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Scenery design through a geometrical model: An application in the theatre of ancient Tyndaris

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ABSTRACT

The revival of ancient drama prioritized the issues of reversible interventions to ensure proper conditions for current performances. Ancient theatres' fragile situation, often with ruined koilon and without a stage building, is nowadays even more damaged by the contemporary use. This article is focused on the evaluation of the addition of a scene building in the theatre of Tyndaris, aiming to restore the natural acoustic function of the space. The pioneering acoustical research on open air theaters, made by Fr. Canac, guided the study. The dimensions, the position and the acoustic contribution of each scenic element were defined and guidelines useful for the designers were provided via geometric functions.

Σχεδιασμός και ακουστική διερεύνηση σκηνογραφίας με την γεωμετρική μέθοδο στο αρχαίο θέατρο Tyntaris

ΠΕΡΙΛΗΨΗ

Οι διαχρονικές καταστροφές στο χώρο της σκηνής των αρχαίων θεάτρων, θέτουν κρίσιμα προβλήματα στη σύγχρονη επαναλειτουργία τους. Η ανακοίνωση επικεντρώνεται στην ακουστική αξιολόγηση μιας σκηνικής κατασκευής στο αρχαίο θέατρο του Τύνταρι, στη Σικελία, με στόχο την ενεργοποίηση της φυσικής μεγαφωνικής ικανότητας του χώρου. Μέσω μιας σύντομης ιστορικής επισκόπησης των διαδοχικών οικοδομικών φάσεων του θεάτρου, διερευνάται η βέλτιστη μορφή και το μέγεθος της σκηνογραφίας, ακολουθώντας τις έρευνες και τα πορίσματα της μεθόδου ειδώλων – πηγών του Fr. Canac. Μέσω γεωμετρικών συναρτήσεων διερευνάται η αλληλεπίδραση των επιμέρους λειτουργικών στοιχείων του θεάτρου και αξιολογείται η ακουστική συνεισφορά τους στην ακουστική του θεατρικού χώρου

Introduction

The ancient theatre dropped a long run of about 7 centuries and spread to the coast and the hinterland of the wider Mediterranean area. Starting with servicing the Dionysos ritual and drama contests, the ancient theatre followed the political and social transformations of the Greek speaking world of antiquity. [1]

The theatre is, in fact, a scientific field, the limits of which are extended to different scientific areas. As an unfortunate consequence of this prominent location, the interdisciplinary approach of the ancient theatre and the multi-parametric dimension of its problems were neglected by modern research. The revival of ancient drama (from the early 20th century) and the demand for return to its natural space (for about a century) has prioritized the issues of reversible interventions to ensure proper conditions for the performances.

Despite the serious distortions brought about by common Roman interventions or destructions caused by time, in most cases the reuse of the theatres is deemed feasible. However, the restoration efforts are incomplete without corresponding acoustic interference; in fact the various stage-design solutions normally fail to activate the natural (passive) acoustic potential of the theatre space. [2], [3]

The theatre space was generally composed by a small number of distinct elements: an inclined *cavea* guaranteed the appropriate visual and acoustic comfort; the *orchestra* allowing the enforcement of the first reflection of the actor's voice and, finally, the scenography.

Unfortunately today, in most cases, only ruins remain of the constructions in the scene area. Nowadays invasive temporary structures required by the new interpretation of the classic drama replace the lost architectural entities: they usually occupy the *orchestra's* place, which originally had the role of a natural sound amplifier. The purpose of this article is to indicate a methodology for the design of a scenography enabling the natural (passive) acoustic function of the theatrical space. Although the current research was focused on the ancient theatre of Tyndaris in Sicily, general guidelines for the scenery design are provided. [4]

1. The theatre of Tyndaris

The Greek ancient theatre of Tyndaris in its current condition was chosen as a case study for the present research. Nowadays, the theatre constitutes one of the remodeled theatres commonly transformed during the Roman times in amphitheatre. Hellenistic in its origins, the theatre presents many differences from the classic theatre of the 5th century. The construction of the theatre at the end of the 3rd century BC was not completed in a single period. In its last form the theatre of Tyndaris presents itself like a system of three parts: the *cavea*, the *orchestra* and the *scene*, each one, as mentioned, originated in a different period. [5]

The narrow *parodoi* and the form of the lateral walls (*analemma*) of the *koilon* indicate that the cavea was built at first and successively the stage building was added (the lateral walls were cut for the construction of *paraskenia* in the edges of the scene). [6] The original wood construction of the scene became a more elaborated architectural construction during the Hellenistic period when the theatrical play and the recitation became the most important artistic manifestation.

Successively, in Roman times (around 22-21 BC), the theatre was transformed into an *arena*. The Greek *koilon* in the natural slope was replaced by the Roman *amphitheatre* supplemented by an artificial embankment. The level of the Greek

orchestra (with a diameter of 20.10m) was lowered by 0.90m and transformed in a *conistra*, a basin almost oval, deep about 3.50m with five openings, mainly used for naval battles. The material from the destroyed *proscenium* and the first four rows of the *koilon*, was used for the construction of the *podium* (2,50m height), around the arena. The corners of the *paraskenia* were truncated in order not to surpass the podium of the arena. Moreover, the Greek-Hellenistic scene collapsed in late-medieval age. [5]. Thus, the parts that last until today come from various interventions and restorations of the original building.

The remains of the footings of the scene allow us to hypothesize a three level monumental building and a podium with three openings. The cavea mostly damaged is now covered by wooden panels for seating purposes.

2. The geometrical method of Fr. Canac

In 1967 François Canac published his famous book *"L' Acoustique des théatres antiques - ses enseignements*" concentrating more than 20 years of acoustic research on the ancient open-air theatres. [7]

The French researcher combined in-situ measurements with simulation experiments in the laboratory. The in-situ measurements consisted of the acknowledgement of the sound intensity distribution and the evaluation of the speech intelligibility in order to assess the overall acoustic quality of a theatre. The laboratory work instead consisted of the acoustic evaluation of various architecture elements with the use of hydraulic and ultrasonic models.

The research, by means of the Image Source Method, concluded to the *"canonical equation"* of a theatre which ensures the identification of the symmetrical images of a source relative to the existing surfaces through the geometrical laws of reflection. The assessment of the effect of each source is obtained by summing the various paths of images-sources according to the distance between the actor and the viewer.

One of the key features for the acoustic comfort in a theatre space is the audition angle (ε), formed by the line connecting the steps of the auditorium to the radius of the sound (direct or reflected). This solid cone, whose minimum angle is quantified equal to 4°, provides visual comfort and prevents the absorption of sound by the spectator's body. [7] The audition angle ε, as function of the inclination of the cavea (q), the diameter of the orchestra (D), the size of the *proscenium* (h, height of the *proscenium* level plus the height to the mouth of the actor) and the position of the viewer (height H from the level of the *orchestra*) defines the canonical equation of the ancient theatre:

$$D_0 - h\frac{\operatorname{cotg}\alpha}{\sin\varepsilon} = D_0 + \mathrm{H}\frac{\operatorname{cotg}\alpha}{\cos(\alpha-\varepsilon)\sin\alpha} \tag{2.1}$$

where:

D_o the diameter of the orchestra [m];
α the inclination of the *cavea* [°];
H the height of the spectator position from the orchestra level [m];
h the height of the proscenium level plus the height of the mouth of the actor [m];
ε the audition angle [°]

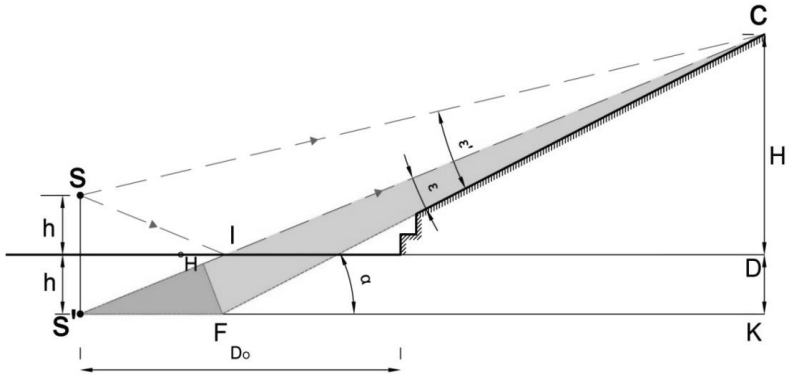

Figure 2.1: Section presenting the canonical equation elements (2.1) in the theatre of Tyndaris

The above mentioned geometrical equation apart from being useful to archaeologists for indicating the likely position of a missing element, it could also be used, in our case, for specifying the place and the dimensions for a contemporary scenography.

3. Application of the geometrical method

3.1 Data collection and general settings

The data collection used for the geometrical model of the ancient theatre of Tyndaris consisted of geometrical information (height and inclination of the cavea, diameter of the orchestra) and sound measurements performed in situ by the Department of Energy of the Politecnico di Torino on 5th-7th September 2015. [8] The measured background noise of the theatre positioned in the middle of a natural ambient was found to be 35 dB(A).

As far as the main performance of the theatre is concerned, the current research focalized on speech requirements in order to be coherent with its historical background. Accordingly, the considered vocal effort by the actor was set at 78 dB at 1m distance (ISO 9921) and the maximum delay of the reflected rays at 35 ms in order to facilitate both hearing and understanding. [3], [7]

Having inserted the above mentioned data into the model, three types of variables were tested:

a) The architectural layout of the theatre (three different configurations of the theatre: only direct sound, direct sound and orchestra reflection, direct sound plus orchestra and scenery reflections). From the "*Only direct*" configuration (without stage building and with a covered orchestra) to a "*Final scenery"* configuration (with a free and reflective orchestra and a narrow stage building), the number of the image sources increased significantly. In particular, the process started from the "*Only direct sound*" case with no reflective surfaces and continued by adding progressively architectural elements: such as the orchestra (+1 image sources) and

the reflection of the background wall combined with the floor of the scenery (+4 image sources)
b) Position of the spectator. In total, calculations were made for eighteen (18) different positions in the amphitheatre (three (3) different rows in six (6) different *kerkides-cunei).*
c) Position of the actor (three (3) different points placed in two (2) different levels on the central axis of the theatre).

3.2 Procedure

Introducing the geometrical data from the theatre of Tyndaris in the formula (2.1) the missing value of different architectural elements was determined.

The first step was the definition of the height of the *proscenium* level. The calculations revealed that by increasing the height, the audition angle ε decreases and so does the acoustic and visual comfort. Furthermore, as it was showed by the calculations the minimum angle ε (4^o), that could be accepted, corresponded to a 4.10 m height which was effectively the level of the *logeion* in the Hellenistic scene. Based on these results the height of the scene (1,80 m.) was finally defined as corresponding to a 6^o audition angle.

The second geometrical function (3.1) aimed to eliminate the possible echo coming from the orchestra. Through the Image-Source method and the similarity of the triangles OCD, SOA and SOA, SS'B, the difference between the direct and the reflected from the orchestra ray, was calculated.

$$d = (S'C - SC) = S'B = 2h\sin\beta \tag{3.1}$$

$$d = 2h\left(\frac{H}{\sqrt{D^2 + H^2}}\right) \tag{3.2}$$

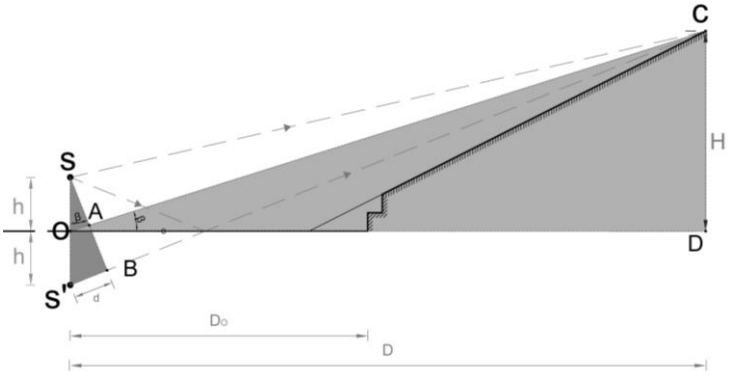

Figure 3.1: Section of the theatre of Tyndaris presenting the variables considered in function 3.1, 3.2

The delay and the final gain of the arriving reflections at the top of the amphitheatre (C worst situation) were calculated (0.4 dB). Applying the laws of the sound propagation, in this case, the addition of the direct and the reflection rays increase the global sound by 3dB.

Subsequently, through the third geometrical function (3.3) the depth of the *proscenium* level was determined. The background wall of the *proscenium* used to play a fundamental role in the acoustic performance of the ancient theatres. Combined to the orchestra level (horizontal), the background wall of the scene building (vertical) constitute the two main sound mirrors of the ancient theatre.

Thus, applying once more the Image-Source method and inserting in the formula the maximum acceptable delay between the direct and reflected sound, the maximum acceptable depth of the scene was calculated (6.5m). Noticed that by decreasing the depth of the proscenium level, the distance between the source and its image sources decreases, and so does the delay of the reflected rays, the final proposed depth of the scene (3,5m) was set at the half of the boundary value calculated above.

$$\Delta t = \frac{d}{c} \approx \frac{[2(P-X)\cos\beta]}{c} \tag{3.3}$$

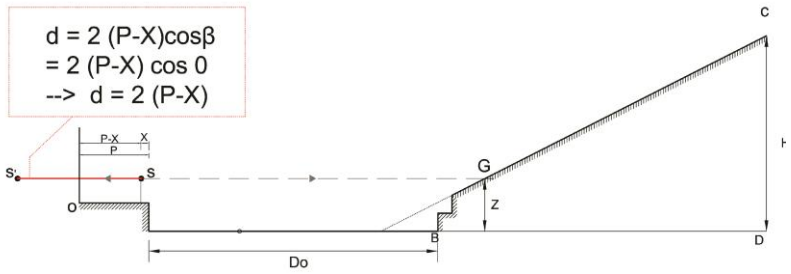

Figure 3.2: Section of the theatre of Tyndaris presenting the variables considered in function 3.3

Finally, a comparison between the contributions of the horizontal sound "mirror" of the orchestra and the vertical sound "mirror" of the *proscenium* back wall was conducted. A 3dB sound increase originated from the orchestra instead of 1.5 dB from the *proscenium* wall underlined further the importance of the orchestra. [4]

Table 3.1 Results

Configuration	First positions [dB]	Last positions [dB]	Divergence (first to last row) [dB]	Raising [dB]	Contribution [dB]
1) Only Direct	51,1 ~ 53,2	45,7 ~ 46,7	6	10,7	-
2) Direct + Orchestra	55 ~ 56,2	48,7 ~ 49,7	6	13,7	3
3) Direct + Orchestra + Scenography	56 ~ 58,3	51,2 ~ 52.9	5	16,2	5,5

3.3 Results

According to the geometrical characteristics of the ancient theatre of Tyndaris the above analysis provided the boundary values and guide lines regarding the basic architectural elements of the scenery. In particular, the height and the depth of the *proscenium* were defined in order to avoid the risk of sound absorption from the spectator's body. Subsequently, using excel files, the acoustic behavior of the whole scenery as well as of each single element were calculated, in order to assess the final effective acoustical function.

The calculations showed that compared to the "*Only direct sound"* configuration, the "Direct + Orchestra + *Scenography"* configuration presented a gain of 5,5 dB. Furthermore, minor divergences (first to last row) (-1 dB) between the sound intensities were noticed after the insertion of the scenery. In fact, a more homogeneous sound distribution was obtained. The results of this part are represented via iso-phonic curves (Figure 3.3) [4]

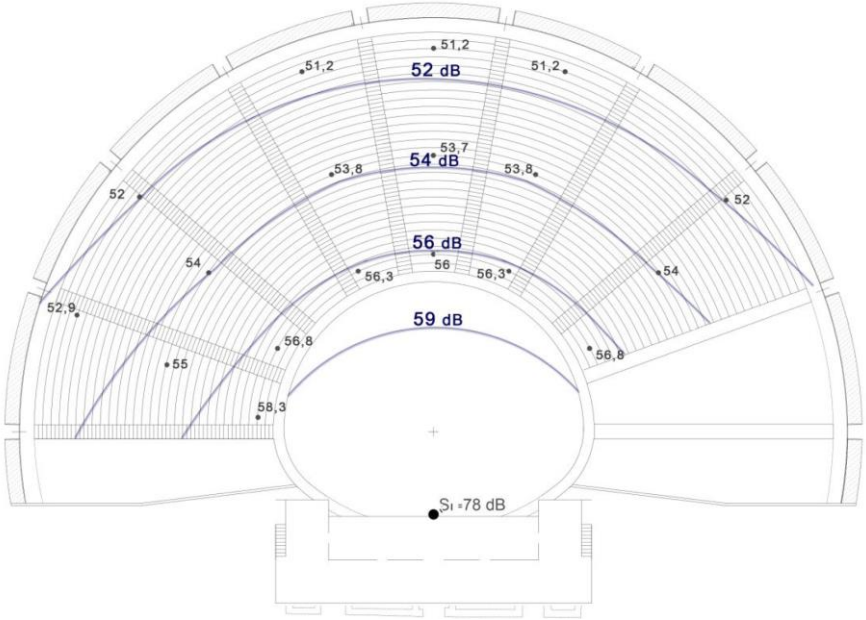

Figure 3.3: Plan presenting through iso-phonic curves the distribution of the direct sound together with the reflections from the orchestra and the final scenery layout.

4. Conclusions

The purpose of the current study was to propose a proper method for the design of contemporary scenery in ancient open-air theatres. After a brief historical review, we defined the most appropriate type of scenery for the theatre in Tyndaris. Specifically, the dimensions and the positions of the scenic elements based on Fr. Canac's study were calculated and the final scenery proposal was tested and validated by means of a geometrical model.

It can be asserted that with the *proscenium* in the lowest level the listening angle is more than 4^o, useful to ensure the acoustic as well as the visual comfort of the spectators. By doubling the height of the *proscenium* level in the theatre of Tyndaris, the value of ε would be less than 4^o. Thus, the majority of the reflected contribution from the orchestra will be absorbed by the bodies of the audience.

Following that, in speech performances the most appropriate choice is a scenography with a low and narrow *proscenium*. A higher and deeper scene could be proved more appropriate in musical performances, where larger delay and greater sound diffusion is sought.

Finally, the research proved that drama performances could not be held in the theatre of Tyndaris, unless strategies of passive acoustics are applied. The proper design of a temporary and reversible stage set enables the restitution of the natural acoustic capacity of the theatrical space.

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