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3pNSc17. Acoustic characterization of three archeological sites in the state of Guanajuato, Mexico

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The present work shows the results obtained in collaboration with the government of the state of Guanajuato in Mexico in a project that looked to include the acoustical analysis of Archaeological sites as a tool for gathering information regarding the historical social use of the areas in question. To that end, the acoustical characterization of 3 archaeological sites recently opened to the public in the state was in order: Cañada de la Virgen, Peralta and Plazuelas. Results include the 3D modeling of the areas of interest and the simulation of the acoustic response of them using the software EASE. Specific acoustic parameters were extracted from the simulations and then analyzed in comparison to archeological hypothesis of the use of such spaces as areas of public appearances, performance, ethno-musicological reports on the type and use of musical instruments and other archaeological findings in the area in order to support or disprove such hypothesis.

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INTRODUCTION

Recently, the Institute of Culture of the State of Guanajuato (Mexico) reached out to several Mexican Education Institutions and Universities to start a interdisciplinary project for the research and recovery of the *acoustic dimension* of the archaeological sites just opened to the public in the state of Guanajuato: Peralta, Cañada de la Virgen, Plazuelas, and El Coporo. The project seeks to identify, retrieve, understand and reassess the sound spaces of the archaeological sites and the various tools and resources to generate sounds found in the surrounding areas. Special emphasis is put on those instances on which the sound is culturally significant, identifying, characterizing, and analyzing the main cultural expressions that generate specific social relations, such as the use of certain musical instruments, language and linguistics, the use of spaces and public places for auditory demonstrations and performances, among others. In particular, it seeks to shed light on the use of the *sunken courts* (*patios hundidos*), characteristic of the region's sites through the development of 3D acoustic models of the spaces. The hypotheses regarding the uses of public spaces and of instruments for sound generation could be further sustained by their acoustical analysis. Preliminary results for the sites of Peralta and Cañada de la Virgen have been obtained and are hereby presented.

Cultural tradition in Guanajuato

Considered the marginal part of Mesoamerica, Guanajuato had very different characteristics from the rest of this vast cultural area. The confluence of cultures of Guanajuato with those of the territory called "The Tunal Grande" (northwest of the state, along with the southwest corner of San Luis Potosi, Zacatecas and southeastern part of the highlands of Jalisco), has allowed researchers to identify the differences and similarities between the sites studied in this research during the Classic and Post-classic periods.

Being predominantly agricultural societies, the ancient peoples of the region were strongly linked to the worship of the earth. The festivities were established as a part of the calendar cycles and with these practices the community tried to influence the will of the gods to achieve its benefits and get rid of their negative effects. They also tried to contribute to the continuity of the world, driving the ongoing land cycles through music, songs, dances, rituals, prayers, penances and representations of the gods. An example of these rituals is the traditional flying dance. The use of the sunken courts, the practice of the ballgame, the cult to agricultural deities and rituals of a multitudinous nature, make it clear that these four settlements had common elements to each other and that they can be compared in many levels.

Sunken Courts in Guanajuato

The use of sunken courts (spaces built on a platform that makes them look "sunken" in relation to the sidewalk that limits them and not the surrounding ground level) has been recurrent in the tradition of the Bajio. These areas had a strong ideological importance because they related to the conception that people had about the world and countless ritual practices that focused on the cult of the earth.

It is the opinion of the archaeologist that have worked on the sites, that the sunken courts housed a large number of attendees who watched the rituals from the walls that functioned as boxes. The basic construction consists of a platform that encloses one or more sunken courts of which one or several pyramidal bases uproots. To access the buildings in this type of construction it is necessary to climb a ladder, which distinguishes them from the more common patios that are accessed by alleys (Nalda, 2008). According to the archaeologists, these buildings suggest a highly stratified and hierarchical culture. The architecture of the sunken courts is of great interest since the ability to modify the sound field is largely due to the acoustic qualities of the boundaries that conform the space.

Archaeological sites of interest: Cañada de la Virgen and Peralta

The following Guanajuato state map indicates the location of the four sites of archaeological interest.



FIGURE 1. Map of the state of Guanajuato and the locations of the most important archaeological sites within the state. Extracted from the State Institute of Culture (IEC) website.

Peralta: vestige of identity and monumentality

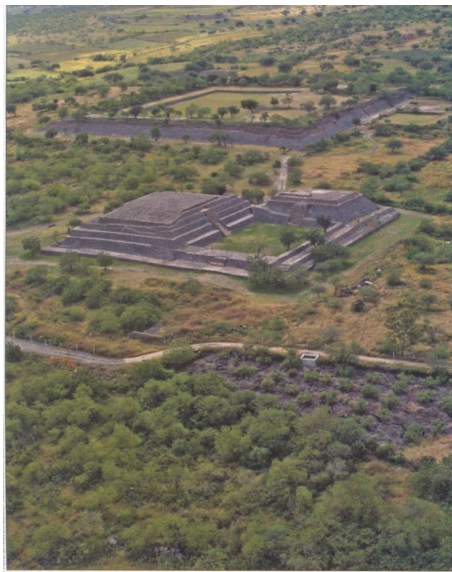


FIGURE 2. Peralta. Picture taken from INAH (National Institute of History and Anthropology) archive.

The archaeological site known as Peralta is located in the southwest of the state of Guanajuato, on the side of the hill of Peralta. It sizes 20 hectares of fertile land. Many centuries before, between the years 300-700 of our era, it served as a ritual space for the culture or tradition of the Bajío (Cárdenas, 2008). Of the 174 sites comprising the Tradition of the Bajío, Peralta is the largest, presenting monumental type architecture. Its buildings include the buildings Double Temple and Sunken Court and the Governors enclosure (*Recinto de los Gobernantes*). The Governors enclosure is the largest architectural element and it is thought it was a space for holding public events and the place of residence of the ruling class, as indicated by burials and offerings found (Cárdenas, 2008). It has a rectangular plant of 147 by 130 m base, and it is 12 meters high. Located at the upper area is the circular building where the flying dance ritual took place.

Cañada de la Virgen: a place for Astronomy



FIGURE 3. *Casa de los 13 Cielos*, sunken court and pyramid. Image of the authors.

Cañada de la Virgen can be found within 30 miles of San Miguel de Allende in a privileged position from which it visually dominated the central basin of the Laja River, indicating its ritual importance and defensive placing (Zepeda, 2008). The buildings here are a good example of the Mesoamerican architectural pattern: its symmetry axis is directed to the rising and setting of the sun and moon. As in other archaeological examples, its construction took three stages from 540 to 1050 of our era. The heyday of Cañada de la Virgen took place between the years of 600 and 900.

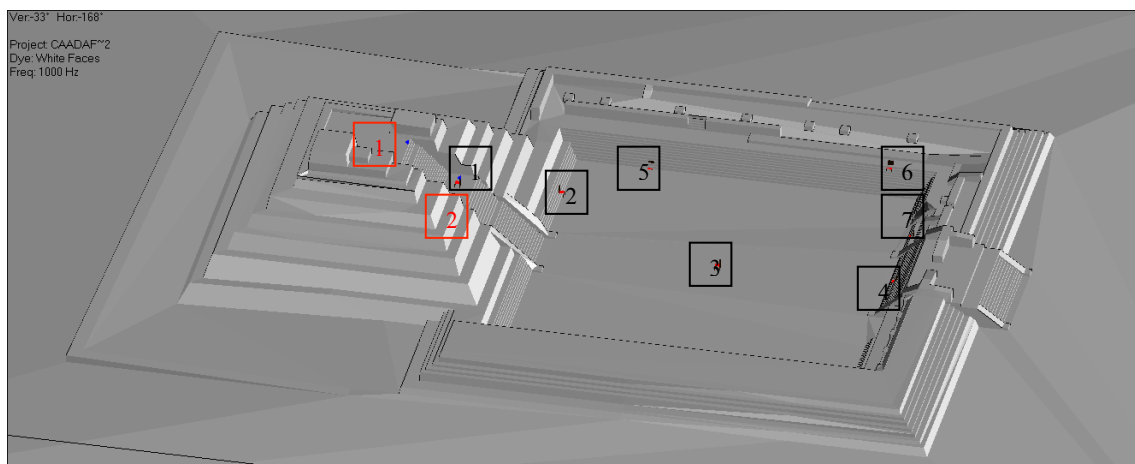
Cañada de la Virgen is comprised of closely related architectonic complexes. The most outstanding construction is the Complex "A" or House of the Thirteen Heavens (*Casa de los 13 Cielos*), a space for celestial observation that integrates the sunken courtyard, the pyramidal base (which exceeds the height of 15 meters), and platforms that close to the east, north and south of this ceremonial complex. The more relevant features of this site are the steps placed at the three walls that enclose the sunken court.

ACOUSTIC MODELING OF THE SUNKEN PATIOS

As the first step in the acoustic characterization of the spaces in question, three-dimensional models were created in order to recreate the sound field in such spaces. Such models were originally created using the AutoCAD architectural software, and then exported to EASE from which a list of specific acoustic parameters was retrieved. Such parameters included: RT time (Eyring), Direct Sound Pressure Level, Total Sound Pressure Level, Arrival time, C50, C80, Sound Transmission Index (STI) and Percentage of Articulation Loss (Alcons). Also, a ray analysis was performed.

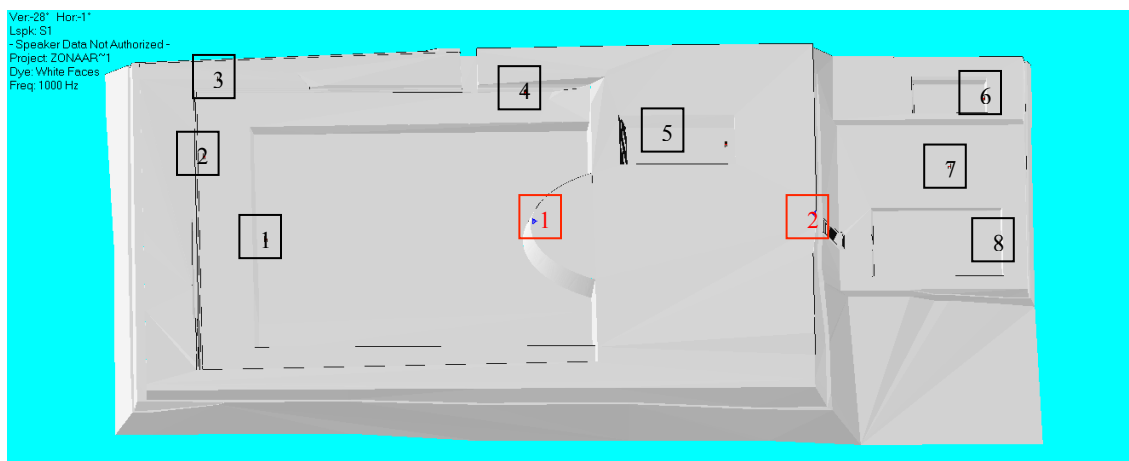
Source and receiver positioning on 3D modeling of Sunken Courts: Cañada de la Virgen and Peralta

The placing of sources and receivers was selected according to the information gathered from historical, archaeological, and anthropological documents in which hypothesis regarding the activities that took place in the sites are proposed. Assuming a hierarchical society, presumably the source of sound would be placed on the top of the pyramids or structures above the public that would in turn be placed around the sunken courts. Since the equipment for the *in situ* acoustical characterization of the sunken courts has not yet been acquired (i.e. measurement microphones, omnidirectional source etc.), the results of the simulations obtained by this study will be compared at a second stage with the experimental results. The source used for the simulations was omnidirectional at an average sound pressure level of 96.78 dB and 100 W. All the simulations were carried under normal conditions of temperature and humidity (20°C and 50% humidity)



(c) EASE 4.3 / Cañada Cañada de la virgen close / 04/11/2012 16:30:09 / F.F.I.I. David Ibarra

FIGURE 4. Positioning of sources and receivers at the “*Casa de los 13 cielos*” in Cañada de la Virgen. Receivers (7) marked by a black square, and sources (2) by a red square.



(c) EASE 4.3 / Peralta Peralta / 19/11/2012 21:26:33 / F.F.I.I. David Ibarra

FIGURE 5. Positioning of sources and receivers at the “*Recinto de los Gobernantes*” in Peralta. Receivers (8) marked by a black square, and sources (2) by a red square.

Results analysis of 3D acoustical modeling of Peralta and Cañada de la Virgen

Cañada de la Virgen: RT (Eyring)

Considering an acceptable reverberation time for speech and music to fall between 0.6 and 1.5 seconds, the reverberation time of the “Casa de los 13 Cielos” is on the low side, particularly between 1 kHz and 8 kHz (below 0.20 s), with the lowest at 4kHz (0.10 s).

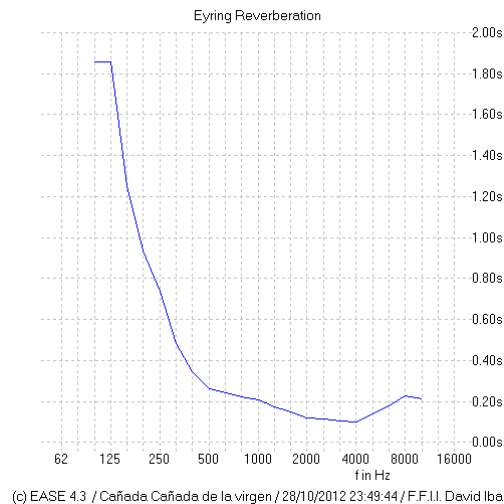


FIGURE 6. RT Cañada de la Virgen

Cañada de la Virgen: Source 1 and 2¹

For Source 1, the direct sound pressure level and the total pressure level is about 60 dB or higher up to 4 kHz in the receivers 1, 3, 4, 5, 6 and 7, and no signal is perceived in the receiver 2. The arrival time ranges between 77 ms for the closest receiver (not considering the one on the stairs) and 160 ms to the farthest. The C50 parameter establishes a good Intelligibility for frequencies from 250 Hz and higher, falling for the receiver number 2. The articulation loss was unacceptable only for the receiver 2, and very low for all other receivers. Also the sound transmission index fails for the receiver number 2 and it is above 0.85% for all others. The space is ideal for percussion instruments with lower fundamental frequency of 250 Hz or lower, but not very good for other type of instruments such as flutes or whistles. It is, albeit a little dry, acceptable for speech. Ray analysis shows an interesting pattern forming at the stairs. For Source 2, the results are analogous to those of the source 1. In receiver 2 the conditions improve a little, but the articulation loss is still large and the sound transmission index rather small.

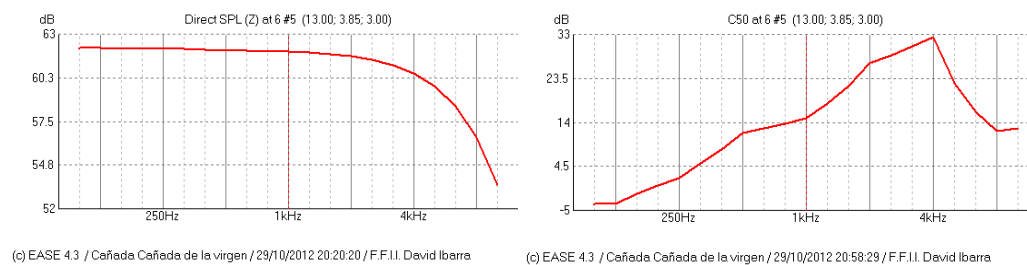


FIGURE 7. Direct SPL (a) and C50 (b) graphs for source 1 at receiver 6, Cañada de la Virgen.

¹ Fort the sake of economy of space, only some of the graphic results are showed on these sections.

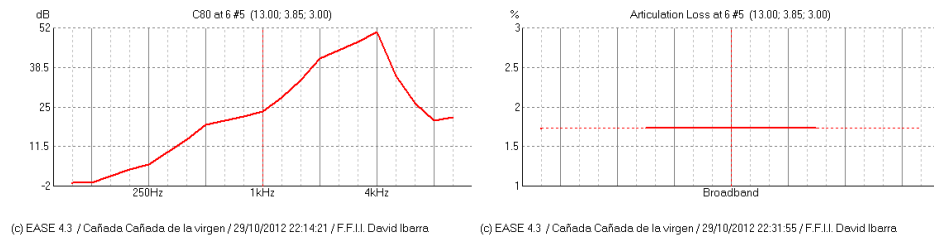


FIGURE 8. C80 (a) and Alcons (b) graphs for source 1 at receiver 6, Cañada de la Virgen.

Peralta: RT (Eyring)

The reverberation time of the “*Recinto de los Gobernantes*” and the sunken court adjacent to it fall well within the interval established as acceptable for speech and music for this work (0.6 s – 1.5 s), the lowest not being to far down from 0.6 s at 4kHz.

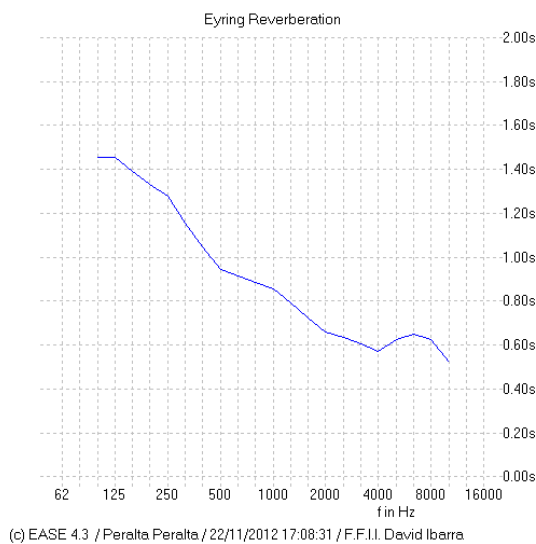


FIGURE 9. RT Peralta

Peralta: Source 1

For source 1, the total sound pressure level for the receivers 1 to 4, is above 60 dB up to 4 kHz; and the direct sound pressure level, for receiving 1 to 4 is maintained between 55 dB and 60 dB up to 4 kHz. No signal is detected in the 5 to 8 (receivers at the back and out of the platform). The arrival time is between 220 ms and 330 ms, for receivers were there is actual signal coming in. There intelligibility (C50) is acceptable from approximately 300 Hz and above in all receivers. The articulation loss is always less than 3% and the sound is transmission index is above 0.75 in all recipients of 1 to 4, but falls to 0 in receivers 5 through 8. From the C80, we can deduce that the large sunken patio is ideal for wind instruments with fundamental frequency of less than 300 Hz and above 100 Hz, and for percussion instruments with fundamental frequency no greater than 500 Hz. Ray analysis shows an interesting reflection pattern generated within the small sunken courtyard on the “*Recinto de los Gobernantes*”.

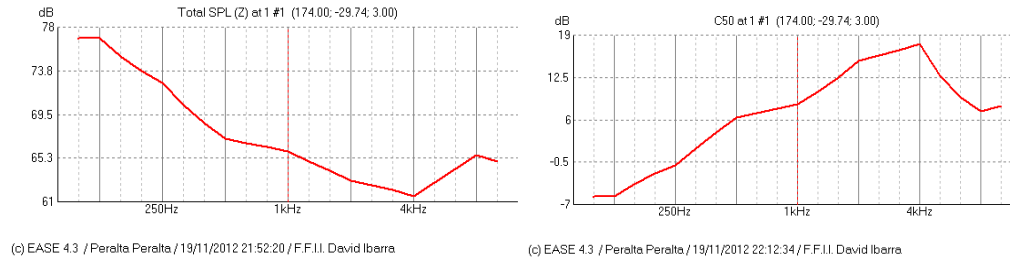


FIGURE 10. Total SPL (a) and C50 (b) graphs for source 1 at receiver 1, Peralta.

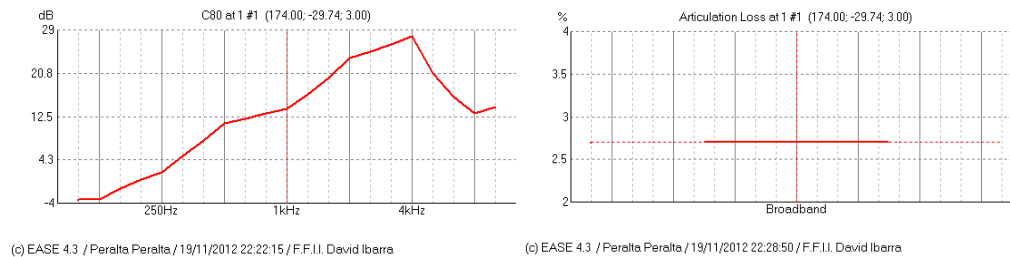


FIGURE 11. C80 (a) and Alcons (b) graphs for source 1 at receiver 1, Peralta.

Peralta: Source 2

The total sound pressure level (SPL) in receivers 1-4 is above 60 dB up to 2kHz, and always above 60 dB in receivers 5-8. The direct sound pressure level is 0 at the receivers 1, 4 and 5 and between 47 dB and 54 dB for frequencies up to 4 kHz in the receivers 2 and 3, while for receivers 6 to 8 is about 60 dB. The arrival time is between 140 ms and 480 ms. Intelligibility (by parameter C50) is very good for frequencies above 250 Hz. The articulation loss is total for the receivers 1, 4 and 5 and very small in the receivers 2, 3, 6, 7 and 8. The sound transmission index (STI) is excellent in the receivers 2, 3, 6, 7 and 8 and unacceptable for 1, 4 and 5. According to the parameter C80, source 2 is a good place for percussion instruments with lower fundamental frequency of 500 Hz. Ray analysis shows again the interesting pattern generated within the small sunken courtyard on the “*Recinto de los Gobernantes*”.

Conclusions

The preliminary results of this work have helped reinforce the theories that archaeologist have proposed regarding the use of the sunken courts in the state of Guanajuato. In the case of *Cañada de la Virgen*, it can be seen that although a low reverberation time is showed, there is still reasonable intelligibility for word showed by C50, STI and Alcons results. Only for receiver marked as 2, is there a considerable loss of intelligibility, but there is also loss of sight of the top of the pyramid due to being in both the light and acoustic shade of the building. Results show therefore that the walls of the sunken court could have been used for spoken word messages and rituals, except for the zone located at the acoustic shade of the building. Results for C80 and reverberation time favor neither the use of wind musical instruments nor the use of percussions in the area. This result, along with the fact that no musical instruments were found on the site, suggests that the type of rituals or events that took place in such area were not of musical nature.

For the case of Peralta, we find that regardless of the monumental size of the sunken court, provided that the level of the sound source is high enough, it would reach at an optimal level the areas that surround it with good or great intelligibility. However, previous results show that for the case of listeners situated inside the sunken area, the sound level would be less than desirable. This is consistent with the archaeological and historical finding that ensure that such an area was mainly used as a market place and not as a gathering area for listening or involving in public. The C80 parameter shows that the area favors the use of percussion and wind instruments of low fundamental frequency. This is of particular relevance since several wind instruments such as the seashell; ocarinas and whistles have been found in the area and are kept in the Plazuelas site museum. The analysis of such instruments shows that in particular the seashells fall well within the obtained parameters of this study for optimal musical intelligibility.

Another important issue that should be brought up is the fact that nowadays the traditional *flying dance* is performed in some areas of Mexico using both flutes and percussion. The fact that it is Peralta where some evidence is showed for the practice of such dance, in conjunction with the findings of this work lead us to believe that perhaps the space was altered or even design to accommodate such activities, ranking such space high up in the intentionality scale. Also, the ray patterns that conform at the small upper sunken court of the *Recinto de los Gobernantes* (placed at a privileged site for watching the *flying dance*) may suggest that such sunken court is in fact were the leaders would gather also for listening to such a dance in a privileged fashion. We would have to consider the fact that for the receiver placed inside this area (number 5), the total and direct SPL is in fact less than desirable, as well as the intelligibility for both sources. However, the placing of the sources was on the ground and not way above on the top of the stick from which dancers would descend so the possibility remains open. Nevertheless, further work is needed since characterization of percussion instruments found in the area is still missing and the comparison with the experimental results has yet to be performed.

ACKNOWLEDGMENTS

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