THE ACOUSTIC DESIGN OF A 5000 SEAT AUDITORIUM IN GUJARAT INDIA

A S Munro Munro Acoustic India and Mediapod UK
K Thirwani Munro Acoustics India
C Thomas Munro Acoustics India
V Beera Munro Acoustics India

1 INTRODUCTION

In November 2023, on the grounds of the Shrimad Rajchandra Ashram in Dharampur, Gujarat, an unusual new space opened its (eight) doors. The ashram sits about 35 kilometres inland from the Arabian Sea on a crescent-shaped hillock overlooking the surrounding landscape. On this modest elevation, Serie Architects built a white-marble-clad, modernistic, 16,000-square-metre discourse and meditation hall. The main auditorium is one of the largest purpose-built oratorial venues in India or even the world. Its purpose is both religious and cultural and as such it was necessary to consider both musical, speech and reverence (ambience) requirements. Over a period of several years a dialogue was maintained between the architects and the Munro India team to establish the interface between the architectural and acoustic requirements followed by an in-depth analysis of the electro-acoustic design for such a diverse operational challenge. An initial presentation of the acoustic design was delivered in 2019 to the Jain client team and work started in earnest the following year. The architectural design of the hall was spectacular with soaring arches and an inverted lotus ceiling canopy. The circular form and large volume was not exactly text book geometry but by mapping the initial radiation and reflection patterns a solution was established. By locating the stage area at the perimeter wall a complex array of contra-lateral and tangential paths produced a remarkably diffused sound-field. As all the construction surfaces comprised marble clad concrete. The next step was to control the reverberation and to calculate the intelligibility and ambient ‘timbre’ of the space.

2 CLIENT AND ARCHITECTURAL BRIEF

2.1 Initial Design Concepts and Discussions

After several years of planning and design the task of Munro Acoustics was to satisfy the main client criteria, that the delivery of speech to as many as 5000 attendees should be achieved with the utmost clarity and fidelity, in keeping with the nature of the spoken material. Additionally, the auditorium was designed with many other activities in mind including video presentations and musical events.
Given these conditions it was decided to follow established best practice for two main performance goals

1. To achieve intelligibility at all seats with %Alcons of less than 10% or better
2. To achieve a ‘point source’ focus at the stage centre from every part of the auditorium

The first goal could only be achieved by considerable control of the reverberant sound field plus the reinforcement of the direct sound field by electronic means.
The second goal led to the conclusion that a single central speaker cluster plus matching left and right speakers would allow stereo enhancement for events other than a single presenter. In other words a cinema styled array would work well, much as it does for film dialog within a movie soundtrack.

2.1.1 Development

In order to develop an acoustic scheme a spread-sheet was devised to allow all variables to be compared and optimized to achieve the target intelligibility values.

%ALCON	CRIT	SND	SND	SND	DIR	DIST	DIST	ROOM	SURF	HALL	AVE	REV'B	Total
%alcons	DIST	LEVL	LEVL	POWER	INDX	POINT	POINT	CONST	AREA	VOLUME	ABS	TIME	Absorption
1	(mod m)												
mods this						*vary*	*vary*						
1	Dc	Lp(5)	Lp(1)	Lw	Q	D2(5m)	D2(xm)	R	S	V	Aave	T60	SABS
0.15	17.15	81.40	81.40	100	4	5	5	3751.29	8753	45284	0.3	2.34	2625.9
0.60	17.15	81.40	76.28	100	4	5	10	3751.29	8753	45284	0.3	2.34	2625.9
1.35	17.15	81.40	73.95	100	4	5	15	3751.29	8753	45284	0.3	2.34	2625.9
2.41	17.15	81.40	72.70	100	4	5	20	3751.29	8753	45284	0.3	2.34	2625.9
3.76	17.15	81.40	71.97	100	4	5	25	3751.29	8753	45284	0.3	2.34	2625.9
5.42	17.15	81.40	71.52	100	4	5	30	3751.29	8753	45284	0.3	2.34	2625.9
7.38	17.15	81.40	71.23	100	4	5	35	3751.29	8753	45284	0.3	2.34	2625.9
9.63	17.15	81.40	71.02	100	4	5	40	3751.29	8753	45284	0.3	2.34	2625.9
12.19	17.15	81.40	70.88	100	4	5	45	3751.29	8753	45284	0.3	2.34	2625.9
15.05	17.15	81.40	70.77	100	4	5	50	3751.29	8753	45284	0.3	2.34	2625.9
18.22	17.15	81.40	70.69	100	4	5	55	3751.29	8753	45284	0.3	2.34	2625.9
21.68	17.15	81.40	70.62	100	4	5	60	3751.29	8753	45284	0.3	2.34	2625.9
											vary		
%alcons	Dc		Lp	Lw	Q		D2	R	S	V	Aave	T60	
27.60	8.73		76.91	100	4.00		20.00	972.56	8753	45284	0.10	7.91	875.3
6.15	13.10		74.19	100	4.00		20.00	2188.25	8753	45284	0.20	3.73	1750.6
2.41	17.15		72.70	100	4.00		20.00	3751.29	8753	45284	0.30	2.34	2625.9
1.17	21.39		71.71	100	4.00		20.00	5835.33	8753	45284	0.40	1.63	3501.2
0.64	26.20		70.98	100	4.00		20.00	8753.00	8753	45284	0.50	1.20	4376.5
0.36	32.08		70.42	100	4.00		20.00	13129.50	8753	45284	0.60	0.91	5251.8
0.21	40.02		69.96	100	4.00		20.00	20423.67	8753	45284	0.70	0.69	6127.1
0.12	52.39		69.59	100	4.00		20.00	35012.00	8753	45284	0.80	0.52	7002.4
0.06	78.59		69.28	100	4.00		20.00	78777.00	8753	45284	0.90	0.36	7877.7
					vary								
%ALcons	Dc		Lp	Lw	Q		D2	R	S	V	Aave	T60	
15.05	8.57		70.77	100	1.00		25.00	3751.29	8753	45284	0.30	2.34	2625.9
7.53	12.13		71.21	100	2.00		25.00	3751.29	8753	45284	0.30	2.34	2625.9
3.76	17.15		71.97	100	4.00		25.00	3751.29	8753	45284	0.30	2.34	2625.9
1.88	24.25		73.19	100	8.00		25.00	3751.29	8753	45284	0.30	2.34	2625.9
0.94	34.30		74.92	100	16.00		25.00	3751.29	8753	45284	0.30	2.34	2625.9
												variable	
											Aave	*T60*	
7.36	16.45		73.98	100	6.00		25.00	2302.05	8753	45284	0.21	4.00	1822.7
5.64	17.93		73.48	100	6.00		25.00	2733.62	8753	45284	0.24	3.50	2083.1
4.14	19.89		72.91	100	6.00		25.00	3364.34	8753	45284	0.28	3.00	2430.2
2.88	22.68		72.25	100	6.00		25.00	4373.40	8753	45284	0.33	2.50	2916.3
1.84	27.10		71.47	100	6.00		25.00	6247.09	8753	45284	0.42	2.00	3645.4
1.04	35.85		70.53	100	6.00		25.00	10929.64	8753	45284	0.56	1.50	4860.5
0.46	71.64		69.32	100	6.00		25.00	43641.36	8753	45284	0.83	1.00	7290.7

Audience

Total floor area is 3000m2 inc balcony 50%

People density overall

Octave	a/m2			Total sabs of absorption		
	1 per	2per	2.7per st	1000	2000	3000
63	0.05	0.1	0.3	50	100	300
125	0.2	0.25	0.25	200	400	750
250	0.2	0.4	0.4	200	400	1200
500	0.6	0.8	0.9	600	1200	2400
1000	0.7	1	1	700	1400	3000
2000	0.8	0.9	1	800	1600	2700
4000	0.8	0.8	1	800	1600	2400

Areas	floor	ceiling	walls	balcony
	2000	2000	3000	1000

Notes

Architectural Mod of 2 for maximum audience absorption

All LF absorptionmust come from walls and ceiling

Ceiling needs to compensate for empty hall

Back wall absorption maximum please!

Q of 4 can be increased to improve %alCons

Directivity

Main cluster 3*60 HOZ 1*60 VERT Q=12

Top Cluster 2*60 HOZ 60 VERT Q=18

Figure 1: % ALCONS, Design Stage Assessment

The chart clearly shows that the target %ALcons of under 10% can be achieved at distances up to 30m but to the maximum of 50m some extra absorption would be required. To err on the safe side a T30 of 1.5s was agreed as is in line with most values recommended in published literature.1
The geometry of the auditorium space was such that a 3D model was the only way to appreciate the coverage and absorption within the audience area. A large balcony and resulting undercover space was difficult to include in the main volume calculations.

2.1.2 Electro-Acoustic Mapping

The physical positioning of the Line Array Modules was achieved through a series of energy mapping and auralization exercises conducted in close tandem with the Loudspeaker OEM. Acoustic Energy Management between the Centre, and the Left/Right Line Array enabled us to create a stark 'point-source focus' at the stage center, uniformly for the entire listening plane.

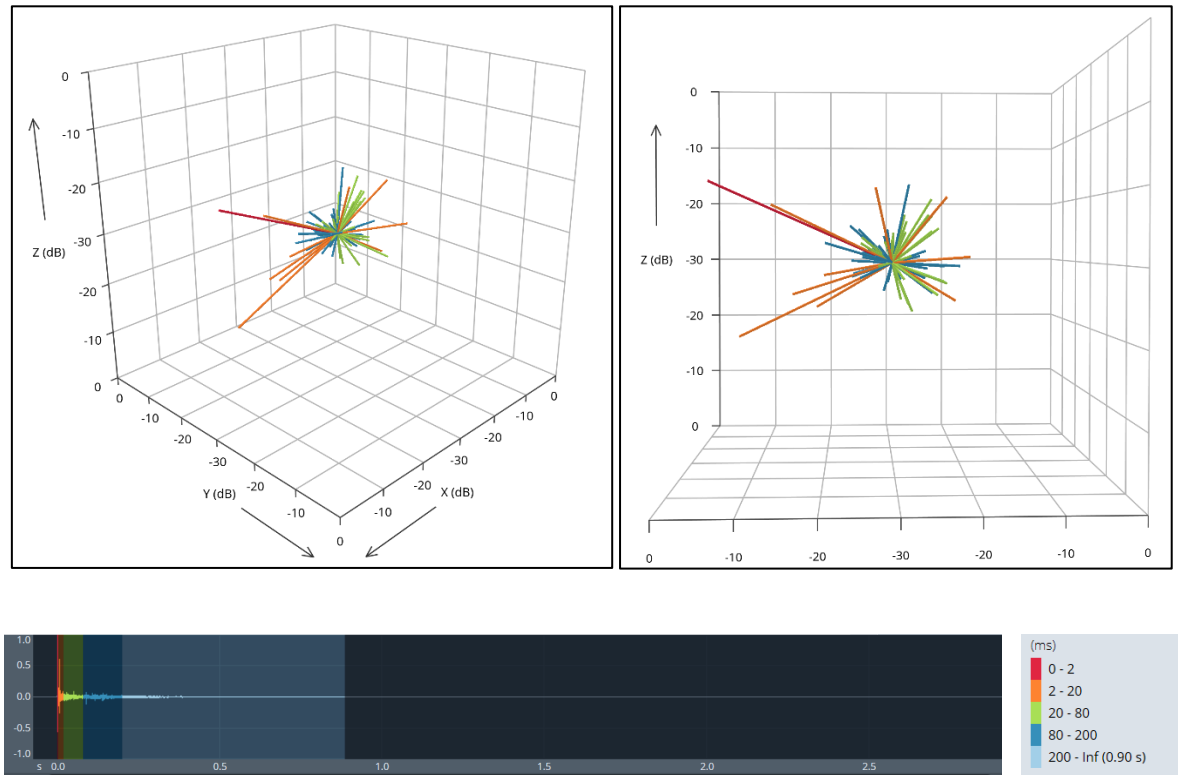

Figure 2: IRIS 3D Impulse Response highlighting the Measured Point-Source Focus

	Mid	63	125	250	500	1000	2000	4000	8000
Decay Range (dB)	-	51	58	44	48	54	52	55	56
EDT (s)	0.73	1.32	1.58	1.12	1.17	0.29	1.00	1.31	1.33
T20 (s)	1.25	1.33	1.46	1.24	1.28	1.23	1.24	1.17	1.07
T30 (s)	1.17	1.41	1.45	1.26	1.21	1.13	1.18	1.13	1.02
ξ T20 (‰)	-	28.9	9.1	8.4	13.2	11.6	5.9	4.7	7.5
ξ T30 (‰)	-	9.6	3.4	3.9	5.6	6.1	2.5	2.0	3.7
Curvature (%)	-	6.5	-0.8	1.9	-5.3	-8.4	-4.8	-3.3	-4.9

Figure 3: Decay Range and Time Parameters for the above measurements

3 ACOUSTIC TREATMENT DESIGN

The architectural vision for the auditorium, characterized by its distinctive tubular form, naturally directed our acoustic design process down a path less-conventional. The imposing concrete arches, initially perceived as structural constraints, ultimately revealed themselves to be advantageous. The expansive recesses spanning between these arches became strategic zones for redirecting acoustic energy. Our design interventions were thus purposefully aligned with these spatial voids, in pursuit of a targeted acoustic response that echoed the unique geometry of the space.

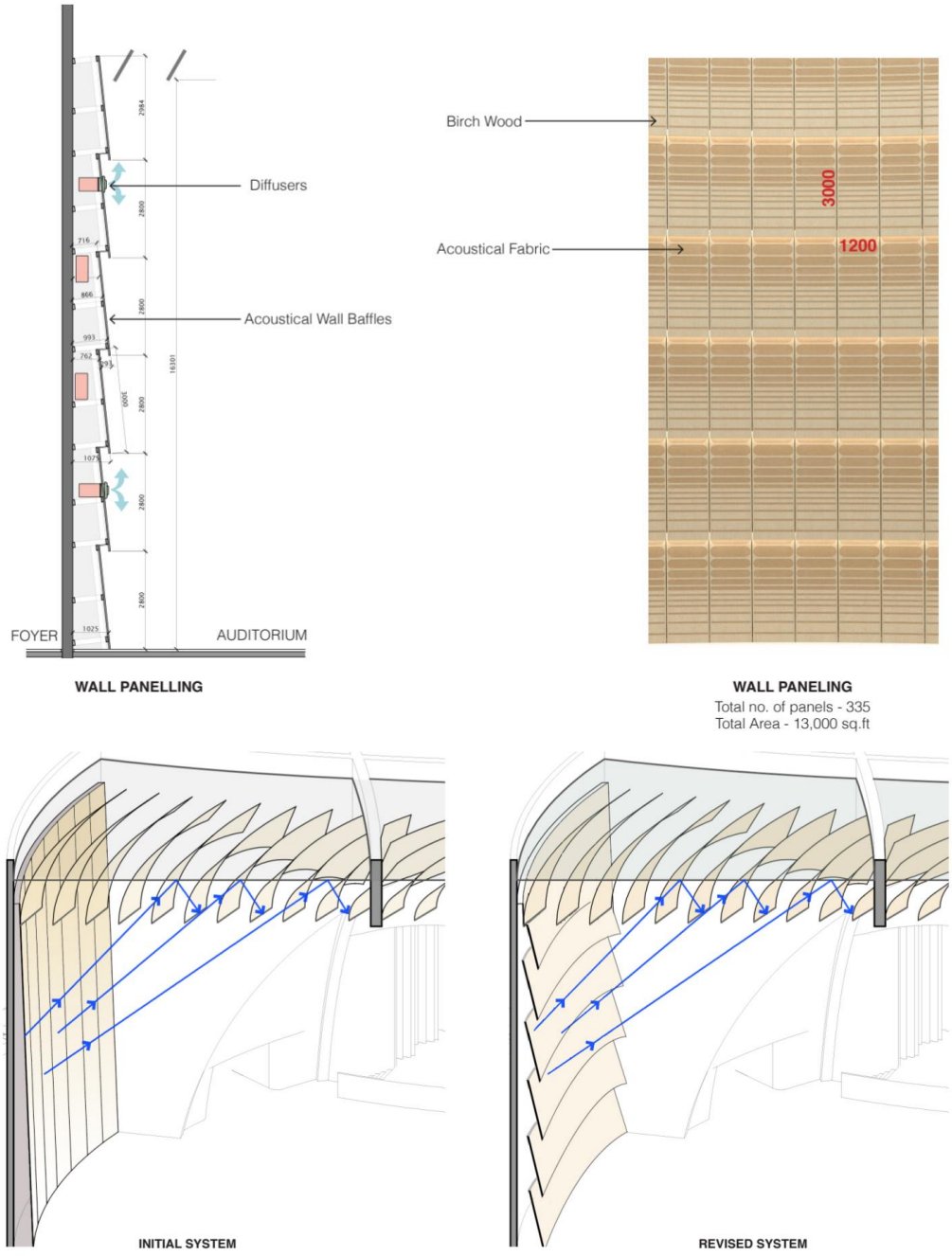

Figure 4: Acoustic Treatment Design Approach: Perimeter Walls

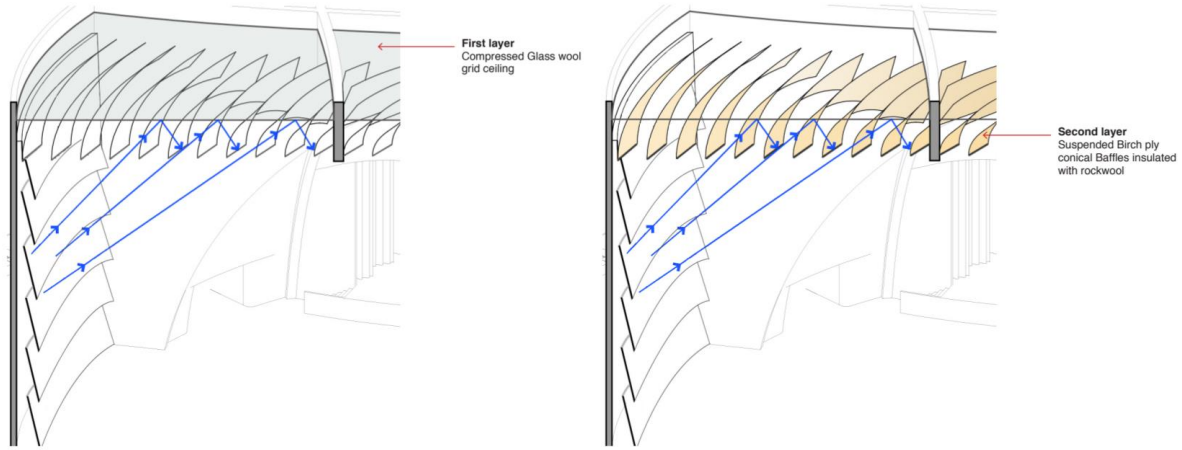

Figure 5: Acoustic Treatment Design Approach: Ceiling

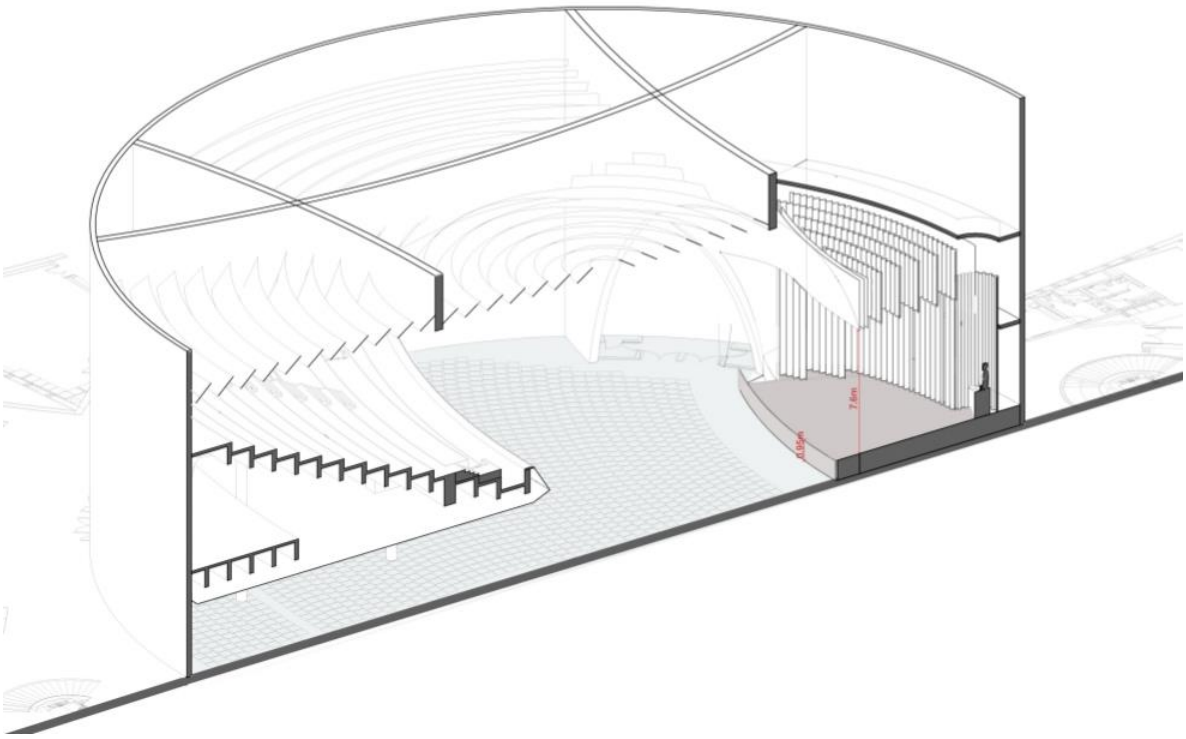

Figure 6: Acoustic Treatment Design Approach: Ceiling Baffle Sequencing

4 ACOUSTIC MODELLING

Owing to the intricate geometry of the space and the demanding specifications of the targeted acoustic response for the auditorium, it was deemed necessary to undertake a meticulous recalibration of our acoustic modelling. This endeavour was guided primarily by the insights gleaned from a series of detailed electroacoustic simulations conducted on EASE v4.4.

The process entailed numerous iterative assessments and an intensive collaboration with the lead architect, focusing particularly on the strategic placement of broadband absorbers along the perimeter wall. These treatment modules were carefully aligned to operate synergistically with ceiling-mounted absorption elements and a set of architecturally expressive features, including a suspended Möbius baffle and imposing concrete arches of substantial mass.

The culmination of these efforts resulted in a space that conformed closely to the acoustic performance criteria established during our initial design phase—achieving a balance both technically sound and bespoke to the client's precise expectations.

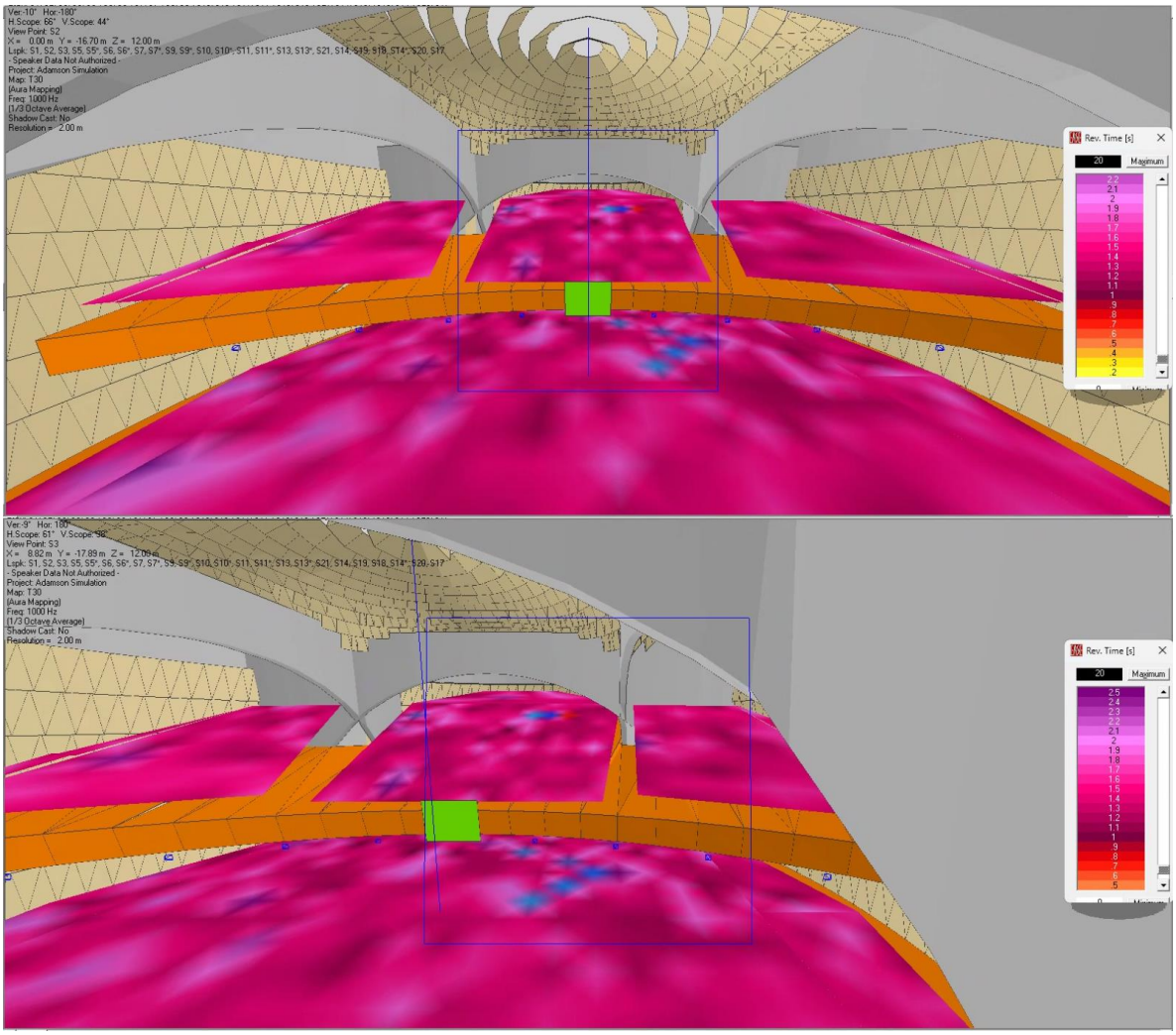

Figure 7: Acoustic Response: Reverberation Time Simulation

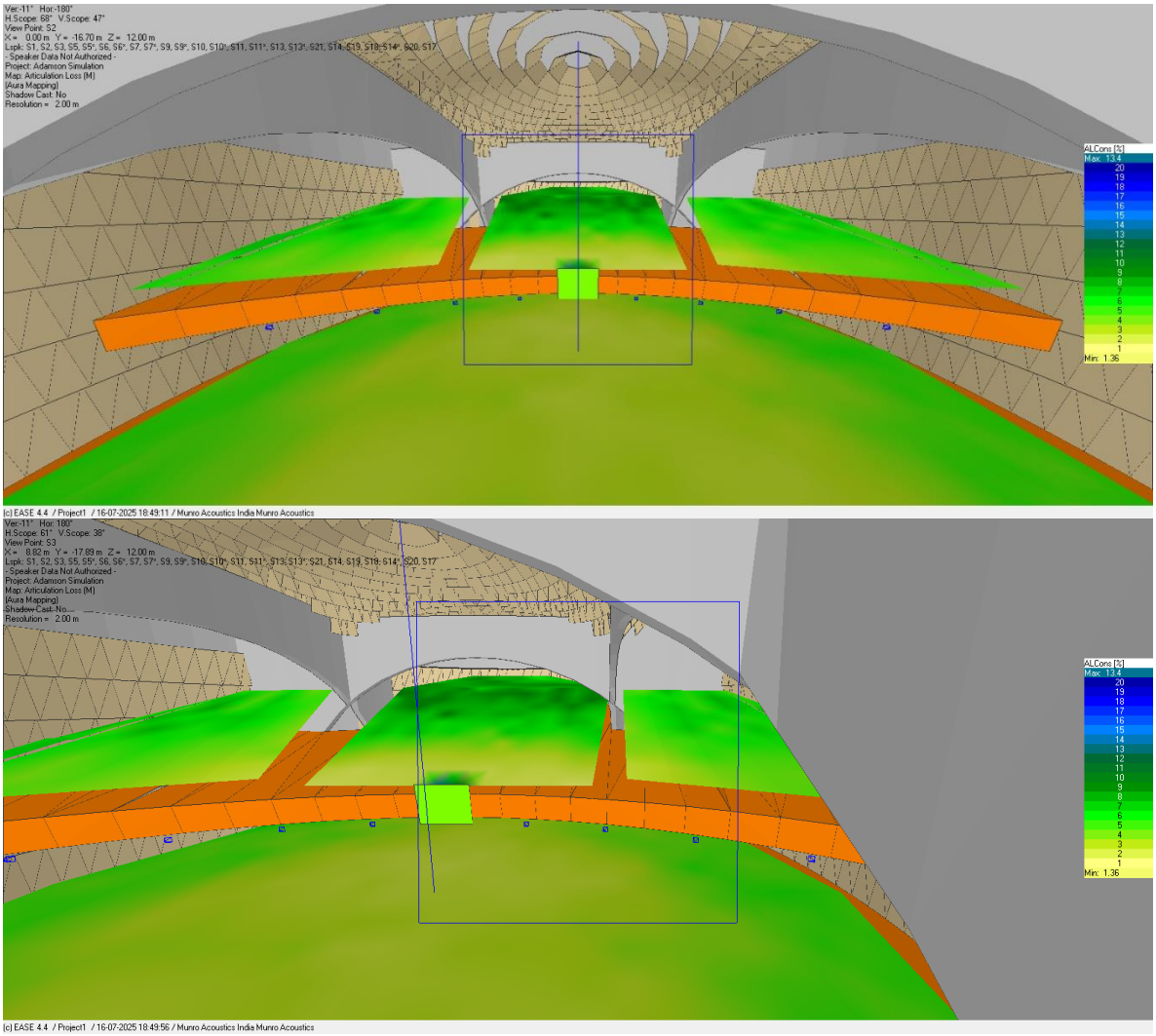

Figure 8: Acoustic Response: %ALCONS Simulation

Percentage Articulation Loss of Consonants (%ALCONS)												
Room Dimensions			Rated Loudspeaker Coverage			Distance from Loudspeaker (m)	Measured Reverberation Time @2kHz (s)	Unaided Critical Distance (m)	Critical Distance for Loudspeaker (m)	%ALCONS for less than 3X Critical Disctance		%ALCONS for greater than 3X Critical Disctance
Room Length (m)	Room Width (m)	Room Height (m)	Horizontal Coverage (deg)	Vertical Coverage (deg)	Directivity Index (dB)					% ALCONS for unaided talker	% ALCONS for Loudspeaker	
44	54	18	110	70	8.1	16.5	1.18	15.3	27.3	0.9	1.4	10.6
44	54	18	110	70	8.1	17.5	1.22	15	26.9	1.1	1.7	10.9
44	54	18	110	70	8.1	17.5	1.29	14.4	26.2	1.2	1.9	11.6
44	54	18	110	70	8.1	23.3	1.01	16.5	29.6	1.3	2	9.1
44	54	18	110	70	8.1	21.8	1.2	15.1	27.1	1.6	2.5	10.8
44	54	18	110	70	8.1	21.8	1.18	15.3	27.3	1.5	2.4	10.6
44	54	18	110	70	8.1	36.6	0.9	17.4	31.3	2.8	4.4	8.5
44	54	18	110	70	8.1	37.6	1.1	15.8	28.3	3.9	6.1	9.8
44	54	18	110	70	8.1	37.6	1.1	15.8	28.3	3.9	6	9.7

Figure 9: Acoustic Response: Measured %ALCONS

5 CONCLUSIONS

Throughout history religion and customs have been tempered by the ability to communicate by means of speech and therefore articulation was fundamental. As civilization became more complex and words overtook war as a means of power, buildings became larger and predominantly sacred of regal in nature. The art of acoustics became important!
From Etruscan tomb resonances to Gregorian Chant and Papal Masses there has been a cause and effect result upon auditorium sound and the way an audience receives and appreciates what they hear. Natural acoustic design evolved to match the size and sophistication of the material offered.
The advent of electro-acoustic technology interrupted this evolution and buildings started to grow in size and complexity to accommodate ever larger audiences and diversity of purpose. The digital age has added signal processing and now it is possible to contemplate events of almost unlimited size and acoustic fidelity. By replacing natural acoustic environments with a ‘blank’ space where reverberation and articulation become part of an algorithm requiring a different approach to design in that the natural acoustic must be tightly constrained. There must be a degree of natural ambiance and we all know the negative experience of anechoic rooms but there is a way to produce a balance and that is what we set out to achieve with this project.

6 REFERENCES

1. H.J.M. Steeneken and T. Houtgast, The temporal envelope spectrum and its significance in room acoustics, Proc. 11th ICA, Vol. 7, 85-88. Paris (1983).
2. T.J. Cox, F. Li and P. Darlington., ‘Extracting room reverberation time from speech using artificial neural networks’, J.Audio.Eng.Soc. 49(4) 219-230. (April 2001).
3. S. Haykin. Neural Networks: A Comprehensive Foundation, 2nd ed Prentice Hall, 300-314. (1999).
4. ##[Reference list style, text starts at 1.25cm, 10pt Arial]