THE NEW THEATRE IN ZWOLLE (NL): ACOUSTICAL DESIGN & SCALE MODEL STUDY

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1. INTRODUCTION

In 2004 the construction of the “New Theatre” in Zwolle, The Netherlands, started. It will be completed in june 2006. For this theatre some extraordinary acoustical starting points have been developed by Peutz. The theatre should not only be suitable for intimate plays performed for about 850 people, but also for opera and symphonic concerts with an audience of about 1000 people, in all situations with natural acoustics. Such a combination will usually be hard to achieve, especially with excellent acoustics, due to the contradictory requirements. For intimacy and sufficient speechlevel in a theatre its roomvolume should usually not be larger than 5000 m^3, whereas a symphonic concerthall suitable for 1000 seats needs at least a minimal volume of 10000 m^3, due to the reverberation time of 2,0 seconds needed as well to limit its loudness sufficiently.

2. ACOUSTIC DESIGN

2.1 Starting points

Peutz proposed to use a large variation of volume in order to realize the variable acoustics needed for the combination of these acoustically different uses, starting with a very compact and intimate theatre/playhouse (volume < 3500 m^3), with optimal speech intelligibility , feedback, and a short reverberation time. The architect (Greiner van Goor Architects in Amsterdam) subsequently designed a very compact theatre, global sizes 19x18x13 m (wxdxh)) with two balconies and 850 seats. The final development of this design is illustrated in figure 1 and 2, where a plan and cross-section of the hall in its theatre-arrangement are given. The red area indicates the size of the acoustical volume.

For symphonic music the actual acoustic volume of the theatre ca be increased for more than 300% up to 11.000 m^3, obtaining the necessary reduction of loudness as well as the reverberation time of 2,0 s. desired for symphonic music. Figure 3 and 4 give a plan and cross-section of the hall in its concert-arrangement are given. Comparison of the figures 1 and 3 as well as 2 and 4 will give a good impression of the size of the volume change that is obtained.

Part of the volume change is realized using an orchestra-chamber (or –shell), a common solution for orchestral environments in theatres, but in this case a quite large one with a volume of 3000 m^3. The orchestra shell applied in this case is specially designed in order to integrate similar diffusers and shape in its walls as for the walls of the theatre itself.

To gain additional volume needed Peutz has proposed to add an additional volume of about 4.000 m^3 to the hall, right above the auditorium and surrounding it above the second balcony. This is illustrated in figure 3 and 4.
This additional volume can be added to the auditorium if needed or be disconnected, using three movable ceiling elements that can move over more than 7 meters height and are fully independently electrically operated. In their lowest position these ceilings connect close to the walls of the second balcony of the auditorium, just leaving a small gap to the wall, and thereby reduce the acoustic volume. This lowest position is still partly obstructed by the fixed lighting bridges, see figure 2, because movable lighting bridges were considered to be too expensive. That might be a possible improvement for other future applications of this principle. The openings in between the ceilings themselves, which have gaps of 1-1,5m, act as additional absorption, because the gallery behind it

can be “deadened” using acoustic drapes. In their highest position, which is about 80 cm under the concrete “roof”, all of the volume of the void and the gallery-volume (……m3) add to the auditorium volume. Intermediate ceilingsettings can be applied for other types of use, for instance for opera only the first ceiling will be lowered and the other two will be fully raised.

An essential part of this additional volume is formed by the gallery with a height of 7m at the third level, which has an additional 150 seats, adding up to the total of 1000 seats for concerts, opera and musical. In case of use as a theatre for plays and alike this gallery volume is being disconnected from the auditorium due to the lowered ceilings, which can be clearly seen in the section in figure 2.

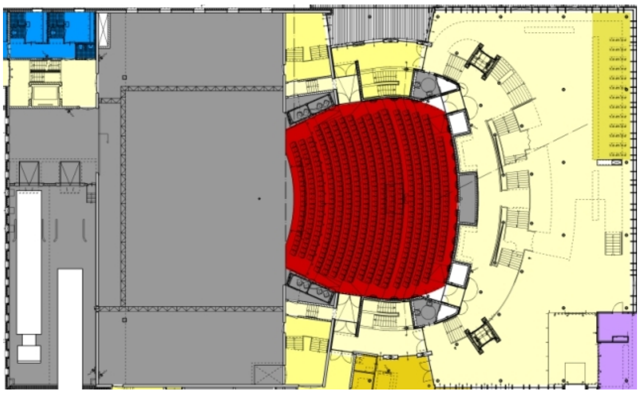

Figure 1. Plan in theatre-situation

Figure 2. Section in theatre-situation

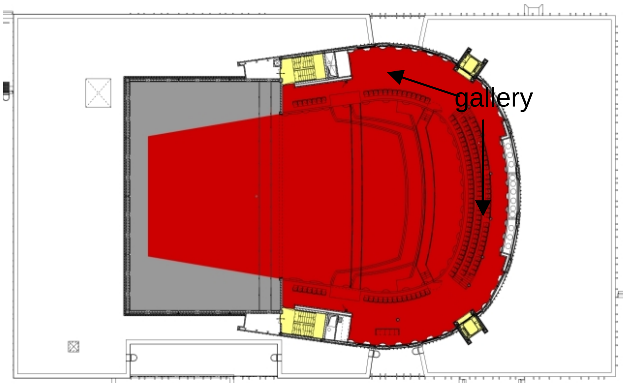

Figure 3. Plan of gallery-level in concertsituation

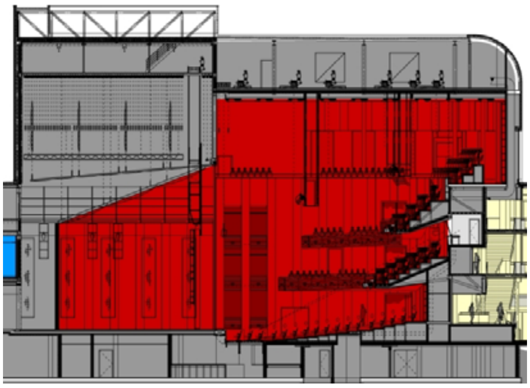

Figure 4. Section in concertsituation

Having a large useful floor area of about 300 m2 the gallery could also be used for additional functions like exhibitions, receptions and alike, in addition to its function as a reverberation space. Its 150 seats will also be usefull in case of musical-performances, in which case 500 m2 of additional acoustic curtains are pulled out of their storage box on a rail in front of the gallery walls to act as variable absorption to reduce the reverberation of the gallery.

2.2 Royal Albert Hall

The idea to apply a gallery as additional reverberation space was based on earlier research done by Peutz in the Royal Albert Hall in London, in which the gallery above balcony level appeared to play an important role in the perceived reverberation in the Hall. Figure 5 illustrates the ressemblance between the real Albert Hall and the scale model (1:12) used by Peutz.

Figure 5: Royal Albert Hall, Londen, Left 1:1, right scalemodel 1:12.

2.3 Unique concept

The provisions mentioned above (gallery, moving ceilings, orchestrashell) supply in such a way an large additional volume to the theatre, that on one hand the large acoustic volume is obtained that is necessary for symphonic music, and on the other hand the theatre itself remains compact and intimate, as needed for a playhouse. These provisions are relatively simple but very effective and give an acoustic volume change of 1:3 in one hall, delivering a real theatre and a real concerthall as well, without any significant compromises. As far we know this has never been done before in this way

The additional cost of this concept compared with a regular theatre without concert-arrangement consists of the cost for additional building volume (4000m3), 300 m² floorsurface of the gallery, the moving ceilings, the orchestrashell and the additional variable absorption on the gallery (curtains) to reduce its reverberation for musical. As such this design can be considered as a real innovation and a real example of multifunctionality without compromise, which will be cheaper than building two separate auditoria, a theatre and a concerthall.

3. SCALE MODEL RESEARCH

3.1 Set up of study

Because of the uniqueness of the concept choosen and the importance of the final results, Peutz was commissioned to test the acoustics of the design using a scale model. During 2002/2003 acoustic measurements were done using a 1:12 scale model, which is a common scale used by Peutz. This large scale is choosen partly because also listening test have been performed using auralisation. In June 2003 the scale model has been exhibited on the “Prague Quadriennal”, the regular theatre exhibition every four years.

Main point of interest during the scale model study were:

- if the variable acoustics would work and what reverberation times would be achieved;
- whether echo’s or non-uniformities would occur due to the curved walls;
- if so, what provisions would be needed to prevent these;
- how well the different volume would connect;

- whether the Energy Time Curve (ETC's) and impulsresponses measured would have the correct properties and acoustical values, like clarity.

Several different type of wall finish and diffusor shapes have been tested in the scale model. Figure 6 and 7 give an impression of the final finish of the interior walls and ceiling of the scale model, which are very close to that of the final auditorium itself.

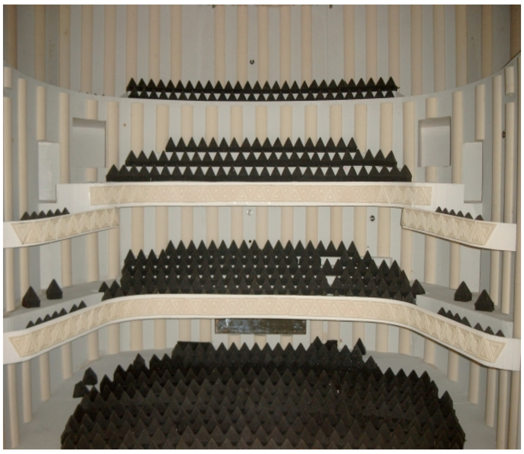

Figure 6: Interior of scale model 1:12

Figure 7: Scale model 1:12 in use

In this scale model study attention was given besides tothe variable acoustics also to the sounddiffusion and echo-reduction due to the curved wall surfaces. Measurements were not only done for the main variants like, theatre, opera and concert, but every intermediate variant was measured as well, in order to determine exactly what influence was caused by what specific variable.
A large number of variables were studied, like different ceiling settings, type of diffusion of walls, diffusion of ceilings, diffusion of balcony-edges, the amount of absorption on the ceilings, the variable absorption (curtains) on the gallery, the width and height of the stage opening, the position of the movable (rotating) sideboxes on each side of the fronthall, the orchestra pit and the orchestra shell.

A standard impulse modelling technique was used to measure the impulsresponses with a special sound source, 3 source positions and small microphones on 16 microphone positions, using a standard Peutz' layout for concerthalls and theatre. In figure 8 and 9 these positions and pattern are indicated in two design drawings, a plan and a section of the hall.

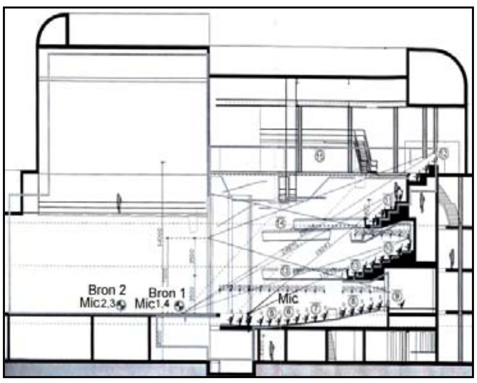

Figure 8: Measuring positions in section

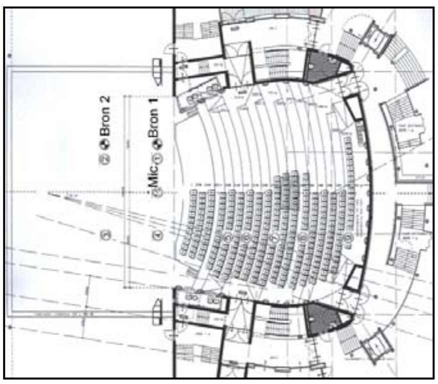

Figure 9: Measuringpositions in plan

The absorption coefficients of the relevant elements used were verified using Peutz' 1:16 reverberation chamber.

In the scale model the ceilings have been made movable as well, in order to be able to measure in all situations possible. Figure 10 and 11 give photo's of details with the ceiling in its lowest position. Figure 11 illustrated in the left side the rotateble sideboxes, as well as the high and fine detailed quality of the diffusive surfaces of ceiling, walls and balcony edges, an cooperative design of the acoustician with the architects, and that were especially moulded in plastic.

Figure 10: Detail moving ceiling in scale model

Figure 11: Interior scale model

3.2 Results of scale model study

In total more than 50 different settings have been measured in the scale model, because every intermediate variant was measured as well, in order to determine exactly the influences of the specific variables. Fixed microphones were used in the scale model, in order to exclude influences of repositioning and to be sure that all changes measured were caused by the specific variable.
The scale model study showed that:
Based on 48 measurements for each variant this means more than 2400 measurements, and considering the ETC curves of every three octavebands (500 Hz, 1 kHz and 2 kHz) more than 7000 results have been judged. Using a standard presentation of the results, the subsequent ETC's (Energy Time Curve) have been judged on their properties desired, and the different acoustic paramters like loudness, clarity and reverberation time have been judged and stored in spreadsheets as well.
In the main variants like the theatre situation and the concertsituation additional impulsresponse measurements have been done using a scaled "dummy head", and the results have been convoluted with "dry" music, called auralisation, in order to judge the final acoustics using music in stereo.
Scale models are also very suitable to investigate (summed) echo-strenght caused by curved surfaces, in which computermodels are known to be very poor. An example is given in figure 12, where variant NK produces a clear echo in the 1 kHz ETC with a delay of more than 200 ms after the direct sound, measured between source (1) and microphone (4) on stage. From the delaytime measured it could be deduced that this echo was caused by multiple reflections via the fixed ceiling of the gallery and its curved rear wall. Applying adequate diffusion against this wall as well as diffusion against the fixed ceiling of the gallery solved this echo for variant NF, as can be seen in figure 12.
Figure 13 illustrates the amount of variability of the two main variants theatre and concert, giving both ETC's at 1kHz between rear stage position (2) and a listingposition in the rear stalls (8). It clearly shows the large addition of sound energy of the concertsituation (NL) compared with the theaterresponse (NJ), adding more early reflections, more late reflections and reverb resulting in a elongation of T30 from 0,8s to 2,0 s and a reduction of C-80 with 5 dB. For variable acoustics this is

a huge effect and significant difference that fulfils the aim set, which was confirmed by listing experience with auralisation.

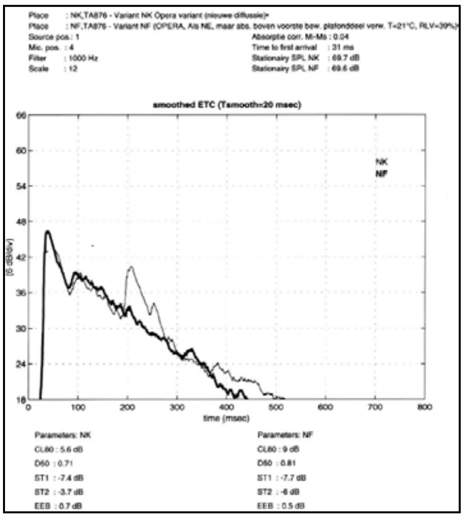

Figure 12:. ETC between 2 stage positions (ETC variant NF/NK), one situation with echo.

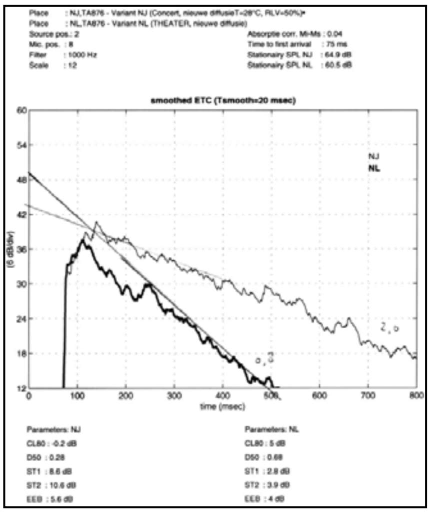

Figure 13: Difference in ETC (@1kHz) between rear stage and rear hall (2-8) for theatre versus concertsituation.

Based on the scale model study several recommendations have been given, such as:

- to apply a lower position for the lowest height of the first moving ceiling;
- to apply sound absorption on the top of the ceilings, to deadened the void behind the ceilings;
- to apply more effective diffusion against the walls and ceilings of the gallery
- to apply more diffusion against the walls of the orchestrashell;
- to apply a sounddiffusing structure against the balconyedges.

All these recommendations done during the scale model study have been implemented in the last and final variants measured in the scale model (see figure 6 and 11).

Some results of the scale model study have been summarized in figure 14 and 15, in which the important parameter values for T30 and clarity (C-80) are represented as a function of the measuringposition.

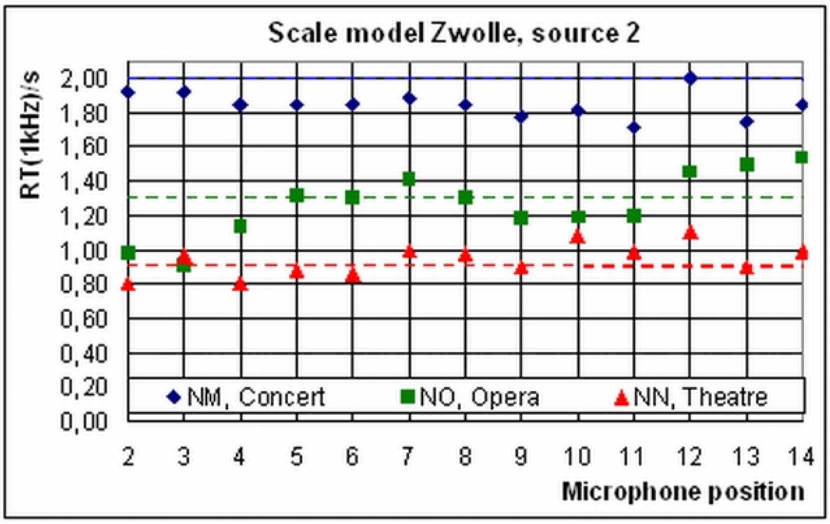

Figure 14: Measured T30 (1 kHz octave) and desired range. Result of scale model measurements for 3 situations (concert, opera, theatre).

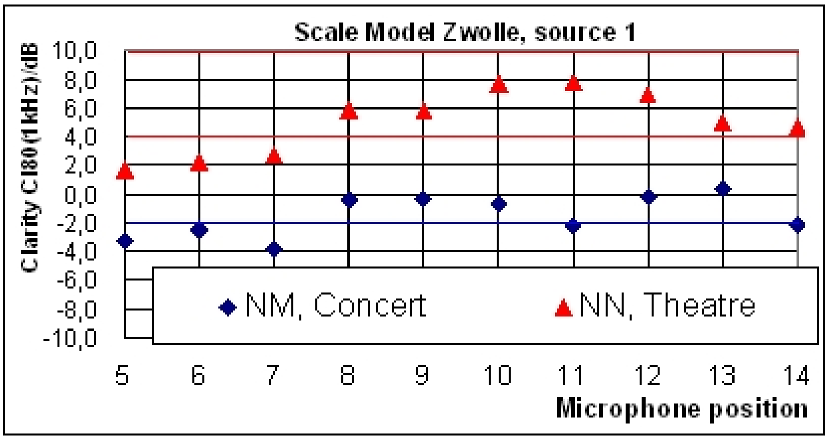

Figure 15: Measured C-80 (1 kHz octave) and desired range. Scale model measurements for 3 situations (concert, opera, theatre).

From the results as given in figure 14 and 15 it is concluded that it can be concluded that the amount of variability realized in the scale model fulfils the demands. It could therefore be expected up to a high degree of certainty that this would also be the case for the variable acoustics in the real hall.

4. BUILDING PHASE

Based on the positive conclusions of the scale model study with respect to the variable acoustics achieved the design process was proceeded. All the further detailing of diffusive elements, movable ceilings, orchestrashell and alike during the further drawingphase and building phase was done in close cooperation between the architect and Peutz.

During the building phase regular checks were performed on the strict demands set for the required mass of interior surfaces like floor, walls, and ceiling and for the diffusers attached to them, for which at least 20 kg/m2 was demanded. Additionally laboratory measurements have been done to check and determine the absorption of relevant elements, such as the wall diffusors, the balcony-edge and the orchestra shell. The sound absorption of the diffusive elements was measured in Peutz' reverberation chamber to be between 8-10% and for the and the balcony-edge 10-15%, which was judged as acceptable.

Also the acoustic absorption of the chairs was carefully specified and measured in the reverberation chamber to ensure that the highest T30 value of 2.0 s for the occupied concertsituation was met and that the change in RT between occupied and unoccupied conditions was minimized. Therefore additional perforation of the seat bottom was applied.

5. CONCLUSION

Based on the scale model study it was concluded that the amount of variability and the quality of the acoustics realized in the scale model fulfils the demands as well for the theatre situation as in the concertsituation. It could therefore be expected up to a high degree of certainty that this will also be the case for the variable acoustics in the real hall.
Therefore, there are high expectations about the acoustical properties of the real hall which will be tested after its completing during the summer of 2006.