THE ACOUSTIC DESIGN OF THE NEW DRAMA HOUSE FOR THE ROYAL THEATRE IN COPENHAGEN

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1 INTRODUCTION

In January 2008, The Royal Theater in Copenhagen, which is the Danish national Theater for Opera, Ballet and Drama, inaugurated a new theatre building exclusively for drama.

The project realized was chosen among almost three hundred entries in an open, international architectural competition which took place in 2002. The winning architects were Lundgaard & Tranberg, Copenhagen, which happen to have their office a few hundred meters from the building site situated at the Copenhagen harbor front (between Nyhavn and the royal palace, Amalienborg). The acoustic design was carried out by Gade & Mortensen Akustik assisted by Rob Harris, Arup acoustics, in the sketch design phase.

The theatre, which has a total floor area of 20.000 m^2 and was built within a budget of about 100 million Euro, contains a large hall with 650 seats, fly tower and large side and back stages, two smaller halls with 200 and 100 seats respectively plus rehearsal halls, workshops and a large foyer. All staff rooms with wardrobes and offices are situated on the top floor with a great view over the harbor – one reason why the employee's representatives in the competition jury voted for this project.

Fig. 1: The new Royal Drama Theater in Copenhagen. View from the harbor

2 THE MAIN AUDITORIUM DESIGN

The acoustic design of the main hall was particularly challenging because its shape changed from a fan to a circle during the design process. This, in turn, was a consequence of the design team striving to realize the vision of the client regarding the hall being an intimate meeting place for actors and audience – combined with a requirement for a classical proscenium stage, which would be the format preferred for the national, classical drama repertoire.

2.1 Development of the detailed geometry

After the decision was made to give up the trivial ”cinema style” shape of the auditorium which had been proposed in the competition, a long process followed during which more than twenty versions of the hall were sketched and built as card board models. Among these, several elliptical shapes emerged until finally the architects and the client agreed that a purely circular shape would be optimal from a theatrical as well as architectural standpoint. The only problem would be the severe risk of focusing and poor distribution of sound over the audience seating. When asked to approve the circular shape, we could only reply that certain changes in the detailed geometry would be needed, and that the success would depend on to which degree both the architects and we would be willing to take the risk of believing in mutual willingness to find a solution within the overall circular shape of the room. In other words, the starting point became mutual trust in a fruitful design process instead of predefined concepts being forced on the architects.

Our wish to break up the interior walls went hand in hand with the architects’ imagination of the hall as a cave with rough irregular inner walls built from bricks. This motif of irregularity was realized in two different geometrical scales in order to obtain diffuse reflection within a large frequency range: 1) the wall was subdivided in angled, linear sections each about 1.5m wide and 2) bricks in every second layer were pushed about 5cm in or out from the wall plane. In order to test the effectiveness of this geometry a 1:5 scale acoustic model of one half of the wall was built. Fig. 2 shows the subdivision of the walls in plane sections while Fig. 3 shows a close up of the segmented wall in the model. The acoustic test against focusing of the sound in the model was made by calculating the spatial standard deviation of the early reflection energy from impulse response measurements with the receiver placed in a grid of positions in the “room” in front of the curved wall. The analysis gave rise to only minor changes in the geometry as indicated by the red line segments in Fig. 2.

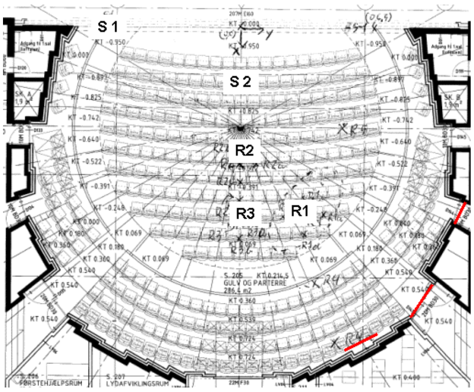

Fig. 2: plan of the circular auditorium

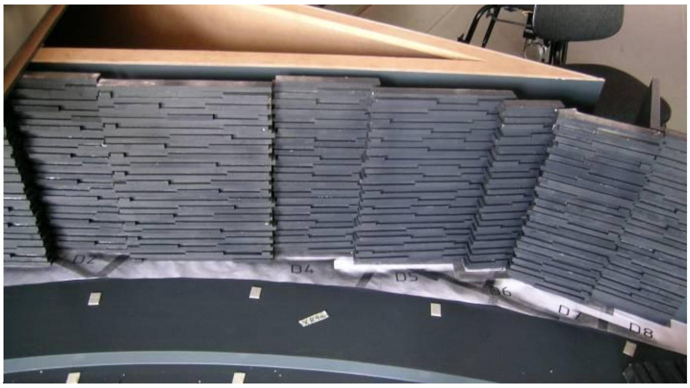

Fig. 3: Section of the 1:5 scale model of the brick wall

Besides avoiding focusing, the detailing of the circular wall geometry also aimed on proper sound distribution. In particular the wall areas close to the proscenium were shaped so as to create early reflections across the stalls area when the actors turn the side to the audience. Along with the scale model analysis, also computer simulations of the hall acoustics were carried out (using ODEON). The scatter coefficient for the brick wall elements entered in the program was determined from measurements of the scatter from a small sample of the 1:5 scale brick wall.

The handmade bricks chosen have an irregular surface which would only increase diffusion at very high frequencies. At the lowest frequencies diffusion is provided by the two balconies and by vertical sections in the rear wall having areas of open vertical joints which couples to the mineral wool filled cavity behind. The change in low frequency impedance across the wall both increases low frequency diffusion and absorption, which is necessary to avoid an increase in reverberation time at low frequencies due to the heavy wall constructions. (For the same reason, the ceiling is light weight plaster board and the floor wood over airspace.)

2.2 Absorption of the brick wall

With the large brick wall areas in the auditorium, there could be a risk of undesirable high frequency absorption due to porosity of the surfaces of mortar and bricks. This was tested in a rather simple manner by measuring the absorption of a small sample of the brick wall in a small reverberation chamber with a volume of only 0.5m^3. Obviously, the measurements would be valid above the Schroeder frequency only (roughly 1000 Hz), which was anyway the only frequency range of interest. The test was made by comparing the absorption coefficient of the two sides of the brick sample, of which one side had been heavily painted in order to avoid any porosity of the surface.

Fig. 4: Brick sample in the (transparent) model Reverberation chamber.

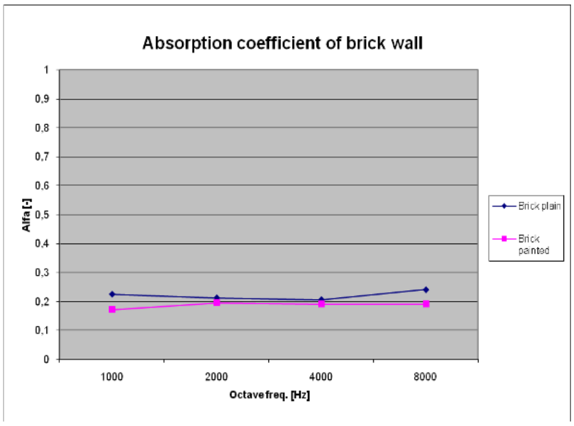

Fig. 5: Measured absorption coefficients of the two sides of the brick sample

As seen in Fig. 5, the difference in absorption between the two sides was marginal, which assured us that we could allow the brick wall to be built without any extra surface treatment. It should be added that the mortar used is very dense - almost like concrete.

For the reverberation time, we aimed towards a value at mid frequencies of just below one second, while the value at low frequencies (125 Hz) should not exceed 1.1s.

3 RESULTS

The hall was evaluated subjectively as well as objectively during a test performance in November 2007 (i.e. two months before the official opening).

Apart from complaints about back ground noise which could be located to the usual problems before a new hall opens: lighting fans which did not work as specified and an unbalanced ventilation system which created noise at the door joints, most of the subjective responses from a listening panel consisting of representatives from the Royal Theatre plus experienced listeners (acoustician colleagues) were highly positive regarding the level of the unamplified speech from the stage as well as intelligibility. Likewise, only positive responses have been received from critics and theatre goers during the first half busy year of operation.

The only objective room acoustic measurements carried out to date are the reverberation time measurements in the occupied hall made during the test performance. The source was placed in four positions on the stage while five receiver positions were distributed in the stalls and on the first and second balcony. The results are shown in Fig. 6.

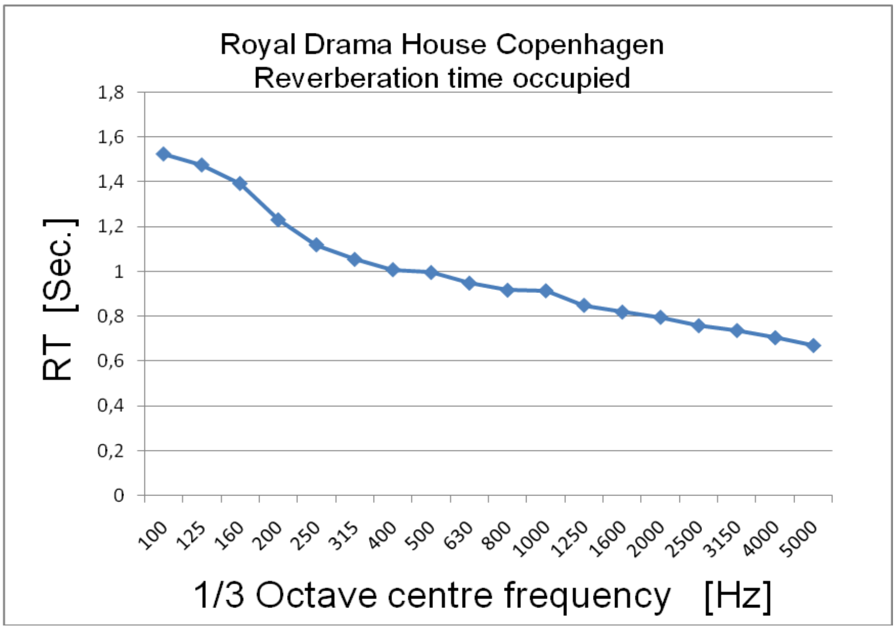

Fig. 6: Measured reverberation time in the occupied large hall auditorium.

The increase towards low frequencies is primarily due to a long reverberation time in the stage house which was coupled to the auditorium through the stage opening. (The fire curtain was raised during the measurements.) However, there is no sense of coloration or rumbling low frequencies in the auditorium during performances. The high frequency reverberation is slightly lower than what we had expected (which might be why one critical listener has mentioned a lack of brilliance from female voices). Fig. 7 shows a view from the interior of the finished auditorium.

Fig. 7: View from the interior of the large hall auditorium. Photo by COWI.

4 CONCLUSIONS

A very positive cooperation between the client, the architects and us has resulted in an auditorium in which the architectural expression and the theatrical and acoustical requirements are all unified in every element of the design. I.e. no detailed shaping of surfaces nor any of the materials applied are only serving one of these aspects. This holistic solution is most likely a major reason for the success of the theatre and its immediate acceptance by the public.

The design process was largely fuelled by all parties being willing to take risks instead of setting up a list of rigid requirements beforehand (e.g. based on what we did in our previous projects). On our part, the risks were covered and justified through thorough testing in computer and digital models along the way.

To us this project has illustrated the superiority of process over preconceptions in the development of acoustic design of auditoria.