the performance polluted by unwanted noise. This is quite a challenge due to the large air amounts and potentially large distances between airsupply and audience, resulting in high air velocities and sound production.

10. CONCLUSION

In sport arenas aiming to host amplified music concerts in good conditions, a carefull attention must be paid to acoustics. In this matter, a proper control of the reverberation (RT) is necessary but not sufficient. It is essential to avoid strong reflections with delay (i.e. echoes) since they have a dramatic effect on sound clarity and intelligibility. The exemple of the AccordHotelArena in Paris, and other venues, has been used to show common acoustic defects and practical solutions used to adapt a sport venue with poor room acoustics into a very good concert hall.

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