

THE ACOUSTIC DESIGN OF THE NEW EGYPT OPERA HOUSE

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1 INTRODUCTION

This paper presents the acoustical design of the Egypt Opera House, located in the New Administrative Capital of Egypt. As a key cultural landmark and one of the largest opera houses in the region, the venue is a state-of-the-art facility capable of staging a range of performances, from West End/Broadway style musicals to Opera as well as Cirque du Soleil (CDS) shows.

The client requested a “classical style” following in the footsteps of the great European houses such as Palais Garnier, Vienna State, La Scala, Milan and London’s Covent Garden. Similarly to other Opera Houses in the region, Dubai Opera for example, the auditorium is a “hybrid” multi-function room rather than a traditional opera house. As such, the design presents a unique case study in balancing aesthetic grandeur with functional acoustics for all uses.

An overview of the auditorium's geometry, materials and seats selection, and the sympathetic integration of horizontal tracking curtains and vertical movement acoustic banners with the classical architecture is presented. Measured acoustic parameters from the commissioning in unoccupied state are also presented.

2 BACKGROUND

The Opera House provides a national arts centre in the New Administrative Capital City of Egypt, located between Cairo and Suez. It will seat 2000 (2150 including seating to the front of the stalls, on the orchestra pit lifts), and will be a receiving house, taking in international as well as home grown touring shows.

Further spaces within the same project include a 1,200 seat symphony hall with a large format pipe organ supplied by Klais Orgelbau. A 600 seat drama theatre completes the main spaces, serving as a supporting and springboard space for the presentation of local and regional work. Additionally, it will accommodate a wide range of educational, outreach and conference events.

While the venue had a soft opening by the Vienna Philharmonic Orchestra conducted by Riccardo Muti in December 2021 for the Concert Hall, the whole performing arts is yet to welcome its first full season while the rest of the project infrastructure connecting the New Capital City is complete.

3 AUDITORIUM DESIGN AND FORM DEVELOPMENT

The classic horse-shoe shaped auditorium consisted of stacked 'boxes' of loose seating arranged vertically, extending to dizzying heights. This was due to a number of factors: stacked boxes allowed 'front-row' seats to a greater number of people, though the viewing and hearing conditions were severely compromised. Often the requirement to 'be seen' rather than to properly appreciate the art on stage was of greater importance. For example the Teatro alla Scala has more than 154 seats from which the stage is not visible when a person is seated.



Figure 1. Teatro Alla Scala Milan (2135+154 seats) and Theatre Colon (2487 seats) Buenos Aires

In some cases, in order to bring the seating capacity up to the required number, the top tier would extend way up 'into the Gods' as seen in the section for the Royal Opera House in Covent Garden, London.

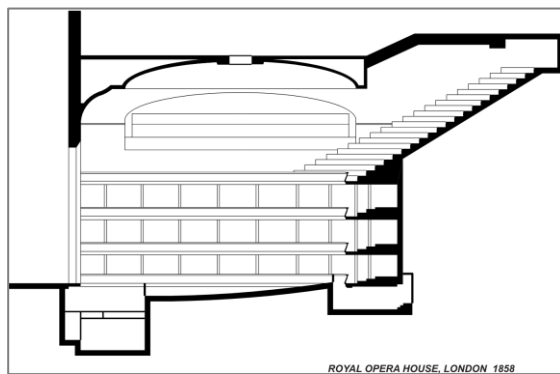


Figure 2. Section of the Royal Opera House, Covent Garden

A purely classic stacked design of boxes is less relevant in contemporary theatre design as it does not afford the best viewing conditions for the audience. Nowadays, a harmonious balance is always sought in terms of the depth of each balcony and its overhang, and the desire to minimise extreme viewing angles from the upper tiers. It has long been established that good sight-lines provide good “sound lines” so this approach was favourable acoustically as well.

In EOH, the initial concept was to have a modern interpretation of the classic form, with stalls, parterre, and four balconies above.

This first draft was then revised when the CDS shows were to be taken into consideration. The demanding technical requirements and the large amount of stage area and technical infrastructure necessary for CDS shows, together with the large seat count pose constraints to the room geometry.

A fundamental requirement of the CDS show is to have a “flying rig” extending into the auditorium creating a performance area 24m wide and 17m high. These dimensions dictate the size of the structural proscenium.

In order for the whole of the audience to be able to view the CDS show below the 17m high rig (from stage level), the design aimed to bring as many seats as possible close to the stage level. This was done by omitting the parterre level and one of the shallower balconies, which in turn allowed the top tier to be brought down having clear views the views below the CDS rig.

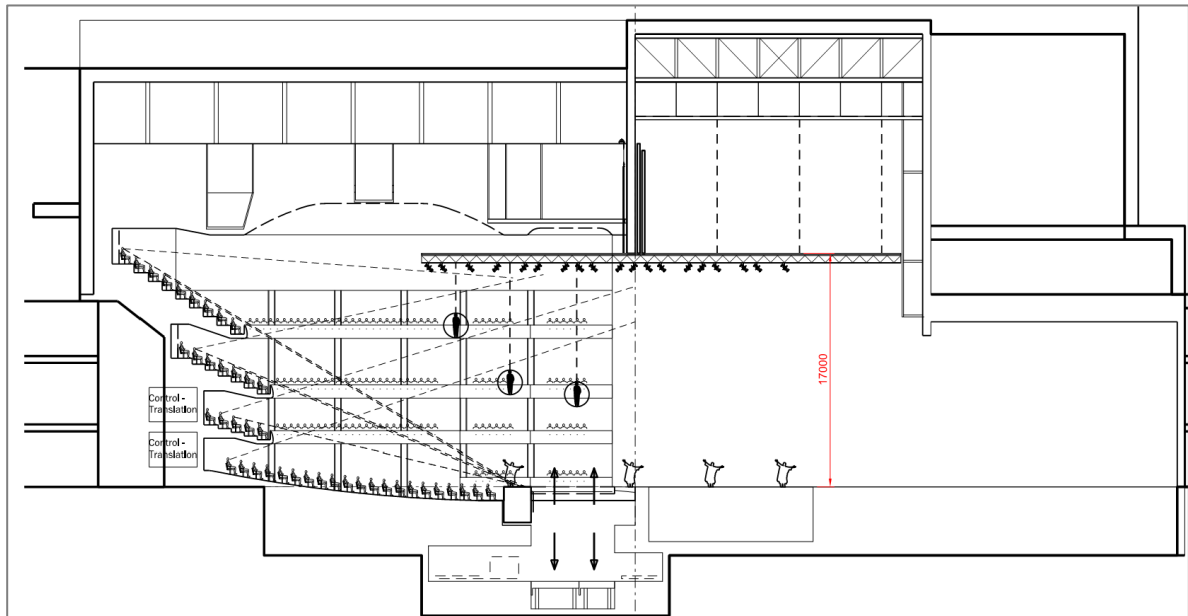


Figure 3. Diagrammatic Stalls Plan and Section, Egypt Opera House

The final setup was therefore with the audience distributed across a stalls level and three balconies above. The resultant internal geometry gives a maximum width at stalls level of 31m a with the furthestmost seat at a distance of 38m on the centerline from the stage edge.

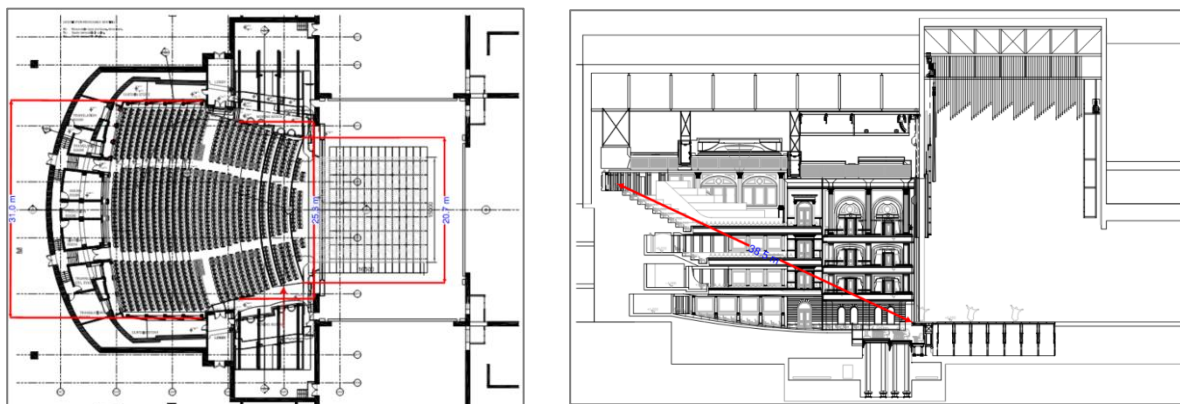


Figure 4. Stalls Plan and Section, Egypt Opera House

4 ACOUSTIC DESIGN

4.1 Acoustical volume and reverberation

For a given size of audience, reverberance is directly proportional to volume. Enough volume must be allowed to achieve sufficient reverberance.

The ceiling design integrates lighting bridges and rear follow spot with a height of +20m above the first row in the stalls.

The resultant acoustic volume of the Opera Theatre is approximately $18,500\text{m}^3$ which for a total audience + orchestra of 2150 corresponds to circa $8.5\text{m}^3/\text{seat}$ which is within the target range of comparable opera houses.

4.2 Room geometry and finishes

The large structural proscenium width (24m) as well as the requirement to accommodate all seats below the technical rig to accommodate CDS shows result in a relatively wide auditorium.

Moving boxes are provided that can reduce the width at the “throat of room” to 21m. The walls under the first and second moving box are angled, fanning out at 7° to the normal of the stage, resulting in timely side reflection towards the centre of the stalls conducive to clarity and support for singers/actors on stage.

The auditorium is wider in the rear stalls and at balcony level on the first and second circle. This will allow the buildup of side-to-side energy to promote reverberation, especially important at high level to give resonance to orchestral sound. The rear section of the stalls is approximately 30m wide. In this area individual panels angled at a reverse fan of 10° have been provided to provide supporting side reflections to the rear seating area.

The wall finishes are 2 layers of MDF mechanically fixed to the concrete or blockwork boundary walls. There is a 4mm neoprene layer between the walls and the MDF boards acting as a gap filling medium. Balcony fronts are formed with multiple layers of bendy ply with plaster mouldings in front.

The soffit is made of multiple layers of MDF to achieve a minimum surface mass of 40kg/m^2 and additional mass is provided by filling prefabricated cassettes with sandbags with the overall construction achieving an overall mass of $60\text{--}80\text{kg/m}^2$.

A flat movable forestage reflector is provided above the pit to provide early sound reflections back to the musicians to support ensemble and self-hearing.

Plaster mouldings are fixed to the ceiling walls and balcony fronts. They provide additional mass and stiffness to the room boundaries and, together with other classical architectural elements including niches, doric columns and architraves they provide a good level of sound scattering at fine and mid-scale.



Figure 5. Section – View of the orchestra reflector and balcony fronts

The seats were originally designed to be medium fabric upholstered chair but at a late stage the client requested a leather upholstered chair.

To minimise the impact of the change the seats were designed and engineered to include an open cell acoustic foam lining and fabric to the back of the seat and the internal and external sides of the armrest. The underside of the chair was also lined with open cell foam and covered with fabric and a perforated timber underside.

Figure 6 provided the measured sound absorption coefficients for the chairs both in unoccupied and occupied state.

Acoustic sound absorption (acoustic plaster) was installed to balance the reduced sound absorption provided at high frequency. This was installed to the underside of the first and second floor side boxes at the locations closest to the stage where sound absorption is effective to minimise image shift for sound coming from the pit.

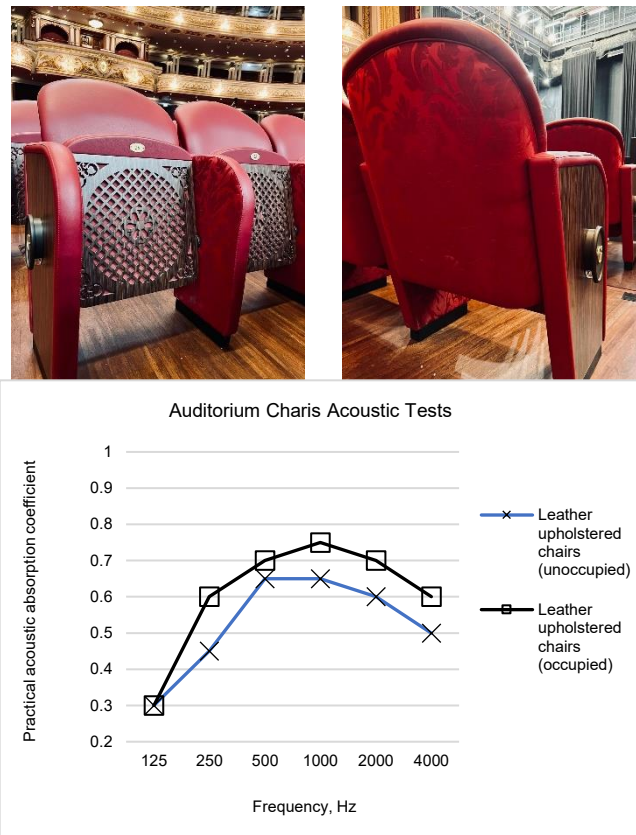


Figure 6. Auditorium chairs and sound absorption coefficient for empty and occupied chairs

Variable acoustic devices have been integrated on the walls using both horizontal tracking acoustic drapes and double layer roller banners. These are deployed to reduce the reverberation for uses that rely on amplification.

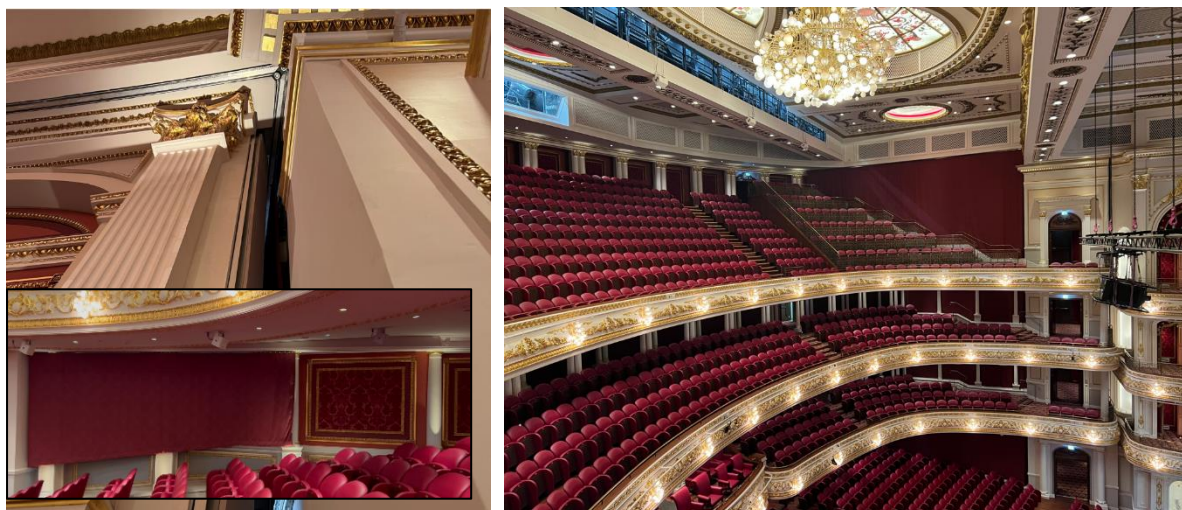


Figure 7. Auditorium variable acoustics - track and storage pocket and auditorium with deployed curtains

The specification for the curtains is a 1000g/m² wool serge while the vertical movement banners are a double layers 500g/m² stitch together, both covered with an addition decorative velour.

5 COMMISSIONING MEASUREMENTS

Room acoustic measurements of the complete auditorium in unoccupied conditions were undertaken during final commissioning. These included measurements with and without acoustic curtains and banners deployed in the room. The results are compared with the Odeon modelling.

Acoustical Parameter	Measured (unoccupied)	Predicted ODEON unoccupied
RT_{mf}	1.5 s	1.6
EDT	1.35	1.55
$EDT/RT_{(av, 500-1000Hz)}$	~90%	~95%
BR (without variable acoustics)	1.1	1.15
$C_{80(pit)}^*$	5 dB	2 dB
$C_{80(pit)}^{**}$	2 dB	0 dB
$D_{50(stage)}$	0.6	0.5
RT_{mf} (with variable absorption deployed in the room, PA source)	1.3s	1.4s
Building services noise	PNC 20	N/A

Table 1 Measured acoustical parameter for the Main Theatre averaged across the audience, measured with an omnidirectional source on stage, unless otherwise stated. *Balconies only. **Stalls only

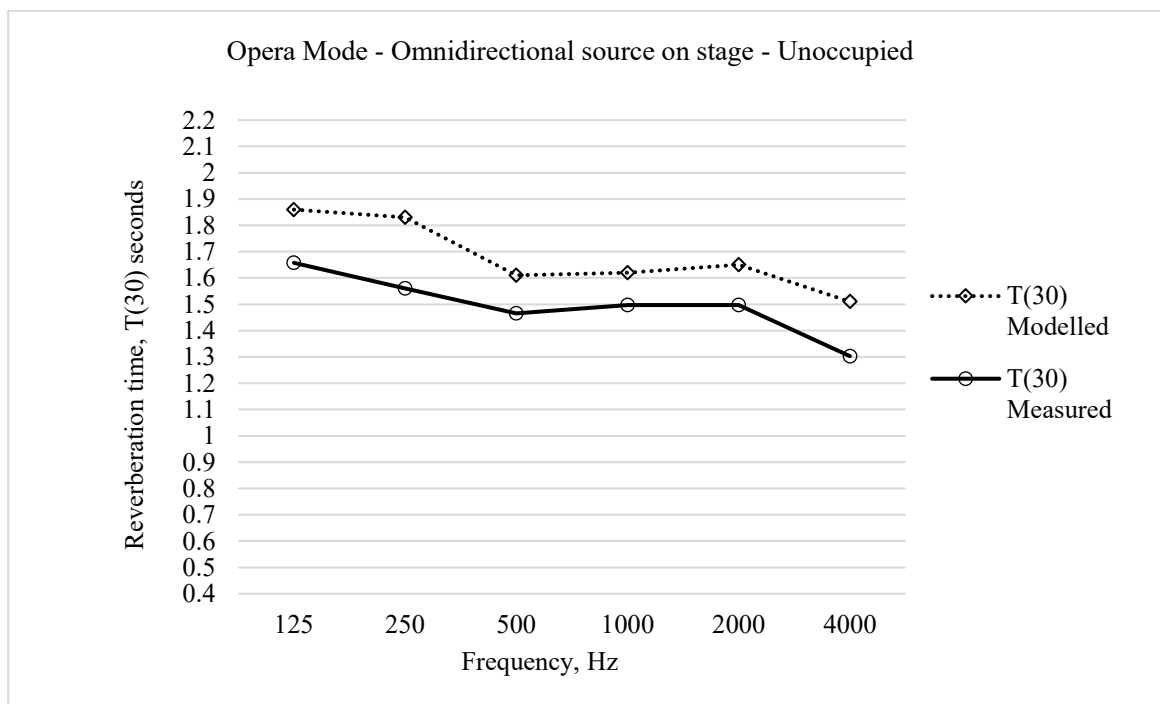


Figure 8. Difference between T30 measured and modelled

Table 1 and Figure 8 show that the model overestimated the RT by approximately 5%. Clarity is higher than modelled, particularly on the balconies.

The chart in Figure 9. provides a comparison of the reverberation with variable sound absorption retracted (black) and deployed (orange) within the auditorium. A reduction of approximately 0.20 seconds has been measured.

The near-uniform reduction in reverberation time across the frequency spectrum is largely attributable to the source position during the measurements. The author would have expected less RT reduction at low frequencies than mid frequencies given the sound absorptive characteristics of the curtains and banners used. However, measurements taken using an omnidirectional source placed on stage have been found to yield longer low frequency reverberation times compared to those taken with the venue's PA system, which is located within the auditorium volume. This difference is primarily due to the contribution of the fly tower to low-frequency reverberation.

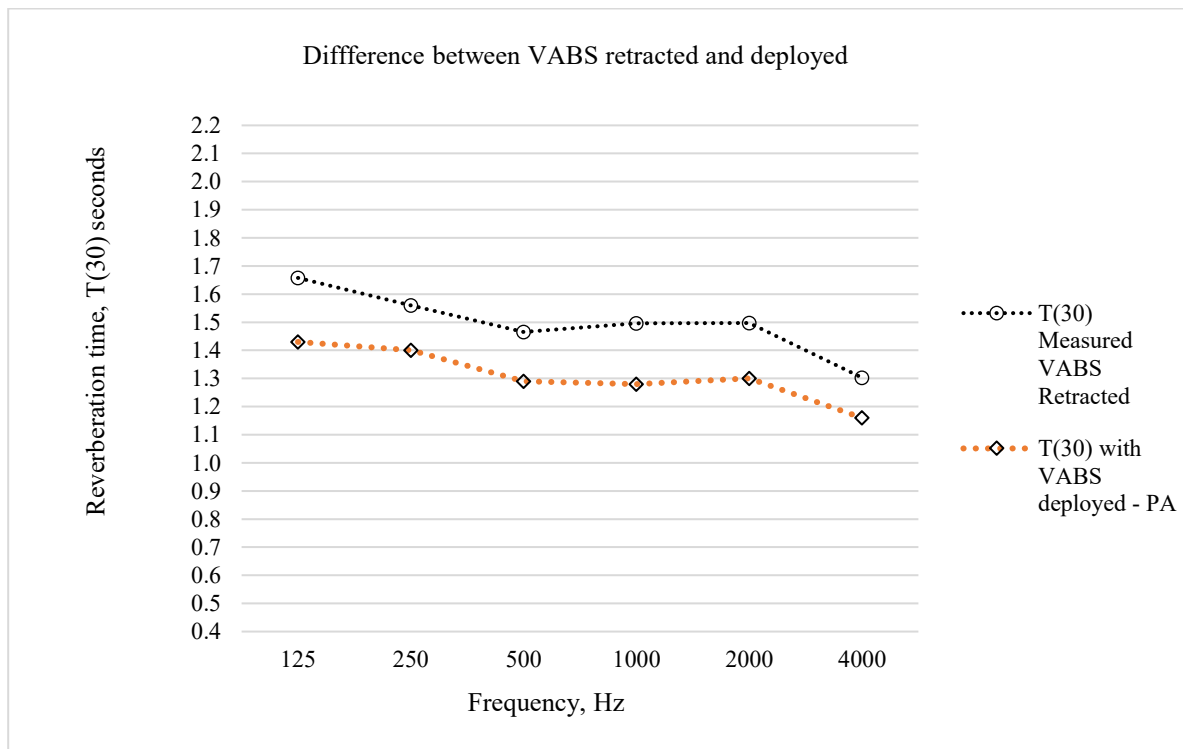


Figure 9. Difference between T30 with variable sound absorption retracted and deployed in the auditorium

6 SUBJECTIVE ASSESSMENT (AMPLIFIED)

Subjective listening assessments were undertaken utilizing the installed electroacoustic reinforcement system in the absence of live performance. A selection of commercially produced Rock and Pop music representative of typical amplified use cases was used. The implementation of the Variable Acoustic Banners System (VABS) yielded a perceptible enhancement in speech and musical clarity, commensurate with the measured reduction in reverberation time. Furthermore, the intelligibility and definition of temporally dense musical passages exhibited marked improvement. Low-frequency reproduction was subjectively characterised by both richness and improved temporal control. The overall impression of amplified sound within the auditorium was judged to be of high quality. A minor anomaly attributed to a delay misalignment in a lateral fill loudspeaker array was detected during assessment; corrective calibration has subsequently been applied.

It is anticipated that the opera house will formally open later this year with an inaugural performance. Although Cairo is home to a resident opera company, and has a great history of opera performance, the geographical separation between the existing Cairo Opera House and the new facility in the New Administrative Capital presents a logistical challenge. At present, the core opera-going audience remains concentrated in Cairo and

New Cairo City. Travel to the new venue from these areas remains difficult, often hindered by traffic congestion and limited public transport connectivity. However, it is expected that as residential occupancy in the New Administrative Capital increases and associated infrastructure continues to develop, the opera house will see greater utilisation and reach its full potential as a national cultural hub.