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Influence of stage risers on stage acoustics

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For musicians, people with trained hearing, finding a good 'balance' within the symphonic orchestra is essential. The right balance can be found by the 'trial and error'-method, for example by changing the stage arrangement (stage risers). However it is unknown to what extent stage acoustics are affected by stage risers.

This study was aimed at determining whether the influence of local differences in stage floor height (stage risers) on stage acoustics is measurable and audible.

The, according to Gade, important stage parameters Support *ST* and Clarity *CS* ('ensemble'), both measured at one meter from the source, have been determined (and used as tools). The difference in sound pressure level between source and receiver (Lp_{Source_1m} - $Lp_{Receiver}$) has been determined as well.

The influence of stage risers on the value of the acoustical parameters has been derived from the results of the measurements on the stage with flat floor and on the stage with stage risers (basic arrangement). An omni-directional sound source and receiver have been used for the measurements.

The difference between the two stage arrangements is found to be measurable as well as audible (difference > Just Noticeable Difference *JND*). Differences in the stage parameters *ST* and *CS*, as a consequence of the stage risers, occur and are largest near the edges at the rear of the stage.

1 Introduction

Although it is not always explicitly mentioned, we have to make a distinction between stage acoustics and room acoustics. In the event of the use of the auditorium for rehearsals and concerts, musicians often discuss the acoustical quality of the stage. Because of this use they have the opportunity to carry out experiments to obtain optimum stage acoustics: they can, for example, fine-tune the stage acoustics by changing their stage arrangement.

Finding a good 'balance' within the symphonic orchestra is essential. The 'balance' [1], a well-balanced distribution of sound, depends on the directional and frequency characterization of instruments, the loudness of instruments, the arrangement of the orchestra, the character of the repertoire and the stage acoustics (orchestral enclosure/area).

Musicians may hear differences in stage acoustics, caused by, for example, changing the stage arrangement (stage risers). To date, there has not been extensive research on the sound distribution on the stage and the 'balance' within the symphonic orchestra.

This study was aimed at determining to what extent stage risers affect stage acoustics and at determining whether the musicians' perception of difference in stage acoustics, as a consequence of difference in stage arrangement, can be correlated to objective measurement results.

2 Concert hall and stage

The Nationale Nederlanden Zaal (Figure 1-4) is the main auditorium in Muziekcentrum Frits Philips in Eindhoven. This auditorium, which is generally considered to be an excellent hall, opened in 1992, and was designed by the architects Van Aken, De Bever en Van de Ven in cooperation with the acoustical consultants P.A. de Lange and L.C.J. van Luxemburg.

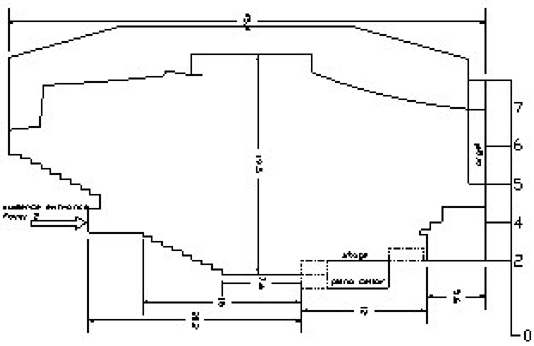

Figure 1: Section of the auditorium

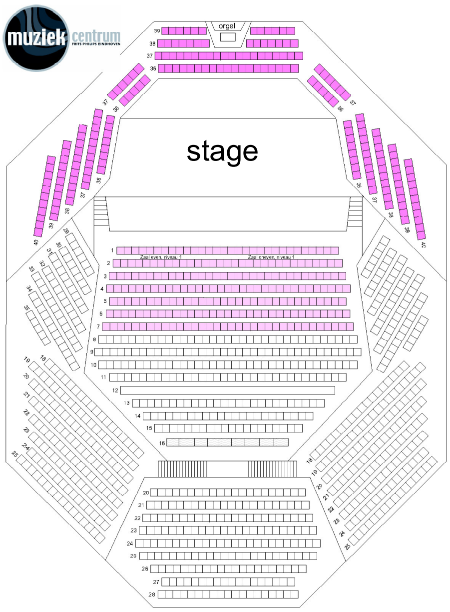

Figure 2: Plan of the auditorium

The auditorium has a volume of 14400 m^3 and a capacity of 1250 seats. The audience surrounds the stage. The rear part of the stage floor (percussion) is hydraulically moveable in height (up to 1 meter above the stage floor). Stage risers are used for the wind instruments and basses. The lateral walls and rear wall of the stage are composed with QRD sound diffusers [2, 3], with a leaning edge above them. Above the stage two reflectors are positioned at a height of approximately 9 meters (Figure 4). The auditorium is the base of the symphonic orchestra Het Brabants Orkest, so they use the auditorium for concerts as well as rehearsals.

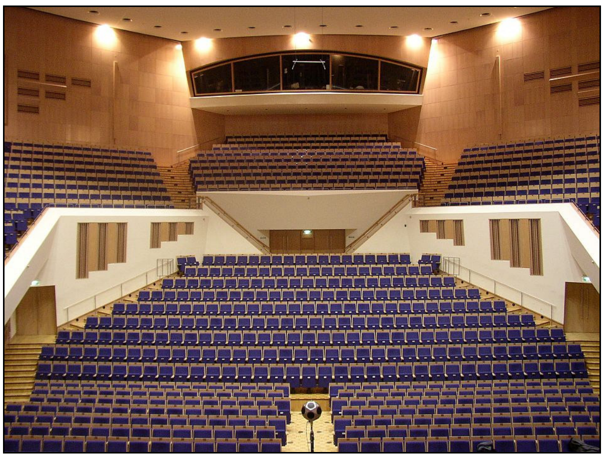

Figure 3: View from the stage

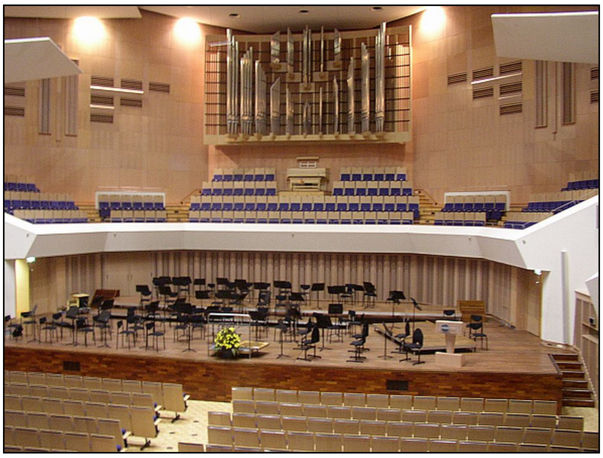

Figure 4: Orchestra enclosure of the auditorium

3 Parameters

Parameters that describe the stage acoustics are derived from parameters, describing the room acoustics. For room acoustics the early, middle-late sound is important. The (very) early sound is important for stage acoustics. The objective (measurable) stage parameters can be correlated to the subjective categories [4, 5].

The objective parameters can be derived from the measured impulse response p(t). Figure 5 shows an impulse response with both source and receiver on the stage ('stage – stage') and an impulse response with source on the stage and receiver in the hall ('stage – hall'). It is evident that the impulse response 'stage – stage' contains less reflected sound relative to the direct sound in comparison to the impulse response 'stage – hall'.

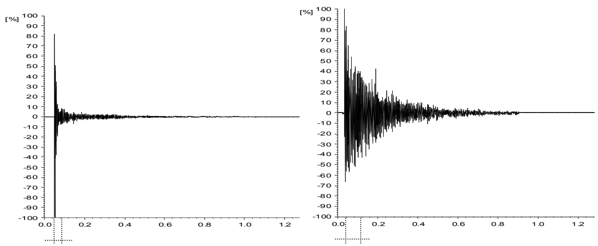

Figure 5: Two different impulse responses p(t);
left: stage – stage, right: stage – hall

The ST_1 and CS are important stage parameters, according to Gade [4, 5]. The objective stage parameter Support ST_1 (1) reflects the ease of playing ensemble. The subjective parameter 'support' reflects to what extent the musicians feel supported on the stage. The 'transparency' (Clarity (2)) reflects to what extent details in music are audible. CS, the Clarity C_{80} measured at 1 meter from the source, also expresses the ease of playing ensemble. Gade defines for the Support and Clarity, both measured at one meter from the source, -12 ± 1dB (ST_1) and 13 ± 1dB (*CS*) as optimum values for stage acoustics [4, 5].

$$ST_1 = 10\lg \frac{\int_{20}^{100} p^2(t)dt}{\int_{0}^{10} p^2(t)dt} \text{ [dB]} \qquad (1)$$

$$C_{80} = 10\lg \frac{\int_{0}^{80} p^2(t)dt}{\int_{80}^{\infty} p^2(t)dt} \text{ [dB]} \qquad (2)$$

The *CS* is defined by Gade [4, 5] as the Clarity C_{80} measured at one meter from the source. In this study the *CS* is defined as the Clarity C_{50} measured at one meter from the source: CS_{50}, due to the importance of (very) early sound on the stage for playing ensemble. Generally considered, the Clarity C_{50} expresses the 'transparency' on the stage more than the Clarity C_{80}. Measurements of the preliminary research of this study establish that in this case the use of CS_{50} is recommended, because it shows a greater correlation to the experiences of the musicians than the CS_{80}. The difference between the stage arrangements is larger for CS_{50} and is audible, according to the *JND*. However, the results for CS_{80} show hardly any correlation between the measurement results (hardly audible differences) and the experience of the musicians.

The loudness distribution of sound can be determined with the difference in sound pressure level *Lp* between source and receiver ($Lp_{Source\text{-}1m} - Lp_{Receiver}$).

The measurements results have been compared to the Just Noticeable Difference (*JND*[1]) [6] to determine whether the difference between the two stage arrangements is audible.

[1] The *JND* is in case of noise 1 dB for people with normal hearing. However, the *JND* for people with trained hearing, like musicians, and in other circumstances (orchestra – tonal sound) might be below 1 dB.

4 Methodology

The influence of the stage arrangement (height of stage floor, stage risers) on the acoustical parameters has been determined from the results of the measurements with two different kinds of stage arrangement: the stage with flat floor (Figure 6) and the stage with the basic arrangement of the stage risers (Figure 7).

Figure 6: Stage with flat floor

Figure 7: Stage with basic arrangement of stage risers. Height of stage: ~stringed instruments: 0 m (except basses: 0,25 m); ~wind instruments 1st row: 0,25 m; ~wind instruments 2nd row: 0,5 m; ~percussion: 1 m

The Support ST_1 and the CS_{50} have been derived from the impulse responses (software Dirac 3.0, e-sweep signal). The impulse responses have been measured at 16 source positions on (the rear of) the stage with flat floor (percussion and wind instruments) and 22 sound source positions on the (total) stage with stage risers (all instruments). Figures 8 and 9 show the source positions and the receiver positions respectively.

For each of the 16 sound source positions the difference in sound pressure level between source and receiver $Lp_S - Lp_R$ in dB has been determined for 14 receiver positions at both stage arrangements.

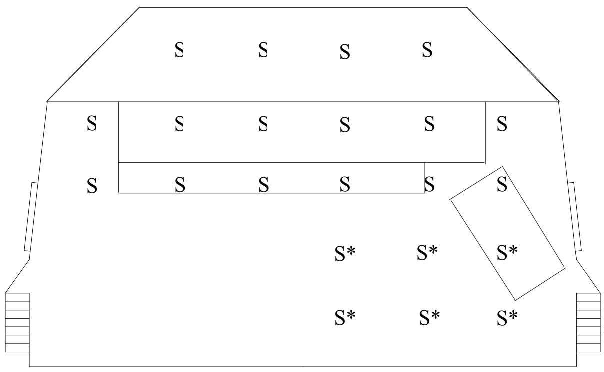

Figure 8: Measurement positions; S = source, S* = extra source position, only used for measurements on stage risers

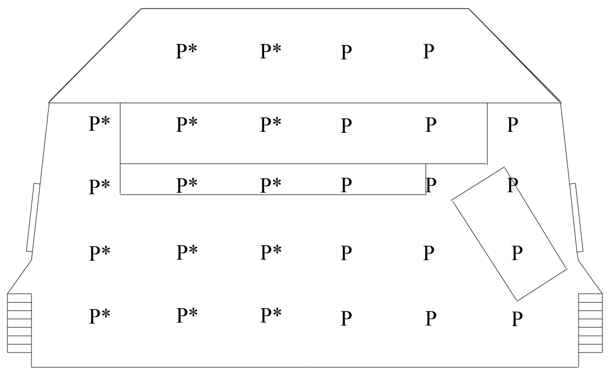

Figure 9: Measurement positions; P = receiver, P* = virtual receiver position, derived from 'mirrored' source for measurements of $Lp_S - Lp_R$

5 Results

Differences between the two stage arrangements are audible (difference is more than 1 dB) throughout the stage, in accordance with the musicians' experience, as well as measurable.

The results for the acoustical parameters, discussed below, have been averaged over the frequencies 250 to 2000 Hz. The results, shown in Figure 10, have been derived by interpolating the measurement results in Matlab (*shading interp*).

An increase of ST_1, compared to the rest of the stage, occurs at the centre (main part) of the stage and is probably caused by the two reflectors above the stage (shape of two reflectors is 'recognizable' in Figure 10). Please note the decline of ST_1 near the doors on the stage with flat floor. This is caused by the absence of QRD diffusers at the door, resulting in fewer reflections relative to direct sound.

Difference in Support ST_1 between the two stage arrangements occurs at the rear of the stage (Figure 10). The lower value of ST_1 (-17 dB) at the rear of the stage (with stage risers) is probably (mainly) caused by the inclined edge above the diffusers: the increase of reflections within 10 ms results in a decrease of ST_1. The difference in ST_1 between the two stage arrangements is more than 3 dB at the rear of the stage. The influence of the stage arrangement is also recognizable in the shown results for CS_{50}. This underscores the influence on ST_1 at the rear of the stage.

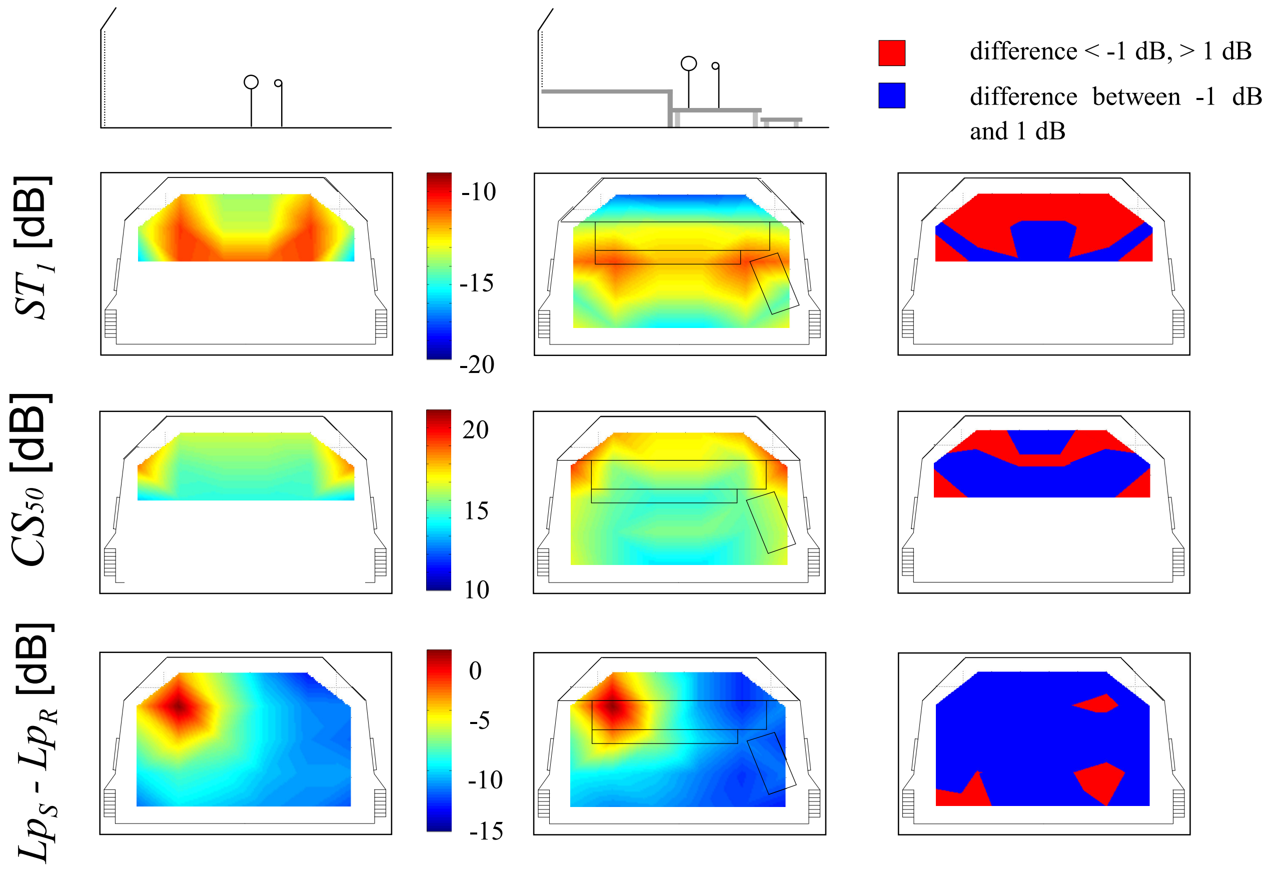

Figure 10: ST_1, CS_{50} and Lp_{Source} - $Lp_{Receiver}$ in dB for the stage with flat floor (1st column) and the stage with stage risers (2nd column); (just noticeable) difference between both stage arrangements in dB (3rd column)

An increase of the CS_{50} mostly occurs at the edge of (the rear of) the stage with stage risers, compared to the stage with flat floor. Most probably the increase is caused by the inclined edge. The difference between the two stage arrangements is 1-2 dB. In this situation the influence of the absence of diffusers in the door is recognizable as well.

For a longer distance to the source the difference in sound pressure level $Lp_S - Lp_R$ is larger on the stage with stage risers. This difference is about 1 dB. The results for the difference in sound pressure level in Figure 10 are for one source position. The results for the other source positions are similar.

6 Discussion

This research has established, that differences in stage acoustics, as a result of differences in stage arrangement, are audible and measurable: the method, used in this research, can be used as a tool to determine the differences in other concert halls. However, the discussed results (values of acoustical parameters) are only valid for the Nationale Nederlanden Zaal: in this study and situation the differences in stage arrangement depend mostly on the inclined edge above the diffusers. The influence of the inclined edge on stage acoustics changes by altering the height of the stage floor, including the height of the source. This results in different reflections of the sound.

Furthermore, the measurement results have been acquired with measurements through an omni-directional sound source and receiver, as the standards prescribe. In an orchestra however, the instruments and ears of musicians are far from omni-directional. The difference between the used method and ‘reality’ will be largest at the high frequencies. Also must considered that the measurements have been carried out on the stage without chairs and orchestra. In reality the orchestra members influence the sound distribution, resulting in possibly different or less reflections than in the measurements of this research.

Further research is required to establish optimum values for CS_{50} and to determine the difference between the two stage arrangements at the front of the stage. Measurements at the front of the stage with flat floor were not made. However the difference between the two stage arrangements at the front of the stage is expected to be small.

7 Conclusion

As discussed earlier in section 3 *Parameters*, in this study the CS_{50} shows a greater correlation with the experiences of the musicians (“audible difference”) than the CS_{80} and is recommended to be used in other studies, similar to this one.

The subjective perception of the musicians seems to correspond to the objective measurement results: the difference in stage arrangement is audible, as well as measurable. Differences in the stage parameters ST_I and CS_{50}, as a consequence of the inclined edge, occur near the edges (at the rear) of the stage of the Nationale Nederlanden Zaal.

A recommendation to the symphonic orchestra Het Brabants Orkest has been to lower the stage riser for percussion from 1 meter (usual configuration stage riser) to 0,75 meter to improve the stage acoustics at the rear of the stage (increase of ST_I). The musicians claim to hear difference and improvement of stage acoustics at the rear part of the stage. This verifies the optimum value that Gade [3, 4] recommends for ST_I (-12 ± 1 dB).

In the measured configuration with stage risers, ST_I is about -17 dB near the edge of the stage. Lowering this stage riser causes increase and improvement of ST_I (see measurement results on the stage with flat floor). This verifies that ST_I is a good tool to determine the quality of stage acoustics.

The measurement method, used in this research, can be used as a tool in other concert halls to determine whether the influence of stage arrangement on stage acoustics is audible, as well as measurable.

8 Acknowledgements

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