THE ROOM ACOUSTIC DESIGN OF THE GUANGZHOU OPERA HOUSE

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1 INTRODUCTION

The 1800 seat Guangzhou Opera House designed by Zaha Hadid Architects opened formally in February 2011. The design of the interior of the performance hall was completed with input from Marshall Day Acoustics (MDA). This paper follows the design process for the Opera House interior from the discussions of the initial design concepts and the development of design parameters for the room, to the creation and modelling of the principal reflection surfaces. The process of modelling in Odeon and with a physical 1:10 scale model is described. Inclusion of diffraction surfaces sympathetic to the design of the venue was achieved. Measured parameters from the commissioning tests are presented.

2 THE OPERA HOUSE

2.1 Design Origins

The origins of the design of the Guangzhou Opera House go back to 1994 and the design competition for the Cardiff Bay Opera House. It is a matter of history that the entry by Zaha Hadid was awarded first prize in the competition but that this design did not proceed to construction.

Inspection of the competition model and paintings from this time show a striking angular exterior with a bold asymmetrical auditorium.

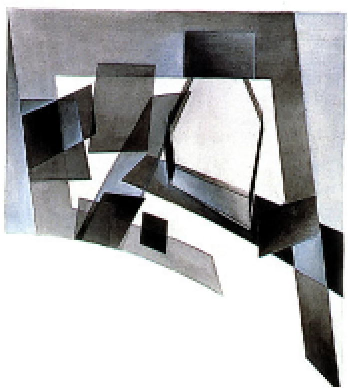


Figure 1: Images from Zaha Hadid's entry for the Cardiff Bay Opera House competition (images Zaha Hadid Architects)

The essence of the six sided shape for the auditorium was established and was rejuvenated to become the core of a flowing design that won the competition for the Guangzhou Opera House.

2.2 Design Process

Marshall Day Acoustics started involvement with this project in mid 2005. While our brief included providing advice on sound insulation, vibration isolation, and building services noise, in this paper we will limit our discussion to topics relating to room acoustics.

The aim is a room in which sound and sight together contribute to the concert experience. It is important that as responsible consultants we use all the resources available to verify and refine the acoustic decisions. It is necessary to check the design with every available metric that is supported by research. The metrics prove the design, they are not the design themselves but at the very least they are a check that gross errors have been avoided.

The goal for the acoustic of the Opera House was to provide good levels of clarity. This could be achieved using a short reverberation time, which would lead to a weaker sound strength, or a fuller reverberation time by providing high levels of early reflections. The uses of the auditorium will include orchestral performances using a stage shell and so the requirement of a fuller reverberation time was acknowledged. Our design targets were established with RT(mid) = 1.6s occupied and $C80 \geq +2dB$ averaged across the seating area. The Opera House is fitted with a sound system for performances using amplification and recorded material. Initial designs included variable absorption but this was removed during the design process.

The competition drawings showed the auditorium as a symmetrical plan with a rear wall sloping away from the vertical. Our view of the first plans since the competition showed a return to an asymmetrical interior form. Analysis of this form started with the construction of a 3d model and ray tracing to verify early reflection paths.

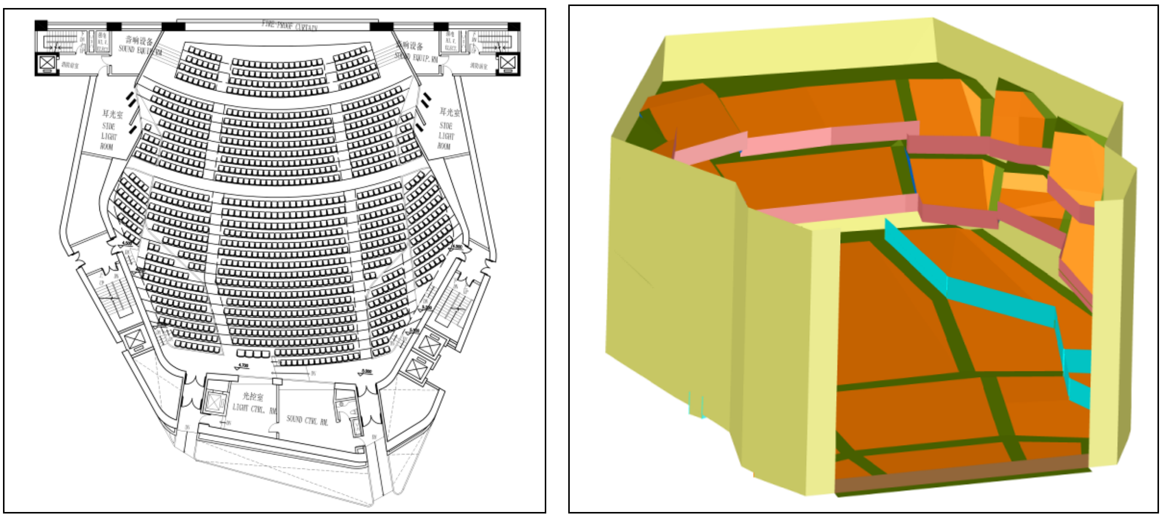
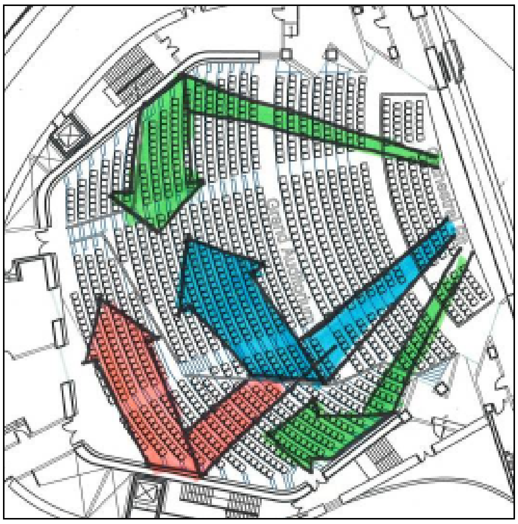


Figure 2: Plan and first 3d model of the Opera House

Features of the interior design included split level terraced seating in the stalls area, and asymmetrical balconies. Developments to the design occurred in workshops with the architects in Guangzhou. Initial schemes were developed to distribute early energy within the auditorium, and it was realized that the asymmetry of the hall could become a virtue by freeing up wall surfaces to provide early reflections.

As Sir Harold comments "I recall our first discussion about asymmetry and suggesting the reflecting surfaces from left and right as arms embracing the stage, within the established architectural idiom and which became the defining character of the space in the architects' hands."



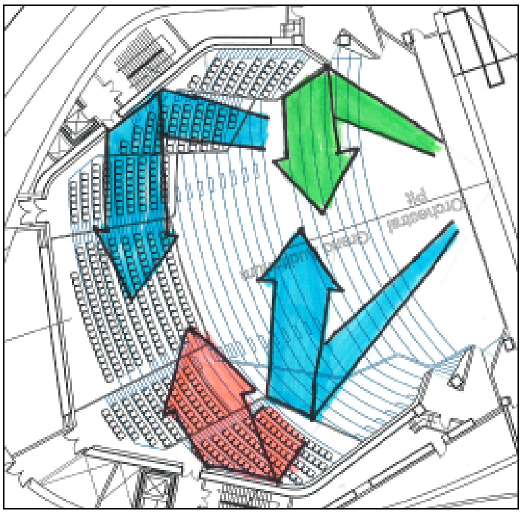


Figure 3: Scheme for distributing first order reflections in the Opera House

This led to a unanimously satisfying exaggeration of the asymmetry and a good rapport was established with the team of architects. This contributed hugely to the free exchange of ideas. The design process for the hall interior became a meeting of minds.

Project Leader Simon Yu recalls:

“There were some iterations before then... which seemed quite symmetrical by comparison, but those were competition stages where more emphasis was placed on the concept of the architectural scheme as a whole. Reference was made to Cardiff and more emphasis on the asymmetry as we progressed - to our delight and excitement when we engaged Harold (I remember it so well) that he was ‘one mind’ with the architects and so began this labour of love.....!”[1]

Figure 4: Development of the design in the workshop

It became clear that the useful direction of early reflected sound was limited with vertical wall surfaces and a flat ceiling. Work was started using a cardboard model to illustrate the orientation of surfaces that would be required to achieve our goals.

Figure 5: Curved wall surfaces appearing in the cardboard model

The architects then developed the first 3d computer models of the hall interior using Rhino.

Figure 6: First published interior rendering (image Zaha Hadid Architects)

We had the task of verifying acoustical performance of this new flowing geometry. Breaking the geometry into large flat surfaces was not going to produce an accurate reflection pattern for analysis. Odeon 8 had just been released and Jens Holger Rindel and Claus Lynge Christensen were generous in discussing our strategy with this model during the IOA Copenhagen Conference in 2006.

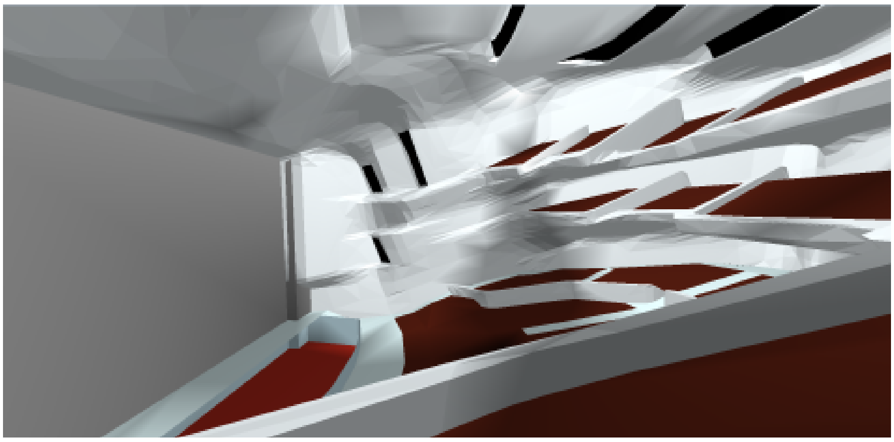


Figure 7: Interior of the Odeon model

The Odeon model was produced and many iterations of the interior design took place as surfaces were moved and reshaped to tune the grid responses. The final version of the model used 6250 surfaces.

Preparation of a 1:25 scale model took place at South China University of Technology (SCUT) and tests were supervised by Dr Stephen Chiles. The model was constructed from moulded GRG segments.

Figure 8: Scale model of the Opera House

Impulse responses were measured in the scale model and then recreated in Odeon. To a large degree good matches were achieved, and it was realized that the convex curvature of the reflection surfaces close to the stage were not sufficient to avoid discrete later reflections at some audience positions. Diffusion was added to the scale model, and the altered late reflection sequence was analysed.

Arriving at a suitable form for the interior wall diffusion did not come easily with several schemes of indentations being discussed with the architects. Eventually a pattern based on the structural steel window frames of the exterior of the building was developed in combination with a complex variation of the depth of the pattern.

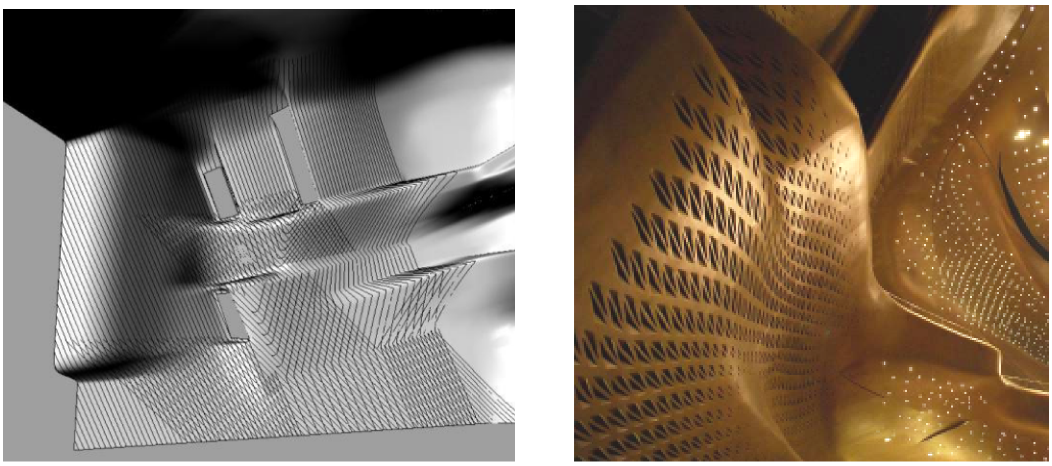


Figure 9: Interior diffusion development drawing and installed form

The walls and ceiling were formed from 40 – 50mm GRG. Sections were created in moulds off site and then fixed to a steel frame. The surface was treated to achieve a warm gold hue.

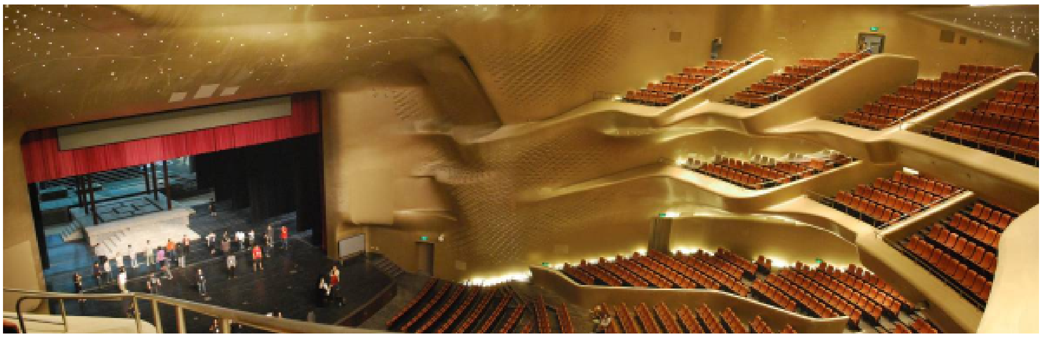


Figure 10: Interior of the Guangzhou Opera House

Orchestra pit walls with a reverse splay were incorporated into the design to assist communication between the pit and the stage.

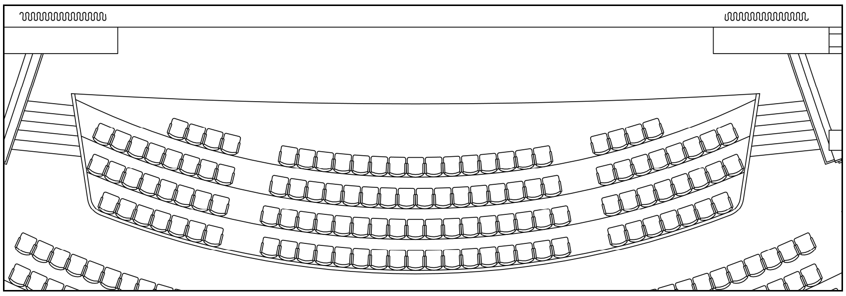


Figure 11: Reverse splay of the orchestra pit walls

2.3 Commissioning Measurements

MDA undertook commissioning measurements in April 2010 in the unoccupied hall, and occupied measurements were made by SCUT a week later at the opening performance of Turandot.

Results of the measurements are shown below. MDA data is for the average of 18 seat locations..

	Octave band mid frequency						
	125	250	500	1k	2k	4k	Hz
RT Odeon model occupied	1.8	1.7	1.6	1.5	1.5	1.3	s
RT occupied measured (SCUT)	1.8	1.7	1.5	1.5	1.5	1.3	s
RT unoccupied (MDA)	2.0	1.7	1.8	2.0	2.0	1.8	s
C80 unoccupied (MDA)	0.3	1.9	2.0	0.9	1.1	1.8	dB

The average C80 measured over 18 receiver positions in the auditorium was 1.3dB in the unoccupied hall. Applying the differences predicted in Odeon between occupied and unoccupied conditions gives an average C80 of 2.2dB.

3 THE MULTIPURPOSE HALL

The 400 seat multipurpose hall is constructed with flexibility of function as its main focus. The floor plan is rectangular with 12 independent seating wagons mounted on separate lifts. This allows seating in flat floor, single tier, thrust stage or cat walk configurations. Operable banners are fitted to allow variation in reverberation time between 1.4 and 1.5s. Additional acoustic drapes recommended for the hall were not fitted at the time of measurement.

4 THE REHEARSAL ROOMS

Two music rehearsal rooms and one for ballet were developed as part of the project. From our initial recommendations of volume allowance and areas of ceiling/wall treatments, considerable changes to the interior treatments were developed. The architectural idiom involved hard surfaces in a smooth and flowing configuration. The imposition of “acoustic panels” was not an option, and the wall surfaces were created with respect for the idiom and the requirements for sufficient acoustic absorption and diffusion.

The resulting pattern is based on 1.4m wide curved panels of GRG and Corian, with a thickness of 25mm. These are perforated with a hole size varying from 91mm to 5mm diameter with a fiberglass backing blanket to provide a broad low frequency absorption. High frequency absorption was addressed with inserts of high density fiberglass incorporated into the trailing edge of the panels. The curvature of the panels develops a highly diffuse surface. Curtains are fitted to the music rehearsal rooms to adjust the reverberation time.

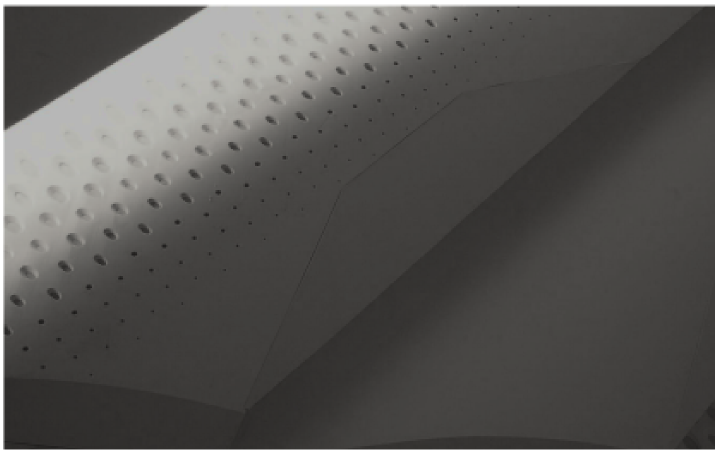


Figure 12: Panels for the ceiling and walls of the rehearsal rooms

The three rooms have different panel arrangements with different proportions of perforated and non-perforated panels.

Figure 13: Interior of the Music and Ballet rehearsal rooms Photography © Iwan Baan

5 SUMMARY

The character of the design process for the acoustics of the Guangzhou Opera House was quickly established based on the search for a seamless connection between the function and form of the interior surfaces. You cannot look at this space and say “the acoustics begins here…or there.”

Figure 14: Audience view of the Guangzhou Opera House

Jonathon Glancy writes in the Guardian “The auditorium proves to be a further wonder, a great grotto like a shark’s mouth set under a constellation of fairy lights.” He goes on to quote Sir Harold “There are very few asymmetrical auditoriums. But asymmetry can be used to play with sound in very satisfying ways; it’s more of a challenge tuning it, but the possibilities are greater, and this one has a beautifully balanced sound.”[2]

The Guangzhou Opera House has opened with a good response. In *Opera Now* tenor Richard Margison is quoted “The auditorium itself is pretty big inside, but still has an intimate feeling. I must also say that the acoustic is fantastic – not too dry and not too bright.”[3] The *Financial Times* referred to the “superb acoustics”.[4]

The design of the Hall has been possible in this case through the meeting of minds which has resulted in an integrated spatial/acoustic experience.

6 REFERENCES

1 Simon Yu, Correspondence with the author
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Jonathon Glancey
3 Opera Now, 10 May 2010, Guangzhou’s ‘twin boulder’ Opera House opens its doors
4 Financial Times, 11 May 2010, Turandot, Guangzhou Opera House, China
Review by Ken Smith