The renovation of De Doelen Concert Hall

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Introduction

The main hall of De Doelen, Rotterdam, the Netherlands, is a concert hall for classical music with a volume of about 27,000 m³ and a seating capacity of 2242. The Hall opened in 1966. The architect was B. Kraaijvanger and the acoustical consultants were Prof. C.W. Kosten and P.A. de Lange. In 2009 the hall will be renovated. As a part of the renovation design, research has been done on the room acoustics. Despite the very good reputation of the main hall acoustics [1],[2], possible improvements are investigated within the scope of the renovation.

An important part of the research had to do with the stage acoustics. When opened, the main concert hall in De Doelen, was fitted with six canopies above the stage platform [3],[4], see figure 1. Their function was twofold:

- to provide a large part of the audience with early reflections;
- to create good ensemble conditions for the musicians on stage.

Despite good reviews after the opening, a few years later the canopies were removed, because they caused unwanted reflections at the recording microphone positions just below the canopy. Since then, a significant percentage of the orchestra is not completely satisfied with the acoustic conditions on stage. During the design process of the renovation, possibilities to re-introduce a stage canopy and influences of shape and materials are investigated.

In this paper we will present an analysis of the existing hall, acoustic objectives for the renovation and the results of the investigations by means of scale model research, a ray tracing computer model and laboratory measurements.

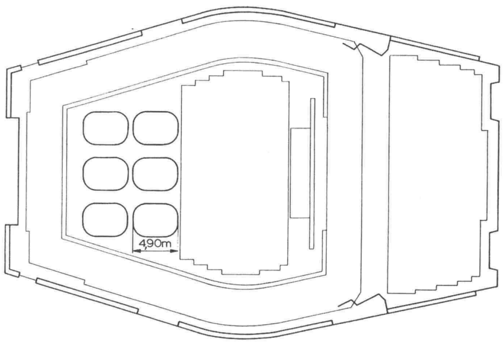

Figure 1: floor plan of the main hall De Doelen, 1966, with the positions of the 6 curved reflectors indicated

Analysis of existing hall

The hall is relative large, with a length of 60 m, max. height about 18 m and width ranging from 29 to 39 m. To keep the delay of the first reflection within 50 ms in the middle (parterre) area, inner walls were created. The parterre area is lowered, thus creating these inner walls. This ‚marble' (actually it is travertine) wall with its sound diffusing blocks is very characteristic for De Doelen (fig.12).

The general opinion on the acoustic of the De Doelen is that it is very good, especially transparent and clear.

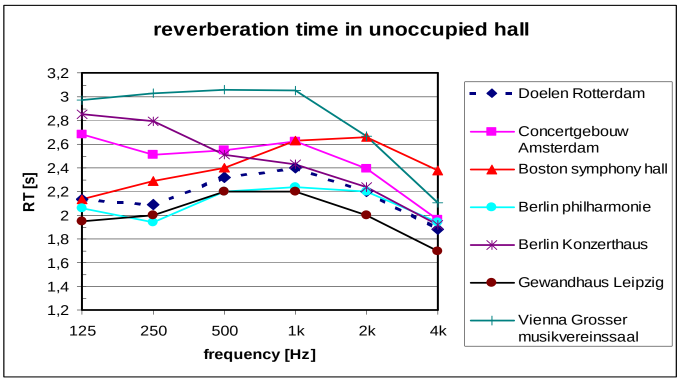

Figure 2: Reverberation times in De Doelen and other halls, unoccupied

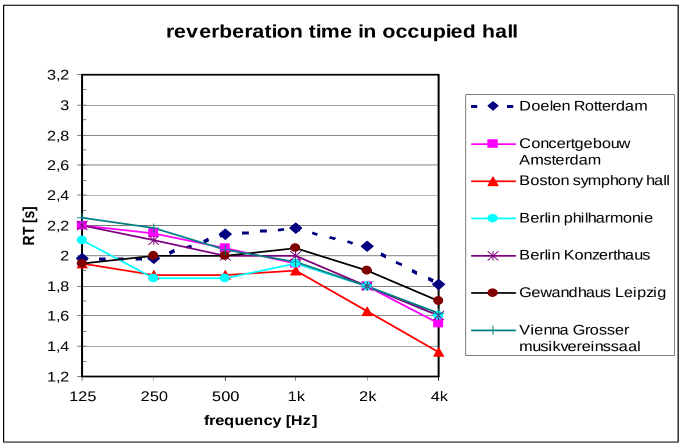

Figure 3: Reverberation times in De Doelen and other halls, occupied

Measurements (figure 2,3) show that it does not lack reverberance. On the other hand, for a hall this big a somewhat longer RT would still be possible. At lower frequencies the RT drops. This was originally not intended. The large volume and large number of seats causes a relative low strength, especially at large distance from the stage (see figure 4).

The clarity in the hall is –1,4 dB (1kHz, average in the audience area). This is relatively high for a concert hall. The support at the front positions at stage is –17 dB, this is low.

The marble blocks give some very high frequency reflections back to the stage area. There used to be complaints about this, but by using stage risers these complaints have diminished.

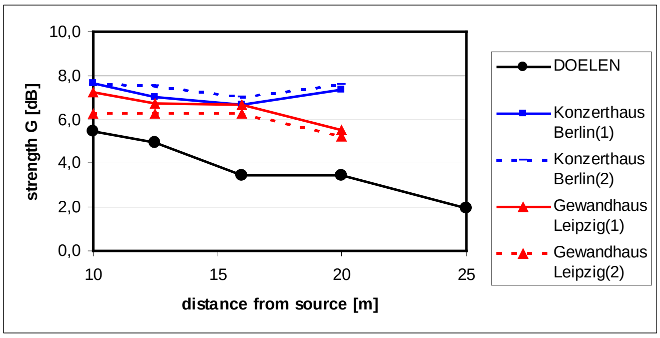

Figure 4: Strength as a function of distance from the source in De Doelen and some other halls

Acoustic objectives for the renovation

The basic characteristics of the hall, such as the volume, shape floor slope etc could not be changed. Also the finishing of the marble and wooden walls had to be maintained due to the monumental status. The degrees of freedom were confined to the floor covering, the seats and the ceiling (shape and material).

The reverberation time aimed at is the existing RT for the high frequencies +0.1 s. For the lower frequencies it should be frequency independent (around 2,3 s. occupied).

Especially in the rear area the G should be increased by 1 dB or more.

The playing conditions for the musicians should be improved, bringing back the functionality of the original stage reflectors (see next chapter).

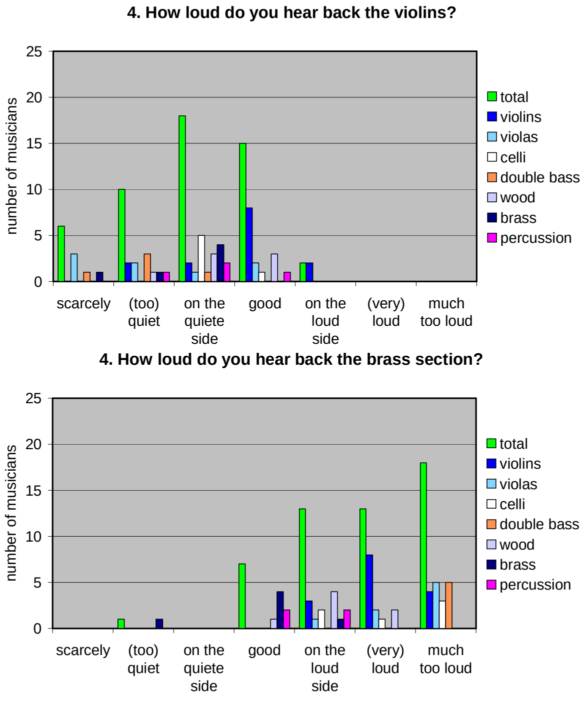

Figure 5: Some results of the questionnaire on the stage acoustics in De Doelen, among the musicians of the Rotterdam Philharmonic Orchestra

Subjective research

In order to obtain a good overview of the opinions concerning the stage acoustics, the musicians of the Rotterdam Philharmonic Orchestra were asked to fill out questionnaires. They were asked to give their opinion on their own playing conditions, the ensemble conditions, the stage and hall acoustics in general. The questionnaires were also taken in the Singel in Antwerpen. Two examples of the results from the questionnaire are given in figure 5.

From the questionnaires the most important conclusion on loudness and intelligibility is that the musicians of the Rotterdam Philharmonic Orchestra judge that De Doelen Main hall has:

- low loudness en intelligibility at the front positions of the stage, especially for the strings;

- high loudness from the rear position of brass and percussion to the other instrument groups.

The timbre in De Doelen of the loud and high-frequency-instruments (brass and violins) is judged as rather shrill, the low-frequency instruments are judged as rather dead/woolly.

Improvements of the acoustic of De Doelen stage will be focussed on an increase of loudness and intelligibility of the strings and to reduce the shrill character of the hall and make it sound warmer.

In addition to the questionnaires, measurements were made on stage, from several source positions to the middle of all instrument groups. These measurements were then correlated to the questionnaire results. Many of the energy parameters did not correlate to the subjective results. Only the ST1 (support) correlated to the result of the question on how loud the musician heard his own instrument back (see figure 6).

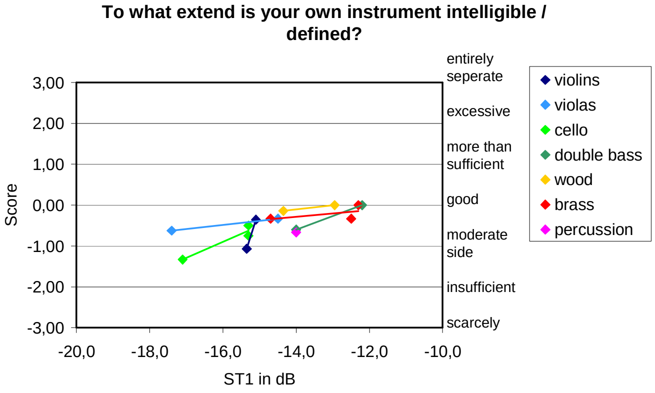

Figure 6: Relation between ST1 and musicians' own playing conditions

To describe the influence of the stage surroundings on intelligibility, only the early reflections are important (with no echoes or flutters present). Therefore the "strength" parameter G is used, but with a time window from 5 to 80 ms after direct sound, which excludes direct sound and takes into account reflections from surfaces up to a distance of roughly 14 m (from middle stage), which is of course arbitrary. It is referred to as Early Reflections Strength, $G_{5\text{-}80}$ in dB:

$$G_{5-80} = 10\log\frac{\int_{5}^{80} p^2(t)dt}{\int p_{10}^2(t)dt}[dB] \qquad [m^2] \qquad (1)$$

Although, for a certain value of Early Reflections Strength, the judgement differs for different instrument groups, within an instrument group there seems a consistent result. When asked “how loud do you hear a particular instrument group”, a higher value relates quite well to a higher $G_{5\text{-}80}$, see figure 7. Increasing the $G_{5\text{-}80}$ on stage was one of the objectives for the renovation.

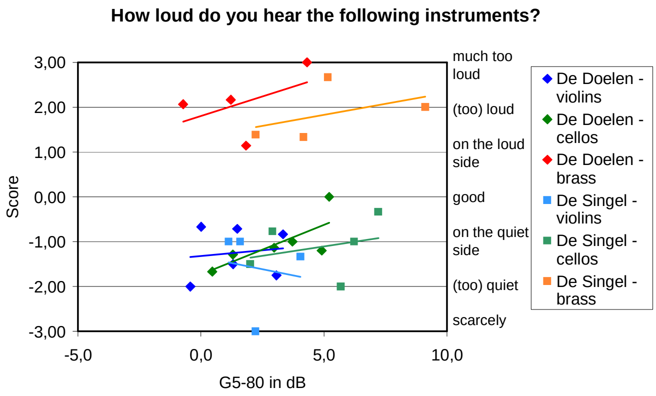

Figure 7: Comparison of $G_{5\text{-}80}$ to the musician’s opinion regarding the loudness of other instruments

Scale model research

Figure 8: Picture of the 1:10 scale model of De Doelen with the new suspended technical ceiling above stage. In this ceiling the reflectors and lighting is integrated.

The scale model is made scale 1:10. The material is mainly mdf, painted to reduce high frequency absorption. The ceiling is made of 2 mm hard Polystyrene. The audience is made from foam material and placed on wooden strips. The measurements are done with special high frequency omnidirectional sources and 1/8“ microphones to be able to perform measurements up to 50 kHz. With a 1:10 scale model this enables measurements up to 5 kHz in reality.

A stage reflector is proposed to improve the support at the front of the stage and the ensemble conditions. The stage reflector is positioned at a height of 10.5 m above the front of the stage and has slightly curved panels for diffusive reflections back to the stage.
Figure 8 gives a picture of the scale model with the reflector. The flat edges will be made acoustically transparent. The theatre lighting will be integrated in this suspended technical ceiling. Several configurations of the reflecting panels were tested, mainly to limit the influence of the reflector in the audience area.

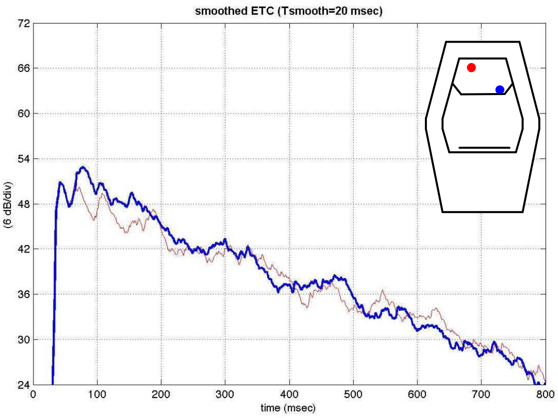

Figure 9: Measured impulsresponse (smoothed ETC) across stage (blue dot = source, red dot = mic). Existing situation (red line) and with new suspended ceiling (blue line)

Figure 9 shows the effect of the final version. The reflector fills the gap between direct sound and early reflections.

Figure 10 shows the effect of the reflector on the $G_{5\text{-}80}$. This is compared to the situation without reflector and the reflectors of 1966. It shows that the new reflectors are very effective for Early Reflected Energy.

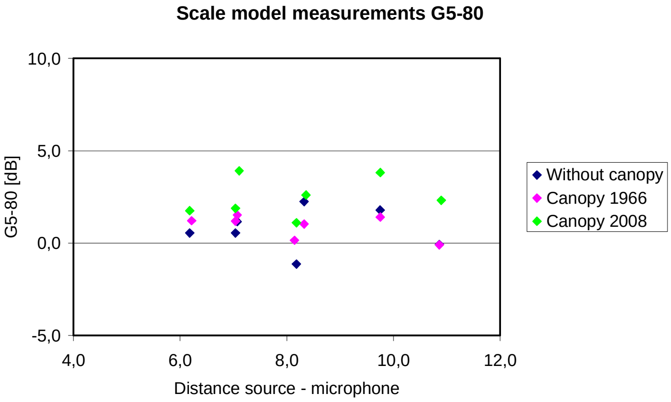

Figure 10: Measured $G_{5\text{-}80}$ in the scale model with different settings of the stage reflector

Figure 10 also shows that there is no systematic dependency of the $G_{5\text{-}80}$ to the distance from the source. Almost all other parameters have that.

With the scale model many other alterations (partly incorporated in the design, partly not) are tested. On of the more important alterations is the reduce of the volume in the rear of the hall. Under the overhang the rear wall is moved to the front, at the expense of 3 rows of seats with a reduced acoustical quality since these were outside the acoustic volume. The scale model showed an increase of the strength in the rear of the hall due to this new rear wall.

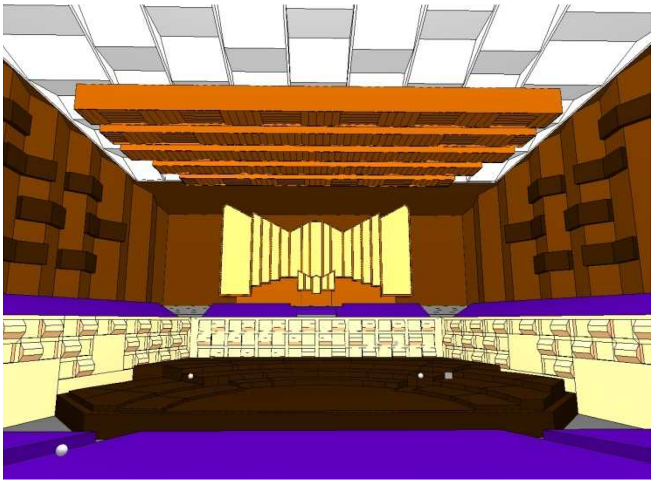

Figure 11: Calculation model with stage reflector

Computer model

Most important objective of the computer model investigation (see figure 11) was to determine the impact of the stage reflector on the reverberation time of the hall. With the proposed reflector the impact on the RT due to the reflector is minus 0.1 s, which will be compensated by other means (reduction of absorption of walls, ceiling, chairs). Just like in the scale model, the computer model calculations show that adding the stage reflector fills the gap between early reflections from the enclosure and the relative late reflections from the existing ceiling, resulting in an increase in ST1 and G_{5-80} of about 1 dB.

Laboratory measurements

In the Peutz Acoustic Laboratory measurements are performed of the absorption of ceiling, wall elements and the existing chairs. Based on these measurements requirements are set on materials and absorption of chairs. The ceiling will be of 30 mm gypsum fibre panel, total weight 35 kg/m^2. Part of the wall panels will be altered, on the backside of these panels gypsum fibre panel will be added. The absorption of the chairs will be reduced, mainly by reducing the thickness and the size of the foam.

Conclusions

The main acoustic objectives for the renovation of De Doelen concert hall are the improvement of stage acoustics, increase of strength in the rear of the hall and increase in (low) frequency reverberation.

Scale model, computer model and laboratory research has been done to define the means to provide these improvements. The most important change will be the introduction of a suspended technical ceiling above the stage, providing early reflections to the musicians. The rear of the hall will be moved in, 3 rows of seats will be removed. By increasing the surface weight of the ceiling and parts of the walls and by lowering the absorption is the chairs the reverberation time will be slightly increased.

The renovation will be ready in September 2009.

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Figure 12: Picture of De Doelen