OPEN-AIR ARCHAEOLOGICAL SHELTERS: PRECEDENTS, TYPES & SYSTEMS

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ABSTRACT

The present paper was studied in three parts. The first part includes a comparative study of certain existing shelters for archaeological sites based on componential systems through literature research and observation. Examples such as a temporary reciprocal shelter in France and a permanent set of timber arched shelters in Greece indicate the case study precedents. Secondly this study develops a rational process that could apply solid parameters for designing such as shelter. Aspects such as reversibility, modularity, flexibility and adjustability indicate different results in terms of deciding on shelter structural and material properties. And finally, the paper develops a new integrated component system. Then, the result is that the ideal system is a-sophisticated combination of geometry, structural type & materials based on the aforementioned criteria such as the notion of lifetime duration.

KEYWORDS: *shelter, modularity, flexibility, structure, membrane*

I. INTRODUCTION

The paper addresses the serious issue of the preservation of heritage and more specifically the topic of sheltering archaeological sites, either temporarily or permanently.[1] 1 It is therefore presented and discussed that building possibilities for archaeological shelters vary as the sites share few characteristics in common. There is the optimal option that a shelter can be properly designed to be installed during the excavation procedure, and not afterwards as is the usual practice. Obviously, this is a case that enables the heritage specialists in their investigation and most of all ensures the preservation of sites themselves. For the architects and designers this possibility comes to be very intriguing in terms of creating the best possible result in an interesting and smartly designed protective structure.

The paper examines certain case study projects, representative of their region, which serve either as temporary or permanent protection. The shelters for archaeological heritage sites of monumental value in the Mediterranean and European context is the main focus that limits the shelters more to an open-air type.

The main research question that drives this paper is based on the main question of how to create an innovative and modular componential system for a protective shelter in order to respond on various contexts, which can be assembled on various sites for a considerable time period and which will function as either a transitional or permanent archaeological shelter. Therefore, the thematic focus – and technical question - is based on built precedents in order to find which is the ideal system(s), with various spans and variations as a combination of structure and envelope, for a modular and flexible archaeological shelter installation?

II. METHOD

2.1 Literature research

The method followed for the realization of this research paper in a major extent from literature research in the existing bibliography and the most recent publications in academia (papers and articles). The nature of the topic drives towards the literature research in quest for precedents and existing and realized examples of shelters. Also, in the future and in a further stage of a project, the results of this research should inform as primary principles for a systematic research by design. Therefore, the paper investigates what is already found and applied by others in similar or corresponding cases of different architectural and scientific research fields.

2.2 Comparative study

Through a comparative study based on matrix diagrams and schemes, the according case studies are compared based on the predefined criteria. The process follows as the comparative analysis per parameter is judged in terms of positive and negative points-aspects. As a result, the end result method comes is the analysis of every parameter per criteria through observation and comparison.

III. Criteria definition

3.1 Main functional aspects

The main functional criteria for a shelter architectural project should be are the protective capabilities. The primary reason of their installation is the protection of sites from the climate condition that usually deteriorate immovable findings in excavations. Therefore, the matter of drainage (directing the rainfall away from site) is the primary issue. Of course, the climate regulation below the shelter, (sun shading, luminance, natural lightning, air flow, moisture condensation). The technical aspect embodies the architectural (geometry) - structural logic, the structural material, and the covering material and the cost. All the positive properties that have to respond at the needs/brief. In addition, the structural stability and the behavior against sidewind and upward wind forces is also an important aspect which is behavior which is also dependent to volume and shape.

3.2 Specific aspects

The lifetime duration and mission are crucial. Even the archaeological shelters that are considered permanent have a maximum 30-year lifespan. The principle of reversibility that of returning the monument in a former state undamaged is the main guiding force. Therefore, a temporary shelter is usually something that has a short duration and is rather low quality. For that reason, the idea-criteria of a transitional structure that can be used multiple times (not exactly temporary nor permanent) drives this research. On the other side, based on a wide range of criteria that can differ per context; aspects such as:

- adaptability (adjustable supports/columns on different terrain inclination or by archaeological restrictions, ability to change the location of some central supports, to be able to transform, grow bigger around the excavation),
- modularity (system of components that can produce variations in sizes and shapes),
- flexibility (transportation, possibility of displacement, non-binding foundation or column positions, simple erection, (dis) assembly by non-specialized group, reuse at new site),
- reversibility (foundation in tensile structures means either heavy ballasts/digs for counterbalance),

The final specifications for sheltering structures must go together with the recording and evaluation of problems that may have appeared up to the date in the specific context (of Greece) while taking into consideration the international experience.[2]

IV. Case Studies

4.1 Archaeological Shelter at Bibracte, France

Figure 1,2. Archaeological shelter at Bibracte, France. Exterior view with the black ballasts. Interior view of the excavation site and the scaffolding corridor for the visitors.

The first case study is a French excavation shelter at Bibracte, in the mountain of Saint-Léger-sous-Beuvray, province of Burgundy.[3] French architect Paul Andreu, and the engineers Bernard Vaudeville and Simon Aubry (RFR, today called T/E/S/S)[4] have created a rare prototype for an archaeological excavation which was conceived in a 2003 competition. It was designed between 2005 and 2008 and built in 2008-2009. Due to the altitude, the climate condition to respond is that of rainfalls and snowfalls.

It falls into the category of a 'temporary', membrane (fabric) structure. Also, its system is mixed in both categories of tensile structures covering and steel grid, post-beam structure. The innovative element of the shelter is found in its overall sophisticated covering structure which is based on the system of nexorades.[5] The nexorade[6] is a rather new and rare geometrical and structural logic that originates from the reciprocal architectural scheme[7], based on the reciprocal frame architecture.[8] The basic module is a triangular element composed of aluminum tubes and castings, 3.75m long.

The ground surface of the excavation is 850 m^2 with 300 m^2 extensions in the perimeter of the existing. It is consisted from 35 peripheral aluminum columns with diameter of 200mm and 183 tubular beams with diameter of 120mm, length 3,75m and height 0,95mm. Each beam weights 43 kg.[9] The roof covering consists of a membrane surface of 946 m^2. The material is coated fiberglass fabric with has been treated accordingly with waterproofing and sun protection [PVDF][10]. On the sides there are removable vertical textile elements that help to regulate the inner climate (wind, air flow). The foundations are reversible since that all the columns rest upon a horizontal double rail-frame that is found on gabions filled with rubble rocks. The cost of the engineering and production of its 2,000 m^2 surface elements has been calculated (excluding installation costs) to about 500 €/m^2. About its erection, the scaffolding to reach the nexorades is made upon an erection stage with corrugated metal sheets that covers the remains along with the application of temporary cables (tension) and polls (compression). The stability of the nexorade is assured only when all of the columns are erected.[11]

The positive attributes of the shelter are numerous. The fact that the design has responded to the initial criteria of reversibility and modularity is positive. With its non-installation of conventional foundations beneath there isn't any future ground destruction. Finally, about its life span and timeframe of installation, the shelter is still serving its purpose till today already reaching a 10-yeat lifetime. The design choices of the engineers have allowed a reversible foundation system, a simplified erection process and economy in terms of scale.[12] The theoretical principle of the nexorade has defined the structural layout which consequently was successfully fabricated and erected, in the application of a real project. Whereas, the architecture of the shelter is truly temporary and reversible with significant durability and efficiency.

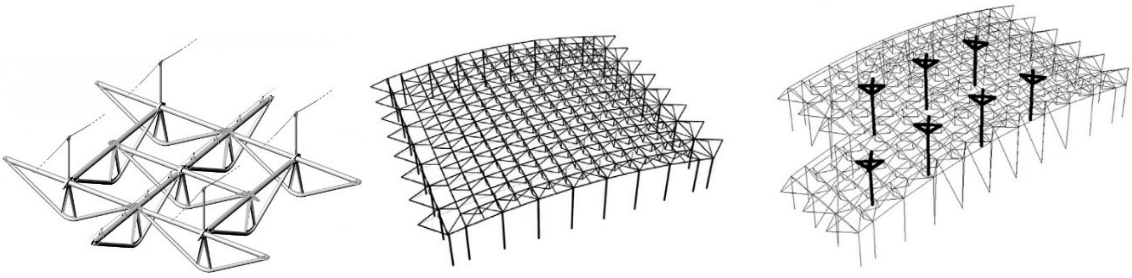
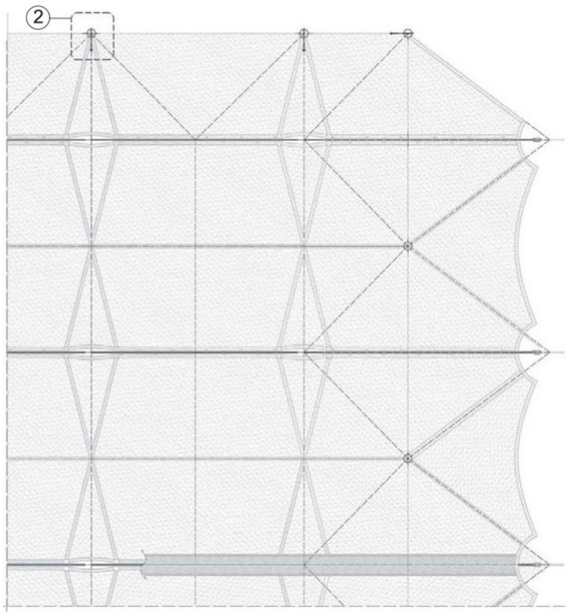


Figure 2. The nexorade module and the repetitional grid with variations applied as a shelter structure.

The extra columns in the middle compensate the snow load.



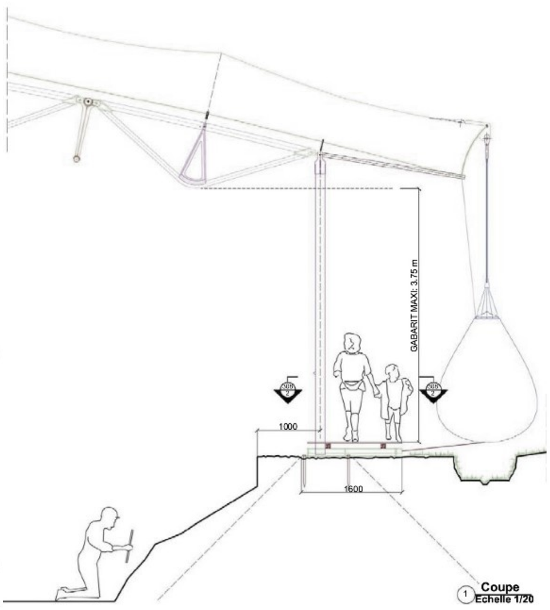


Figure 3. Plan of the fabric covering with the cables.

Figure 4. Cross Section of the shelter with the excavation.

4.2 Archaeological Shelter Malia, Greece

Figure 5,7. Archaeological shelter Malia, Greece, site plan and aerial view of the site, the uncovered palace and the white shelters.

Another case study is the shelters of the archaeological site of the Minoan palace and settlement in Malia, Crete. Located near the sea, the shelters were designed in 1989 and constructed in 1990, following the masterplan of 1985.[13] The masterplan proposed essentially the management and enhancement of the central zone of the archaeological site that includes the palace, the surrounding remains northeast of the palace (the districts of Zeta, Kappa, Delta and Mu, the agora and the crypt), with an approximately a surface of around 45.000 m^2.[14]

All the structures are designed in the structural logic of parallel two-dimensional arches as primary loadbearing structure that is fixed away from the remains while forming barrel vault shapes. The sheltering structures are constructed by GLT (glue laminated timber). The secondary vertical substructure is also in timber along with galvanized steel joints and connectors, ending with white polycarbonate panels as roof covering. The arches rely on foundations which are reinforced concrete pads, always installed away, on the periphery and outside the limit of the monumental remains.

The GLT curved beams allow the covering the large span without any intermediate supports while avoiding to harm the monumental remains below the roof. The color of the wood is in harmony with the dominant colors of the site. Also, the timber is by default very resistant and durable against the salty winds (proximity to the sea) than any other structural material. The secondary structure is also timber cover fixed on the structure consists of translucent double-faceted polycarbonate sheets. [15] In order to assure an effective protection of the monumental ruins from the rain, the coverings substantially overflows the surfaces to be protected. All structures are adapted to every monument. In 2013 there has been a series of repairs and reinforcement with steel brackets to the columns.[16]

The largest shelter (west) is formed by different size barrel vaults and a small additional vertical to the side protecting the 'Quarter Mu' which is the cemetery. The vaults' direction follows the main direction of the ancient walls below. The expression is contemporary as the vaulted volumes are not reminiscent of any Minoan architectural elements. The curvilinear structures that were adapted in each particular case are either supported on vertical columns (only on the East shops/magazines' site) or reformed to themselves (to the Crypt and the Quartier Mu). Their shape can be considered as mimicking the curves of the surrounding mountains.

In the shops east of the palace (covered surface: 413 m^2), the structure is consisted of 6 arches of 16.50 m length and span 12 meters, It relies on the vertical poles with an asymmetrical manner arranged outside and against the west and east walls of the magazines. With a west-east direction, these arches are arranged in the axis of the square pillars bordering the gap under which the visitors will have all the leisure, in the shade of the cover, to admire not only the shop remains but also the monumental architecture bordering the west, north and south sides of the central courtyard.

At the hypostyle crypt and at the adjoining shops (covered surface: 978 m^2), 9 parallel arches with direction north to south cover the remains. The in-between spacing of the columns varies from 4,80 m to 7,60 meters. The 4 of arches (span 20m) are cut off and supported on vertical columns whereas the other are founded normally in angle and away from the excavation. The rest 5 arches, are of 30 m span and cover the magazines with a quarter of a circle geometry in section. The supporting-foundations are implanted inside the soil each other on the ground.

At the quartier Mu, where the covered surface is 2.700 m^2, two large arches spanning 38 meters escalate in plan in order to sufficiently cover the whole site while extending above the part of Building A, B and part of D. The shelter is extended with smaller arches that protect the Ateliers and the Building E. These are supported in the large arches because are found in perpendicular direction to the main ones that cover the building C.

The visitors arrive below the shelters on the NE of the ateliers/workshops and follow the path towards the site's building remains. Bypassing the Ateliers and the Building B, the visitor is directed to the west can step in the middle of the Building A, on a suspended walkway in the middle of the shelter.

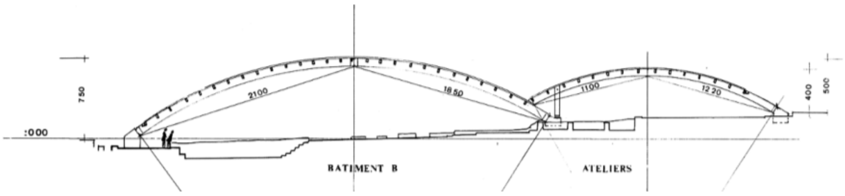


Figure 8. Archaeological shelter Malia, Greece. Section of shelter of Mu quarter.

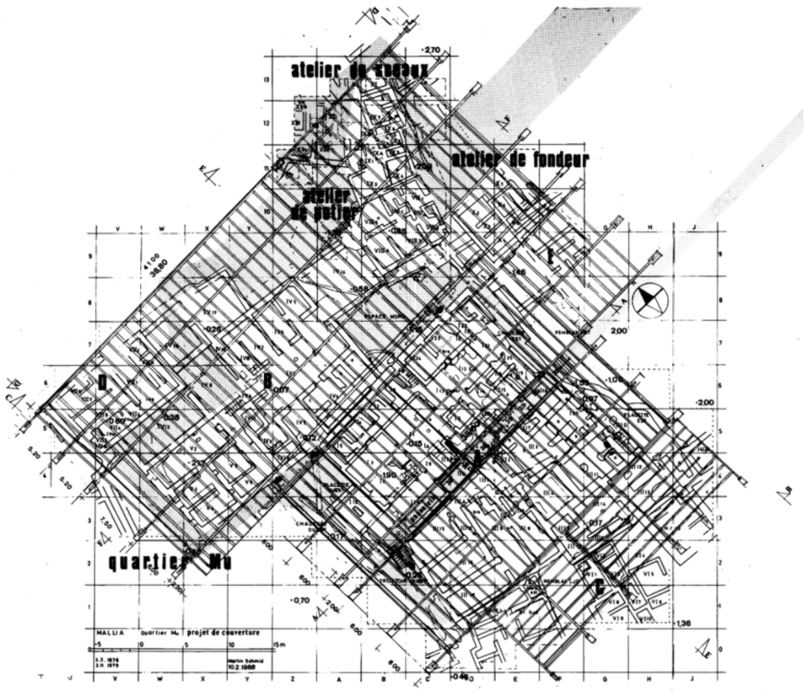


Figure 9. Plan of the covering of the Mu quarter.

4.3 Shelter in Cartagena, Spain

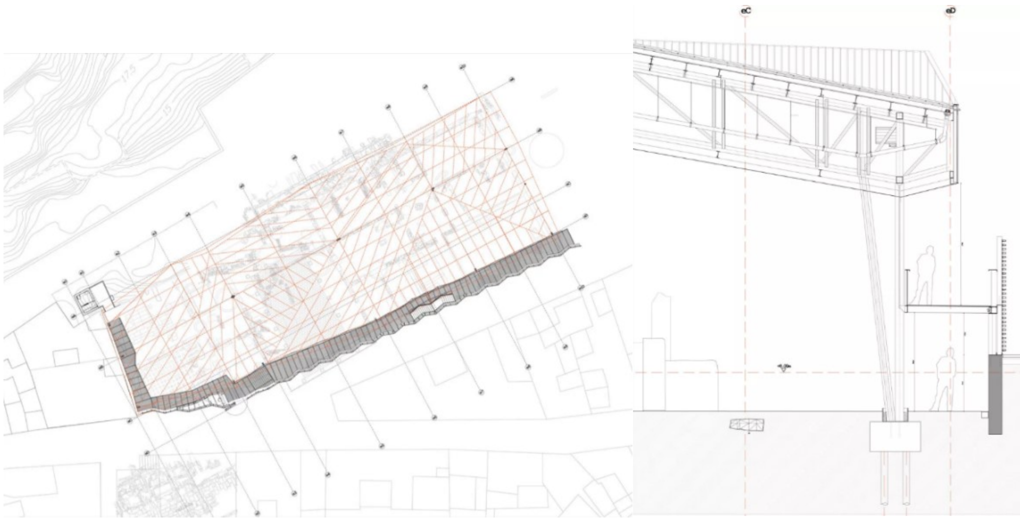


Figure 10. Canopy in Cartagena, Spain, Plan and Cross section of the roof.

Figure 11. Inner view of the canopy from the level of the visitor over the archaeological remains.

Designed by Amann, Cánovas & Maruri, the canopy protects the remains of a Roman ensemble (thermal baths, forum and domus) in the archaeological site of Molinete Park in Cartagena, Spain. The extreme aesthetic appearance of the cover is adding aesthetic value to the historic area of the city, whose main challenge is to reconcile very different architectures styles. It is an element of transition[17], between very diverse urban conditions: in size, material and structure. The primary goal of the work is to respect the existing remains, using a long-span structure that requires the least amount of support for lifting the roof covering. The intervention unifies all the remains in a single space, allowing a continuous perception of the whole site. The cover also generates a new urban facade in the partition wall. The project also pursues a sense of lightness and is conceived as an element that allows natural light penetration. Nevertheless, the roof structure is made by conventional steel profiles as a space-truss grid whereas, each column is a tree network of 3-4 sub-columns ending in a concrete foundation with piles. The inner layer is built with a modular system of corrugated multiwall translucent polycarbonate sheets and the outer is, constructed with perforated steel plates. The plates allow the light penetration and give the uniform exterior appearance. There is also an elevated walkway parallel to the street, also accessible to the disabled visitors. It is a very light structure suspended from the steel beams which offers general view over the restored roman remains.

4.4 Other shelters

Since the example of Malia is rather outdated, two contemporary examples in the Greek context are the new shelters in Orthi Petra archaeological site at Eleutherna in Crete (2013) and the new shelter for the palace of Nestor in Pylos, Messenia (2016) which has replaced a former one. Both shelters share the same principal barrel vault geometry. The Nestor palace architectural space is identical to Malia since both share the same principal geometry of parallel arches where the walking bridges of visitor are suspended from the beams. The main difference is that the roof structure is built in conventional H steel profiles and custom tube profile columns structure. The Orthi Petra open-air shelter in Eleutherna is an ancient *necropolis* (cemetery) and also it is an ongoing excavation-research site, an open-air museum, very similar to the Bibracte excavation. The characteristic of the site is that it is located in a slope so the inclined terrain has forced the roof design towards a 3-part roof in steps and ramps as routing bridges for the visitors.

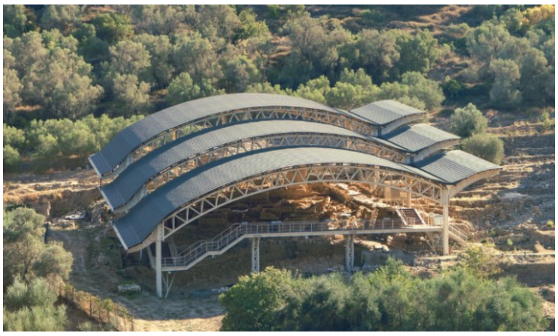


Figure 12,13. The Eleutherna shelter. Overall view and view below the roof.

Figure 13. Nestor palace shelter by night with the suspended corridors.

V. RESULTS

The comparative results of the case study shelters are visible on the Table 1. Since the comparison was limited to these three projects, it is profound that they have many differences. In general, the shelters of Malia have an average and low result in specific criteria (modularity/flexibility). Their best result is their durability, considering their location. On the other hand, the Cartagena shelter shows extreme differences either with very low or very high results. The very high architectural appearance constitutes the project as very significant. The quality, the aesthetics, the durability and its optical effect of the high roof structure constitutes it as an example of good civic architecture. However, in terms of efficiency and economy, it is the last one in the battle. Lastly, the Bibracte shelter in France has almost no negative aspect. The main and single one is the fact that it has a rather industrial, informal appearance. Its architectural value is based on the sophisticated structural concept which goes along with the design. Also, it is an ingenious example of an efficient structure which responds positively in terms of cost. Considering the specific criteria aforementioned, it is the one that seems to fulfill most of the criteria aspects.

Table 1. Criteria per case matrix

	Bibracte	**Malia**	**Cartagena**
Time	temporary	permanent	permanent
Durability	+	+++	++
users	Visitors & Specialists	Visitors & Specialists	visitors
Cover material	PVC fabric	Polycarbonate	Polycarbonate
Structure material	aluminum	timber	steel
structural logic	Mix of tensile & compressive	Mainly compression	Mainly compression
Roof structure	Nexorade / space grid	Arches / Barrel vault	Trusses / Space grid
Cover	fabric	polycarbonate	polycarbonate
Foundations/ reversibility	rails & ballasts +++	concrete pads +	concrete pillars --
columns	periphery	periphery	centre
cost	+	-	--
quality	++	+	+++
Aesthetics	+	++	+++
climate	++	++	++
modularity	+++	+	--
Flexibility /adaptability	+++	+	--

VI. CONCLUSIONS & DISCUSSION

The issue of protection and amelioration of working and visiting conditions of archaeological sites with the method of sheltering monumental ruins is an interesting challenge. The results based on the matrix comparison per each case study, geometry and materials show that the answer is not pointing only to one direction.-As referred above, the answer to the research question is that a temporary shelter for both visitors and specialists can exist with positive results and properties. The main issue to be addressed is the aesthetic. For example, the certain combination of aluminum and fabric constitutes the example as an ideal project that can surpass the usual structural thinking in a unique way. Therefore, the componential system of the nexorade is ideal for a reusable shelter. On the other hand, although the Cartagena shelter is more customized, the quality of the architecture contributes enough so that the idea of an enormous and hollow roof can work in parallel with the French structural philosophy. Last but not least, the Malia project showcase that a series of shelters/pavilion can be thought as the middle solution to the problem. It is obvious that the research has been limited to a very small number of examples and so, as a result, it has to extend to compare other structural types (ex. gridshells) and materials in order to be considered as a holistic proposal over precedents, types and construction systems.

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