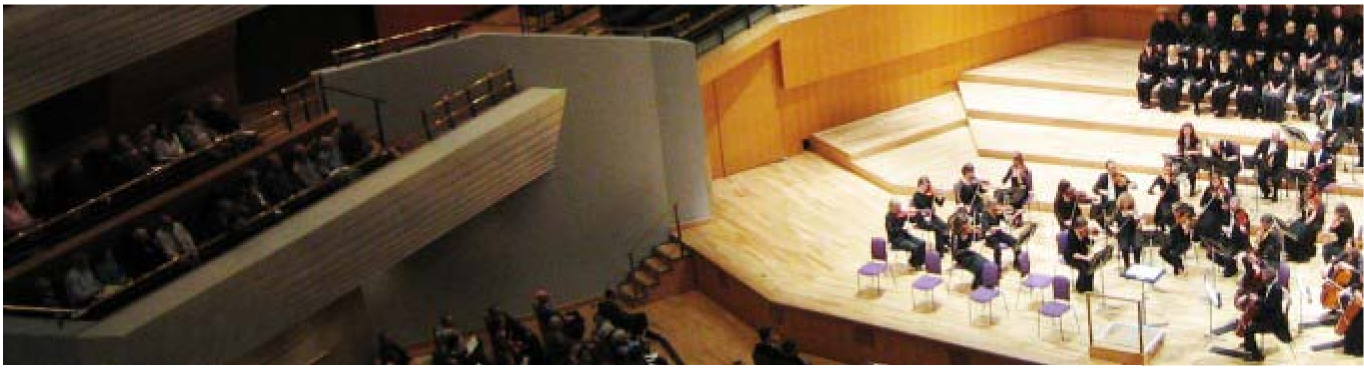
Comments of Ph.D.J. J. Dammerud about:

Stage acoustics for symphony orchestras

Research on orchestra acoustics – acoustic conditions for orchestral musicians



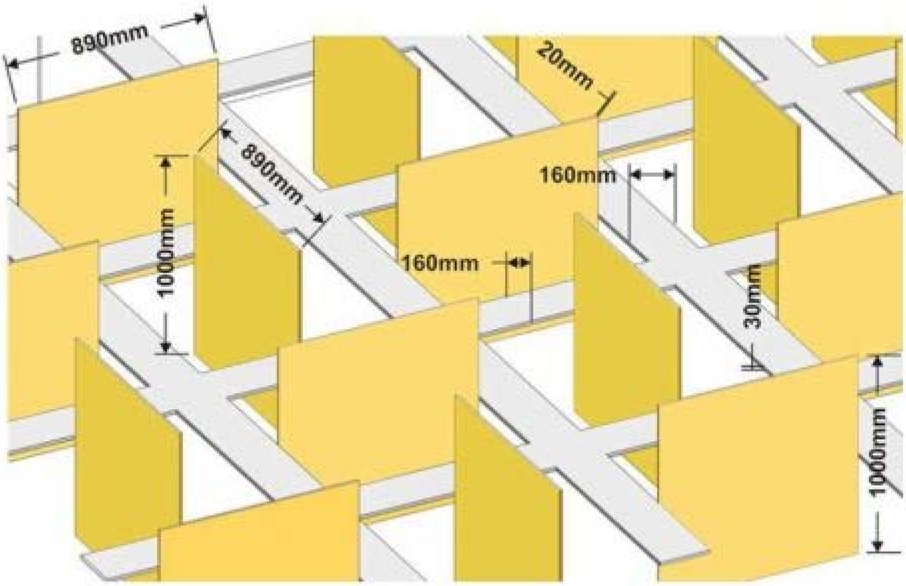
Improving the acoustics for orchestras under a low ceiling

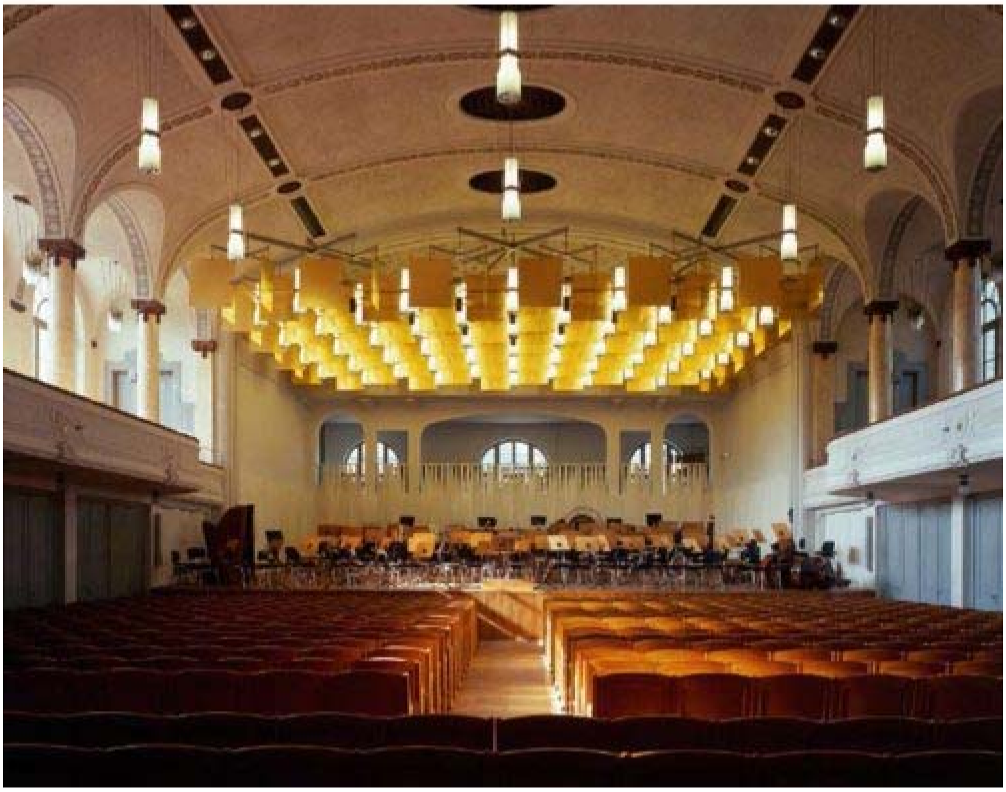
Posted on March 30, 2012 | Leave a comment

One of the major findings from the research project documented on this website was that low ceiling can be very problematic for a symphony orchestra. Recently a paper by Higini Arau-Puchades (Arau Acustica) has been published in Acta Acustica united with Acustica; *Increasing the Acoustic Volume of Performance Spaces without Altering the Internal Dimensions*.

http://www.ingentaconnect.com/content/dav/aaua/2012/00000098/00000002/art00010

The cases covered in this paper suggest that a low ceiling is the major reason for difficult acoustic conditions experienced by the orchestras playing in their specific venues. The paper also includes a design of a grid of vertically oriented solid panels suspended above the orchestra, called an *acoustic labyrinth*. The picture below is taken from the mentioned paper.





The apparent effect of this construction is to block the direct reflection from the ceiling particularly above 500 Hz. Blocking the direct path results in the sound travel a longer path from the orchestra via the ceiling back down towards the orchestra, resulting in lower level and larger delay on the ceiling reflection. The grid also contributes to scatter the ceiling reflection into different directions. The ceiling of the actual venues had curved ceiling that focused the reflected sound down towards the orchestra. Blocking the direct reflection by the grid will in such cases have a very significant effect on the level of reflection sound from the ceiling.

The orchestras reported on significantly improved acoustic conditions with the grid installed. This is very encouraging since it suggests that there can be a cost-effective alternative to improve conditions for orchestras under a low ceiling. Rising the ceiling physically will in most cases be too expensive to be feasible.

There are only given a few suggestions in the paper to why the grid improves the perceived conditions. Apparently the experienced improvement can largely be explained by the findings from my PhD thesis http://stageac.wordpress.com/phd/ ; a high ceiling was here found beneficial for avoiding loud instruments becoming too loud and contributing to make the string section and the acoustic response from the main auditorium audible to the whole orchestra. This conclusion was based on comparing acoustic conditions with the orchestra present on stage, related to the psycho-acoustic effects masking, presence effect and the cocktail-party effect. The real stages studied in the PhD also supported this conclusion.
It will be interesting to hear more about the players' experiences with Arau-Puchade's grid in the future. To further understand the effect of the grid it would be very interesting to see measured acoustic responses in detail and results for *G*late and *C*80, both on stage and in the main auditorium for these venues – not only Schroeder curves, *T*30, *G* and *ST*early on stage.

New material update

Posted on November 23, 2011 | Leave a comment

1) A new spreadsheet for calculating *G* has been added. See the spread sheets page.
2) A journal paper is now due to be published in Building Acoustics. See thearticles page.
3) The results from the project suggest that important features a stage enclosure is to provide effective compensation for the inherent skewed level balance between the different instrument groups of the orchestra. Such an effective compensation appears to be best accomplished by having reflections with small delay from specific directions – particularly from surfaces close to the orchestra at the sides. But maybe as important, or even more important: to allow or aid the players to hear the late reverberant response from the main auditorium. (The response from the main auditorium will always be late due to the distances involved). This is likely to contribute to a sense of acoustic communication with the audience area, that appears to be an important aspect of the acoustic conditions for the player. Measuring *G*late on stage and in the stalls area (in the main auditorium) appears to be a useful method to investigate the level of contribution of late reverberant sound from the stage enclosure and main auditorium on stage. A brief article has been added regarding details on measured *G*late in the stalls area (audience area) compared to on stage for eight different venues (the BSO venues).

Why G appears superior to ST for acoustic levels

Posted on September 29, 2011 | Leave a comment

For more details and background on why measures based on *G* appears to be both more reliable and subjectively relevant compared to the *ST* measures, I have written a 3 pages long article that include some results previously not presented. See the Articles page.

The message from the article in brief: feel free to continue measuring *ST* on stage, but please make sure that you also measure and report *T*, *C*80, *G*e and *G*lon stage as well as in the audience area for the venues you investigate!

Creating a fuller sound of the orchestra

Posted on September 16, 2011 | Leave a comment

A full or warm sound of the orchestra is normally preferred. An experience of a full sound is normally associated with sufficient levels and acoustic response at low frequencies. An increase of reverberation time at low frequencies is often recommended for this purpose. By having bass-reflecting surfaces close to the orchestra at the sides and at the back, close to coherent reflections will be added to the source that will effectivily boost the sound source levels at low frequencies. The need for low frequency reverberant sound to produce a fuller orchestra sound may therefore be reduced with surfaces close to the orchestra. Such proximate bass-reflecting surfaces can therefore potentially contribute to both a full (warm) and distinct orchestra sound.

This apparent benefit of side and back reflecting surfaces was covered in myPhD thesis with emphasis on raising the levels of the double basses. But the percussion section may also benefit from being close to surfaces that reflect at low frequencies. The back wall has been associated with negative effects, like unnecessary raising the level of percussion. But such negative effects of percussion could to be relevant primarily at frequencies above 500 Hz. The back wall behind the percussion can be made reflective at low frequencies, while more absorbing or diffusing (sound scattering) at higher frequencies to avoid the negative effects. The brass instruments appear loud enough in the first place so there may be no need to raise the levels of brass at all with reflecting surfaces close to them. The results from the questionnaire studies suggest that the exception could be the horn section. Horn players have commented positively on having a reflecting surface behind them that could be caused by the directivity of the horn.

Phase relations between sound waves are normally not included when sound levels are summed in computer simulating software for auditorium acoustics. By ignoring phase information the effect of the surfaces will be underestimated regarding total levels at low frequencies. For a source close to one reflecting surface, calculated acoustic gain *G* (Strength) from the simulation software can be typically 2–3 dB lower than the real value. If making design decisions based solely on the resulting *G* values from software the need for long reverberation time at low frequencies can be overestimated and resulting in too high levels in the bass for the orchestra and other users of the hall, like pop/rock bands

Our paper published in JASA (more or less Chapter 4 of my PhD thesis) demonstrates how to calculate the combined level based on the direct sound and a reflection with phase relation taken into account. A spreadsheet is also available for carrying out such calculations (comb filtering interference), see the Spreadsheets page. The total level presented in the spreadsheets will be relative to the direct sound level. If knowing the source-receiver distance, the total value of *G* can be found. If exporting wave files for auralisation from the computer simulation software, phase relations between the direct sound and early reflections can be included, but then there can often be a problem with obtaining correct values of *G* based on the exported (often normalised) wave files.

Details on the proposed architectural measures

Posted on September 15, 2011 | Leave a comment

There may be some confusion regarding how the proposed architectural measures should be obtained and what aspects of the stage enclosure the meaures can assess. I have therefore written a two-pages long article going into some more details on these measures. See the Articles page to read the article. Your opinions, questions or comments to this are most welcome.

Project results in brief

Posted on June 20, 2011 | Leave a comment

For a brief overview on stage acoustics and the major results from the research project, please see this two-pages long article, also available on the Articles page. (This article has been slightly revised 16 September 2011).

Project results in detail

Posted on June 20, 2011 | Leave a comment

I have recently been working on making the major results from research project accessible for non-acousticians, like musicians, sound engineers who don't have any background in acoustics. The focus is on findings that are relevant primarily for orchestral musicians. The hope is that by making the findings accessible it will be easier to have fruitfull discussions and exchange of experiences between acousticians, musicians and sound engineers regarding acoustic conditions. For instance to further test the validity of the actual findings.

An article aiming at presenting the results in detail for non-acousticians is now available in the Articles page. This article is also published at Polyphonic.org(part I and II). Any comments on the content or presentation are welcome.

Acousticians are of course also welcome to have a look. A summary of the most important findings relevant for acousticians was presented at ISRA 2010. This paper is available on the Articles page.

Why bother with calibrating for measuring G?

Posted on June 20, 2011 | Leave a comment

The acoustic measure *G* (Strength) represents the total level of the acoustic response, in other words how much an acoustic space gains the sound level within an acoustic space. The reference level for *G* is the direct sound level at 10 m from the source. Measuring *G* requires that the measurement system is calibrated and this is probably the major reason for why this measure often is not included when acousticians investigate acoustic conditions. The calibration is normally done by testing the measuring equipment in use within an anechoic chamber, where the direct sound level at 10 m is obtained. It can alternatively be done in-situ (at the location), but this puts some restriction on the frequency range where correct values of *G* are obtained. A brief article on how to calibrate or confirm *G* in-situ (that will result in sufficiently valid values of *G* from the 250 Hz octave band and above, dependent on your source) is available on theArticles page.

So why bother with calibrating the system for being able to measure *G*? From measured *G* and *C*80 the level of the early and the late (reverberant) acoustic response from an acoustic environment can be obtained – namely *G*e and *G*l, the level G for the early (e) acoustic response arriving before 80 ms and the late (l) acoustic response arriving after 80 ms (relative to the direct sound arrival). The reverberation time *T* and the level of the reverberation appears to be essential attributes of an acoustic space. By knowing the level of the reverberation (as well as the early acoustic response) we can tell for instance if an acoustic space will contribute to an excessively loud environment or if the reverberant response will be inaudible. If knowing the reverberation time *T* and the volume of the acoustic space *V*, the level of the acoustic response can be estimated. But the estimate can often be too far off from the actual situation, so by actually measuring the acoustic level we will get rid of some uncertainty factors.

Recent articles where the relevance and benefits of measuring *G* are discussed includes Barron (2008) , Buen (2010) and Beranek (2011), the latter is unfortunately not freely available (abstract only). Regarding the relevance of *G*and *G*l for stage acoustics, see the articles on suggested objective assessment of concert hall stages, Dammerud et al (2010) and Dammerud (2011).

Also see the Spreadsheets page for spreadsheets on how to calculate *G*e and *G*lbased on measured *G* and *C*80 or estimate *G*l based on measured *T* and hall volume *V*.

On early reflections in concert halls

Posted on June 19, 2011 | Leave a comment

Lokki *et al.* have recently published an express letter in JASA proposes that large and flat surfaces surrounding the listeners are better than diffusing surfaces. It also suggests that reflecting surfaces above the listener and stage contribute to reduce the perceived sound quality. In concert halls early reflections are normally needed to raise the total perceived sound level. According to this paper, early reflections from directions outside the sagittal plane that have a frequency and phase response comparable to the direct sound are most effective for boosting sound level within leading to negative sound characteristics. This express letter is freely available and includes a video with auditory demonstrations.

This proposal support the findings from the research project presented in this website: that a narrow and high stage enclosure is more beneficial than a wide and low, and that the reflecting surfaces close to the orchestra at the sides can be made flat and non-diffusing to effectively compensate for low direct sound levels from strings.

David Griesinger has studied how early reflections and reflected sound in general affect our engagement as listeners. In a recent paper presented this year, available from his web site, he proposes a psycho-acoustic model that links aspects of perceived speech and music to the physical acoustic response from an enclosed space. The proposed model differ from the precedence effect, but implication of the model also agree with the conclusion that a high stage enclosure is beneficial for an orchestra.

Whereas the model of Lokki *et al.* favours early reflections from the sides, Griesinger's model doesn't. But they both demonstrate that the acoustic measure C_{80} has limited relevance for perceived clarity of the sound. The last word has definitely not been said regarding early reflections within performance spaces.

Welcome to the stage acoustics blog

Posted on June 17, 2011 | Leave a comment

This blog is an updated version of home.no/jjdamm/stageac. Please feel free to share, comment and ask questions to the content, anonymously if you prefer.