Design of the Sala Minas Gerais Concert Hall, Belo Horizonte, Brazil

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1 INTRODUCTION

This paper describes the design process of Sala Minas Gerais the new home for the Orquestra Filarmônica de Minas Gerais (Minas Gerais Philharmonic Orchestra). The building has a 20.000 m^2 built area and was planned and designed specifically for the orchestra. The facilities include the concert hall, administration area, dressing rooms, rehearsal rooms and foyers/public areas.

2 PRESENTATION

The acoustical consultants and the Principal Conductor Fabio Mechetti started conversations about the program and design of the hall on October 2008. In the first semester of 2009 a concept design was presented to the Orquestra: a hybrid shape combining a shoebox and surround hall. The concept phase involved visits and listening sessions to different halls in the US, Europe and Japan. The concept design and program served as the baseline for the architecture design. The design phase was from 2010 to 2012 and construction from 2013 to 2015. The gala opening was on February 2015.

During the design, a 1:50 scale physical model was built and tested. Each important change or adjustment to the project was included in the model and a new set of tests run. The reverse process also took place: findings from the acoustical model drove adjustments to the architecture. Computer modeling using ray trace acoustics and NURBS software helped the design process translation from acoustical requirements to architectural design.

3 DESIGN AND MAIN CHARACTERISTICS

Sala Minas it is built inside the Orchestra Building has a 20.000 m^2 built area and was planned and designed specifically for the orchestra. The facilities include the concert hall, administration area, dressing rooms, rehearsal rooms and foyers/public areas.

The concert hall has 1500 seats with a hybrid shape combining a shoebox and surround hall – or a surround hall in a rectangular shape. The hall has a series of adjustable acoustic elements: a moveable canopy over the stage, motorized acoustical banners and shutters on the stage walls.

Main construction data are shown in the Table 1

Data	Size
Length	50,0 m – longest dimension
Width	32,8 m – wider dimension
Height	16,5 m – main floor to ceiling
Number of seats	1480

Figures 1 to 3 show the plan view, transverse and longitudinal section.

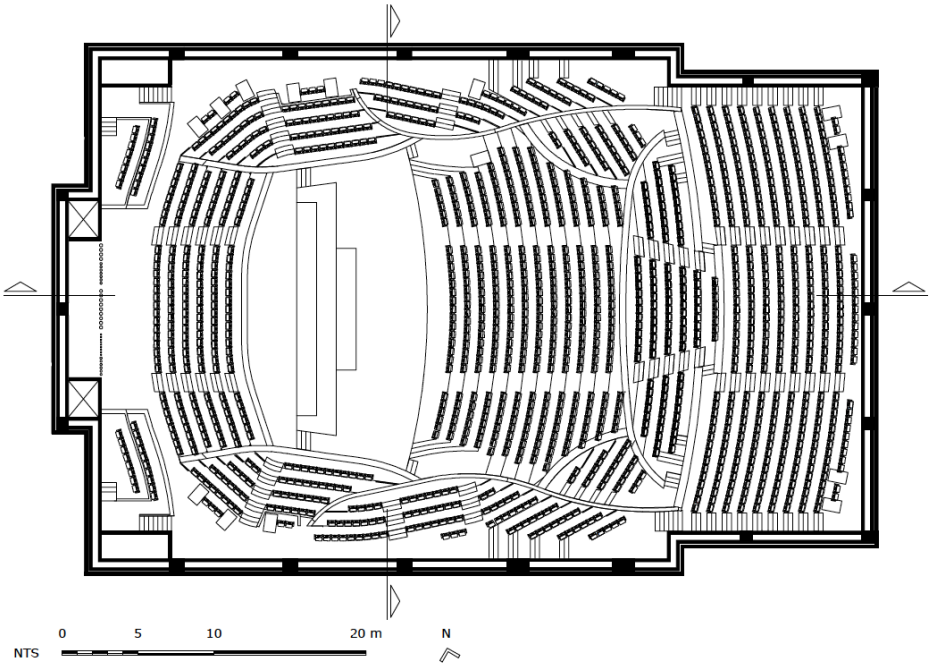

Fig. 1. Plan view

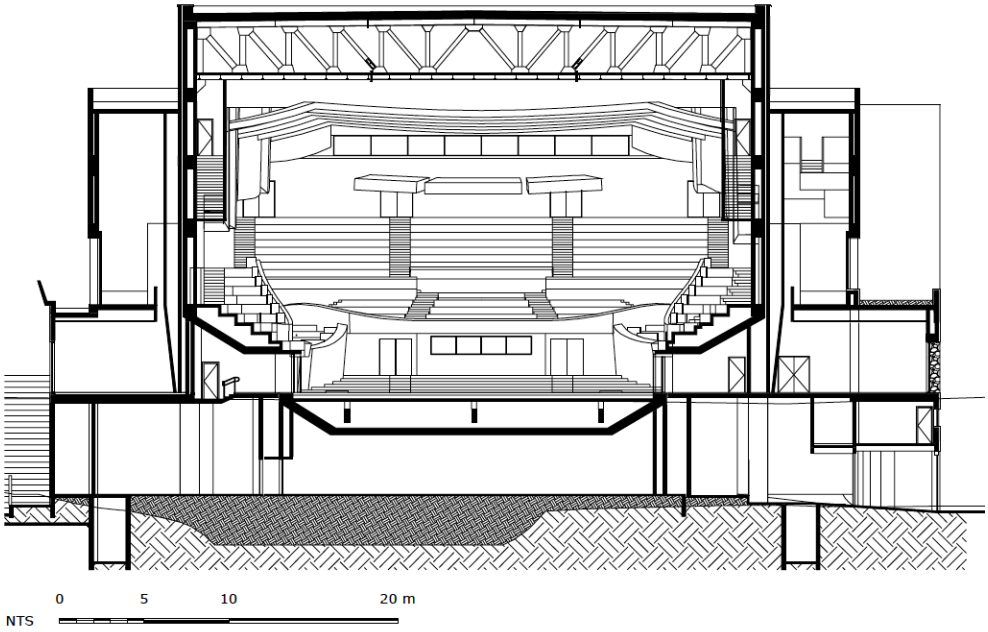

Fig. 2. Transverse section

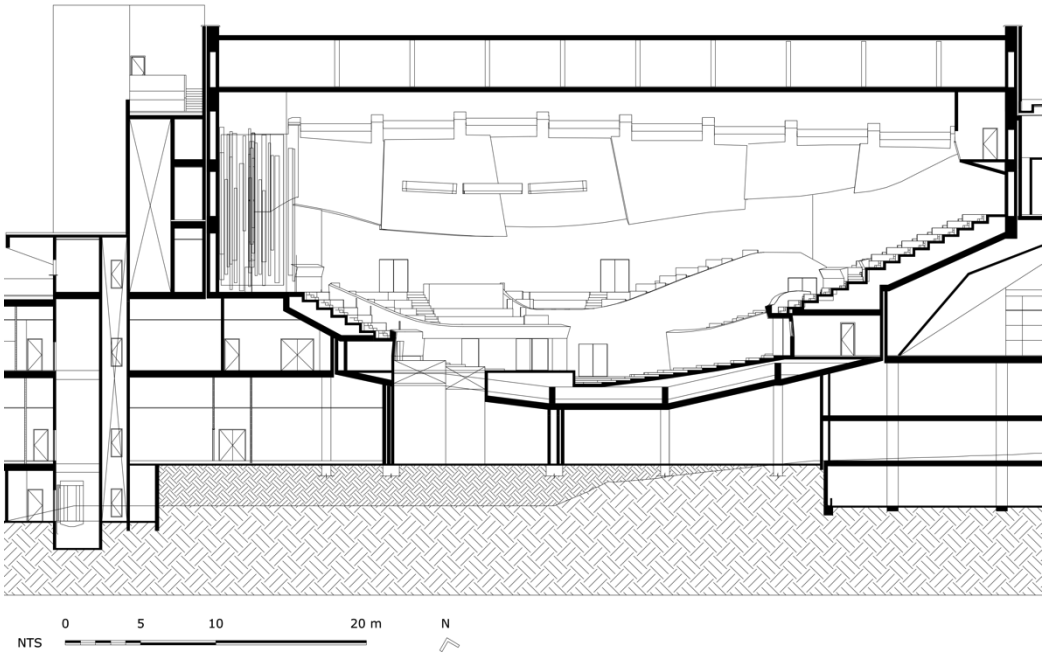

Fig. 3. Transverse section

4 MODEL STUDIES

A 1:50 scale model of the Sala Minas was tested as part of the design process. The model was build primarily of acrylic plastic, though the curved surfaces at high level were constructed of flexible plastic sheet. The model was tested with model seating which had sound absorbing characteristics close to full-size seats. The testing procedure followed many of the principles proposed in 1979 [1]. The sound source was a 4mJ spark; for most measurements it was located near the front of the stage. 1/8" (3.2mm) microphones were mounted vertically, facing upwards with nose cones fitted. By using a second microphone mounted to receive clear direct sound, measurements of Strength, G, could be made. Analysis by computer of the acquired impulse response, allowed the reverberation time, early decay time (EDT) and early-to-late index, C_{80}, to be calculated. Measurements at the full-size octaves of 125 – 1000Hz were made, with an emphasis on the mid-frequencies 500 and 1000Hz. Computed corrections for excess air absorption were made. Possible echo situations were also tested.

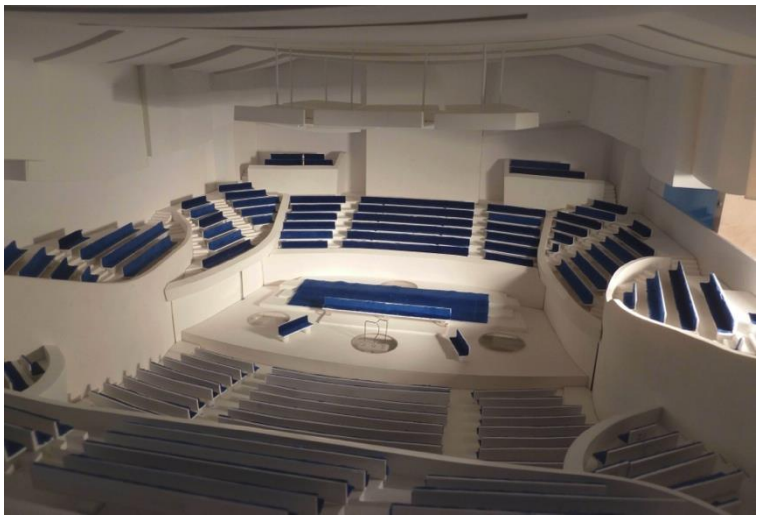

Figure 4. Interior of the 1:50 scale model

4.1 Reverberation time and EDT

The reverberation time (RT) was measured before and after the model seating was installed. With knowledge of the absorption coefficient of the seating (as measured in a model reverberation chamber), it was possible to compare predicted and measured RT in the model with seating. The agreement was very close.

The mean measured EDT was also compared with the RT. Again the agreement was very close. In both cases, the close agreement points to a diffuse sound field.

RT predictions for the full-size concert hall were however in excess of values expected in large concert halls, in line with the generous volume of 12.8m^3/seat. In the case of the occupied hall, a mid-frequency RT of 2.4s was predicted. The Sala Minas auditorium contains 355m^2 of adjustable acoustic banner. A proportion of these banners can be extended to bring down the RT in normal concert mode.

4.2 Objective clarity and strength

Two more quantities in addition to RT and EDT are important for listening, namely the early-to-late index (C_{80}) and Strength (G). These relate to perceived clarity and loudness. Measurements were made at 20 audience positions. The table shows that measured mid-frequency values of C_{80} are acceptable.

Source position	**C_{80} dB**		**G dB**	
	Mean	**Range**	**Mean**	**Range**
Source A	0.0	-2.3 → 2.0	4.5	2.2 → 6.7
Criteria		-2.0 → 2.0		see figure

Figure 5 plots measured values of G against source-receiver distance. These measured values are compared with revised theory (which represents average behaviour, [2]) and a criterion for sufficiently loud sound [3]. Measured results show good uniformity and satisfactory values.

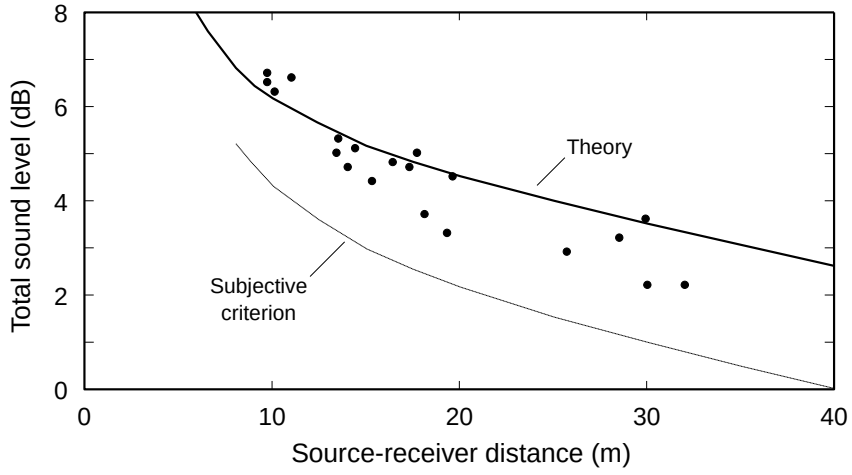

Figure 5. Measured total sound level at 20 positions in the standard concert configuration, mean of 500/1000Hz. Comparison is made with expectations according to revised theory [2] and the minimum criterion for acceptable loudness.

4.3 Adjustable sound absorption

Adjustable banners are mounted round the perimeter of the actual hall at high level, the total of 43 banners with total area 355m^2, which is about 1/3rd of the area of seating. These were modelled by small pieces of dress fabric, which had been measured suspended in a model reverberation chamber. The reverberation time in the model was tested with half and then the total number of banners; the results are shown in Figure 6. Agreement with predictions is very good, with maximum errors of 5%.

This result shows that the maximum expected absorption due to the banners should be achieved in the hall. In other words, the maximum variability in reverberation time can be achieved.

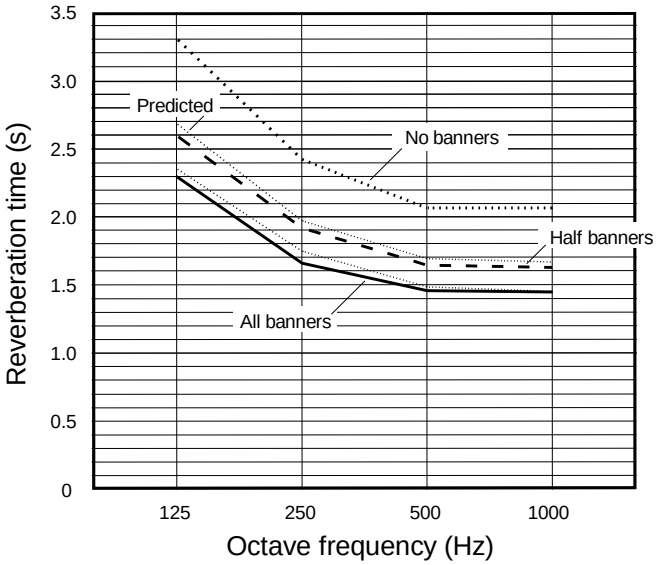

Figure 6. Measured reverberation times in the model as banners were introduced. The lines of fine dots indicate predictions based on the measured absorption properties of the model banners.

4.4 State of diffusion

The design of the Sala Minas Gerais contains many convex surfaces. The surfaces dividing the seating areas are mostly segments of vertical cylinders, whereas at high level surfaces are segments of horizontal cylinders orientated parallel to the main axis of the hall. This combination of convex surfaces can be expected to promote a diffuse sound field. The model tests confirmed a high degree of diffusion in the hall. Already mentioned above in this respect was:

1. Good agreement between measured and predicted RT as model seating was introduced.
2. Good agreement between mean EDT and RT.
3. Good agreement between measured and predicted RT when absorptive banners were installed.

A further check was made by comparing the measured standard deviation of RT with theoretical values for a diffuse field proposed by Davy *et al* [4]. By calculating the ratio of measured standard deviation to theory, which can be called the Normalised Standard Deviation of Reverberation Time (NSDRT), the criterion becomes an NSDRT of less than unity for a diffuse sound field. In the standard configuration (Figure 4), a NSDRT of 0.93 was measured at 500Hz. (The NSDRT proves to be particularly sensitive to source or receiver directivity. In this case, the modest directivity at 1000Hz of the microphones causes the NSDRT to be higher at that frequency [5]).

4.5 Conclusions

The scale model tests demonstrated good objective behaviour in the Sala Minas Gerais, with values within acceptable ranges for perceived reverberance, clarity and loudness. Added absorption in the form of absorbing banners behaved as predicted. The design appears to have produced a diffuse sound field.

5 FINAL REMARKS

In December 2014 listening tests with the Orquestra Filarmônica were conducted to help the Orquestra to know the new hall sound signature. On February 2015 Sala Minas opened and the hall has been greeted with great enthusiasm for its acoustics.

6 REFERENCES

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5. M. Barron 'The diffuse sound field and its relevance for concert auditoria', *Proc. Institute of Acoustics* - this meeting (2015).