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AN APPROACH INTO THE ACOUSTIC EVOLUTION OF ANCIENT ODEA

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Abstract

Ancient Roman Odea, in contrast to ancient Greek ones which were used exclusively for musical events, were roofed buildings used for multiple purposes such as theatrical performances, singing exercises, musical shows and poetry competitions among others and they were designed to be in use all year long, in all weather conditions.

They were the closed theaters of the Roman elite which from some point in time onwards could not be contempt with just having privileged seats in the open public theaters.

The evolution of the typology of the Odeon is in close relation to the evolution of the large halls of archaic and classical years (such as Telesterion and Bouleuterion), in which there was a permanent trend to move the central pillars to the edges as these were seen as optical and auditory obstructions to the function of the room.

This paper examines the variations that have taken place with the evolution of the typology of the odea in the typology (geometry) and the materials of the constructions using mathematical models and sound prediction software analysis.

Keywords

Odeon, Acoustic evolution, Acoustic simulation, ancient performance halls, reverberation time.

1. Introduction.

Roman era odea, in contrast to open theaters were always roofed buildings and as a consequence, their size was limited. Another difference with Greek odea, which were used almost exclusively for the holding of musical contests, was that roman odea were covered small theaters [1] used for multiple events such as recitation, music, dance, prose, mimodrama and pantomime[2], lectures etc. There are even some cases where odea have been used in place of open theaters, if the theater of a city was destroyed or if it was converted to an arena[3].

So the functional difference of odea and open theaters was more socially needed than technically required, as the odea were at this time the theatrical buildings of the elite of the imperial years and after in which, the high society of the roman empire could enjoy any event or show without care of the weather conditions, privately separated from the rest of the society which only used the open public theaters.

The building type of the roman odeon is an evolution of the Greek Buleuterium[4], which in its turn has its origins in the large rectangle hypostyle halls of the Attica type, like the Telesteria, in which rectangular rows of seats were incorporated for the spectators of the ceremonies from the time of Pesistrates.

The odeon of Pericles in Athens belongs to this category (Telestiria), a square 62x62m building of the second part of the 5th century B.C, which Plutarch describes as a hall with many spectator seats and also many columns supporting the roof.

The conducting of musical contests was the almost exclusive use of Greek odea. The basic disadvantage of the large hypostyle hall was the large number of internal columns that limited the optical and, as will be seen later on, the acoustic fidelity for many of the spectators. This was further decreased by the need of an elevated skylight, a demand brought about by the need to bring light to the interior of these large buildings.

In the end of the 6th century B.C we see for the first time the architecture of the Buleuteria, which were roofed buildings in which the parliament met. Since they were designed to host a smaller number of people than the Telestiria and the Ecclesiasteria, they had smaller dimensions, which gave the opportunity to improve the optical and acoustical fidelity by moving the smaller number of interior columns now required to the sides.

The Buleuteria were necessarily rectangular externally in order to support the roof, as were the Telestiria. But internally the seats were in some cases rectangular like in the Telestiria and in others semi circular, obviously influenced from the design of open theaters, for the design of which the theories of the Pythagoreans and later on the theory of Aristoxenos[5] were used from the end of the 4th century B.C and onwards.

To illustrate the case, the old Bouleuterion of Athens (end of 6th century B.C) was a hypostyle hall with rectangular seating while in the new Bouleuterion (5th century B.C) the seating was semicircular. The architecture of the Buleuteria continued to evolve until the roman conquest, the Bouleuterion of Miletus (175-164 B.C) being a well known example of the final form of this type of architecture.

A non typical Bouleuterion – Ecclesiasterion is the Thersilion of Megalopole[6] of the 4th century B.C which belongs to the large hypostyle type of halls, having dimensions of (52.5X66.5m), a choice dictated by the need to accommodate the 10.000 members of the Arcadian confederation. The radial placement of the interior columns is a logical step in the improvement of the optical accessibility of the central stage and may have helped the acoustical fidelity also. The wooden seats were placed in a rectangular shape.

The Bouleuterion type of architecture was at the base of the evolution of both the roman odeon and the roman theater. In 62 B.C Pompey visited the Bouleuterion of Mytilene. In 55 B.C he gave orders for the construction of the first stone theater in Rome, using the Bouleuterion of Mytilene as the prototype. This theater had the basic characteristics of a Bouleuterion, except for the external rectangular stonewall perimeter, since it was not a roofed building. This is perhaps why roman open theaters are semicircular externally and internally from the beginning, while roman odea remain rectangular externally until the second half of the 2nd century A.D, a period at which the technical ability to support semicircular roofs has not yet evolved.

Before arriving at the final form of the roman odeon, which has a semicircular exterior, certain intermediate evolutionary types of this architecture interceded. In the first roman odea such as the one at Pompeii, the one at Epidaurus or the one at the agora in Athens (1st century A.D) the hall is elongated in depth, as the beams holding the roof are supported on the side walls. This results in a reduction of the side seats and a narrowing of the stage.

The next step in the evolution of this architecture was to transfer the support of the roof from the side walls to the back wall and the wall of the stage, resulting in an elongation of the hall in width. This experimentation must logically be connected not only with the optical enhancement of the halls but with their acoustical enhancement also, taking into account that from the 1st century and onwards the blossoming of the neo-Pythagoreans, coupled to the resurfacing of the musical theory of Aristoxenos via Vitruvius's writings, new efforts were made for the enhancement of the acoustics of open theaters.

The final step in the evolution of the roman odea was the removal of the Π shaped external wall and its replacement with a semicircular wall, something that, as we will see below, improved the acoustics of the hall considerably.

2. Morphological evolution.

It follows from the above description that an evolution of the morphology has taken place in discrete steps from the first hypostyle halls of the 5th and 6th centuries B.C to the final semicircular form of the roman odeon of the 3rd century A.D and after. Four characteristic types of representative odea and two intermediate ones (one Ecclesiasterion and one Buleuterium) were chosen to be further analyzed in this paper, as they seemed a fair representation of the evolution of the odea in antiquity.

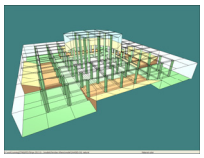
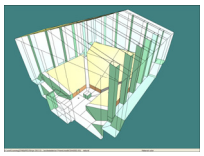
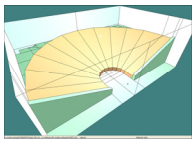
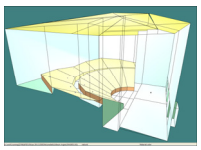
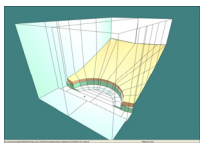
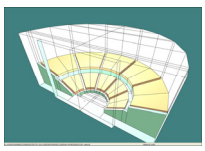
In the following table 1 the characteristic types are shown together with their timeline, showing their evolution.

Table 1. Timeline of chosen odea.

		B.C.						A.C.						(- for B.C. and + for A.C.)
	Century	-6	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	+6	Building type
1	**Pericles**		-5											**odeum - Telesterium**
2	**Prines**					-2								**Ecclesiasterion**
3	**Miletus**					-2								**Bouleuterium**
4	**Argos**								+2					**Odeum**
5	**Epidaure**								+2					**Odeum**
6	**Aphrodisias**									+3				**Odeum**

In order to investigate the acoustic properties of the odea, a 3D model of each space was constructed and examined using acoustic simulation software. The basic parameters of each model are shown in the following table 2.

Table 2. The basic parameters of the computer model

	Spaces under investigation	Type of space	Model	Period (cen)	Volume (m^3)	Total Surface (m^2)	Audience Surface (m^2)	V/S (m)	V/AUD
1	Odeum/Telesterium of Pericles	Hypostyle hall with large dimensions		5th B.C.	25389	11388	1264	2,23	10,04
2	Ecclesia-sterion of Prines	Hall in which the roof support columns have been moved to the back so as to not interfere. Square tier formation.		2nd B.C	4502	2342	260	1,92	8,66
3	Bouleute-rium of Miletus	Effort to support roof mainly on front and rear walls and minimize columns.		2st B.C	6669	2942	576	2,02	5.79
4	Odeum of Argos	Hall with elongated width.		2nd A.C.	6450	2339	323	2,76	9,98
5	Odeum of Epidaure	Hall with elongated depth.		2nd A.C.	7971	2558	401	3,12	9,94
6	Odeum of Aphrodisias	Final form of semicircular odeo.		3rd A.C.	15598	4509	576	3,46	13,54

3. Mathematical models.

Since the spaces under consideration were all reconstructions from archaeological remains, 3D models of all the halls were examined using acoustic simulation software, in our case CATT V8f [7]. The extrapolated geometrical data used for the models is from published theoretical reconstructions (G. Izenour[8]).

Since precise knowledge about the materials inside these halls is nowhere to be found, and in order to make the results easily comparable between themselves, three main materials were used for the models:

A) Hard and smooth material like stone or marble was used for the walls and the floors (including corridors).

B) Audience with density of 1 person per square meter.

C) Wooden panels (plastered or not) were used for the ceilings.

The absorption coefficients of the chosen materials are shown in the figure below

Table 3. Absorption coefficient (%) of materials

	125	**250**	**500**	**1000**	**2000**	**4000**
Marble or smooth stone (walls, etc)	1	1	1	1	2	3
wooden panels (ceiling)	15	10	6	8	10	5
side of audience	8	12	27	34	40	37
Audience	16	24	56	69	81	78

The results of these simulations are very useful for comparison of the different types of odea, and fine for our current use which is to seek an evolutionary pattern in their design principles, but they are not thought to represent the reality of these spaces.

When the models were inside the simulation software, omnidirectional sources using the “Human Raised” curve were employed and a minimum of 12 receivers were used for each model (more when needed).

Four parameters[9] were examined in order to determine and compare the acoustic behavior of each hall.

A) The reverberation time in sec

B) Definition D50 in %. This parameter was chosen so as to give us a perception of the intelligibility of each space. It is important for events which have speech, prose and generally voice but not music.

C) Clarity C80 in dB. This parameter was chosen in order to examine the suitability of the spaces for singing and musical events. It is generally used for events having music and singing, with or without musical instruments.

D) Strength G10 in dB this parameter was chosen to determine the amplification effect that the space has on the acoustic sound level.

The results of the computer simulation on the models are shown analytically in table 4 and graphically in table 5 for comparison purposes.

Table 4. Results of simulation using CATT software.

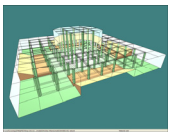
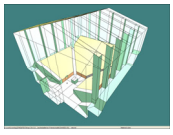
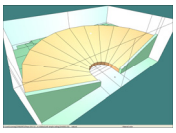
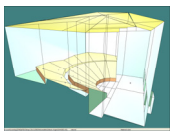
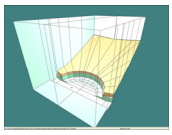
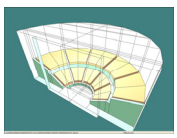
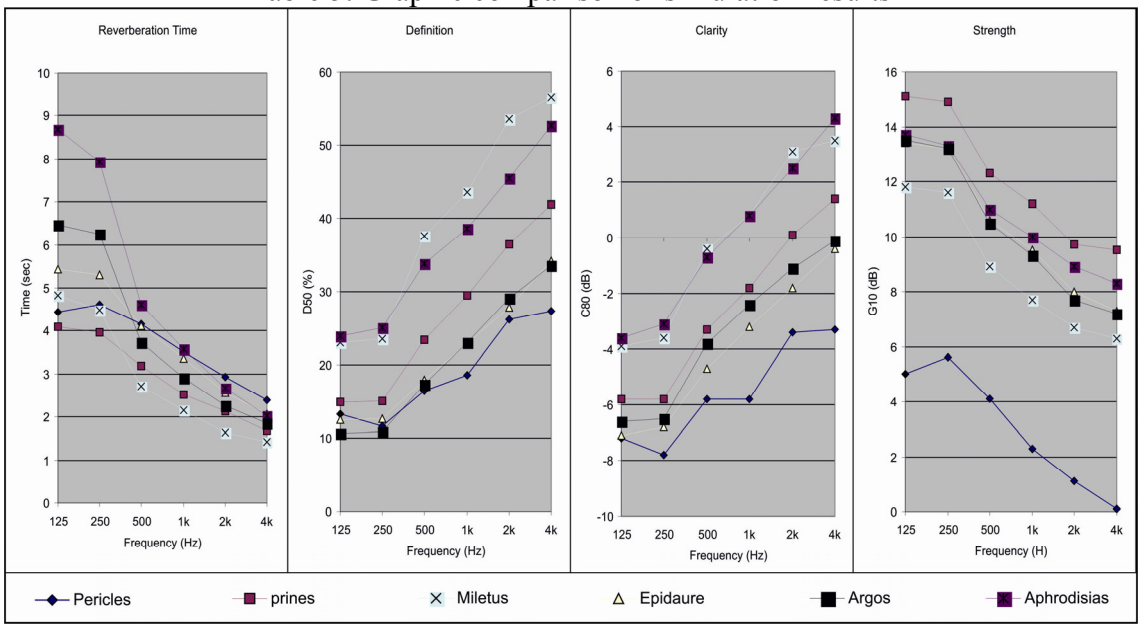
				125	250	500	1k	2k	4k
1	Pericles		T30	4,44	4,62	4,16	3,52	2,94	2,39
	Odeum /		D50	13,30	11,70	16,50	18,60	26,20	27,40
	5th B.C.		C80	-7,20	-7,80	-5,80	-5,80	-3,40	-3,30
			G10	5,00	5,60	4,10	2,30	1,10	0,10
2	Prines		T30	4,10	3,96	3,19	2,52	2,13	1,69
	Ecclesiasterion		D50	15,00	15,10	23,40	29,50	36,50	41,90
	2nd B.C.		C80	-5,80	-5,80	-3,30	-1,80	0,10	1,40
			G10	15,10	14,90	12,30	11,20	9,70	9,50
3	Miletus		T30	4,8	4,5	2,7	2,2	1,6	1,4
	Boueleterium		D50	23,0	23,5	37,6	43,5	53,6	56,4
	2st B.C.		C80	-3,9	-3,6	-0,4	0,8	3,1	3,5
			G10	11,8	11,6	8,9	7,7	6,7	6,3
4	Argos		T30	6,47	6,24	3,73	2,90	2,26	1,86
	Odeum		D50	10,60	10,90	17,40	23,10	29,10	33,60
	2nd A.C.		C80	-6,60	-6,50	-3,80	-2,40	-1,10	-0,10
			G10	13,50	13,20	10,50	9,30	7,70	7,20
5	Epidaure		T30	5,43	5,31	4,11	3,37	2,57	2,07
	Odeum		D50	12,50	12,70	18,00	22,90	27,90	34,20
	2nd A.C.		C80	-7,10	-6,80	-4,70	-3,20	-1,80	-0,40
			G10	13,40	13,20	10,60	9,50	8,00	7,30
6	Aphrodisias		T30	8,69	7,93	4,62	3,57	2,67	2,02
	Odeum		D50	23,90	25,10	33,80	38,60	45,40	52,60
	3rd A.C.		C80	-3,60	-3,10	-0,70	0,80	2,50	4,30
			G10	13,70	13,30	11,00	10,00	8,90	8,30

Table 5. Graphic comparison of simulation results



4. Comments on the results

The first parameter that is examined is the reverberation time of the various spaces. Comparing the results we find that our examples do not follow the expected relation to their respective volumes, and the discrepancy is Aphrodisias, which has the largest reverberation time but half the volume of the much bigger Odeon of Pericles. This does not look like a chance finding but an intended design feature, which is only logical if one relates to the uses of the spaces. It also has to do with the V/S parameter which represents the inner complexity of the structure. We already believe they were well aware of this parameter looking at another construction of that age (crypt of the Necyomanteion of Efyra[10]).

Another interesting fact to note from this comparison is that the elongated in width hall has a greater reverberation time than the elongated in depth hall, even though the volume of the second hall is greater than that of the first.

The second parameter that is examined is Definition (D50). We see here that the majority of the halls have very similar results, with Prines and Aphrodisias and Miletus standing out. Prines seems to have a better D50 most probably because of its much smaller size, while Aphrodisias has the best D50, comparable only to Miletus which also has a much smaller volume and the smallest ratio of persons per m^3 of all of them. It could be implied that since Aphrodisias is the most advanced of them chronologically, this might again not be a chance result but an evolution of their knowledge of closed space acoustics.

Exactly similar are the results for the clarity C80 with two slight variations. Prines is now closer to the main group and of course Pericles Odeon which has a very poor result, well below the main group. This is of course due to its very large volume and the increased complexity of the interior.

The fourth parameter examined is the strength G10. Here we find the majority of spaces having very good results with the exception of Pericles Odeon which in contrast does not perform in this quality. As expected the Aphrodisias is second to top, second only to Prines (4 times smaller) obviously because of its much bigger size.

5. Conclusions

Looking at the results of the above models, an evolutionary pattern is seen which starts from the relatively simple Odeon of Pericles, with its many problems, culminating at the Odeon of Aphrodisias which, incorporating inside it the semicircular shape, has dealt with all of the previous problems of acoustic and optical fidelity and applied solutions to them. This final design has clearly improved acoustic and optical parameters in comparison to all the previous designs, offering itself as a better place to a variety of uses.

Since, as we commented before, the models are simplistic and useful only for comparison, it would be interesting to know what the real parameters of such a space would be. If just open windows are incorporated in the model of the Aphrodisias, the D50 and C80 parameters[11] as well as the reverberation time are improved by more than 20%. A similar improvement is expected if all the proper materials are incorporated in our model (curtains, carpets, stage constructions etc).

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